Did Central Clearing of Interest Rate Products Impact Market Activity?

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Alicia Borja Alvarez

Advised by Heather Tookes Professor of Finance Yale School of Management

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Abstract

Since the recent financial crisis, regulators around the world have been addressing the vulnerabilities in the financial system. To increase the transparency and reduce the counterparty risks of OTC derivatives markets they have introduced mandatory central clearing of some OTC derivatives contracts and high capital charges, collateral charges, and margin requirements for uncleared derivatives. Market participants received the mandate with heavy criticism and claimed it would harm how markets operate. This paper analyses whether these measures had a negative impact in the activity in affected markets. Contrary to expectations, my findings suggest that central clearing did not decrease (or increase) the amount of activity in the markets where it was implemented.

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1. Introduction

Following the series of failures of large financial institutions in 2008 and the U.S. government intervention to ensure the stability of the financial system, regulators around the world took a number of steps to limit the excess risk of the uncleared, over-the-counter (OTC) derivatives market. One such measure was the adoption of central clearing. In 2009 leaders of the G-20 committed to having as many OTC trades as possible cleared by central counterparties (CCPs). CCPs are privately owned firms whose purpose is to clear trades. The U.S. was one of the first jurisdictions to take steps to change the structure of OTC markets into markets where trades are cleared: in 2010 central clearing was captured by Title VII of the Dodd-Frank Act, and in 2013 central clearing became mandatory for a set of products. Assessing the impact of forcing market participants to rapidly adopt central clearing is important because it sheds some light on whether this clearing system works in practice, outside of the theoretical models, whether it has negatively impacted the markets, and whether its implementation could have been smoother. Such insights could be used when implementing central clearing for other products, and by jurisdictions which have not yet made central clearing mandatory. The Commodity Futures Trading Commission has only so far made central clearing mandatory for certain interest rate products and credit default swaps (CDS), but it intends to soon include other products in the mandate such as energy and equity indices.

Mandatory central clearing has been widely contested by market participants every time regulators have attempted to introduce it. They claim that when being forced to clear trades they assume higher risks and costs than when allowed not to clear. These claims are difficult to assess because costs and risks are almost impossible to estimate in these opaque markets. I offer an alternative approach to looking at costs and risks to assess the impacts of the policy in the interest rate markets: looking directly at the market activity impact.

For reasons explained in this paper, to adequately offset the risks of CCPs and to protect the financial system, CCPs need users to post large amounts of collateral. In addition it is costly to become a new CCP client. So with the rule which made central clearing mandatory for certain types of products, costs were expected to increase and participation in the interest rate markets was expected to suffer a decrease (J.P. Morgan 2012, and Watterson, Suh, and Stein 2013). To date, there is no empirical evidence that I am aware of measuring the effect on the markets of mandating to centrally clear derivatives. This paper fills this gap by asking whether forcing market participants to centrally clear transactions changed the activity in these products. I examine the notional amount of contracts of affected products that major banks have held since 2009 and find that making central clearing mandatory for these institutions did not significantly change how much they participated in the markets. This is contrary to what was expected prior to the central clearing mandate.

So far the central clearing mandate is only applicable to certain types of interest rate products (see Appendix Table 1) and credit default swaps. I focus on this paper only on interest rate products, and measure whether the mandate affected the notional amounts of interest rate products that banks held before and after the introduction of the regulation.

A potential concern of any study of the market impact of a policy is accounting for the general economic trend. I use a difference-in-differences analysis on panel data with a product that has historically moved parallel to the variable of interest (interest rate activity), foreign exchange notionals, and measure whether immediately after the mandate came into effect there were any changes in the amount of these products that banks were holding. I find a statistically insignificant short-term decrease in the activity of banks in the interest rate markets. Similarly, I run an analysis using interest rate swaps as the treatment group and interest rate forwards as the control group (forwards were not included in the mandate) and find the opposite: a statistically insignificant short-term increase in the centrally clearable product relative to the control. There is also a sharp decrease in activity in the interest rate markets some periods later. In Section 5.5 I show that this decrease is not likely to be a delayed observation of the impact caused by introducing central clearing. I conclude that the mandate did not have a negative effect in interest rate markets. My findings are important because they demonstrate that despite the complaints of market participants, introducing central clearing has been neutral to the markets and therefore can be extended to other scenarios with less concern. My analysis is also noteworthy because it unveils an untapped data source for analyzing market activity and the behaviour of market participants: the FFIEC Call Reports.

The remainder of the paper is organized as follows. Section 2 describes the process of centrally clearing trades and the literature on the costs associated with it. Section 3 presents the hypothesis. Section 4 describes the data and variables. Section 5 presents the empirical specification and results of the analysis. Section 6 concludes.

2. Central Clearing and its Costs

In interpreting the main results of this paper it is useful to understand why previous research disagrees on whether central clearing is more or less costly than trading bilaterally and why market participants have protested against it. Below I provide a discussion of the many costs associated with changing from clearing trades bilaterally to doing so with a CCP.

2.1. Central Clearing

Introduction to derivatives and clearinghouses

A derivative is an agreement to transfer risk from an underlying asset such as a commodity, a company's equity, currencies, or interest rates. Derivatives can be organized into three categories: OTC, exchange-traded, and cleared. OTC derivatives are customized bilateral agreements. Exchange traded derivatives are standardized, and executed over centralized trading venues before being booked with a central counterparty. Cleared derivatives share characteristics with the other two, since they are negotiated bilaterally and then booked with a clearing house (ISDA Education).

After 2008, and as a consequence of the collapse of Lehman Brothers and the intervention

of the U.S. government in preventing other institutions from failing, many began arguing that actions should be taken to prevent institutions from being "too big to fail." Better risk prevention and regulation would only come with banks' being more transparent about how much risk they were holding. Part of the drive to transparency and risk prevention involved OTC derivatives. The trading of these OTC derivatives had been growing exponentially and the transactions were opaque because the market for these products consisted of parties negotiating bilaterally with one another. There was no central body keeping records of transactions (Leising, 2014) and no regulations determining how much risk banks could hold when running these operations.

More specifically, the lack of transparency and market structure of interest rate swaps and credit default swaps when Lehman declared bankruptcy prevented regulators from determining which institutions were at risk of failing (Leising, 2014). Interest swaps are instruments that allow investors to either be exposed to (or protected from) the risk of interest rates rising or falling. Credit default swaps protect the holder of the swap from the default of another financial counterparty, in exchange for regular payments. Many entities had interest rate swap agreements with Lehman, and many also had credit default swaps protecting them from Lehman's bankruptcy. This meant that they could claim payments from other counterparties. Hence entities were interconnected with complex contracts, and at first no one could determine who was holding risk.

In order to prevent large crises like the one in 2008, in September 2009, G-20 leaders agreed to force firms to trade all possible standardized OTC derivatives on exchanges or electronic trading platforms or to clear them through CCPs. They hoped to introduce some structure and standardization to these markets to better monitor and regulate the OTC trading of interest rate swaps and other products (Leising, 2014). By monitoring these products, regulators can determine whether a single entity is holding too much risk, and thereby reduce the risks of the system as a whole failing and causing a catastrophic global ripple effect. On July 15, 2010, the Dodd-Frank Wall Street Reform and Consumer Protection Act

was passed, the first step in achieving this goal. As described by the CFTC, "one key goal of the Dodd-Frank Act was to bring greater pre-trade and post-trade transparency to the swaps market. [...] Such transparency lowers costs for investors, consumers, and businesses; lowers the risks of the swaps market to the economy; and enhances market integrity to protect market participants and the public" (CFTC, 2014).

This market structure took the form of clearinghouses.

The rationale behind mandating central clearing

A version of this system arose in the U.S. over 150 years ago. At the time, there was no central bank and no Federal Reserve, and banks would send a runner to settle the net cash balances between each other at the end of each day. To reduce the inefficiencies, some banks assembled in 1853 to arrange for their runners to meet in one location and settle accounts together. That was the first bank clearinghouse. Several more were created and would perform three functions: they would net transactions, they would monitor banks, and they would support member banks in times of crisis so that in such times depositors would not lose everything. Modern day CCPs provide the first two services to the markets (Skyrm, 2009).

When two parties want to trade through a CCP, they first agree to the trade and then communicate it to the CCP, which replaces the trade with two separate trades in opposite directions, with each of the parties and through the CCP. That way, the CCP becomes the buyer to all sellers and the seller to all buyers. CCPs then match trades so they are not exposed to any market risks (see Figure 1 and Figure 2 for a diagram of how trading relationships are simplified).

In every trade between two firms, each firm is exposed to the risk (counterparty risk) that the other party will not live up to the obligations of the contract between them. If a firm trades through a CCP it will be exposed to the very small risk of the CCP defaulting, and the CCP will be exposed to the risk of that firm defaulting. CCPs are theoretically able to reduce the net risks (or exposures) in the market. In addition since each entity trades

only with the CCP, entities are no longer interconnected with each other so there is less risk of the failure of one entity causing more to fail and the market to collapse. A further benefit of a system with CCPs is that CCPs have the information of every trade transacted through them, which market participants otherwise do not disclose. They can make this trading and risk data public or can share it with regulators. One of the main difficulties faced during the recent financial crisis was that due to the opaqueness of the system and the interconnectedness of market participants, it was difficult to determine who was exposed to too much risk and the weakest points of the financial system. If most of the transactions were cleared, CCPs would be in possession of most of the data relevant during stress scenarios. This could facilitate responding in periods of crisis.

Some economists have argued that all these forces would make markets mostly operated by CCPs cheaper and less risky and therefore allow for more trading. But others have argued that the introduction of CCPs causes frictions in the markets, that with more pricing data available competition between dealers will be too fierce, that CCPs ask for too much collateral and therefore are more expensive to trade with, and that the information disclosures CCPs require will deter companies from trading with them.

2.2. Potential risks

Many concerns have been raised about the safety of a market structure dominated by CCPs. Several are described in this section.

If a clearing member defaults (Figure 1), the CCP intervenes so it offsets the market risk of that member's position by replacing the position. It might take some time for the CCP to replace it, and during this time, markets may move against the CCP. For this reason the CCP has a *default waterfall* in place to withstand any losses (Figure 3). First the CCP will cover any losses with the Initial Margin¹ posted at the commencement of clearing by

¹ The initial margin is a form of collateral that clients must post to a CCP when transacting with it. When a member defaults, the CCP tries to replace the trade to avoid being exposed through that trade to market movements (see Figure 4). The amount of initial margin that members have to provide to the CCP is

the defaulting member. The amount of Initial Margin each member must post is calculated using the assumption that it would take 5 days for the trade to be replaced. This period of time is called the *margin period of risk*. If the Initial Margin resource is exhausted, then the Variation Margin² contributions of the defaulting member are used, and after that, that member's contributions to the CCPs default fund. After all contributions of the defaulter are used up, then the CCP will assume part of the remaining losses. This is called the CCP's skin in the game, since it helps ensure that CCPs are not incentivised to take on too much risk and are instead incentivised to closely monitor risks (CCPs are privately owned). If all the above resources are used and losses have not yet been covered, then the CCP will begin to use mutualised resources. First the default fund contributions of non-defaulting clearing members will be used. If this resource is depleted then most CCPs can call nondefaulting members for further contributions (an "assessment"). Then a second tranche of the CCP's capital will be used. Finally each CCP has different approaches to end-of-thewaterfall situations. For example, some may have support and access to liquidity from the central bank of their jurisdiction. See ISDA (2013) for a discussion on how CCPs may deal with these end-of-the-waterfall situations.

Therefore the level of risk carried by CCPs or probability that the CCP will default or will cause other market participants to default depends on the financial structure and the crisis resolution policies of the CCP. Its ability to withstand default pressures and prevent the system from collapsing depends on factors including the initial and variation margin policies, the level of default fund contributions by clearing members, the level of equity capital in the CCP, and capital call mechanisms.

This robust capital structure that makes CCPs so unlikely to fail is built with contribu-

the expected amount needed to protect the CCP from extreme price changes during the time the CCP could take to replace the trade. See Section 2.3.4. When trading without clearing, parties must also post initial margin to each other. It is higher than the initial margin CCPs require because it is calculated assuming it would take longer for the dealer to replace the trade than it would take a CCP. See Section 2.3.3.

 $^{^{2}}$ The variation margin is a form of collateral exchanged daily between clearing members and CCPs, or between firms trading without a CCP, to keep the risk of the transaction manageable. Parties exchange the amount necessary to fully collateralise all mark-to-market exposures of the derivative (see Figure 4 and Sections 2.3.3 and 2.3.4).

tions from its clients. Forcing clients to contribute with so many resources can have adverse effects. One of them is the risk of *procyclicality*. Procyclicality occurs during periods of market stress, when there is a decrease in the value of collateral. To stay safe, in such scenarios CCPs could require members to post additional collateral. Precisely at periods of market stress liquid margin is hard to source, and this increased demand may cause the value of the margin already posted to decrease further. This in turn would drive margin requirements higher and higher. The consequences can be very detrimental to members and the system. Clearing members might be forced to deleverage to obtain the liquid and safe collateral CCPs require, which could cause fire sales, particularly in periods of market stress. Members might also be subject to "runs" if they are perceived as vulnerable by other market participants, which could cause them to suffer and expectations to become self-fulfilling. Procyclicality can also lead to a liquidity shortage as members will be demanding more and more liquid assets (Rahman 2015, Murphy, Vasios and Vause 2014, and Diamond and Dybvig 1983).

If risks are adequately accounted for, the CCP's default waterfall should ensure that the CCP does not fail. But a risk to consider is that those risks may not be adequately accounted for. Following this idea Pirrong (2009) strongly criticises central clearing and shows that due to asymmetric information problems regarding the value and risk of the products traded and the creditworthiness of the parties, central clearing can increase risks in the financial system and be more costly than trading bilaterally. Most of his criticism is based on the claim that information asymmetries are smaller when trading bilaterally than with a CCP, and that incentives to monitor and manage risks are stronger for dealers than for CCPs.

In theory, a single CCP does enhance netting efficiency and reduces counterparty exposures (Duffie and Zhu, 2011). But there are currently several CCPs operating, which theoretically significantly diminishes netting efficiency and results in greater counterparty exposures, according to analysis by Duffie and Zhu (2011), Heller and Vause (2012), Ghamami and Glasserman (2016) among others. There are several reasons why this might happen. For example, it makes sense intuitively that if a member defaults and there is more than one CCP in the system, then every CCP transacting with them will be contending for the same assets and positions (Glasserman and Ghamami, 2015).

Even if CCPs themselves are safe and make the markets they operate in safer, they could still make other markets less safe. At the European Central Bank and Federal Reserve Bank of Chicago Joint Conference, Governor Randall S. Kroszner explained an additional concern regarding using CCPs to clear trades rather than managing risk bilaterally: Since CCPs clear only plain vanilla products, non-clearable "exotic" products must still be traded bilaterally. If there was no mandate to trade through a CCP, then the risks of these products and plain vanilla trades could be managed together at a bilateral level with techniques similar to those that CCPs use (netting and margin requirements). But with central clearing the scope of bilateral netting is very limited, so counterparties are exposed to more risk and therefore higher costs of protection (Kroszner, 2006).

There are also transaction risks to market participants that, although do not cause the system to fail, do translate into higher costs for them. An example is the transaction risk arising from the delay between the time when the bilateral transaction is agreed upon, and when the CCP is effectively able to novate the two separate trades that constitute the transaction. In the case that the CCP rejects clearing or is unable to clear the transaction, the trade will remain bilateral (Murphy, 2012).

Given that CCPs are not risk-free entities and there are other risks associated with transacting with a CCP, banks have to assess their risk and establish a "credit appetite" to limit the maximum exposure the firm is willing to have with each CCP (Murphy, 2012). They have to take into account that their own funds might be used to bail out the CCP if enough layers of the default waterfall are exhausted. This may at some point become an issue, since it may restrict market liquidity and trading options available to dealers.

Significant prior research has shown that, in practice, CCPs have *shifted* counterparty risk instead of having eliminated or decreased it, because CCPs themselves are subject to concentration risk (Pirrong 2011, Federal Reserve 2011, Ruffini 2015, Ghamami and Glasser-

man 2016, and remarks by Bernanke 2011 and Yellen 2013). CCPs become a principal to all the trades they transact, and so must carry out the future performance obligations to which both parties initially agree to. If several counterparties fail, the CCP might have difficulties meeting its obligations. This could cause a system wide-collapse. As a result, some economists and agencies argue that CCPs are now themselves too big to fail (BlackRock 2014, McCrank 2016, Stafford 2017, and Federal Reserve 2011).

Recent evidence supports these theoretical claims that the current system with multiple CCPs is not very efficient. Younger in 2016 points out that since mid 2015 standard U.S. dollar interest rate swaps were trading at different rates in the two largest U.S. CCPs. One of the CCPs offers portfolio margining between swaps and listed Treasury futures while the other CCP does not. So fixed-rate payers prefer the first. This is expected to have driven the difference in price, which indicates that the current CCP system is not efficient.

But authors are far from agreeing about whether risks have increased or shifted. Loon and Zhong (2014), for example, disagree and show that for the credit default swaps market, CCPs decreased risk and increased market liquidity.

2.3. Costs of switching to trading through a CCP

Because CCPs are not riskless entities and could pose large risks to the system if they were not protected well enough, CCPs ask for large amounts of collateral posting. This could raise costs of trading for products mandated to be centrally cleared. Sections 2.3.1 to 2.3.4 compare the capital and collateral requirements that banks are subject to when trading bilaterally or when centrally clearing transactions. Table 3 summarizes these sections. It is worth noting that to some extent capital and collateral costs offset each other because when the margin is greater, the counterparty exposure is smaller and so the associated costs are smaller. This is particularly important when counterparties trade bilaterally (Ghamami and Glasserman, 2016).

2.3.1. Capital Requirements when trading bilaterally

The Counterparty Risk capital requirement charged to banks trading bilaterally is composed of two elements. The first is the *Basel II Counterparty Credit Risk* capital requirement, similar to what one party would face if it had made a loan to the other. The second is the Basel III (DCDS, 2011) *Credit Valuation Adjustment* capital requirement, which captures any decline in the other bank's creditworthiness because the decline causes a loss in the market value of the position of the other bank (Ghamami and Glasserman, 2016).

2.3.2. Capital Requirements when trading through a CCP

The CCP Risk capital requirement is also composed of two elements. The first is the *trade* exposure capital charge, similar to the Basel II Counterparty Credit Risk capital requirement but smaller because CCPs are considered to be less risky. The charge is based on the bank's exposure to the CCP in its existing trades. The second is the Default Fund exposure capital charge, which accounts for the risk of other clearing members failing, in which case the bank's contribution to the CCP's default fund would be used to prevent more defaults (Ghamami and Glasserman, 2016).

2.3.3. Collateral Requirements when trading bilaterally

For bilateral transactions new reforms (BCBS and IOSCO, 2012 and 2015) now mandate counterparties to hold *initial* and *variation margins*. These requirements were put in place in part to promote central clearing by increasing the costs of trading without clearing (IMF 2010, and BCBS and IOSCO 2015). The initial margin protects dealers from suffering losses during a *margin period of risk*³ of 10 days. The initial margin is calculated with a onetailed 99% confidence interval based on historical data with a period of financial stress, to

 $^{^{3}}$ The margin period of risk is the estimated time between a counterparty default and when the position could be closed out. It is set to 10 days for bilateral trading if the variation margin is exchanged daily. But if the variation margin is exchanged less frequently, the margin period of risk equals 10 days plus the number of days between variation margin exchanges (BCBS and IOSCO, 2015).

mitigate the risk of procyclicality (see Section 2.2). The variation margin is exchanged daily to keep the risk of the transaction manageable. Parties exchange the amount necessary to fully collateralise all mark-to-market exposures of the derivative (see Figure 4). It should be exchanged very frequently and it is most often exchanged on a daily basis. Additional instructions on calculating margin requirements for non-centrally cleared derivatives can be found in BCBS and IOSCO (2015).

2.3.4. Collateral Requirements when trading through a CCP

For centrally cleared transactions the CCP requests *initial margin*, *variation margin* and contributions to the *default fund*. The initial margin is collected to protect the CCP from potential price changes during the margin period of risk in the position the CCP is left holding if the client defaults. It is also calculated with a one-tailed value-at-risk (VaR) model based on the 99th percentile of potential losses and therefore using potential rather than realized price changes. For centrally cleared transactions the margin period of risk is of 5 days. When trading with more than one CCP, clients must post separate initial margin and guarantee fund contributions to each CCP. The variation margin is set regularly and reflects the mark-to-market of the client's portfolio with the CCP, so it's based on realized price changes (Ghamami and Glasserman, 2016).

It is worth noting that variation margin collateral costs should be approximately the same for both bilateral and centrally cleared transactions because they depend on realized market price movements, while initial margin collateral costs may vary greatly from when trading with a CCP and with another dealer because they depend on how the dealer organizes the portfolio and on the different margin periods of risk. For bilateral transactions portfolios are organized by counterparty, whereas for CCPs they are organized by derivative classes.

Therefore, both under bilateral and centrally cleared transactions, counterparties are subject to capital and collateral costs. Ghamami and Glasserman (2016) introduced a calibrated model of OTC clearing to compare the costs to banks of transacting fully bilaterally with the costs of clearing fully through a CCP. They found that the main cost drivers are the netting benefits of CCPs and of netting bilaterally, the margin period of risk which determines the initial margin and capital requirements, and the CCP's guarantee fund requirements. They concluded that it is unclear whether costs are higher or lower when centrally clearing transactions and that the answer depends on the above factors.

Others have argued that system wide collateral demand was certainly not going to be higher with central clearing. Bruder, Hereil and Roncalli (2011) argued that with initial margin requirements for dealers, system-wide collateral was going to increase significantly and that mandatory central clearing would lower, not raise, system-wide collateral demand given that the number of CCPs remained small. Heller and Vause (2012) estimated how much collateral CCPs should demand in order to safely clear all the interest rate and credit default swaps of the major dealers and found that these dealers already had sufficient assets to meet the necessary initial margin requirements, and that only some may have had to increase their cash holdings to meet variation margin calls.

Some more recent estimates also support the hypothesis that cost increases for trading non-cleared derivatives are likely to exceed costs of trading through a CCP. Deloitte's 2014 study estimated that transaction costs (margin requirements, capital requirements, reporting costs and other compliance costs) for centrally cleared OTC derivatives would be of EUR 13.60 per EUR 1 million notional (0.136 basis points). They estimated that would cost an additional total EUR 2.5 billion per year for European OTC derivatives. But because of the stricter risk and more costly risk management requirements for non-cleared OTC derivatives, they also estimated costs increases for uncleared OTC derivatives of EUR 170.50 per EUR 1 million notional amount, ten times the estimated increase for cleared transactions. They estimated the higher costs would offset the smaller reporting requirements and other compliance costs for non-cleared compared to centrally cleared transactions.

Whether or not costs of clearing were higher than for not clearing derivatives, it was still expensive for firms to adopt central clearing. In the text of the regulation of December 2012 (17 C.F.R. §39 and 50), the CFTC estimated that if every transaction of interest rate swaps or CDS that was not being cleared at the time, began being cleared, an additional initial margin of \$19.2 billion for interest rate swaps and \$53 billion for CDS would have to be posted. This was consistent with Morgan Stanley's estimate of \$20 billion in additional margin in their "bull case" scenario, \$480 billion in their "base case," and \$1.3 trillion in their "bear case" scenario. TABB Group conducted similar research prior to the mandate and estimated that the total amount of margin that would be required for both cleared and uncleared swaps would be between \$2.9 trillion and \$4.1 trillion. They estimated that at the time \$1.34 trillion of margin was already posted for all OTC swaps, leaving an additional \$1.56 trillion to \$2.76 trillion in margin that would need to be posted after the mandate.

There are other one-time costs of centrally clearing trades that may have also had a detrimental effect in how banks trade and in the smooth functioning of the markets. Firms involved had to review their ISDA agreements and to pay for the costs of developing new collateral management and margin calculation mechanisms, and for setting up new IT processes to clear trades through CCPs. They had to face operational challenges, particularly segregating the assets of clients (Deloitte, 2014) and establishing processes to deal with disputes about the valuation of the collateral and of the underlying positions (IMF, 2010).

A shortage of collateral may have also affected the OTC markets. CCPs only accept certain highly liquid and low-risk assets as collateral, so many companies demanding these products at the same time to meet the clearing requirements may have contributed to a systemic collateral shortage.

An additional cost of trading with CCPs also regarding collateral is the inability to rehypothecate collateral. Rehypothecation refers to when trading firms can use part of the collateral that other firms post to them to carry out operations or to protect the firm. When firms clear a trade through a CCP they do not have access to the collateral the other party posts because both parties are trading with the CCP and not with each other, so they can't rehypothecate it and earn revenues from it. This opportunity cost is currently small because of low interest rates in the U.S. but will rise as rates rise.

To summarize, the literature suggests that researchers have not reached a conclusion about whether the current system and cost structure does incentivise the use of central clearing as was intended.

It could also be the case that the reforms to raise costs of trading without clearing (BCBS and IOSCO, 2012 and 2015) incentivised some but not all market participants to centrally clear trades. In 2012 ISDA conducted a survey which indicated that 22 percent of OTC derivative transactions were uncollateralized, what is consistent with Heller and Vause's (2012) claim that in many cases non-dealers (end users of derivatives) were not posting initial margin before the reforms. If they wanted to continue trading the products the mandate encompasses after the rule had passed, they had to prepare new infrastructure and calculation methodologies to meet those margin requirements, which in addition were disproportionately high precisely for smaller market participants (Heller and Vause, 2012). This was probably a very costly process and may have deterred these smaller firms from centrally clearing their trades, thereby forcing them to decrease their presence in these markets.

Some of these institutions faced the additional difficulty that only part of their portfolios was clearable. After the mandate they had to choose one of two options: to change their product offerings so all their products were clearable through CCPs, or to keep some of their trades bilateral. If they had chosen to clear some and bilaterally trade the rest, they would have had to margine their portfolios as two separate directional portfolios and would have consequently been subject to higher margins and costs (Callahan, 2013).

In Europe, smaller counterparties have firmly resisted adopting central clearing. They claim that due to the very high costs of clearing, banks are not incentivised to provide clearing services and even four clearing brokers exited the business of offering client clearing services (ESMA, 2016).

If central clearing increases risks or trading costs for some or all market participants,

the mandatory introduction of central clearing can be expected to have decreased how much banks transact interest rate products. With higher costs banks may want to either restructure product offerings or pull back from affected asset classes. That reaction from the market would indicate that central clearing is constraining for institutions and harmful to market liquidity. It would also indicate that the introduction of the mandate may have been too abrupt or confusing for market participants.

In the remainder of this paper I measure whether obliging market participants to centrally clear their trades had an effect on the affected markets, and find that it did not.

2.4. The Central Clearing Mandate

On December 13, 2012, the Final Rule for the Clearing Requirement Determination Under Section 2(h) of the CEA was published (Federal Register Vol.77, No. 240. 17 C.F.R. §39 and 50). It mandated certain classes of credit default swaps and interest rate swaps to be cleared. The mandate did not include any form of foreign exchange contracts or interest rate forwards (see Table 5 of the products included in the mandate). I have focused on these products because of their market importance and because they were already widely cleared. The mandate applied to both new swaps and swaps subject to a change in ownership (17 C.F.R. §39 and 50).

Compliance dates were different for different types of institutions. Category 1 entities comprised swap dealers, security-based swap dealers, major swap participants, major security-based swap participants, and active funds (non-3rd party subaccounts with 200 or more swaps per month per year). Category 2 entities were all remaining entities except for third party subaccounts, and including commodity pools, private funds, and financial entities. Category 3 entities were all remaining entities including third party subaccounts. Category 1 entities were required to clear all the trades they entered on or after March 11, 2013 (phase 1), category 2 entities were required to clear all the swaps they entered on or after June 10, 2013 (phase 2), and category 3 entities were required to clear swaps entered on or after September 9, 2013 (phase 3).

The rule gave only 90 days from the time of the announcement of the mandate to category 1 dealers to understand the mandate and prepare all systems and mechanisms to start clearing all their trades (17 C.F.R. §39 and 50). In addition, if they had wanted to respond to the rule by decreasing their participation in these markets they would only have had Q1 of 2013 (from December 2010 up to March 2013) to make those adjustments.

This paper looks at whether the interest rate markets suffered a decline in activity after the mandate came into effect by measuring whether activity decreased on or after March 2013. I use a variable measuring the activity of banks in the foreign exchange market and a variable measuring the activity of banks in the interest rate forwards markets as controls in my analysis, because both products were not included in the mandate.

This mandate was only valid in the United States. But similar mandates have since been put in place in other jurisdictions for the same products. In Europe, a longer phased-in implementation is currently happening, and since June 21, 2016 some entities are already mandated to clear their trades (EU 2015/2205).

A discussion of this rule is relevant because it has not yet been implemented in every jurisdiction and for most products. Understanding the effects that this regulation had in the markets can help market participants prepare for such changes, and can allow regulators to better design rules to have minimal detrimental impact on the markets.

2.5. What was happening during the period when central clearing was introduced

During the same quarter that central clearing was made mandatory, the U.S. economy was improving and interest rates were at very low levels. Firms responded by issuing corporate bonds. With bond issuance comes more hedging of interest rate risk to protect against potential monetary changes. Issuing companies use interest rate swaps to convert debt payment obligations from a fixed to a floating rate. It should also be taken into account that this quarter corresponds to the first quarter of the year, which has historically been the most active one in these markets (Q1 2013 OCC's Quarterly Report on Bank Trading and Derivatives Activities).

The first quarter of 2013 was very active relative to previous quarters. For five of the previous six quarters, the notional amount of derivative contracts held by insured U.S. commercial banks and savings associations had fallen by 10.5% (\$26 trillion). This quarter it rose by 4% up to \$232 trillion. The decline in previous quarters resulted from trade compression and the low volatility environment that naturally decreased the need for risk management products (see Table 4) (Q1 2013 OCC's Quarterly Report on Bank Trading and Derivatives Activities).

Insured U.S. commercial banks and savings associations reported \$7.5 billion in trading revenues in the first quarter of 2013, \$3.1 billion higher (72%) than the \$4.4 billion in revenue in the previous quarter, and \$466 million higher (7%) than the revenues in the first quarter of 2012. This increase in revenues was driven by an increase in credit trading revenues. Interest rate products reported 50% less revenues compared to Q4 2012, and 60% less compared to the first quarter of 2012, one year before central clearing was introduced (see Table 5) (Q1 2013 OCC's Quarterly Report on Bank Trading and Derivatives Activities).

All the forces driving the markets at the time are almost impossible to account for: the improvement of the U.S. economy, world macroeconomic trends, corporate bond issuance, risk perceptions... So to identify the effect of central clearing in market activity I take a different approach and look at whether activity changed in the markets affected by central clearing relative to other markets that were expected to follow the same trend if central clearing had not been introduced. I account for the time variant and time invariant differences between these markets.

3. Hypothesis

The introduction of mandatory central clearing could have caused turmoil in the markets, with participants reacting negatively to the potentially higher costs and risks associated with trading through a central counterparty. If my findings show that it had significantly disrupted the activity of major dealers, the implementation may have been too abrupt and contrived, which should be taken into consideration when facing the implementation of similar regulations in other regions or for other products.

I measure whether major dealers experienced a significant decrease in market activity immediately after central clearing was made mandatory. Since the rule was published on December 13, 2012, and the first phase of the implementation mandated major dealers to clear all their trades entered on or after March 11, 2013, most of the reaction of major dealers to the rules should have happened during the first quarter of 2013. Seemingly major dealers were less affected than category 2 entities⁴ by the mandate, so I measure any decreases in the notional amounts of interest rate products that major banks were holding before the mandate and after phase 2 of the implementation.⁵ Because category 3 institutions are large in headcount but amount to a small share of the market (ESMA, 2016), they are not included in this analysis.

⁴ See Section 2.4. Category 1 entities were swap dealers, security-based swap dealers, major swap participants, major security-based swap participants, active funds (non-3rd party subaccounts with 200 or more swaps per month per year. Category 2 entities were all remaining entities except for third party subaccounts, and including commodity pools, private funds, and financial entities. Category 3 entities were all remaining entities including third party subaccounts.

⁵ Phase 1 made central clearing mandatory for the specified products for category 1 entities on March 11, 2013. Phase 2 for category 2 entities and came into effect on June 10, 2013. And phase 3 for category 3 entities on September 9, 2013.

4. Data

4.1. Call Reports

In an effort to increase bank oversight, since March 31, 2001 all national banks must file Consolidated Reports of Condition and Income (FFIEC 031 and 041) (Call Report) every quarter with the FDIC. They are all published on the FDIC website. The Call Reports are organized in Schedules, and I focus on two: RC-L and RC-R. Schedule RC-L⁶ shows amounts of derivatives and off-balance-sheet items purchased and sold for different purposes. Schedule RC-R⁷ compiles data on Regulatory Capital.

In the analysis I use a number of variables from section RC-R of the Call Reports, mostly from the Memorandum section. These are items for which banks must record the notional principal amounts of off-balance-sheet derivative contracts. Such contracts include swaps, forwards, and purchased options. Gross quantities are reported, so reporting banks do not net "(1) obligations of the reporting bank to purchase from third parties against the bank's obligations to sell to third parties, (2) written options against purchased options, or (3) contracts subject to bilateral netting agreements."

I also use variables from section RC-L of the Call Reports. The items I use from this section measure the same volumes of interest rate products held by banks as the items I choose from section RC-R but are distributed into product type buckets rather than distributed into maturity buckets.

⁶ For further information refer to FFIEC: Reports of Condition and Income Instructions for report forms FFIEC 031 and 041. Schedule RC-L. Derivatives and Off-Balance Sheet Items. Available online https://www.fdic.gov/regulations/resources/call/crinst/2016-09/916RC-L_093016.pdf

⁷ For further information refer to FFIEC: Reports of Condition and Income Instructions for report forms FFIEC 031 and 041. Schedule RC-R - Part II Regulatory Capital. Available online https://www.fdic.gov/regulations/resources/call/crinst/2016-09/916RC-R_Part_II_093016.pdf

4.2. Variables

4.2.1. Notional principal amount of all interest rate products held by each bank

The notional principal amount of all interest rate products held by each bank as reported in the Call Reports Schedule RC-R is used in this analysis to measure whether the banks or their clients reacted negatively to the mandate by reducing their activity in the interest rate markets. I name the variable "interest rate notionals" and " ir_{all} " in this paper.

This variable is used to measure whether the banks or their clients reacted negatively to the mandate by reducing their activity in the interest rate markets.

This variable is also broken into three maturity buckets: With a remaining maturity of one year or less (*short maturity* in my specification); with a remaining maturity of over one year through five years (*medium maturity*); and with a remaining maturity over five years (*long maturity*). The maturity corresponds to the contract's remaining term to maturity from the report date.

It could be that banks reacted to the mandate but were still holding a large amount of interest rate products from deals settled before the mandate. In that case, a reduction in activity would first be noticeable only after the existing contracts expired. If that was the case, the data would show activity decreasing first for short term interest rates (remaining maturity less than one year), then for products with a remaining maturity between a year and five years, and later for products with a remaining maturity over five years. Note that products had to be cleared if they had gone through a change in ownership even if the original trade had been made prior to the mandate.

4.2.2. Bank selection

The sample analyzed in this paper consists of the 20 banks with highest total consolidated (balance sheet) assets in December, 2012, as reported in the Call Reports on the Schedule RC-Balance item 12 and Schedule RC-R Part II item 11. These banks are very large and also have significant trading activity. The sample does not include more banks because other banks are either much smaller than those in the sample (as measured by total consolidated assets) or do not have as significant trading activity.

Table 6 shows the 20 banks included in the analysis and their total assets in December 2012, the quarter prior to the central clearing mandate's coming into force.

4.2.3. The top 4 banks as the treatment and the other 16 banks in the sample as the control group

The derivatives trading activity is very concentrated in four banks. This has been the case for many years. In 2013, for example, these four banks held 93% of the total banking industry notional amount of derivative contracts. The four banks are J.P. Morgan, Bank of America, Citibank, and Goldman Sachs (Q1 2013 OCC's Quarterly Report on Bank Trading and Derivatives Activities). Even though they trade significantly more, these four banks are not necessarily largest in terms of assets. For example in 2013 Goldman Sachs ranked 18 in total consolidated assets.

I tested the hypothesis that the top four banks might react differently to the introduction from central clearing with a difference-in-differences approach using the remaining 16 banks as a control group.

4.2.4. Interest rate contracts as the treated group and foreign exchange contracts as the control group

I use foreign exchange activity as a control in the regression because interest rate and foreign exchange trading are closely aligned; both products were subject to the same collateral (and capital) requirements if bilaterally traded; and the foreign exchange market was not subject to mandatory central clearing. The interest rate and foreign exchange markets tend to move together because dealers often use interest rate contracts to hedge foreign exchange risk (Q1 2013 OCC's Quarterly Report on Bank Trading and Derivatives Activities). In the data is it evident that there is a relationship between the notionals of both since prior to the mandate they move parallel, and that the volume of both foreign exchange and interest rates was significantly larger than that of other products.

The variable is also reported in the Call Reports Schedule RC-R. I name the variable "foreign exchange notionals" and " fx_{all} " in this paper.

This variable is also broken into three maturity categories: With a remaining maturity of one year or less, with a remaining maturity of over one year through five years, and with a remaining maturity over five years. The maturity corresponds to the contract's remaining term to maturity from the report date.

When using foreign exchange notionals in the difference-in-differences estimation (Specification 2), the variable *product irp* is an indicator equal to one if the observation corresponds to a measure of interest rate notionals of all maturities, and zero if it corresponds to an observation of foreign exchange contracts.

4.2.5. Interest rate swaps as the treated group and interest rate forwards as the control group

In the third regression specification, I use the notional amounts of interest rate forwards contracts as the control and of interest rate swaps as the treatment group in a difference-indifferences analysis. Both contract types serve similar functions and are subject to capital and collateral requirements, so all else being equal, it is reasonable to expect that the size of their markets should grow or shrink similarly over time. Forwards are not centrally cleared, but swaps are (see Table 1), so I measure whether this parallel trend in the size of both markets changes after firms are mandated to clear certain types of swaps.

Schedule RC-L of the Call Reports provides the relevant variables. They again measure the notional principal amounts of each interest rate derivative contract type. I name the variables "swaps notionals", "swaps", or "*irp swaps*" and "forwards notionals", "forwards" or "*irp forwards*" in this paper. When using forwards notionals in the difference-in-differences estimation (Specification 3), the variable *product swap* is an indicator equal to one if the observation corresponds to a measure of the notional amounts of interest rate swap contracts of all maturities, and zero if it corresponds to an observation of forwards contracts.

4.2.6. Seasonality

Seasonal patterns are pronounced in trading activity and revenues. For example, the first quarter of every year is usually the most active one.

But accounting for seasonality in the regressions was not a significant addition to any of the models, so I only account for seasonality in the first specification. In addition when doing difference-in-differences analysis seasonality should already be accounted for by the control variable, so there should be no need of accounting for it separately.

4.3. Summary Statistics

Table 7 reports summary statistics for the variables described in the previous sections. The variables measure the notional amounts of each derivative contract type that banks in the sample hold: interest rate contracts of remaining maturity of one year or less (*short maturity*); interest rate contracts of remaining maturity of over one year through five years (*med maturity*); interest rate contracts of remaining maturity of over five years (*long maturity*); interest rate forwards contracts of all remaining maturities (*irp forwards*); interest rate swaps contracts of all remaining maturities (*irp forwards*); interest rate contracts including contracts of all remaining maturities and all interest rate contract types (*ir_{all}*); the sum of all foreign exchange contracts including contracts of all remaining maturities and all remaining maturities and all foreign exchange contract types (*fx_{all}*).

The distribution of all the variables is significantly right skewed and their standard deviations are very high. This is a consequence of the very large differences in activity between the most active four banks and the other 16 banks that constitute the sample.

5. Empirical Specification

5.1. First Specification: Basic Regression

I first run a simple regression measuring whether there were any changes in the notional amounts of trading.

My regression specification is:

$$log(ir_{all}) = \beta_0 + \delta_1(Q2, 2009) + \delta_2(Q3, 2009) + \dots + \delta_{15}(Q4, 2012) + \delta_{16}(Q1, 2013) + \delta_{17}(Q2, 2013) + \dots + \delta_{29}(Q2, 2016) + u$$
(1)

The dependent variable is the log of the interest rate notionals of all maturities and types, ir_{all}, defined in Section 4.2.1. *Q2*, 2009, *Q3*, 2009, ..., *Q2*, 2016 are binary variables (dummies) equal to one if the measurement corresponds to the Call Report of that quarter, and δ_1 , δ_2 , ..., δ_{29} are their respective coefficients. The variable *u* represents the disturbance error.

I obtain the results in Table 8. Also see Figure 5 for related graphs.

The results show that immediately after central clearing was introduced, there was more activity in the markets. Particularly there is an increase in activity in June of 2013, which corresponds to the quarter where the second phase of the mandate had just been implemented.

But not many conclusions can be drawn from this specification since it does not capture almost any variation in the outcome variable. It is evident from the F-test testing the null hypothesis that nothing is happening in the data: the p-value equals one in the first specification and the R^2 is very low. Including a variable accounting for each bank name in the second regression (column two of Table 8) shows that most of the variation in the outcome variable is explained by the differences between banks. Meanwhile the variable accounting for the seasonality explains none of the variation in the market activity of interest rate products. The results are still not robust: they do not account for the general economic trend. To obtain robust results, in the following sections I instead use a difference-in-differences approach. I use different control groups that were not affected by the mandate and which were moving parallel to the variable of interest, interest rate notionals, and measure whether this relationship between the variables changed after the mandate.

5.2. Second Specification: Difference-in-differences analysis using foreign exchange contracts as a control

To measure the effect of the policy in this second specification, I use a difference-indifferences analysis and use the notional amounts of foreign exchange contracts as the control group to measure whether major dealers were negatively impacted by central clearing becoming mandatory and for that reason reduced their activity in the interest rate markets.

My specification is:

$$log(notional) = \beta_0 + \beta_1(post) + \beta_2(product \ irp) + \beta_3(post * product \ irp) + \beta_4(bankID) + \beta_5(bankID * product \ irp) + u$$
(2)

The outcome variable, $\log(notional)$, is either the log of the interest rates notionals of each bank (if *product irp* equals 1), or the log of the foreign exchange notionals of each bank (if *product irp* equals 0). The variable *post* is a dummy variable equal to one if the observation is from after the mandate was passed (Q2 2013). The variable *post* * *product irp* is the interaction between the dummy variable indicating whether the regulation had come into force and the dummy indicating which of the products are in the control and treatment groups. So this variable is equal to one only if the observation is of interest rate products and the regulation was already in place.

I include in the regression a categorical variable, the *bankID*, and the interaction *bankID* * *product irp*, because each bank might have its own different sizes of interest rate or foreign exchange derivatives businesses.

The coefficient of post * product irp (did in Table 9) corresponds to the difference-indifferences analysis. It measures the difference $\Delta_{log(IR)} - \Delta_{log(FX)}$, where $\Delta_{log(IR)}$ is the change in the log of the notional amounts outstanding of interest rate derivatives that banks held when central clearing was mandated (i.e., the post-event notionals minus the pre-event notionals) and $\Delta_{log(FX)}$ is the average change in the log of the notional amounts outstanding of foreign exchange derivatives that banks held when the regulation came into force.

I run this specification for two different time frames: (1) from the quarter before the mandate was implemented (Q4 2012) to the quarter after phase 2 (Q2 2013), and (2) comparing all periods prior to the mandate to all periods after Q1 2013.

Table 9 presents the results of this difference-in-difference analysis.

Both specifications explain most of the variation in the outcome variable, and so have high R^2 . The second column of Table 9 (looking only at the change from Q4 2012 to Q2 2013) shows that immediately after phase 2 of the mandate had been implemented, banks were less active in the interest rate markets and more active in the foreign exchange markets. For this reason the difference between the sum of the notionals of foreign exchange contracts and the sum of the notionals of interest rate products decreased. This decrease is however too small to be statistically significant: the p-value associated with the decrease in the difference between both product's notionals is 0.835.

A more pronounced change in the same direction happens over time. Banks decrease their activity in the interest rate markets and increase their activity in foreign exchange markets. This is statistically very significant. Before the mandate the levels of notional amounts of interest rate contracts that banks were holding varied together with those of foreign exchange contracts, but several periods after the mandate came into force that was no longer the case. Figure 6 shows this evident change in the relationship between both variables over time and that it does not happen immediately after central clearing is introduced. It is therefore very unlikely that the clearing mandate explains this shift. This change in the relationship between the activity in the foreign exchange markets and the interest rate markets could instead be caused by, for example, attractive prospects in emerging market economies, changing attitudes towards the U.S. economy as it recovered from the financial crisis, or the low interest rate environment in the U.S..

5.3. Third Specification: Difference-in-differences analysis using interest rate forwards as a control

To determine whether these results are robust I run a similar analysis to Specification 2 using different control and treatment groups. I measure whether dealers reduced their activity in the interest rate swap market after the mandate but not in the forwards market. This would indicate that they reacted negatively to the mandate. The control group is needed, as in Specification 2, to account for any changes that the swaps market would have suffered even if central clearing had not been introduced.

My specification is:

$$log(notional) = \beta_0 + \beta_1(post) + \beta_2(product \ swap) + \beta_3(post * product \ swap) + \beta_4(bankID) + \beta_5(bankID * product \ swap) + u$$
(3)

The outcome variable, $\log(notional)$, is either the log of the interest rates swap notionals of each bank (if *product swap* equals 1), or the log of the interest rate forwards notionals of each bank (if *product swap* equals 0). The *post* dummy variable is again equal to one if the observation is from after the mandate was passed (on or after Q2 2013).

I include in the regression a categorical variable, the *bankID* and the interaction *bankID* * *product swap* for the same reasons as in Specification 2.

The coefficient of post * product swap (did in Table 9) corresponds to the difference-indifferences analysis $\Delta_{log(swap)} - \Delta_{log(forward)}$, where $\Delta_{log(swap)}$ is the change in the log of the notional amounts outstanding of interest rate swaps that banks held when the regulation passed (i.e., the post-event notionals minus the pre-event notionals) and $\Delta_{log(forward)}$ is the average change in the log of the notional amounts outstanding of interest rate forwards that banks held when central clearing was introduced.

I run this specification for the same two different time frames as before: (1) from the quarter before the mandate was implemented (Q4 2012) to the quarter after phase 2 (Q2 2013), and (2) comparing all periods prior to the mandate to all periods after Q1 2013.

Table 9 presents the results of the difference-in-difference analysis. Figure 7 shows a graphical representation.

The results show a slight increase in activity in the market of interest rate swaps and decrease in activity in the market of interest rate forwards immediately after central clearing was introduced. So the differences between them increases (the *did* coefficient is positive). These changes are, as in the second specification, not statistically significant. Comparing all periods before the mandate with all periods after the mandate came into force yielded statistically significant results in the same direction. For swaps, activity increased, and for forwards, activity decreased, so the gap between them narrowed (there is less activity in the market for forwards). This is the opposite of what I find in Specification 2, where activity for the control group (foreign exchange products) increased, but decreased for the treated group (interest rate products). It indicates that central clearing was not the main cause of the observed changes.

5.4. Fourth Specification: Difference-in-differences analysis using the top 4 banks as the control

J.P. Morgan, Bank of America, Citibank, Goldman Sachs together account for most of the activity in these derivative markets. As mentioned in Section 4.2.3, at the time the central clearing mandate came into force these four banks represented 93% of the total banking industry notional amounts. If the mandate was detrimental to market participants, I expected these four banks to react to it in a different way than the other 16 banks in the sample. I tested the hypothesis that the four most active banks might react differently to the introduction of mandatory central clearing with a difference-in-differences approach using the remaining 16 banks as a control groups.

The corresponding specification is the following:

$$log(notional) = \beta_0 + \beta_1(post) + \beta_2(top4) + \beta_3(post * top4) +$$

$$\beta_4(bankID) + \beta_5(bankID * top4) + u$$
(4)

The outcome variable, $\log(notional)$, is the log of the interest rates notionals of each bank. The dummy variable top4 is equal to one if the observation corresponds to one of J.P. Morgan, Bank of America, Citibank or Goldman Sachs, and equals zero if it corresponds to any other bank in Table 6. The variable *post* is again a dummy equal to one if the observation is from after the mandate was passed (on or after March 2013 or Q2 2013). So the interaction *post* * *top4* (*did* in Table 9) equals one only if the observation is of J.P. Morgan, Bank of America, Citibank or Goldman Sachs on or after Q1 2013.

The results are shown in columns 5 and 6 of Table 9 (and Figure 8). The coefficient accounting for the group of 16 smaller dealers shows that their activity in the interest rate markets decreased slightly immediately after the mandate was passed. Meanwhile for the group of the four larger dealers it increased slightly, so the difference between the activity levels of both groups increased. The change was too small to be statistically significant. When comparing all terms before the mandate with all terms after the mandate, both groups exhibited decreases. The decrease was sharper for the most active four banks, so the gap between the trading levels of both groups was generally smaller. An explanation for these results could be that more active dealers did not adapt as fast to changes in the markets, and so this points to the importance of assessing whether banks did react to the mandate but due to the volume of contracts already in their books the decrease was difficult to detect from the given data until the existing contracts had expired.

However all these difference-in-differences results are not statistically significant; the p-

values associated with the null hypothesis that the difference between both groups does not change are very high.

5.5. Fifth Specification: Comparing maturities

The reduction in the participation of banks in the markets could be noticeable at different periods in time for products of different remaining maturities (see Section 4.2.1). In that case, the data would show activity decreasing first for interest rate products with remaining maturity of less than one year, then for products with a remaining maturity between a year and 5 years, and later for products with a remaining maturity of over 5 years.

To test this hypothesis, I run the following specification:

$$log(notional) = \beta_0 + \beta_1(post) + \beta_2(product \ maturity) + \beta_3(post * product \ maturity) + \beta_4(bankID) + \beta_5(bankID * product \ maturity) + u$$
(5)

The dependent variable, $\log(notional)$, is the log of the notional amounts of interest rates contracts held by each bank and of every maturity bucket ((1) products with remaining maturity of less than one year, (2) products with a remaining maturity between a year and 5 years, and (3) products with a remaining maturity of over 5 years). The categorical variable *product maturity* has a different value for each maturity bucket, and the variable *post* * *product maturity* is the interaction between the *product maturity* variable and the dummy variable equal to one if the observation is from after the mandate was passed (Q2 2013).

I run this specification comparing the quarter before the mandate was implemented (Q4 2012) to the quarter after phase 2 (Q2 2013).

Table 10 presents the results. Appendix 1 shows the results of carrying out this analysis for different time frames. See Figure 9.

The results are similar to those obtained in previous sections. There is no statistically significant change immediately after the law had passed. It appears that the reason why the results of previous sections do not show banks reacting to the mandate is not because they had contracts in their books that had expire for any changes to be noticeable.

It is also worth mentioning that contracts of longer maturities carry higher risk. The higher the risk, the larger the capital and collateral charges both from bilateral trading and trading with a CCP. Once the rule had come into effect, if costs associated with higher risks had increased then banks would have likely been discouraged of engaging in contracts of long maturities and would have instead tried to substitute those contracts with contracts of shorter maturities. If that was the case, the data would show a relative increase in short term contracts and decrease in longer dated ones. We do not see such pattern in the data, what indicates that mandating central clearing of interest rate products did not increase the costs to banks of entering into riskier contracts.

5.6. Summary

The takeaway from this analysis is that the slight increase in activity in the interest rate markets after the introduction of central clearing cannot be attributed only to the impact of central clearing. Using different control groups changes the outcome, and none of the shortterm changes are statistically significant. Several quarters after the regulation coming into force, activity in the interest rate markets suffered a sharp decrease. These results are robust and remain valid after controlling for the general trend in the activity of banks. Results also do not change significantly when including adjustments for trading levels or bank assets in the specifications.

With specification 5, I then show that the decrease in notional amounts of contracts of interest rate products held by banks that happened several periods after the regulation came into effect is not likely to have been a consequence of central clearing becoming mandatory. There is no evidence supporting that it would take time for the data to show a decrease in activity.

In summary, this analysis shows that the introduction of central clearing did not have a

direct effect in the amount of interest rate activity of banks. This in turn implies that the introduction of mandatory central clearing was not as costly as has been claimed.

6. Conclusion

After the failures of large financial institutions in 2008 and the severe impact that they had, regulators across the world decided to address the vulnerabilities of the financial system to prevent these financial institutions from holding too much risk and thereby posing a threat to destabilize economic and financial markets worldwide. Regulators identified significant risks in the OTC derivatives markets and committed to addressing them. One of the measures that resulted from this resolution was the introduction of central counterparties. CCPs are supposed to reduce the risks in the system, increase market transparency, and prevent any bank from being too big or important to fail.

But CCPs are themselves private companies that are too big to fail. If not adequately protected they can carry too much systemic risk. Protecting them requires large amounts of collateral, which comes at a very high cost for market participants.

In light of these costs, to incentivise central clearing regulators increased the costs of trading bilaterally. These efforts were not completely successful at encouraging market participants to adopt central clearing. When the decision was made to make central clearing mandatory for certain products, as happened with many other Dodd-Frank measures, many firms protested and claimed that costs would increase and the rule would force them to adopt measures to reduce their participation in the interest rate markets. Recently, in other jurisdictions, there has also been strong resistance to initiatives to make central clearing mandatory. But the G-20 maintains its commitment to implement central clearing in all markets where it is feasible, so more rules mandating central clearing are expected to come into force soon.

It is therefore important to see whether central clearing really is as harmful as it appears

to be, both for market participants and for the markets. So far it has been challenging to assess whether forcing firms to clear harmed them and to what extent; to adequately compare the risks and costs, one would need firm-level exposure data of each firm to every other firm, or more detailed pricing and cost information from before and after the mandate was passed; and this information is not publicly available.

Instead, I propose the approach of looking at the direct market impact of the policy. If making central clearing mandatory had been as harmful as was expected to market participants (because of its being more risky or not sufficiently transparent or too constraining or because of high initial costs) then markets would have shrunk because of this. Figure 5 shows that volumes of notionals held by banks increased slightly immediately after the rule came into force, and several periods later they markedly decreased, which could indicate that central clearing indeed harms markets. But controlling for the general trend in trading of OTC derivatives I find that the initial increase was relatively very small and not statistically significant. In addition I find that the later decreases in market activity cannot be directly attributed to central clearing by justifying the delay in the decrease of activity to a delay in noticing change in the data because of contracts not expiring until later dates.

If central clearing did not negatively impact the markets, then the question remains of why market participants received these measures with so many objections.

It could be that incentives were not strong enough to incentivize central clearing. In that case, the costs of trading bilaterally had not increased enough to make central clearing the least costly option. But if that were true, mandating markets to centrally clear trades would have made trading more costly and would have forced companies to restructure their activity to avoid the higher costs, so it would have had an impact in the affected markets (in my study, the interest rate market). This contradicts the findings of this paper, so this explanation is unlikely.

Similarly, it could be argued that the reason why mandatory central clearing rules are received with widespread criticism is because of the high initial costs. This is also unlikely, given the findings of this paper.

An alternative explanation could be that while central clearing was initially more costly than bilateral trading for many market participants, as more adopted it, the netting benefits and lower costs associated with lower risk exposures materialized for major dealers.

While CCPs (if adequately managed) are the socially optimal solution to minimizing risks in the system by reducing both net exposures and the variability of exposures, reaping these netting benefits requires a critical mass of users. The larger the network of market participants, the greater the netting benefits of the CCPs relative to bilateral netting. This is because the CCP nets across members rather than across products. To some extent Garratt and Zimmerman (2015) formalize this when they analyze the effect of introducing a single CCP in markets with different network structures. They find that bilateral netting (without a CCP) is very efficient if there are very few key dealers who are linked to most of the system, or, equivalently, when the network heavily relies on a small group of dealers. In these market configurations, the introduction of a CCP disrupts the existing dynamic and is not always beneficial in terms of expected net exposures. This disruption may have happened when CCPs were initially introduced but used only by a few market participants.

As more participants enter the network with the CCP, benefits theoretically increase.⁸ So the larger the network is and the less reliant it is on key dealers who can net bilaterally, the larger the likelihood that introducing a CCP will not harm markets. This is again a consequence of CCPs' being able to net trades among any members if they are of the same asset class⁹, and of dealers' only being able to bilaterally net trades by counterparty but

⁹ Garratt and Zimmerman (2015) use the word "asset class," and assume CCPs can net trades among

⁸ More specifically Garratt and Zimmerman (2015) show this by comparing different core-periphery network structures and scale-free networks. They find that for a given number of agents introducing a CCP is more likely to be beneficial in a core-periphery network, and as α increases in a fat tailed network defined as a network whose degree of distribution has a tail which can be expressed as $P(S = s) s^{(-\alpha)}$, for some real valued parameter $\alpha > 1$ (i.e. a network with fatter tails in its distribution, so with a small number of nodes having most of the connections and the majority of nodes having few connections), introducing the CCP brings more netting benefits. It is realistic to picture financial networks as scale-free networks. In this case, we can think of major dealers as the highly connected nodes, and the smaller market participants as being greater in number and with few connections. An example can be found in the data used in this paper: in the interest rate markets four dealers carry out most of the activity and the majority of market participants carry out only a very small percentage of it.
across any asset class.¹⁰ Intuitively, netting is more beneficial the more trades that can be netted with each other. So agents who can net with many other agents (agents who are more connected, making them dealers) will prefer to net trades of one counterparty with another. This would be true even if they had to be restricted to netting within asset classes, because there are not as many asset classes and so the netting pool will still be very large. But agents with few trades (links) to other market participants and who for example have trades in only one asset class (and maybe even in only one direction) will prefer to net within that asset class. More likely, small agents will be relatively indifferent to how their trades are netted and will be concerned with additional costs of each system. This is for example the intuition behind Heath, Kelly and Manning's (2013) analysis showing that netting benefits of central clearing accrue disproportionately to core nodes.

Following this hypothesis, at the start, for major dealers it was too expensive to set up central clearing with smaller counterparties. The fixed costs were too high for these counterparties with limited trading activity since they do not bring in enough business and they are often risky entities that are consequently subject to high capital requirements. But if the network is large enough, dealers are benefited, not harmed, by central clearing. So at some point during the transition to mandatory central clearing and before phase 3 of the mandate (September 2013), the central clearing market was widespread enough that major dealers netting started to translate to lower costs. This benefit may have helped them be more willing and able to bring in smaller market participants into the cleared markets. This would also explain why smaller market participants complained more about costs of central clearing than did banks, and why banks instead complained about lack of transparency of

CCPs.

any members if they are of the same asset class. However in practice there are more qualities trades must have in common so a CCP can net the trades of two counterparties, so "asset class" might not be the best descriptor.

¹⁰ They show this in a very simple model without even taking into account that CCP exposures are less risky than counterparty exposures, so heavily underestimating the efficiency of CCPs' netting. They also assume that dealers can net bilaterally across asset classes with no restrictions, what means that they largely overestimate the netting efficiency of dealers netting bilaterally.

Finally, I offer the explanation that market participants feared that introducing CCPs would disrupt the existing market structure. It could decrease or increase barriers to entry for some players to become more important dealers in the system and carry out more business. For example, large dealers may have feared that with CCPs netting all transactions their market share would significantly decrease over time, or medium-sized dealers may have feared that smaller dealers would be able to offer some of the services that they could not offer before and that way would take over some of their business. This would also explain that participants complained about expanding central clearing but that its implementation did not negatively affect the markets.

Regardless of the reason why firms are not sufficiently incentivised to adopt central clearing by their own accord, this paper has shown that forcing them to do so has not been as harmful as it has been claimed. At least in the case of the interest rate markets in the United States, forcing firms to clear all their trades did not negatively impact the functioning of the markets. What's more, if the mandate had not been adopted, it seems unlikely that markets would have started to clear all their trades, which may have meant that the necessary critical mass needed for central clearing to be beneficial would not have been reached.

If central clearing is indeed safer and CCPs are well protected, it appears that regulators across the globe will continue to adopt similar measures to push for central clearing for most OTC contracts.

37

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Appendix 1

In this section I show in detail that there is no relationship between the remaining maturity of the interest rate products and the decline in the notional amounts of interest rate contracts held by banks.

I run the following regressions:

- (i) $log(notional) = \beta_0 + \beta_1(post) + \beta_2(short maturity) + \beta_3(post * short maturity) + \beta_4(bankID) + \beta_5(bankID * short maturity) + u$
- (ii) $log(notional) = \beta_0 + \beta_1(post) + \beta_2(med maturity) + \beta_3(post * med maturity) + \beta_4(bankID) + \beta_5(bankID * med maturity) + u$
- (iii) $log(notional) = \beta_0 + \beta_1(post) + \beta_2(long maturity) + \beta_3(post * long maturity) + \beta_4(bankID) + \beta_5(bankID * long maturity) + u$

Where *product* measures the interest rate notionals of any remaining maturity, *short maturity* is an indicator variable equal to one if the observation corresponds to an observation of interest rate products with remaining maturity of less than one year and zero otherwise, *med maturity* is an indicator variable equal to one if the observation corresponds to an observation of products with a remaining maturity between a year and 5 years and zero otherwise, and *long maturity* is an indicator variable equal to one if the observation corresponds to an observation of products with a remaining maturity between a year and 5 years and zero otherwise, and *long maturity* is an indicator variable equal to one if the observation corresponds to an observation of products with a remaining maturity of over 5 years and zero otherwise.

I run these three regressions for different time frames: (A) from the quarter before the mandate was implemented (December 2012 or Q4 2012) to the quarter after phase 2 (June 2013 or Q2 2013), (B) from the quarter before the mandate was implemented (December 2012 or Q4 2012) to one year after phase 2 (June 2014 or Q2 2014), (C) from December 2012 to June 2015, (D) from December 2012 to June 2016).

If the hypothesis that the reduction in the participation of banks in the markets is only noticeable at different periods in time for products of different remaining maturities is correct and banks did react to the mandate, then:

• Regressing (i):

- for time frame (A) would show the smallest change because banks even if banks had reacted to the mandate their portfolio of short term interest rate products would still contain the contracts entered before the date.
- for time frame (B) would show a greater change because all the contracts of less than one year of maturity remaining at the time central clearing was mandated would have expired. At this time banks still held many contracts entered before the date that would fall into this bucket because they were previously in the one to five years bucket.
- For subsequent time frames the change would be even smaller and increasing in magnitude. But the further out in time the greater the likelihood that other important market shocks will have affected banks' trading patterns.
- Regressing (ii) for any time frame would show smaller changes than for the corresponding time frames when regressing (i).
- Regressing (iii) would show even smaller changes than (ii) for every time frame.

The results (Table 11 and Figure 9) show very clearly that products of the three maturities are transacted at similar levels. There is no statistically significant gradual change in the notional amounts of interest rate contracts of different remaining maturities that banks held after the mandate passed. Consequently I reject the hypothesis that the reduction in bank activity in markets affected by the mandate was only noticeable after contracts entered into before the mandate came into effect expired. This is an indication that the eventual significant decrease in interest rate activity that most results show when comparing all periods before the mandate to all periods after the mandate is unlikely to be a direct consequence of introducing mandatory central clearing of interest rate products.

The results are also evidence that banks did not substitute longer maturity contracts for shorter maturity contracts. Longer maturity contracts are more risky, so such a substitution could suggest that trading risky assets became relatively more expensive.

Index of Tables and Figures

Tables:

- 1. Appendix Table 1: Products affected by the mandate
- 2. Table 2: Clearing Implementation Phases
- 3. Table 3: Bank's collateral and capital requirements under bilateral and central clearing
- 4. Table 4: Notional value of outstanding derivative contracts for March 13
- 5. Table 5: Trading revenues for March 13
- 6. Table 6: List of banks
- 7. Table 7: Summary statistics
- 8. Table 8: Results discussed in Section 5.1
- 9. Table 9: Results discussed in Sections 5.2, 5.3, 5.4
- 10. Table 10: Results discussed in Section 5.5
- 11. Table 11: Results discussed in Section Appendix 1

Figures:

- 1. Figure 1: Example of how a default is dealt with and without centrally clearing the trade.
- 2. Figure 2: Diagram of simplified trading relationships
- 3. Figure 3: Default waterfall
- 4. Figure 4: Diagram of collateral requirements
- 5. Figure 5: Graphs discussed in Section 5.1
- 6. Figure 6: Graphs discussed in Section 5.2
- 7. Figure 7: Graphs discussed in Section 5.3
- 8. Figure 8: Graphs discussed in Section 5.4
- 9. Figure 9: Graphs discussed in Section 5.5 and Appendix 1

Appendix Table 1: Products affected by the mandate

Specification	Fixed-to-floating swap class					
Currency Floating Rate Indexes Stated Termination Date Range Optionality Dual Currencies	U.S. Dollar (USD) LIBOR 28 days to 50 years No No	Euro (EUR) EURIBOR	Sterling (GBP) LIBOR 28 days to 50 years No No	Yen (JPY). LIBOR. 28 days to 30 years. No. No.		
6. Conditional Notional Amounts	No	No	No	No.		
Specification		Basis Sw	ap Class			
Currency Floating Rate Indexes Stated Termination Date Range Optionality Sould Currencies Conditional Notional Amounts	U.S. Dollar (USD) LIBOR	Euro (EUR) EURIBOR 28 days to 50 years No No No	Sterling (GBP) LIBOR	Yen (JPY). LIBOR. 28 days to 30 years. No. No. No.		
Specification	Forward Rate Agreement Class					
Currency Floating Rate Indexes Stated Termination Date Range Optionality Sual Currencies Conditional Notional Amounts	U.S. Dollar (USD) LIBOR 3 days to 3 years No No No	Euro (EUR) EURIBOR	Sterling (GBP) LIBOR 3 days to 3 years No No No	Yen (JPY). LIBOR. 3 days to 3 years. No. No. No.		
Specification	Overnight Index Swap Class					
Currency Floating Rate Indexes Stated Termination Date Range Optionality Sual Currencies Conditional Notional Amounts	U.S. Dollar (USD) FedFunds 7 days to 2 years No No No	Euro (EUR) EONIA	Sterling (GBP). SONIA. 7 days to 2 years. No. No. No.			

TABLE 5-INTEREST RATE SWAP DETERMINATION

Source: Federal Register. Clearing Requirement Determination Under Section 2(h) of the CEA; Final Rule. Vol. 77, No. 240. Part II. 17 CFR Parts 39 and 50. Commodity Futures Trading Commission. December 13, 2012.

Category/ Phase	Description	Required to clear
		on or after
Category/Phase 1	Swap dealers, security-based swap dealers, major	March 11, 2013
	swap participants, major security-based swap partic-	
	ipants, and active funds (non-3rd party subaccounts	
	with 200 or more swaps per month per year)	
Category/Phase 2	All remaining entities except for third party sub-	June 10, 2013
	accounts, and including commodity pools, private	
	funds, financial entities	
Category/Phase 3	All remaining entities including third party subac-	September 9, 2013
	counts	

 Table 2: Clearing Implementation Phases

Table 3: Bank's collateral and capital requirements under bilateral and central clearing

	Trading Bilaterally	Clearing through CCPs
Collateral Requirements	+ Initial Margin	+ Initial Margin
	+ Variation Margin	+ Variation Margin
		+ Default Fund Contribu-
		tion
Capital Requirements	Counterparty Risk Capital:	CCP Risk Capital:
	+ Basel II Counterparty	+ Trade exposure capital
	Credit Risk capital require-	charge
	ment	
	+ Basel III Credit Valua-	+ Default fund exposure
	tion Adjustment	capital charge

Source: Ghamami and Glasserman (2016)

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\$ in billions	Q1,2013	Q4,2012	\$Change	%Change	% of Total	% of Total
					in Q4,2012	in Q1,2013
Interest Rate Contracts	184,950	178,937	6,014	3%	80%	71%
Foreign Exchange	29,297	27,672	1,624	6%	12%	19%
Equity Contracts	2,023	1,952	71	4%	1%	1%
Commodity/Other	1,450	1,402	48	3%	1%	1%
Credit Derivatives	13,901	13,190	711	5%	6%	8%
Total	231,621	223,153	8,468	4%	100%	100%

$-\mathbf{L}(\mathbf{L}(\mathbf{L}))$ $+\mathbf{L}(\mathbf{L})$ $+\mathbf{L}($	Table 4: Notional	Value Outstanding	of Derivative	Contracts for	March 2013
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Source: OCCs Quarterly Report on Bank Trading and Derivatives Activities First Quarter 2013. Available at: https://www.occ.gov/topics/capital-markets/financial-markets/derivatives/dq113.pdf.

\$ in millions	1Q13	4Q12	Change	%Change	1Q12	Change	%Change
			1Q13 - 4Q12	1Q13-4Q12		1Q13 - 1Q12	1Q13 - 1Q12
Interest Rate Con-	2,217	4,151	-1,934	-47%	5,627	-3,410	-61%
tracts							
Foreign Exchange	3,185	753	2,432	323%	1,505	1,680	112%
Equity Contracts	831	136	695	511%	260	571	220%
Commodity/ Other	364	30	334	1113%	412	-48	-12%
Credit Derivatives	889	-713	1,602	225%	-784	1,673	213%
Total	7,486	4,357	3,129	72%	7,020	466	7%

Table	5.	Commercial	Bank	Trading	Revenues	for	March	2013
Table	J :	Commercial	Dank	Traumg	nevenues	101	Marcin	4 013

Source: OCCs Quarterly Report on Bank Trading and Derivatives Activities First Quarter 2013. Available at: https://www.occ.gov/topics/capital-markets/financial-markets/derivatives/dq113.pdf.

Table 6: List of Banks

This table presents the sample of 20 banks analyzed in this paper. The list consists of the 20 banks with highest total consolidated (balance sheet) assets in December, 2012, as reported in the Call Reports on the Schedule RC-Balance item 12 and Schedule RC-R Part II item 11. December 2012 is the quarter prior to the central clearing mandate's coming into force. In the table they are ranked by consolidated assets in descending order.

Bank Name	Consolidated Assets (Mil \$)	Bank ID	Rank
JPMORGAN CHASE	852218	1,896,773	1
BANK OF AMERICA	480228	1,474,077	2
CITIBANK NA/CITIGROUP	476810	1,313,401	3
WELLS FARGO	451965	1,266,125	4
USBC	504713	345,089	5
PNC	817824	295,026	6
BANK OF NY MELLON	541101	282,443	7
CAPITAL ONE	112837	250,961	8
STATE STREET	35301	218,655	9
TD	497404	203,986	10
HSBC	413208	186,790	11
BRANCH BKG&TC	852320	178,034	12
SUNTRUST	675332	169,077	13
FIA CARD SVC	1830035	167,464	14
CHASE & CO	489913	120,652	15
REGIONS	233031	120,421	16
FIFTH THIRD	723112	119,445	17
GOLDMAN SACHS, THE	2182786	118,536	18
RBS CITIZENS	3303298	104,824	19
NORTHERN TC	210434	97,139	20

Table 7: Summary statistics

Table 7 presents the summary statistics for the variables discussed in this paper. There are 468 observations: one per bank (see Table 6 for a list of all banks in the sample) per period. Each period corresponds to a quarter starting in Q2 of 2009 through Q2 2016. The table presents summary statistics for each variable for each of the time periods discussed in the paper. All variables are described in Section 4.

- The variable ir_{all} measures the sum of the notional principal amounts of all interest rate contracts held by the banks in the sample, including contracts of all remaining maturities and all interest rate contract types (e.g., interest rate swaps and interest rate forwards).
- The variable *short maturity* corresponds to the notional principal amount of interest rate contracts held by banks with a remaining maturity of one year or less (see Section 4.2.1).
- The variable *med maturity* corresponds to the notional principal amount of interest rate contracts held by banks with a remaining maturity of over one year through five years (see Section 4.2.1).
- The variable *long maturity* corresponds to the notional principal amount of interest rate contracts held by banks with a remaining maturity of over five years (see Section 4.2.1).
- The variable *irp forwards* corresponds to the notional principal amount of interest rate forwards contracts held by banks (of all remaining maturities) (see Section 4.2.5).
- The variable *irp swaps* corresponds to the notional principal amount of interest rate swaps contracts held by banks (of all remaining maturities) (see Section 4.2.5).
- The variable *fx all* measures the sum of the notional principal amounts of all foreign exchange contracts held by the banks in the sample, including contracts of all remaining maturities and all foreign exchange contract types (e.g., foreign exchange swaps and foreign exchange forwards).

It is important to note that because of the large differences between the trading volumes of banks, all variables are very positively skewed: four banks hold much more of the products than the other 16 banks in the sample.

Variable	N	Mean	St. Dev.	Min	Median	Max		
Summary Statistics for all periods								
short maturity	468	$4.40E{+}12$	$9.30E{+}12$	1.80E + 09	5.60E + 10	3.90E + 13		
med maturity	468	2.00E + 12	$3.60E{+}12$	4.90E + 08	7.50E + 10	2.20E + 13		
long maturity	468	$1.40E{+}12$	$2.50E{+}12$	1.50E + 09	5.50E + 10	$1.10E{+}13$		
irp forwards	468	$1.30E{+}12$	$2.40E{+}12$	5.30E + 05	$2.30E{+}10$	1.10E + 13		
irp swap	468	7.60E + 12	$1.30E{+}13$	2.40E + 09	$1.70E{+}11$	$4.90E{+}13$		
ir all	468	7.70E + 12	$1.50E{+}13$	3.80E + 09	$1.80E{+}11$	5.60E + 13		
fx all	468	1.30E + 12	2.40E + 12	27000	1.60E + 10	$1.10E{+}13$		
		Summary	y Statistics (Q4 2012				
short maturity	16	5.20E + 12	1.00E + 13	3.70E + 09	5.60E + 10	3.10E + 13		
med maturity	16	$1.90E{+}12$	$3.10E{+}12$	$1.50E{+}10$	7.80E + 10	8.60E + 12		
long maturity	16	$1.30E{+}12$	$2.30E{+}12$	4.80E + 09	5.50E + 10	$6.90E{+}12$		
irp forwards	16	$1.60E{+}12$	$3.00E{+}12$	$2.10E{+}07$	$3.70E{+}10$	$1.10E{+}13$		
irp swap	16	7.70E + 12	$1.30E{+}13$	$2.30E{+}10$	$1.80E{+}11$	$3.30E{+}13$		
ir all	16	$8.40E{+}12$	$1.50E{+}13$	$3.00E{+}10$	$1.80E{+}11$	$4.50E{+}13$		
fx all	16	1.20E + 12	2.30E + 12	4.60E + 07	1.80E + 10	$7.50E{+}12$		
Summary Statistics Q1 2013								
short maturity	16	5.40E + 12	1.10E + 13	2.20E + 09	5.10E + 10	3.20E + 13		
med maturity	16	$1.80E{+}12$	$3.00E{+}12$	9.40E + 09	7.70E + 10	7.80E + 12		
long maturity	16	$1.20E{+}12$	$2.10E{+}12$	2.90E + 09	5.20E + 10	$6.10E{+}12$		
irp forwards	16	$1.70E{+}12$	$3.30E{+}12$	9.50E + 06	$2.70E{+}10$	$1.10E{+}13$		

irp swap	16	7.90E + 12	$1.30E{+}13$	$1.40E{+}10$	$1.80E{+}11$	$3.40E{+}13$			
ir all	16	8.50E + 12	$1.60E{+}13$	$1.50E{+}10$	$1.80E{+}11$	$4.50E{+}13$			
fx all	16	$1.20E{+}12$	$2.30E{+}12$	$6.50E{+}07$	$1.50E{+}10$	7.40E + 12			
Summary Statistics Q2 2013									
short maturity	17	5.20E + 12	1.10E + 13	4.10E + 09	4.00E + 10	3.40E + 13			
med maturity	17	1.80E + 12	$3.10E{+}12$	$1.40E{+}10$	$6.20E{+}10$	8.70E + 12			
long maturity	17	1.20E + 12	$2.10E{+}12$	4.80E + 09	5.50E + 10	6.60E + 12			
irp forwards	17	$1.50E{+}12$	$3.10E{+}12$	4.60E + 06	$2.00E{+}10$	$1.10E{+}13$			
irp swap	17	7.70E + 12	$1.30E{+}13$	$2.60E{+}10$	$1.50E{+}11$	$3.50E{+}13$			
ir all	17	8.20E + 12	1.60E + 13	$3.10E{+}10$	$1.60E{+}11$	4.70E + 13			
fx all	17	1.20E + 12	2.30E + 12	5.30E + 07	1.80E + 10	7.50E + 12			
Summar	y Stat	istics before	the regulat	ion was pass	ed (Q1 2013	5)			
short maturity	251	4.90E + 12	1.00E + 13	1.80E + 09	6.40E + 10	3.90E + 13			
med maturity	251	1.90E + 12	$3.30E{+}12$	4.90E + 08	7.50E + 10	1.30E + 13			
long maturity	251	1.40E + 12	$2.50E{+}12$	1.50E + 09	5.40E + 10	9.80E + 12			
irp forwards	251	1.20E + 12	$2.30E{+}12$	5.30E + 05	$3.10E{+}10$	1.10E + 13			
irp swap	251	7.70E + 12	$1.40E{+}13$	2.40E + 09	$1.70E{+}11$	4.90E + 13			
ir all	251	8.10E + 12	$1.50E{+}13$	3.80E + 09	$2.00E{+}11$	5.60E + 13			
fx all	251	1.10E + 12	2.00E + 12	27000	$1.50E{+}10$	7.80E + 12			
Summa	ry Sta	tistics after	the regulation	on was passe	ed (Q1 2013)				
short maturity	217	3.80E + 12	8.40E + 12	1.80E + 09	2.70E + 10	3.40E + 13			
med maturity	217	$2.10E{+}12$	$3.90E{+}12$	8.30E + 09	7.40E + 10	2.20E + 13			
long maturity	217	1.30E + 12	$2.50E{+}12$	2.90E + 09	5.90E + 10	1.10E + 13			
irp forwards	217	1.40E + 12	2.50E + 12	4.60E + 06	$1.70E{+}10$	$1.10E{+}13$			
irp swap	217	7.50E + 12	1.20E + 13	$1.40E{+}10$	$2.20E{+}11$	4.40E + 13			
ir all	217	7.30E + 12	$1.40E{+}13$	$1.40E{+}10$	$1.70E{+}11$	4.90E + 13			
fx all	217	$1.50E{+}12$	$2.80E{+}12$	5.30E + 07	$2.50E{+}10$	$1.10E{+}13$			

Table 8: Results discussed in Section 5.1

Table 8 presents the results from the first regression (Section 5.1). The specification is: $log(ir_{all}) = \beta_0 + \delta_1(Q2, 2009) + \delta_2(Q3, 2009) + \ldots + \delta_{15}(Q4, 2012) + \delta_{16}(Q1, 2013) + \delta_{17}(Q2, 2013) + \ldots + \delta_{29}(Q2, 2016) + u$, where the dependent variable is the log of the notional amounts of the interest rate contracts of all maturities and types, ir_{all} , defined in Section 4.2.1. Q2, 2009, Q3, 2009, ..., Q2, 2016 are binary variables (dummies) equal to one if the measurement corresponds to the Call Report of that quarter, and $\delta_1, \delta_2, \ldots, \delta_{29}$ are their respective coefficients.

The first column presents the result when the regression is run as described above. The second column presents the result when an additional regressor, accounting for each of the banks, is included in the regression. Clearly it accounts for most of the variation in the outcome variable, which makes intuitive sense because each bank has a very different activity level. Finally the third column presents the result when adding an additional regressor accounting for the seasonality (see Section 4.2.6). The variable explains no significant variability in the interest rate activity levels.

	(1) notional	(2) notional	(3) notional
Q22009	0.166 (0.950)	$0.246 \\ (0.165)$	0.246 (0.165)
Q32009	$\begin{array}{c} 0.215 \ (0.936) \end{array}$	$0.244 \\ (0.151)$	$0.244 \\ (0.151)$
Q42009	-0.0996 (0.932)	0.287 (0.148)	0.287 (0.148)
Q12010	$\begin{array}{c} 0.0219 \\ (0.885) \end{array}$	$\begin{array}{c} 0.578^{***} \\ (0.164) \end{array}$	$\begin{array}{c} 0.578^{***} \\ (0.164) \end{array}$
Q22010	$\begin{array}{c} 0.354 \\ (0.928) \end{array}$	$\begin{array}{c} 0.550^{***} \\ (0.138) \end{array}$	$\begin{array}{c} 0.550^{***} \\ (0.138) \end{array}$
Q32010	$\begin{array}{c} 0.444 \\ (0.925) \end{array}$	$\begin{array}{c} 0.641^{***} \\ (0.137) \end{array}$	$\begin{array}{c} 0.641^{***} \\ (0.137) \end{array}$
Q42010	$\begin{array}{c} 0.433 \\ (0.924) \end{array}$	$\begin{array}{c} 0.630^{***} \\ (0.145) \end{array}$	$\begin{array}{c} 0.630^{***} \\ (0.145) \end{array}$
Q12011	$\begin{array}{c} 0.0603 \\ (0.893) \end{array}$	$\begin{array}{c} 0.617^{***} \\ (0.176) \end{array}$	$\begin{array}{c} 0.617^{***} \\ (0.176) \end{array}$
Q22011	$\begin{array}{c} 0.458 \\ (0.928) \end{array}$	$\begin{array}{c} 0.655^{***} \\ (0.190) \end{array}$	$\begin{array}{c} 0.655^{***} \\ (0.190) \end{array}$
Q32011	$0.538 \\ (0.924)$	$\begin{array}{c} 0.724^{***} \\ (0.198) \end{array}$	$\begin{array}{c} 0.724^{***} \\ (0.198) \end{array}$
Q42011	$\begin{array}{c} 0.441 \\ (0.933) \end{array}$	$\begin{array}{c} 0.653^{***} \\ (0.197) \end{array}$	$\begin{array}{c} 0.653^{***} \\ (0.197) \end{array}$
Q12012	$\begin{array}{c} 0.404 \\ (0.928) \end{array}$	$\begin{array}{c} 0.590^{***} \\ (0.135) \end{array}$	$\begin{array}{c} 0.590^{***} \\ (0.135) \end{array}$
Q22012	$\begin{array}{c} 0.204 \\ (0.958) \end{array}$	$\begin{array}{c} 0.417^{***} \\ (0.123) \end{array}$	$\begin{array}{c} 0.417^{***} \\ (0.123) \end{array}$
Q32012	$\begin{array}{c} 0.160 \\ (0.971) \end{array}$	$\begin{array}{c} 0.373^{**} \\ (0.136) \end{array}$	0.373^{**} (0.136)

Dec12	0.166 (0.960)	0.379^{**} (0.129)	0.379^{**} (0.129)
Mar13	$0.174 \\ (0.961)$	0.360^{**} (0.136)	0.360^{**} (0.136)
Jun13	$\begin{array}{c} 0.235 \\ (0.952) \end{array}$	$\begin{array}{c} 0.374^{**} \\ (0.130) \end{array}$	$\begin{array}{c} 0.374^{**} \\ (0.130) \end{array}$
Sep13	$\begin{array}{c} 0.0565 \ (0.993) \end{array}$	$\begin{array}{c} 0.359^{*} \\ (0.139) \end{array}$	$\begin{array}{c} 0.359^{*} \ (0.139) \end{array}$
Q42013	$\begin{array}{c} 0.0971 \\ (0.968) \end{array}$	0.295^{*} (0.142)	0.295^{*} (0.142)
Q12014	-0.136 (1.029)	$\begin{array}{c} 0.167 \\ (0.171) \end{array}$	$\begin{array}{c} 0.167 \\ (0.171) \end{array}$
Q22014	$\begin{array}{c} 0.0141 \\ (0.989) \end{array}$	$\begin{array}{c} 0.317 \\ (0.164) \end{array}$	$\begin{array}{c} 0.317 \\ (0.164) \end{array}$
Q32014	-0.0694 (1.005)	$\begin{array}{c} 0.306 \\ (0.158) \end{array}$	$\begin{array}{c} 0.306 \ (0.158) \end{array}$
Q42014	$\begin{array}{c} 0.167 \\ (0.940) \end{array}$	$\begin{array}{c} 0.359^{*} \\ (0.159) \end{array}$	$\begin{array}{c} 0.359^{*} \ (0.159) \end{array}$
Q12015	$\begin{array}{c} 0.223 \\ (0.905) \end{array}$	$\begin{array}{c} 0.126 \\ (0.118) \end{array}$	$\begin{array}{c} 0.126 \\ (0.118) \end{array}$
Q22015	$0.158 \\ (0.906)$	0.0604 (0.122)	$\begin{array}{c} 0.0604 \\ (0.122) \end{array}$
Q32015	$\begin{array}{c} 0.136 \\ (0.899) \end{array}$	$\begin{array}{c} 0.0393 \\ (0.138) \end{array}$	$\begin{array}{c} 0.0393 \\ (0.138) \end{array}$
Q42015	0 (.)	-0.0625 (0.125)	-0.0625 (0.125)
Q12016	-0.131 (0.868)	$\begin{array}{c} 0.00117 \\ (0.151) \end{array}$	$\begin{array}{c} 0.00117 \\ (0.151) \end{array}$
Q22016	$\begin{array}{c} 0.0625 \\ (0.898) \end{array}$	0 (.)	0 (.)
bank		\checkmark	\checkmark
quarter			\checkmark
Constant	$\begin{array}{c} 26.07^{***} \\ (0.639) \end{array}$	$22.86^{***} \\ (0.263)$	$22.86^{***} \\ (0.263)$
Observations R^2 p	$546 \\ 0.004 \\ 1.000$	$546 \\ 0.978 \\ 0$	$546 \\ 0.978 \\ 0$

se in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001

Table 9: Results discussed in Sections 5.2, 5.3, and 5.4

Table 9 below presents the results from Specifications 2, 3 and 4, described in Sections 5.2, 5.3, and 5.4.

The variable *post* is a dummy variable equal to one if the observation is from after the mandate was passed (Q2 2013). The variable *treated* is equal to 1 if the observation corresponds to the treatment group and is equal to 0 if it corresponds to an observation of the control group. That is, if for specification two, treatment = 1 if the observation is of interest rate notionals (and not of foreign exchange notionals, the control group); for specification three, treatment = 1 if the observation is of interest rate swaps (and not of interest rate forwards, the control group); for specification four, treatment = 1 if the observation is of J.P. Morgan, Bank of America, Citibank, Goldman Sachs and equals zero otherwise. The variable *did* is the interaction between *treated* and *post*.

The two columns (S2) present the results of Specification two, $log(notional) = \beta_0 + \beta_1(post) + \beta_2(productirp) + \beta_3(post * product irp) + \beta_4(bankID) + \beta_5(bankID * product irp) + u$. The first column presents the results of comparing all periods before March 2013 to all periods after and including March 2013. The second column presents the results of running the regression only for two quarters: the quarter before the mandate was implemented (Q4 2012), and the quarter after phase 2 (Q2 2013).

The two columns (S3) present the results of Specification three, $log(notional) = \beta_0 + \beta_1(post) + \beta_2(product swap) + \beta_3(post * product swap) + \beta_4(bankID) + \beta_5(bankID * product swap) + u$. The first column presents the results of comparing all periods before March 2013 to all periods after and including March 2013. The second column presents the results of running the regression only for two quarters: the quarter before the mandate was implemented (Q4 2012), and the quarter after phase 2 (Q2 2013).

The two columns (S4) present the results of Specification four, $log(notional) = \beta_0 + \beta_1(post) + \beta_2(top4) + \beta_3(post * top4) + \beta_4(bankID) + \beta_5(bankID * top4) + u$. The first column presents the results of comparing all periods before March 2013 to all periods after and including March 2013. The second column presents the results of running the regression only for two quarters: the quarter before the mandate was implemented (Q4 2012), and the quarter after phase 2 (Q2 2013).

	(S2) All periods	(S2) 4Q12–2Q13	(S3) All periods	(S3) 4Q12–2Q13	(S4) All periods	(S4) 4Q12–2Q13
post	$\begin{array}{c} 0.534^{***} \\ (0.0658) \end{array}$	$0.0122 \\ (0.0595)$	-0.218^{**} (0.0672)	-0.130 (0.126)	-0.292^{***} (0.0519)	-0.00850 (0.0421)
treated	5.154^{***} (0.101)	$\frac{4.629^{***}}{(0.478)}$	$\frac{1.130^{***}}{(0.0631)}$	0.826^{***} (0.0860)	8.024^{***} (0.271)	9.014^{***} (0.0306)
did	-0.840^{***} (0.0781)	-0.0142 (0.0677)	0.226^{**} (0.0800)	$0.209 \\ (0.128)$	-0.0598 (0.0756)	$0.0293 \\ (0.0499)$
bank	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
$bank^*treated$	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
constant	$ \begin{array}{c} 18.21^{***} \\ (0.274) \end{array} $	17.50^{***} (0.478)	21.70^{***} (0.283)	$21.36^{***} \\ (0.121)$	$23.35^{***} \\ (0.267)$	$22.13^{***} \\ (0.0223)$
Observations R^2 p	$ \begin{array}{r} 1111 \\ 0.967 \\ 0 \end{array} $	78 0.999 0.999	$ \begin{array}{r} 1019 \\ 0.960 \\ 0 \end{array} $	71 0.998 0.998	$546 \\ 0.975 \\ 0$	38 1.000 1.000

se in parentheses

* p < 0.05, ** p < 0.01, *** p < 0.001

Table 10: Results discussed in Section 5.5

Table 10 below presents the results from Specification 5, described in Section 5.5: $log(notional) = \beta_0 + \beta_1(post) + \beta_2(product \ maturity) + \beta_3(post * product \ maturity) + \beta_4(bankID) + \beta_5(bankID * product \ maturity) + u$

The dependent variable, $\log(notional)$, is the log of the notional amounts of interest rates contracts of each bank and of every maturity bucket: products with remaining maturity of less than one year, products with a remaining maturity between a year and 5 years, and products with a remaining maturity bucket, and the variable *post* is a dummy variable equal to one if the observation is from after the mandate was passed (Q2 2013). The variable *post* * *product maturity* is the interaction between the *product maturity* variable and the dummy variable equal to one if the observation is from after the mandate was passed (Q2 2013).

	$\begin{array}{c} \log(\text{notional}) \text{ for} \\ \text{Q4, 2012 and Q2, 2013} \end{array}$
post	-0.219 (0.164)
product maturity	-0.0411 (0.0594)
post*product maturity	$0.155 \\ (0.102)$
bank	\checkmark
bank*product maturity	\checkmark
constant	21.46***
	(0.126)
Observations	112
R^2	0.994
р	0.994

I run this specification comparing the quarter before the mandate was implemented (Q4 2012) to the quarter after phase 2 (Q2 2013).

se in parentheses

* p < 0.05, ** p < 0.01, *** p < 0.001

	(A) (short)	(A) (med)	(A) (long)	(B) (short)	(B) (med)	(B) (long)	(C) (short)	(C) (med)	(C) (long)	(D) (short)	(D) (med)	(D) $(long)$
post	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)	-0.306^{***} (0.0295)
short maturity	1.53e-13 (0.0493)			1.53e-13 (0.0493)			1.53e-13 (0.0493)			1.53e-13 (0.0493)		
med maturity		1.63e-13 (0.0493)			1.63e-13 (0.0493)			1.63e-13 (0.0493)			1.63e-13 (0.0493)	
long maturity			1.67e-13 (0.0493)			1.67e-13 (0.0493)			1.67e-13 (0.0493)			1.67e-13 (0.0493)
$post^*maturity$	1.79e-14 (0.0511)	2.79e-14 (0.0511)	1.21e-14 (0.0511)	1.79e-14 (0.0511)	2.79e-14 (0.0511)	1.21e-14 (0.0511)	1.79e-14 (0.0511)	2.79e-14 (0.0511)	1.21e-14 (0.0511)	1.79e-14 (0.0511)	2.79e-14 (0.0511)	1.21e-14 (0.0511)
bank	>	>	>	>	>	>	>	>	>	>	>	>
bank*product maturity	>	>	>	>	>	>	>	>	>	>	>	>
constant	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)	23.36^{***} (0.257)
Observations R^2 p	$\begin{array}{c} 1638 \\ 0.975 \\ 0 \end{array}$	$\begin{array}{c} 1638 \\ 0.975 \\ 0 \end{array}$	$1638 \\ 0.975 \\ 0$	$1638 \\ 0.975 \\ 0$	$1638 \\ 0.975 \\ 0$	1638 0.975 0	$1638 \\ 0.975 \\ 0$	$1638 \\ 0.975 \\ 0$	$1638 \\ 0.975 \\ 0$	$1638 \\ 0.975 \\ 0$	$\begin{array}{c} 1638\\ 0.975\\ 0\end{array}$	$1638 \\ 0.975 \\ 0$
se in parentheses	- ** **	100.0										

Table 11: Results discussed in Appendix 1

* p < 0.05, ** p < 0.01, *** p < 0.01

The table above presents the results discussed in Appendix 1:

- (i) short: $log(notional) = \beta_0 + \beta_1(post) + \beta_2(short maturity) + \beta_3(post * short maturity) + \beta_4(bankID) + \beta_5(bankID * short maturity) + u$ (ii) med: $log(notional) = \beta_0 + \beta_1(post) + \beta_2(med maturity) + \beta_3(post * med maturity) + \beta_4(bankID) + \beta_5(bankID * med maturity) + u$ (iii) long: $log(notional) = \beta_0 + \beta_1(post) + \beta_2(long maturity) + \beta_3(post * long maturity) + \beta_4(bankID) + \beta_5(bankID * long maturity) + u$ (A) Columns (A)short, (A)med, and (A)long present the results of regressing the following only comparing the measurements in 4Q2012 to 2Q2013:
- Columns (B)short, (B)med, and (B)long present the results of regressing the same equations as above but instead comparing the measurements in 4Q2012 to 2Q2014 only. B
- Columns (C)short, (C)med, and (C)long present the results of regressing the same equations as above but instead comparing the measurements in 4Q2012 to 2Q2015 only. 0
 - Columns (D) short, (D) med, and (D) long present the results of regressing the same equations as above but instead comparing the measurements in 4Q2012 to 2Q2015 only. $\widehat{\mathbf{Q}}$

All variables are defined in Appendix 1.

Figure 1

Example: An interest rate swap where party A defaults at t = 2.

t = 0

t = 1

t = 2



Figure 2

Market with no CCP







Figure 3: Default Waterfall

A Desirable CCP Default Waterfall:



Source: International Swaps and Derivatives Association (ISDA), 2013, "CCP Loss Allocation at the End of the Waterfall," ISDA Analysis Paper (New York: International Swaps and Derivatives Association, August).

Figure 4: Collateral Requirements



CCP trading (after a trade has been accepted by the CCP and novated, i.e. two new trades, one with each counterparty, have replaced the original trade between Bank A and Bank B.)



Frade CCP Guarantee Fund (GF) contributions CCP's "skin in the game" GF contribution	Legend
CCP Guarantee Fund (GF) contributions CCP's "skin in the game" GF contribution	Frade
CCP's "skin in the game" GF contribution	CCP Guarantee Fund (GF) contribution:
	CCP's "skin in the game" GF contributio

Initial margin is only posted once between the CCP and each bank. The initial margin is smaller when trading with a CCP than when trading bilaterally because it is calculated with a 5 day margin period of risk



Figure 5: Activity in the markets of all interest rate products Figure 5.1

The figure above plots the average across banks of the notional principal amounts of interest rate contracts held by the 20 banks in the sample from Q2, 2009 to Q2, 2016. The vertical line indicates the date at which the mandate came into force (Q1, 2013).

Figure 5.2



Figure 5.2 above plots the notional principal amounts of interest rate contracts held by each of the 20 banks from Q2, 2009 to Q2, 2016. The mandate came into force on Q1, 2013.

Figure 5.3



Figure 5.3 above plots the log of the notional principal amounts of interest rate contracts held by each bank from Q2, 2009 to Q2, 2016. In my analysis I use the logarithm of the notional amounts of interest rate contracts as the outcome variable.

Figure 5.4



Figure 5.4 above plots the log of the notional principal amounts of interest rate contracts held by banks on Q4, 2012 and Q2, 2013. In my analysis I use the logarithm of the notional amounts of interest rate contracts as the outcome variable. Figure 6: Average of all interest rate and foreign exchange notional amounts of derivative contracts (Specification 2) Figure 6.1



Figure 6.1 plots the average of the notional principal amounts of interest rate contracts (left) and of foreign exchange contracts (right) held by banks from Q2, 2009 to Q2, 2016.

The vertical line indicates the time when mandatory central clearing was introduced (March 2013).

70

Figure 6.2



Figure 6.2 above plots the log of the average of the notional principal amounts of interest rate contracts (left) and of foreign exchange contracts (right) held by banks from Q2, 2009 to Q2, 2016.

The vertical line indicates the time when mandatory central clearing was introduced (March 2013).
Figure 7: Average of all notional amounts of contracts of interest rate swaps and interest rate forwards (Specification 3) Figure 7.1



Figure 7.1 plots the average across banks of the notional principal amounts of contracts of interest rate swaps (left) and of interest rate forwards (right) held by banks from Q2, 2009 to Q2, 2016.

Figure 7.2



Figure 7.2 above plots the log of the average of the notional principal amounts of contracts of interest rate swaps (left) and of interest rate forwards (right) held by banks from Q2, 2009 to Q2, 2016.

Figure 8: Average of the notional amounts of all interest rate contracts held by each group of banks (Specification 4) Figure 8.1



Figure 8.1 above plots the average across each group of banks of the notional principal amounts of interest rate contracts that they held from Q2, 2009 to Q2, 2016. J.P. Morgan, Bank of America, Citibank, and Goldman Sachs from the group named *top 4*. The other 16 banks in the sample belong to the other group. This figure is relevant to Specification 4.

Figure 8.2



Figure 8.2 above plots the log of the average across each group of banks of the notional principal amounts of interest rate contracts that they held from Q2, 2009 to Q2, 2016. J.P. Morgan, Bank of America, Citibank, and Goldman Sachs from the group named *top 4*. The other 16 banks in the sample belong to the other group. This figure is relevant to Specification 4.

Figure 9: Average of the notional amounts of interest rate contracts of different remaining maturities (Specification 5)



This figure plots the average across banks of the notional principal amounts of interest rate contracts. Each line corresponds to the notional amount of contracts of each of the three maturity buckets used in Specification 5 and Appendix 1.

The vertical line indicates the time when mandatory central clearing was introduced (March 2013).