Central clearing, derivative portfolios, and bank hedging

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Abstract

The empirical literature about the effect of OTC derivatives market reforms focuses on major market participants (clearing members or dealers) and concludes that the framework creates an overall incentive towards central clearing. In this paper, we investigate the impact of the central clearing requirement on US banks and we include derivatives end-users in the analysis. We document a heterogeneous treatment effect of the clearing rule. Several years after the enactment of the clearing mandate in 2013, there is still an important heteregoneity in the extent of clearing within the group of treated banks, with a mass at zero. We provide robust evidence of a portfolio rebalacing by banks who clear less ex-post. The later substituted interest rate swaps, that are subject to the reform, for OTC interest rate options, that are not required to be cleared. As treated banks are among the biggest US banks in terms of total assets, we then investigate the treatment effect of the clearing rule on interest rate risk management. We find no evidence of a significant treatment effect on banks' off-balance-sheet hedging of interest rate risk.

JEL Codes: G21, G28, G32
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1 Introduction

OTC derivatives market reforms were mandated in 2010, under Title VII of the US Wall Street Reform and Consumer Protection Act ("Dodd-Franck Act" or DFA). This paper focuses on the impact of the central clearing requirement on the US banking sector.

Over the past few decades, OTC derivatives played a primary role in several crisis episodes such as the collapse of Long Term Capital Management (LTCM) in 1998, or the 2008 financial

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crisis with the collapse of AIG. In 1998, LTCM was betting on a reduction of the yield spread between high and low risk bonds. The notional value of LTCM's derivative contracts was more than 200 times its equity. Moreover, illiquid financial assets, and in some cases, assets of which LTCM was a substantial holder, were used as collateral in these contracts. The worsening of the Asian financial crisis that followed pushed up the yield spread. The potential for systemic risk that could result from the liquiditation of illiquid positions by counterparties in the event of LTCM default led the Federal Reserve to step in (Edwards, 1999). The high LTCM leverage was reached due to loose collateral requirements from counterparties (IMF 2003). Similarly, in 2008 AIG's portfolio of credit default swaps turned out to be under-collateralized (McDonald and Paulson, 2015)[1].

These episodes suggest that risk is mispriced in the OTC derivatives market. Acharya and Bisin (2014) relate this market failure to the lack of position transparency. In the framework of Zawadowski (2013), private agents undervalue hedging of counterparty default risk as they do not internalize that this would also benefit other market participants. Regulators are concerned by inefficient risk exposures of large market participants. This increases the chance of a systemic crisis where the fire sale of collaterals by their counterparties would bring any holder of these assets closer to default.

The DFA mandates the central clearing of standard interest rate and credit default swaps[2]. This reform essentially targets direct interconnectedness between active market participants by involving experts in counterparty risk management and by increasing payments netting opportunities.

A cleared contract involves two counterparties, A and B, and an intermediary, the central clearing counterparty (CCP). The CCP takes two opposite positions, a position with each of the counterparties. The main difference with respect to a direct contract between A and B (bilateral trading) is that the CCP insulates A and B from each other default, ie the CCP bears the losses in the event of a counterparty default. To perform this role of insurer, they rely on different protections. They have stringent collateral requirements, including both initial and variation margins. They also mutualize risk, asking for contributions to a default fund, which they use in case the guarantees provided by a defaulting counterparty is not sufficient to absorb default related losses. CCPs proved to be creditworthy counterparties after the Lehman's collapse (Cunliffe, 2018)[3].

Central clearing can potentially increase payments netting, and thereby reduce debts and exposures to counterparty credit risk. A CCP is an intermediary between a market participant and many of its counterparties. It transforms all the associated gross payments receivable and payable on a given date by a single net payment. In this sense, the advantage of a central clearing mechanism is to allow for payments netting across counterparties (multilateral netting). In this sense also, central counterparties have an informational advantage over market participants as they have a broader view on the derivative portfolios of potential counterparties. They are thus better able to measure default risk and to collect appropriate collateral.

In this paper, we study the impact of the central clearing requirement on the US banking

[1] (Singh, 2010) argues that OTC transactions were generally under-collateralized before the 2008 crisis

[2] Standard swaps or standardized swaps designate the most traded swaps.

[3] Claims against uncleared derivatives are still ongoing, while it took three weeks to the clearing house LCH to hedge and close out the $9 trillion cleared derivatives portfolio of Lehman

sector. Our goal *is not* to evaluate whether the reform achieved its objective of reducing systemic risk, which would require to have a close look at the largest market participants. On the contrary, we exclude these institutions from the sample, and instead we ask what is the effect of the reform on institutions who do not threaten the stability of the system. This has been an important concern for policy makers since the beginning of the regulatory cycle. For this reason, the rule includes an "end-user exception". Institutions with total assets below $10 billion are exempt from the clearing rule if they are derivatives end-users, that is if they use derivatives for hedging purposes[4]. Above this threshold, the reform applies to all institutions, regardless of their derivatives activity. We use the size threshold to identify treated banks, that is to split the sample into two groups including either banks to which the reform applies (treated banks) or banks that are eligible to the end-user exception (non-treated banks). Then, we investigate the heterogeneity of the treatment by focusing on treated banks.

There are several reasons for why the clearing rule may have a heterogeneous treatment effect. First, the stringent collateral requirements of CCPs place a liquidity burden on banks. This burden is mitigated if a bank benefits from the type of payments netting offered by CCPs and can effectively reduce its debt by relying on a central counterparty. This is typically the case for large dealers with portfolios rich in offsetting positions and who have multiple counterparties. Second, central clearing involves to pay fixed costs, such as minimum clearing fees, which penalizes banks with a smaller derivatives activity. Third, clearing service providers may be selective. The first post-implementation analysis documents that some market participants may find themselves denied access to clearing.

We use the US Reports of Condition and Income (Call Reports). Financial institutions such as banks are required to fill these reports by the Federal Financial Institutions Examination Council (FFIEC) on a quarterly basis. Beyond balance-sheet and income statements, Call reports also provide information about banks' derivative positions. We limit the analysis to interest rate derivatives because they are the most traded derivatives, especially interest rate swaps, which account for 59% of the total gross notional amount outstanding at the end of 2018[5]. Moreover, they represent the biggest share of banks' derivative portfolios. In our sample, interest rate derivatives represent on average 94% of the total notional amount of derivatives[6]. Also, the reform is recent and applies only to new positions in standard swaps. As the average maturity of interest rate derivatives is shorter (30% of interest rate contracts have a maturity up to one year against 10% for credit derivatives), it should affect interest rate derivatives activity first (Sidanius and Zikes, 2012).

Our first result is that overall the share of cleared interest rate derivatives is low for non-treated banks. This finding supports the idea that either central clearing does not have

[4]The exact definition of end-user positions is "positions taken for a purpose other than trading". See for instance `https://www.occ.gov/news-issuances/bulletins/2014/bulletin-2014-8a.pdf`. Moreover in the clearing rule, regulators specify that only positions used to hedge are exempt from clearing.

[5]See BIS OTC derivatives statistics. In comparison, credit default swaps represent 1.5% of total notional outstanding. In the US, standard swaps are mandated to be cleared through a central counterparty (CCP) since 2013. Standard swaps or standardized swaps designate swaps whose terms, such as maturity or payment frequency, are the most traded.

[6]Among the different types of interest rate contracts available in our data (ie future, forwards, options and swaps), swaps represent 64% of the total.

much value for these banks, or that central clearing involves substantial costs for these banks, or that they face difficulties in accessing central clearing. This result is interesting in itself because most of non-treated banks are derivatives end-users. Moreover, we find that several years after the reform, there are still treated banks who do not clear their derivatives, and that the dispersion in the extent of clearing within the group of treated banks is high. For this reason, we complement our identification strategy of the effective treatment by dividing the treatment group into two subgroups with more (HC banks) or less (LC banks) of cleared derivatives in their portfolio. Then, we pursue the analysis with difference-in-difference estimations.

Our second result is that after the reform, LC banks substituted OTC interest rate swaps (subject to the clearing rule) for interest rate options (not required to be cleared). This result is robust to change of counterfactual, using alternatively either banks that are eligible to the end-user exception or HC banks. This suggests that a significant part of treated banks either avoid central clearing, or are denied access to central clearing.

Then we study the potential determinants of this portfolio reallocation. We find that, before the reform, banks who rebalance their portfolio had less multilateral netting opportunities and were therefore likely to face a higher collateral demand (ie a higher liquidity burden) with central clearing. An alternative way to interpret the indicator of multilateral netting opportunities is in terms of dealer activity. Under this interpretation, banks who rebalance their portfolio have a smaller dealer activity or are pure end-users. Moreover, we also find that these banks had a smaller derivatives activity which supports the idea that they may face a higher average fixed cost of central clearing.

Then, we continue this analysis by focusing on the incentive provided by the Basel III framework. Capital charges have been modified to include higher risk weights for uncleared derivatives and thereby to promote central clearing and mitigate regulatory arbitrage. We find that banks who reallocate ex-post were significantly better capitalized ex-ante. In this sense, therefore, Basel III provides less incentive to banks who reallocate because the distance between their level of capitalization and the regulatory bound is significantly higher. We also study the treatment effect of Basel III on LC banks relative to HC banks. We find no evidence of a significative treatment effect. Moreover, we find that overall LC banks hold less risky derivative positions relative to HC banks. This suggests that in absence of reallocation, LC banks would have face a significantly lower extra Basel III capital charge, and that the portfolio reallocation neutralizes the treatment effect of Basel III.

At this stage, we showed that the clearing rule had a heterogenous treatment effect in that part of treated banks do not comply with it. This reflects a portfolio rebalancing towards interest rate derivatives that are not subject to the reform. As treated banks are among the biggest US banks in terms of total assets, we then continue by asking whether the clearing rule had a treatment effect on banks' off-balance-sheet interest rate risk management. We find no evidence of a significant treatment effect on bank hedging of interest rate risk. Our work is still ongoing.

The rest of the paper proceeds as follows. Section 2 presents a review of related research. Section 3 documents the new regulatory environment. Section 4 describes the data, and presents the stylized facts that motivate the paper. Section 5 presents the empirical model used to perform the estimations. In section 6, we analyze the treatment effect of the clearing rule on derivative portfolios. Section 7 investigates the determinants of this portfolio reallocation. In section 8, we focus on the treatment effect of the clearing rule on banks' off-balance-sheet hedging of interest rate risk. Section 9 concludes.

2 Literature review

Our paper is related to the literature focusing on the drivers of counterparty risk and the benefits of central clearing. In the framework of Zawadowski (2013), private agents hedge idiosyncratic risk with derivatives. They undermine counterparty risk as they do not endogenize default contagion. In (Biais et al., 2016), finding good protection sellers requires to pay a search cost. Depending on their degree of risk aversion, protection buyers may prefer an insurance of lower quality. In (Acharya and Bisin, 2014), the portfolio of the insurer is private information, and insurance is mispriced. This creates a moral hazard. Provided that the cost of bankruptcy is not too high, the insurer may prefer to cumulate premiums upfront and to default ex post. In (Biais et al., 2016), a clearing mechanism is welfare improving as it allows protection buyers to mutualize idiosyncratic risk, while in (Acharya and Bisin, 2014), it solves the opacity problem.

Several papers investigate the effect of central clearing requirements on prices. Regarding credit default swaps, Loon and Zhong (2014) and Akari et al. (2019) find that CDS spreads increase with the introduction of central clearing, which suggests a reduction of counterparty risk premia. On the contrary, Du et al. (2019) find that counterparty risk affects the choice of counterparties and that central clearing had a limited impact on CDS spreads. For interest rate swaps, Cenedese et al. (2019) find evidence that dealers pass regulatory costs on to clients, and that the fixed rate in uncleared contracts is higher.

Another strand of the literature focuses on the trade-off between cleared and uncleared derivatives. Duffie and Zhu (2011), Kubitza et al. (2018) and Cont and Kokholm (2014) investigate the effect of multilateral versus bilateral netting on collateral demand. Duffie et al. (2015) present a margin model calibrated on bilateral exposure data for the CDS market. They find that aggregate collateral demand increases with intial margin requirements, but, conditional on these margin requirements, mandatory central clearing reduces system-wide collateral demand. Ghamami and Glasserman (2017) focus on derivatives dealers within bank holding companies that are clearing members of CCPs. They find that the degree of netting, the calibration of margins and capital charges (especially the period of risk), and the size of the contribution to the default fund of the CCP are important drivers of the choice between cleared and uncleared derivatives.

Our paper is also related to interest rate risk management by banks (see Vuillemey (2016) for a survey of the literature). Several papers show that banks' hedging with interest rate derivatives is limited (Purnanandam, 2007), (Rampini et al., 2019), and point to financial constraints as the main explanation. In an environment where debt finance and hedging are both subject to collateral constraints, hedging has an opportunity cost in terms of lending. As the reform we are focusing on possibly affects collateral demand, this suggests that it may also affect hedging.

3 A new regulatory framework

In this section, we first present the bilateral environment that prevailed before the reform. Then we introduce central clearing to highlight the role of central counterparty clearing houses (CCPs) and the main differences with respect to bilateral trading. The section ends with a presentation of the new regulatory environment and a brief review of the insights drawn from the first post-implementation analysis of OTC derivatives market reforms.

3.1 The pre-reform regime : mostly bilateral

Prior to the crisis, market participants were free to negociate either a bilateral trade or a trade that was then submitted to a CCP. Most derivative transactions were bilateral. FSB (2018) estimates the outstanding notional amount of cleared interest rate derivatives (IRDs) to 24% of total notional in 2009.

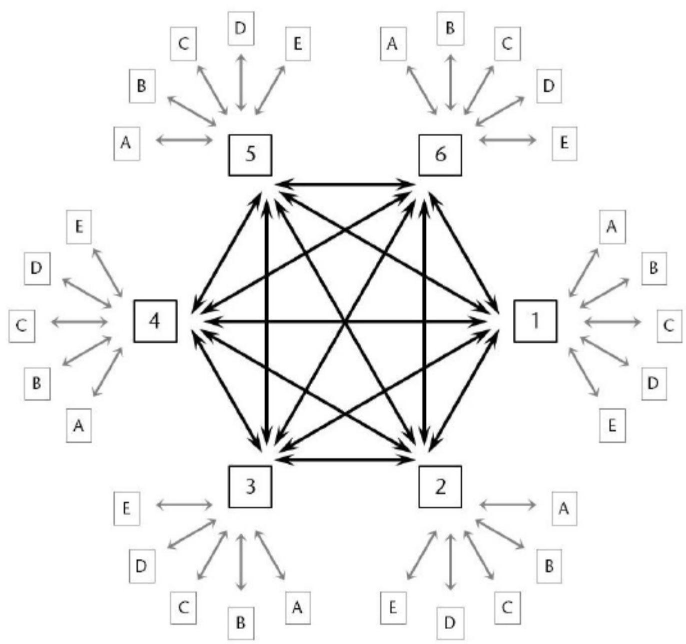


Figure 1: Conceptual schematic of the OTC derivatives market. The dealers are represented by the large boxes, with the thick arrows representing the large inter-dealer portfolios. End-users are symbolised by smaller boxes, with fewer trades connecting them to their dealers. Source Murphy (2013)

As depicted in Figure 1, a bilateral OTC derivatives market includes two types of market participants, end-users and dealers. End-users take positions in derivatives for their own account and mostly to hedge, for exemple to hedge against an interest rate increase. Dealers can either take positions as end-users or on behalf of their clients, the end-users. Dealers have prepared price quotes and are thus prepared to address the demand of end-users. Then, they typically hedge this risk by taking opposite positions in the inter-dealer market. Some dealers, the largest ones, are market-makers in the sense that they are prepared to enter into a trade without taking an opposite position with another counterparty. Bilateral trading refers to the fact that the terms of the contracts, including the execution prices and collateral amounts posted as a guarantee, are not public. They are set and known only by the two parties involved in the transaction who are free to negociate any mutually attractive deal.

Market participants have significant numbers of trades with each others, some of which may potentially offset[7]. Typically, two parties sign a master agreement[8], which allows to pool together all the transactions executed between them, and to replace all the associated gross payments owed on a given date by a single net payment. This net payment is as low as there are offsetting risk positions in the portfolio (ie netting or diversification opportunities). This payments netting is known as bilateral netting. One advantage is that this may allow to significantly reduce the losses in the event of a counterparty default (ie the exposure to counterparty credit risk).

In order to further reduce the net exposure to counterparty credit risk, market participants usually sign collateral agreements. The question is to which extent they do reduce this risk. From survey data, ISDA (2009) estimates that the average level of collateralization in 2009 was 66 % of net credit exposure before collateral taken. Moreover, Murphy (2013) documents that prior to the crisis, variation margins (ie devoted to cover changes in the market value of a portfolio) were the most common form of collateral posted. Analyses of institution failures such as AIG (McDonald and Paulson, 2015) also reveal that market participants agreed on a threshold below which additional collateral was not transferred. In the case of AIG, this threshold was based on AIG's credit rating.

3.2 Central clearing

A CCP is an intermediary between a buyer and a seller[9], who offers protection against the default of bilateral partners. Assume A and B are willing to take a position in a cleared interest rate swap, A being the fixed rate payer, and B the floating rate payer. In a cleared trade, the CCP takes two opposite positions, a long position against A, and a short position against B. The two parties are exposed to the CCP default rather than to each other default, while the CCP bears the credit risk of each counterparty. In practice, CCPs delegate part of the insurance to clearing members that are typically the largest dealers in the market[10]. In this sense, from the standpoint of market participants, relying on a CCP may reduce their exposure to counterparty credit risk.

[7] One reason is that a few dealers serve a large number of end-users with diversified needs. Another one is that this may be more interesting to take a new position to offset an existing position rather than selling an ongoing and thus less standard (less liquid) position.

[8] The Master Agreement published by the International Swaps and Derivatives Association, known as the ISDA Master Agreement, is the international standard to determine contract terms and includes a credit support documentation which defines the conditions for collateral exchanges.

[9] For interest rate swaps, the buyer is the fixed rate payer.

[10] In the US, the agency model of clearing prevails for institutions that are not clearing members (ie that are clearing member clients). Clients trade directly with the CCP but clearing members guarantee their contractual requirements and handle their default if any. See Murphy (2013), Gregory (2014).

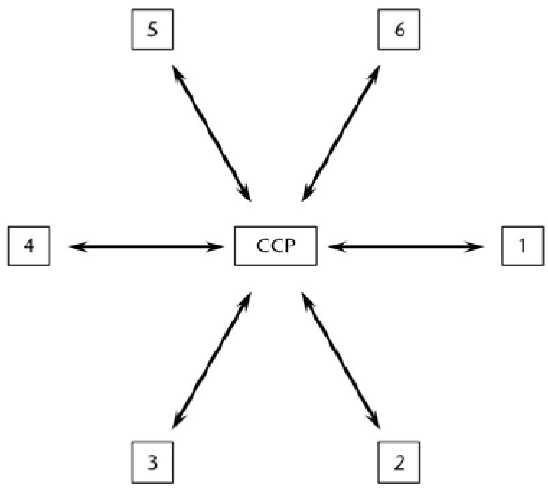


Figure 2: Conceptual schematic showing the six bilateral OTC derivatives dealers of figure 1 clearing all trades at a single CCP. Source Murphy (2013)

In the same way as in bilateral trading, CCPs sign master agreements with their counterparties. They offer multilateral netting opportunities. Figure 2 provides a simplified exemple of multilateral netting in which there is only one CCP, all derivatives are cleared, and we abstract from end-users. The main idea is that the master agreement between the CCP and a market participant includes the trades of this participant with many counterparties while in a bilateral environment, portfolios are splitted across counterparties. In this sense, multilateral netting may further reduce net exposures to credit risk compared to the bilateral scenario, and reduce collateral amounts posted by market participants. This form of payment arrangement should primarily benefit to dealers. As discussed in the previous subsection, part of their business is hedging in the inter-dealer market the diversified positions taken to serve the demand of end-users. This implies that dealers have more offsetting risk positions than end-users. This also implies that they have more counterparties because this seems unlikely that the same two dealers hedge two exactly opposite positions in the same time at any point in time.

CCPs perform their role of insurer by requiring several guarantees[11], including stringent collateral requirements. On top of variation margins, they require initial margins (ie devoted to cover losses that might occur between the default of a counterparty and the portfolio close-out). Margins are restricted to high quality assets. They are typically recalculated daily and there is no threshold below which they are not posted. In this sense, central clearing introduces a liquidity burden on market participants as this requires to always have cash available to meet margin calls (see Murphy (2013)). The effect of central clearing on

[11] CCPs have four levels of protection to absorb default related losses. First, they delegate part of insurance to clearing members that are selected based on criteria such as a certain level of financial ressources. Second, stringent initial and variation margins are demanded to clearing members and clearing member clients. Third, they mutualize losses associated to a clearing member default by requiring clearing members to contribute to a default fund. Fourth, they have a mechanism to recapitalize. They can require clearing members additional contributions to the default fund if needed. See Heller and Vause (2012) among others for more details.

collateral amounts posted by market participants is therefore unclear and largely depends on their derivatives activity.

3.3 Clearing rule and Basel III framework

The DFA mandates the central clearing of new standard interest rate swap and credit default swap contracts[12]. Implementation was phased in over the first three quarters of 2013. The clearing rule includes an exemption, the end-user exception. Banks with total assets below $10 bn who are derivatives end-users are not subject to the clearing requirement. They are still free to choose between bilateral and cleared contracts[13]. Moreover, the clearing requirement does not apply to trades with exempted banks. This exemption relates to the fact that the reform targets inefficient risk exposures and systemic risk, especially direct interconnectedness between systemic institutions. Moreover, the potential extra costs associated with central clearing could reduce the ability of end-users to hedge (ISDA 2013).

In January 2015, i.e. two years after the enactment of the clearing requirement, Basel III became effective in the US, with new standards regarding risk-weighting of derivatives[14]. They include the abolition of the 50 % cap, and the introduction of positive risk weights for centrally cleared derivatives (a weight of 0 % was used before). However, in order to support central clearing, they are significantly lower than those applied to non-cleared derivatives. Weights for derivatives traded with a CCP are between 2% and 4% whereas they are of at least 20% for other counterparties (except for sovereigns). Compared to the clearing mandate, there is no exemption.

The first post-implementation analysis (FSB 2018) uses different data sources, mostly survey data, and provides some insights regarding the effect of post-crisis reforms. The report documents that central clearing of IRDs has increased, even for products to which the clearing rule does not apply, and amounts to 62% in 2017. This suggests that central clearing became a common practice, and that CCPs became sort of liquidity pools, which increases netting efficiencies. Both dealers and non-dealers report that counterparty risk management and regulatory capital costs are among the main incentives to clear. Netting opportunities are also an important incentive for dealers. For both, dealers and non-dealers, initial margins and fixed costs of clearing are the main disincentives. Moreover, some market participants also report difficulties in accessing clearing services, or having restrictions on their activity of cleared derivatives. The analysis concludes that the clearing rule might benefit to participants with larger derivatives activity and might involve substantial costs

[12]Standard interest rate swaps include a subset of swaps, the most traded, with specific caracteristics (ie type of swap, currency, floating rate index, maturity). The list of swaps required to be cleared is available at: `https://www.cftc.gov/sites/default/files/idc/groups/public/@otherif/documents/ifdocs/clearingrequirementcharts.pdf`. The clearing mandate does not apply to legacy trades.

[13]Banks of which the deposits are insured by the FDIC, of which total assets do not exceed $10 billion on the last day of the bank's most recent fiscal year, and that are using the swap to hedge or mitigate commercial risk, are eligible to the exemption. See `https://www.cftc.gov/sites/default/files/idc/groups/public/@lrfederalregister/documents/file/2012-17291a.pdf`

[14]Basel III entered into US law in September 2013 and became effective for most institutions in January 2015. See `https://www.fdic.gov/regulations/laws/federal/2013/2013-09-10_final-rule-interim.pdf`. For a summary of the main changes regarding risk weights, see `http://usbaseliii.com/tool/index.html`

for others, especially for non-dealers.

4 Data and Stylized Facts

Our analysis is based on the US Reports of Condition and Income (the Call Reports), which provide quarterly financial data of US banks.[15] These reports are monitored, ensuring an homogeneous and reliable reporting. In addition to balance sheet and income statements, Call Reports provide information on banks' derivative portfolios. Regarding IRDs, the data provide a breakdown of the total notional amount across the different types of contracts available to banks, i.e. swaps, futures, forwards and options. Additionally, we have a breakdown between positions held for trading and positions held for other purposes (mostly to hedge)[16]. Notional amounts of centrally cleared IRDs are available but only from 2015 onwards (ie two years after the enactment of the clearing mandate). We use these data to investigate the ex-post heterogeneity in cleared derivative positions. Banks also report the net current credit exposure associated with the entire portfolio of derivatives (ie this includes IRDs and other categories such as credit derivatives). We use this variable to measure multilateral netting opportunities.

We consider a balanced sample of banks operating from 2010q1 to 2018q4. We limit the sample to non-clearing members with a positive notional amount of interest rate swaps during at least one quarter over the period considered.[17] We first split our sample into a group of treated banks and a group of non-treated banks. The former includes banks that *are not* eligible to the end-user exception over the whole period following the implementation of the reform, i.e. banks with total assets greater than \$10 billion from 2013q1 onwards. On the contrary, the group of non-treated banks includes banks that are eligible to the exception, i.e. with total assets below the \$10 billion threshold throughout the period considered.[18] Our final sample includes 53 treated banks and 254 non-treated banks.

Figure 3 presents the evolution of the mean share of cleared IRDs from 2015q1 onwards. We observe a positive trend for the group of treated banks. The share of cleared contracts increases from 17% in 2015q1 to 40% in 2018q4. This reflects the fact that only new contracts are subject to the clearing requirement, and that the average treated bank complies with the clearing requirement. Regarding the group of non-treated banks, the mean share of cleared contracts is very low, closed to zero. This suggests either that they face difficulties

[15]Every national bank, state member bank, insured state nonmember bank, and savings association is required to file a consolidated Call Report, available at `https://cdr.ffiec.gov/public/`

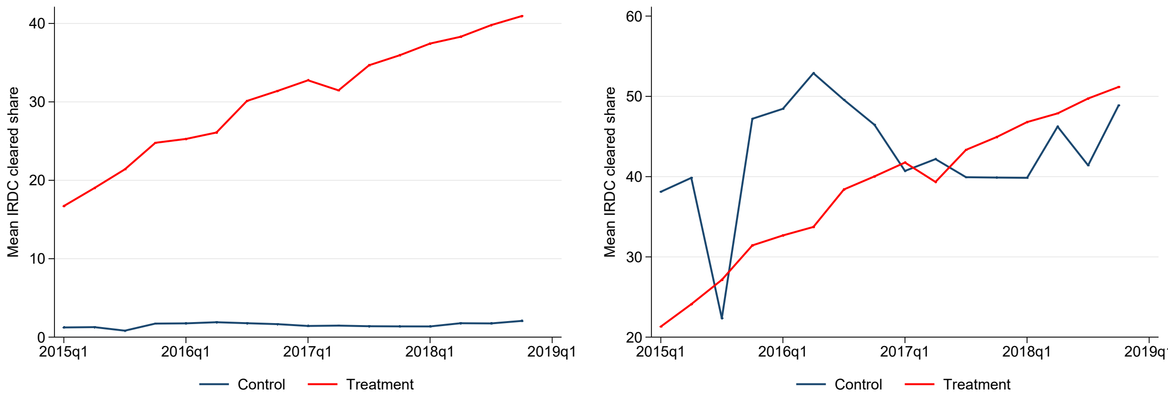
[16]The definition of derivatives held for trading purposes is provided in the user's Guide for the Bank Holding Company Performance Report : "The gross notional amount or par value of derivative contracts (interest rate contracts, foreign exchange contracts, equity derivative contracts, and commodity and other contracts) that are held for trading purposes. Besides derivative instru ments used in dealing and other trading activities, this line item covers activities in which the BHC acquires or takes derivatives positions for sale in the near term or with the intent to resell (or repurchase) in order to profit from short-term price movements, accommodate customers' needs, or hedge trading activities". See `https://www.federalreserve.gov/boarddocs/supmanual/bhcpr/UsersGuide13/0313.pdf`

[17]We identify clearing members with their contribution to CCPs' default funds registered in their balance sheets.

[18]We exclude banks with total assets lower than \$1 billion from the sample of non-treated banks to improve comparability.

in accessing clearing services or that they avoid clearing. Moreover, we do not observe a similar trend, which may suggest that they are using the end-user exception.

Figure 3: **Share of cleared interest rate derivatives: treated versus non-treated banks**



(a) All banks

(b) Banks that clear at least once

Note: Mean ratio of the notional amount of centrally cleared interest rate derivatives over total notional amount of interest rate derivatives, in percentage. Panel (a) is based on the full sample of banks in treatment and control groups. Panel (b) includes only banks with a positive notional amount of centrally cleared interest rate derivatives during at least one quarter.

Figure 4 presents the distribution of the share of cleared IRDs within the group of treated banks over the same period (white bars). The mean share amounts to 30%. We observe a high dispersion, with a mass at zero. The notional amount of cleared IRDs is zero for about 30% of observations despite the clearing mandate enacted in 2013.

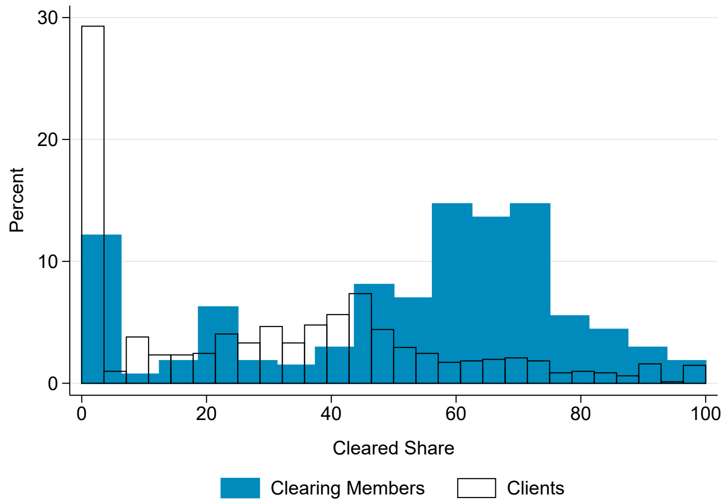
This heterogeneity, especially the low shares, may be due to several factors. First, the clearing requirement applies only to new standard swaps. The mass at zero and low values could be due to a slow portfolio turnover. However, the maturity of interest rate contracts is relatively low in our sample[19] and there are 12 treated banks (out of 53) that do not clear once over this period. Second, some banks may prefer non-standard products, ie that are not required to be cleared or not available in cleared form[20]. Third, they may not have access to clearing services[21]. Fourth, the value of central clearing is low or the cost is high and banks prefer to not clear. Under the last two hypotheses, the reform should translate into portfolio reallocations or into a reduction of derivatives activity. In section 6, we investigate the impact of the reform on the composition of derivatives portfolios. The impact on banks' hedging of interest rate risk is addressed in section 8.

[19] 30% of interest rate contracts have a maturity below 1 year.

[20] ISDA (2013)

[21] FSB 2018: "Some client clearing service providers reported having high fixed costs and may in some cases be disinclined to provide access to some classes of clients".

Figure 4: **Share of cleared IRDs: clearing members versus non-clearing members**



Note: This figure shows the distribution of the share of cleared interest rate derivatives in the portfolio of IRDs within the group of treated banks (white bars). As a comparison, it also shows the distribution for clearing members.

5 Empirical setup

We use the difference-in-differences specification (1) to estimate the impact of the reform.

$$\begin{aligned} \mathrm{E}[Y_{it}|\alpha_i, Group_i, \mathbf{x}_t] = \quad & \alpha_i + \sum_{Year \neq 2012} \lambda_{Year} \mathrm{Year}_t \\ & + \sum_{Year \neq 2012} \beta_{Year} (\mathrm{Group}_i * \mathrm{Year}_t) \end{aligned} \tag{1}$$

where i and t denote respectively a bank and a quarter, α_i is a bank fixed effect, $Year_t$ are indicator variables for years, and $Group_i$ is a dummy variable equal to one if bank i belongs to $Group_i$ and equal to zero if bank i belongs to the counterfactual group.

We estimate this model with ordinary least squares. The reason why we use bank fixed effects rather than a group fixed effect is that in our case the treatment is not randomly assigned since it depends on total assets. However, the two alternative specifications generate very similar estimates. We also extend the standard specification to track the dynamics of the treatment. The intuition is that one should not expect the treatment to have an early impact. On the one hand, the phase-in period lasts for three quarters. On the other hand, as discussed in section 3, the reform applies only to new positions. In that context, the treatment depends on banks' portfolio turnover. We use 2012 as the reference year, that is the year preceding the reform. The parameters β_{Year} measure the average treatment effects. Under the parallel trend assumption, one should expect to observe that there is no treatment effect before the reform, that is $\beta_{Year} = 0 \; \forall Year \in \{2009, 2010\}$. Table B2 in the appendix also provides a comparison of relevant financial ratios between groups before the reform.

Alternatively, for specifications in which the dependent variable is a share (ie. the share of interest rate swaps or the share of OTC interest rate options in derivative portfolios),we follow Papke and Wooldridge (2008) and proceed to a quasi-maximum likelihood estimation of the fractional logit model (2). Beyond the consideration of non-linear effects, this method has been developed to impose a bounded effect of explanatory variables on the dependent variable.

$$\begin{aligned} \mathrm{E}[Y_{it}|Group_i, \mathbf{x}_t] = \quad & \Lambda\Big(\alpha Group_i + \sum_{Year \neq 2012} \lambda_{Year} \mathrm{Year}_t \\ & + \sum_{Year \neq 2012} \beta_{Year} (\mathrm{Group}_i * \mathrm{Year}_t)\Big) \end{aligned} \tag{2}$$

where $\Lambda(z) = \exp(z)/[1 + \exp(z)]$ denote the logistic function.

6 Central clearing and derivative portfolios

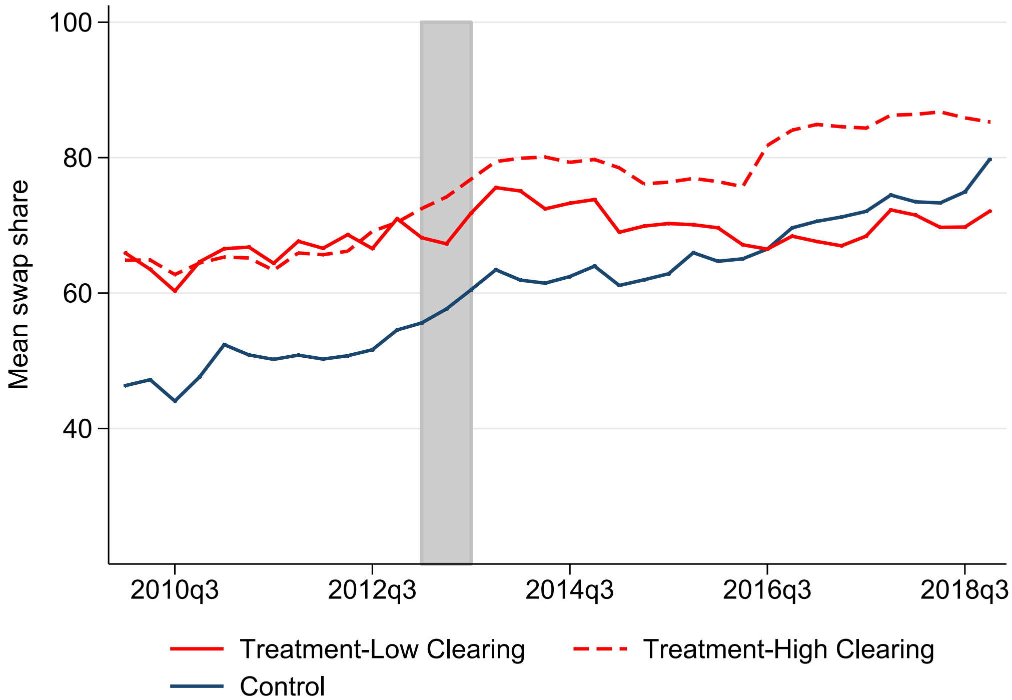
In this section, we investigate the impact of the reform on the composition of derivative portfolios, especially on the share of interest rate swaps and OTC interest rate options. We test the hypothesis of a portfolio rebalancing for treated banks who clear less ex-post. To do this, we divide the group of treated banks in two subgroups including either banks with a mean level of cleared contracts above the median over the period 2015q1-2018q4 (HC banks), or banks with a mean level of cleared contracts below the median (LC banks).

Figure 6 shows the evolution of the mean share of OTC interest rate options. From 2013 onwards, the option share decreases steadily for both treated banks that rely more on clearing (dotted red line) and for non-treated banks (solid blue line), while there is a trend reversal for treated banks with low clearing levels (solid red line). These observations suggest that treated banks with relatively less of cleared derivatives ex-post rebalanced their portfolio by substituting OTC interest rate swaps for interest rate options.

Figure 5 shows the evolution of the mean share of interest rate swaps (i.e. the notional amount of interest rate swaps divided by the total notional amount of IRDs) for LC and HC banks. While the trends are very similar in the pre-reform period, they differ from 2013 onwards. There is a slow decrease of the swap share for LC banks (solid red line) compared to both HC banks (dotted red line) and to non-treated banks (solid blue line). Summary statistics of derivatives portfolios for either of the three groups are presented in Table A1 of appendix A.

To confirm this result, we estimate the model (1) by replacing the variable $Y_{i,t}$ with the swap share, and the variable $Group_i$ with a dummy variable equal to one if the bank belongs to the group of LC banks and equal to zero if it belongs to the group of HC banks. The first column of Table A2 presents the parameter estimates. The results indicate that LC banks reduced significantly the share of interest rate swaps in their portfolio from 2016 onwards relative to other treated banks. The difference ranges from -12 percentage points in 2016 to -17 percentage points in 2018. Importantly, the coefficients for pre-reform years (i.e. 2010 and 2011) are not significantly different from zero. This confirms the assumption of pre-treatment parallel trends needed to insure identification in the difference-in-differences framework. Alternatively, column 2 displays the coefficients obtained when the reference period includes all pre-reform years (2010-2012). The results are robust to change in the reference period.

Figure 5: **Share of Interest Rate Swaps for *LC* Banks, *HC* Banks and non-treated banks**



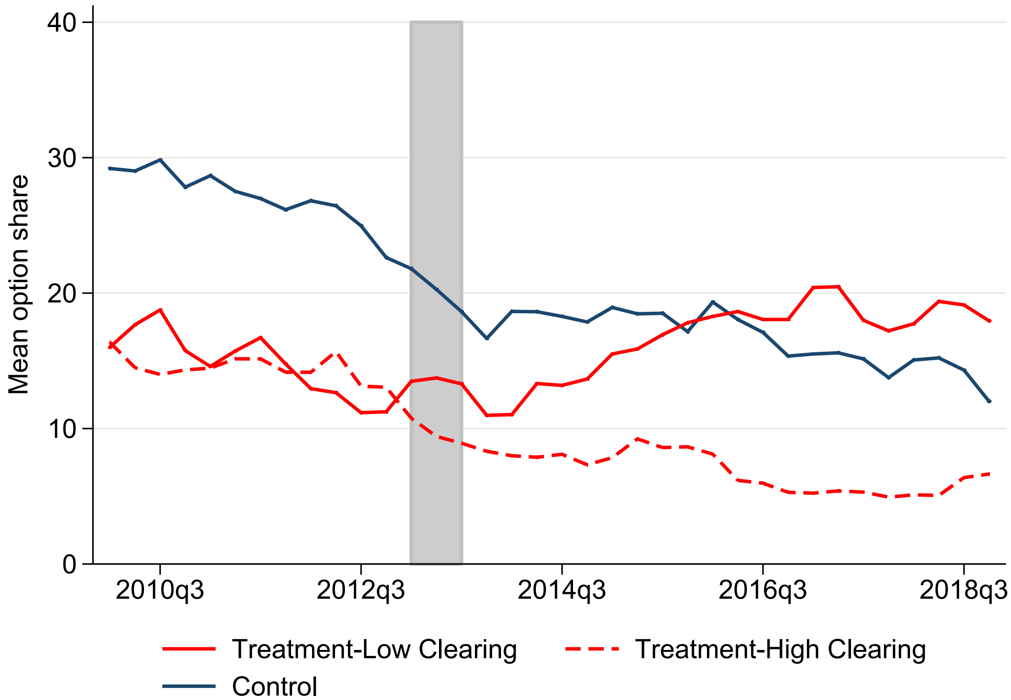
Note: Mean share of interest rate swaps, in percentage. The share of interest rate swaps is the ratio of the notional amount of swaps divided by the total notional amount of interest rate derivatives in bank's portfolio. *High clearing* banks are those with a mean clearing level above the median level of the group (i.e. *HC* banks). *Low clearing* banks are those with a mean clearing level below the median level of the group i.e. *LC* banks. The shaded area represents quarters 1 to 3 of 2013, which correspond to the implementation of the clearing mandate.

The same model is estimated by replacing the variable $Y_{i,t}$ with the option share. The results are reported in columns 3 and 4 of Table A2. The parameters of interest are positive and significant for the years 2016 to 2018, which indicates that LC banks increased significantly the share of OTC options in their portfolio compared to HC banks. The parameter estimates vary between 11 percentage points and 14 percentage points. Columns 5-8 present the results associated with the estimation of the fractional outcome model (2).[22] The estimates are consistent with those obtained in the linear case.[23]

[22] The fractional logit model does not successfully converge when bank fixed effects are included. As a result, we estimate the model with group fixed effects, as specified in equation (2).

[23] We also computed the average marginal effects of each fractional logit model presented in columns 5 to 8. They are very close to the marginal effects obtained in the linear case and hence not reported.

Figure 6: **Share of Interest Rate Options of *LC* Banks, *HC* Banks and Control Group**



Note: Mean share of interest rate options, in percentage. The share of interest rate options is the ratio of the notional amount of purchased and written options divided by the total notional amount of interest rate derivatives in bank's portfolio. *High clearing* banks are those with a mean clearing level above the median level of the group (i.e. *HC* banks). *Low clearing* banks are those with a mean clearing level below the median level of the group (i.e. *LC* banks). The shaded area represents quarters 1 to 3 of 2013, which correspond to the implementation of the clearing mandate.

These findings may be driven by other factors that are independent of the clearing mandate, ie a time-varying omitted variable that would affect differently the two subgroups. As a robustness check, we compare HC banks with banks that are exempt from the clearing requirement. We replace the variable $Group_i$ with a dummy variable equal to one for HC banks and zero for non-treated banks. Parameter estimates are presented in Table A3. We do not find that the portfolios of derivatives evolve differently. This suggests that HC banks are a valid counterfactual, and that the reform had no impact on HC banks.

To complete the analysis, we also compare LC banks with non-treated banks. We replace the variable $Group_i$ with a dummy variable equal to one for LC banks and zero for non-treated banks. The results are similar to those obtained in Table A4. *LC* banks reduced significantly the share of swaps and increased significantly the share of options in their portfolio relative to non-treated banks [24].

This set of results provides robust evidence that treated banks with relatively less of

[24] Due to the higher number of observations, estimates are associated with lower p-values in this specification

cleared derivatives ex-post engaged in a portfolio rebalancing by substituting mandated instruments (i.e. swaps) for non-mandated products (i.e. OTC options).

7 The determinants of portfolio reallocation

In this section, we investigate the determinants of the portfolio reallocation documented in section 6.

7.1 Heterogeneous netting opportunities and scale of activity

In practice, the efficiency of multilateral netting is reduced. All derivatives are not clearable. Moreover, CCPs are typically specialized in the clearing of one derivatives category such as IRDs or credit derivatives (see Benos et al. (2019)). In this sense, one should view multilateral netting as a payments netting across different counterparties and across a single class of derivatives (see Duffie and Zhu (2011)).

This suggests that we can proxy multilateral netting opportunities by comparing the net and gross credit exposures across IRD positions. Call reports provide net credit exposures on the entire portfolios without breakdown. That being said, the average share of IRDs in the portfolio of treated banks amounts to 85%. To some extent, therefore, the net credit exposures should reflect the netting of IRDs positions. In what follows, we construct a proxy for multilateral netting opportunities based on the *gross positive fair values* and on the *net current credit exposures*.

The gross positive fair value of a portfolio corresponds to the gross payment that a bank would be owed should all its counterparties default.

$$\text{GPFV}_{i,t} = \sum_{j=1}^{N} \max[0, \text{FV}_{i,j,t}] \tag{3}$$

where i denotes the bank, t denotes the quarter, N is the number of derivative contracts of bank i at time t, and $\text{FV}_{i,j,t}$ denotes the fair value of contract j at time t. The net current credit exposure is the net payment that a bank would be owed should all its counterparties default.

$$\text{NCCE}_{i,m,t} = \sum_{m=1}^{N_m} \max[0, \text{FV}_{i,m,t}] \tag{4}$$

where N_m denotes the number of master agreements signed by bank i at time t, and $\text{FV}_{i,m,t}$ denotes the fair value of master agreement m at time t. Combining the two, we obtain the following indicator.

$$\text{MNO}_{i,t} = 1 - \frac{\text{NCCE}_{i,t}}{\text{GPFV}_{i,t}} \tag{5}$$

Table B1 in the appendix compares the MNO of HC and LC banks before the reform. The netting ratio of LC banks is lower by about 20 percentage points (10% compared to 30.5% for HC banks). The difference is statistically significant at the 5% level. There is a subtantial heterogeneity within each group but the same qualitative result is obtained by comparing the medians. We interpret these results as evidence that banks reallocating their portfolio would face a higher collateral demand by relying on central clearing because they benefit less from the payment arrangement offered by CCPs.

One may also interpret the MNO indicator as reflecting the size of a bank dealer activity. As discussed in section 3, dealers hedge in the inter-dealer market the diversified positions taken to serve the demand of end-users. This implies that dealers have far more netting opportunities than end-users. Under this interpretation, banks reallocating their portfolio have a smaller dealer activity (if any). The fact that the gross notional amount of derivatives held for trading purposes over total assets is lower for LC banks (see Table B1) supports this interpretation. However, the difference in means between the two groups is not significant.

We also observe that both the mean and the median of the gross notional amount of interest rate derivative contracts over total assets are about two times lower for LC banks. The mean ratio amounts to 15.5% against 29.6% for HC banks while the median amounts to 7.4% against 15.6% for HC banks. This suggests that banks reallocating their portfolio may effectively face a higher average fixed cost of clearing.

7.2 Extra Basel III capital charges

Different risk weights between cleared and uncleared derivatives have been introduced in the Basel III framework in order to incentivize clearing.

Table B2 provides a comparison of main financial ratios between the two groups before the reform. The only significant differences between the groups are in terms of size and capitalization[25]. We observe that LC banks are significantly better capitalized than HC banks. We interpret this result as evidence that banks who reallocate had less incentive to clear because the distance between their level of capitalization and the regulatory bounds was significantly higher.

Then, we investigate whether banks with low clearing levels faced extra capital charges compared to banks with high clearing levels.

Banks report a breakdown of credit equivalent amounts of derivative positions per counterparty risk weight[26]. The risk-weighted sum of credit equivalent amounts is used by regulators to evaluate banks' exposure to counterparty credit risk, and enters the denominator of risk-based capital ratios. We use this information and measure capital charges associated with derivative positions as the risk-weighted credit equivalent amount scaled by total assets (RWCEA ratio).

Figure 7 presents the mean evolution of this indicator for both LC and HC banks. The vertical line in 2015 indicates the Basel III compliance date. Overall, we observe that banks who reallocate have a less risky derivatives activity. Regarding the dynamics, we observe very similar dynamics before and after the implementation of Basel III. We estimate the model (1) by replacing $Y_{i,t}$ with the RWCEA ratio and $Group_i$ with a dummy variable equal

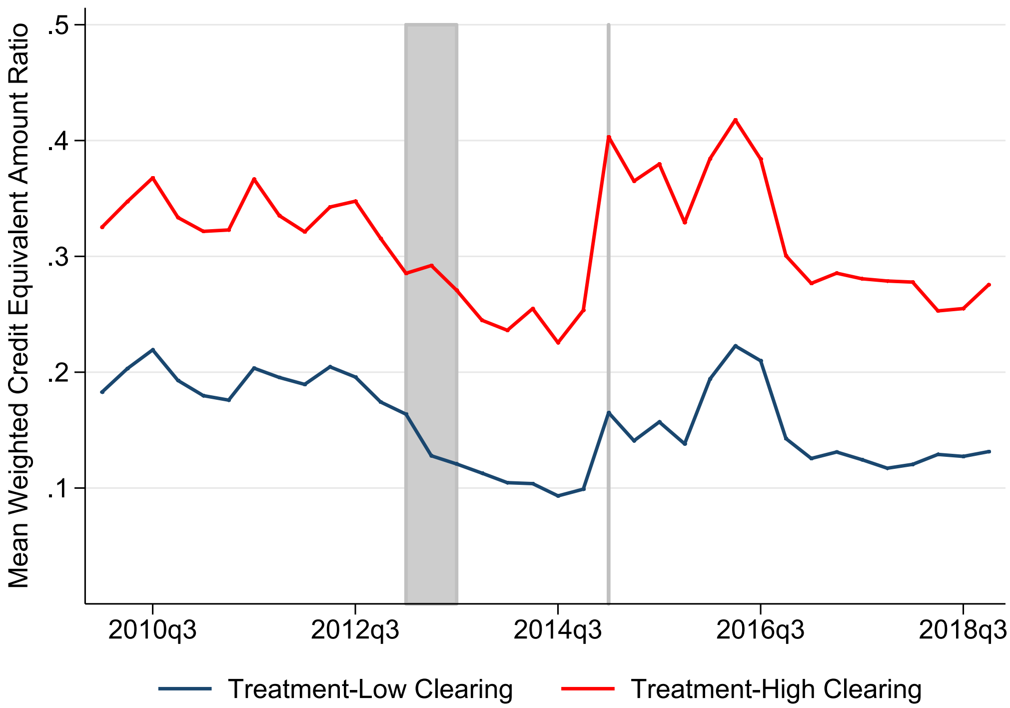
[25]Notice that this does not question the parallel trend assumption because these differences are stable over time.

[26]Credit equivalent amounts are computed as the sum of net current credit exposures and potential future credit exposures. The later are computed from notional amounts weighted by credit conversion factors that depend on the remaining maturity of contracts.

to one for LC banks and zero for HC banks. The results are presented in columns (1) and (2) of Table C1 in the appendix. We find that banks who clear less do not face extra capital charges compared to banks with relatively more of cleared derivatives in their portfolio. Only the interaction term $2015 \times \text{Group}_i$ is significant and negative. On impact the RWCEA ratio increased actually less for *LC* banks than for *HC* banks.

These results suggest that the portfolio reallocation cancels out the treatment effect of Basel III. In absence of portfolio reallocation, LC banks might have to face significantly lower extra Basel III capital charges because their derivatives positions were less risky. In this sence also, the Basel III framework might provide less incentive to clear to banks who reallocate their portfolio.

Figure 7: **Mean RWCEA ratio of *HC* and *LC* banks**

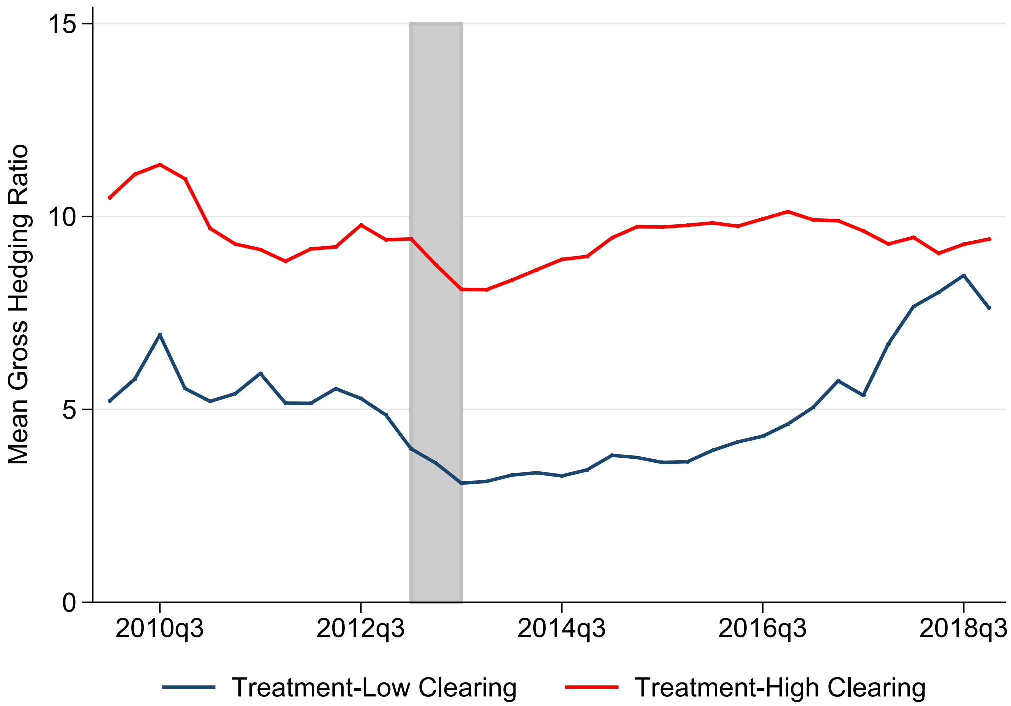


Note: Mean weighted credit equivalent amount ratio. *High clearing* banks are those with a mean clearing level above the median level of the group (i.e. *HC* banks). *Low clearing* banks are those with a mean clearing level below the median level of the group (i.e. *LC* banks). The shaded area represents quarters 1 to 3 of 2013, which correspond to the implementation of the clearing mandate. The vertical line indicates 2015q1, which corresponds to the implementation of Basel III.

8 Central clearing and bank hedging

Portfolio reallocations involve costs such as transactions costs. Moreover, derivatives may not be perfect substitutes. Derivatives other than swaps may be less liquid. In this section, we test the hypothesis that banks who clear less after the reform reduced the size of their IRDs portfolio, and we focus on bank off-balance-sheet hedging of interest rate risk.

Figure 8: **Mean Gross Hedging Ratio of *HC* and *LC* banks**



Note: Mean gross hedging ratio defined by equation (6). *High clearing* banks are those with a mean clearing level above the median level of the group (i.e. *HC* banks). *Low clearing* banks are those with a mean clearing level below the median level of the group (i.e. *LC* banks). The shaded area represents quarters 1 to 3 of 2013, which correspond to the implementation of the clearing mandate.

Call reports provide a breakdown between derivatives held for trading purposes and derivatives held for purposes other than trading. The former category includes for instance derivatives used in dealing, or to hedge trading activities, or speculative positions[27]. The later category has been used in various papers to quantify hedging (see Purnanandam (2007) and Rampini et al. (2019) among others). Following this literature, we measure bank hedging with the gross hedging ratio (6).

$$\text{GH}_{it} = \frac{\text{Gross notional amount of IRDs used for Hedging}_{it}}{\text{Total assets}_{it}} * 100 \tag{6}$$

Figure 8 plots the evolution of the mean gross hedging ratio for both LC and HC banks. We observe very similar trends after the implementation of the clearing rule. To confirm this

[27]Speculative positions here refer to derivatives held to profit from short-term price movements

observation, we estimate the model 1 by replacing the variable $Y_{i,t}$ with the gross hedging ratio, and the variable $Group_i$ with a dummy equal to one for LC banks and equal to zero for HC banks. Table D1 in the appendix presents the results. We do not find a significant impact of the reform on the gross hedging ratio. These results are robust to the inclusion of control variables such as measures of on-balance sheet exposures to interest rate risk (ie income gap[28] and duration gap[29]), and to change of counterfactual group. This suggests that the clearing rule had no impact on bank hedging activity.

9 Conclusion

In this paper, we document a heterogeneous treatment effect of the clearing rule on US banks other than clearing members. We find that several year after the implementation of the clearing rule, there is still a substantial part of treated banks who do not clear interest rate derivatives. We use this ex-post heterogeneity in clearing activity to identify the group of effectively treated banks. It seems to include derivatives end-users that are not eligible to the end-user exception as well as small dealer banks. Our difference-in-difference estimations show that banks who clear less ex-post rebalanced their portfolios by substituting interest rate swaps for interest rate options. We find no evidence of a treatment effect on bank off-balance-sheet heding of interest rate risk.

This paper contributes to a rapidly growing body of research trying to understand the pros and cons of a clearing mechanism, and the impact of the new regulatory framework on derivatives market participants and derivatives activity. From our knowledge, this is the first paper focusing the attention on the distorsive effect of the reform on derivatives end-users.

Our work is still ongoing. There is significant room for improvement. To begin with, measuring off-balance-sheet hedging of interest rate risk is challenging. Our indicator of bank hedging is not exhaustive. This is partly due to the limited data availability.

However, important questions have been addressed using the gross hedging ratio. Purnanandam (2007) asks whether derivatives allow banks to make their lending activities less sensitive to the monetary policies. English et al. (2018) ask how the reaction of stock returns varies with bank characteristics such as the mismatch between maturity of bank assets and liabilities and the usage of interest rate derivatives. Rampini et al. (2019) provide an empirical support to the theory that financial constraints impede both financing and hedging. The positive correlation between the gross hedging ratio and banks' on-balance-sheet interest rate risk exposure is an empirical fact (see Rampini et al. (2019) for instance).

There is also a bit of a debate going on. The main issue with this indicator is that it provides no indication regarding the direction of the position and the magnitude of the hedging position. Moreover, Begenau et al. (2015) stress that there is no clear mapping between the call report category "held for purposes other than trading" and hedging. They argue that this category could contain speculative holdings, as long as they are not short term. They propose an alternative strategy to estimate exposures to interest rate risk and conclude that there is little evidence that derivative positions are used to hedge. Vuillemey (2019) challenges this view and keeps on working with call reports categories. He measures

[28] Gomez et al. (2019), Rampini et al. (2019)

[29] English et al. (2018)

net hedging by using 1. call report data of notional amounts of pay fixed swaps held for purposes other than trading and 2. the fact that a subset of banks only use swaps. He documents that a large fraction of hedging banks use derivatives to take additional exposures to interest rate increases. Then, he develops a model showing that this is in fact consistent with optimal hedging under financial frictions. Vuillemey (2019)'s measure of net hedging is restrictive in the sense that it can be computed only for a selective sample of banks. Rampini et al. (2019) recently updated their work and propose to approximate net hedging with the marginal effect of a change in a reference interest rate on the market value of the portfolio of interest rate derivatives held for purposes other than trading.

All of this suggests that a natural improvement in our work would be to complement the analysis of the treatment effect on bank hedging by using instead a measure of net hedging.

Another substantial improvement in our work would be to use our identification of the treatment effect to investigate the on-balance-sheet implications of the clearing rule. The clearing rule applies to the top of the distribution in terms of bank total assets. For this reason, any on-balance-sheet implication would be good to know.

There is in particular one relevant question related to our work. Who bears interest rate risk ? [30] The starting point on this question is to remark that one of the primary functions of banks in the economy is to transform maturities, not to insure non-financial agents against interest rate risk. This goes back to the work of Diamond and Dybvig (1983). They show that the role of banks is to intermediate funds between savers (households) and borrowers (firms) in a world where the former have idiosyncratic short-term needs and the later have long term needs. This does not say that, in presence of aggregate uncertainty, one should expect from banks to keep the interest rate risk accompanying this business. In fact, they engage in active risk management. The interest rate sensitivity of net interest margins is low. On-balance-sheet, this takes the form of state-contingent contracts. Off-balance-sheet, for 10% of US banks, this takes the form of derivative positions. To conclude on this, a natural improvement to our work would be to investigate the treatment effect of the clearing rule on banks' on-balance-sheet interest rate risk management. Then, combining the effect on and off-balance-sheet, one should be able to conclude on the overall treatment effect of the clearing rule on banks' interest rate risk management. This matters because "in the presence of financial constraints for non-financial agents, these transfers (namely transfers of interest rate risk) have real effects" (see Vuillemey (2016)).

References

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

Akari, M.-A., Ben-Abdallah, R., Breton, M., and Dionne, G. (2019). The impact of central clearing on the market for single-name credit default swaps. *Available at SSRN.*

Begenau, J., Piazzesi, M., and Schneider, M. (2015). Banks' risk exposures. Technical report, National Bureau of Economic Research.

[30]see Hoffmann et al. (2019), Vuillemey (2016)

Benos, E., Huang, W., Menkveld, A. J., and Vasios, M. (2019). The cost of clearing fragmentation.

Biais, B., Heider, F., and Hoerova, M. (2016). Risk-Sharing or Risk-Taking? Counterparty Risk, Incentives, and Margins: Risk-Sharing or Risk-Taking? *The Journal of Finance*, 71(4):1669–1698.

Cenedese, G., Ranaldo, A., and Vasios, M. (2019). Otc premia. *Journal of Financial Economics*.

Cont, R. and Kokholm, T. (2014). Central clearing of OTC derivatives: Bilateral vs multilateral netting. *Statistics & Risk Modeling*, 31(1).

Cunliffe, J. (2018). Central clearing and resolution-learning some of the lessons of lehmans. *Sspeech at the FIA International Derivatives Expo*.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy*, 91(3):401–419.

Du, W., Gadgil, S., Gordy, M. B., and Vega, C. (2019). Counterparty risk and counterparty choice in the credit default swap market. *Available at SSRN 2845567*.

Duffie, D., Scheicher, M., and Vuillemey, G. (2015). Central clearing and collateral demand. *Journal of Financial Economics*, 116(2):237–256.

Duffie, D. and Zhu, H. (2011). Does a Central Clearing Counterparty Reduce Counterparty Risk? *Review of Asset Pricing Studies*, 1(1):74–95.

Edwards, F. R. (1999). Hedge Funds and the Collapse of Long-Term Capital Management. *The Journal of Economic Perspectives*, 13(2):189–210.

English, W. B., Van den Heuvel, S. J., and Zakrajšek, E. (2018). Interest rate risk and bank equity valuations. *Journal of Monetary Economics*, 98:80–97.

Financial Stability Board (2018). Incentives to centrally clear over-the-counter (otc) derivatives: A post-implementation evaluation of the effects of the G20 financial regulatory reforms. *FSB publications*.

Ghamami, S. and Glasserman, P. (2017). Does OTC derivatives reform incentivize central clearing? *Journal of Financial Intermediation*, 32:76–87.

Gomez, M., Landier, A., Sraer, D. A., and Thesmar, D. (2019). Banks' exposure to interest rate risk and the transmission of monetary policy. *Available at SSRN 2220360*.

Gregory, J. (2014). *Central counterparties: mandatory central clearing and initial margin requirements for OTC derivatives*. John Wiley & Sons.

Heller, D. and Vause, N. (2012). Collateral requirements for mandatory central clearing of over-the-counter derivatives. *BIS working paper*.

Hoffmann, P., Langfield, S., Pierobon, F., and Vuillemey, G. (2019). Who bears interest rate risk? *The Review of Financial Studies*, 32(8):2921–2954.

International Monetary Fund (2003). *Global Financial Stability Report, September 2003: Market Developments and Issues*. Global Financial Stability Report. International Monetary Fund, Washington, D.C.

ISDA (2009). Isda margin survey. *International Swaps and Derivatives Association*.

ISDA (2013). Non-cleared otc derivatives: Their importance to the global economy. *International Swaps and Derivatives Association*.

Kubitza, C., Pelizzon, L., and Getmansky Sherman, M. (2018). The Pitfalls of Central Clearing in the Presence of Systematic Risk. *SSRN Electronic Journal*.

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

McDonald, R. and Paulson, A. (2015). AIG in Hindsight. *Journal of Economic Perspectives*, 29(2):81–106.

Murphy, D. (2013). *OTC Derivatives: Bilateral Trading & Central Clearing*. Palgrave Macmillan UK, London.

Papke, L. E. and Wooldridge, J. M. (2008). Panel data methods for fractional response variables with an application to test pass rates. *Journal of Econometrics*, 145(1-2):121–133.

Purnanandam, A. (2007). Interest rate derivatives at commercial banks: An empirical investigation. *Journal of Monetary Economics*, 54(6):1769–1808.

Rampini, A. A., Viswanathan, S., and Vuillemey, G. (2019). Risk management in financial institutions.

Sidanius, C. and Zikes, F. (2012). Financial Stability Paper No 18: Otc derivatives reform and collateral demand impact. *Bank of England Financial Stability Papers 18*.

Singh, M. (2010). Collateral, Netting and Systemic Risk in the OTC Derivatives Market. *IMF Working Papers*, 10(99):1.

Vuillemey, G. (2016). Interest rate risk in banking: a survey. *Available at SSRN 2708804*.

Vuillemey, G. (2019). Bank interest rate risk management. *Management Science*, 65(12):5933–5956.

Zawadowski, A. (2013). Entangled Financial Systems. *Review of Financial Studies*, 26(5):1291–1323.

Appendix

A Impact of the clearing requirement on derivatives portfolios

Table A1: **Summary Statistics**

	LC Banks		*HC* Banks		Control Group	
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean	(6) Median
Interest Rate Derivatives:						
IRDC (% of TA)	14.1	7.24	29.4	15.8	6.78	2.34
GH (% of TA)	4.99	1.74	9.50	5.19	4.35	1.18
GT (% of TA)	9.06	0.47	18.7	7.91	2.20	0
Trading IRDC (% of IRDC)	49.2	68.3	47.9	62.5	21.0	0
Futures (% of IRDC)	1.98	0	2.34	0	0.16	0
Forwards (% of IRDC)	12.8	3.17	12.1	1.87	17.7	0
Written options ET (% of IRDC)	0.10	0	0.044	0	0.047	0
Purchased options ET (% of IRDC)	0.34	0	0.19	0	0.15	0
Written options OTC (% of IRDC)	10.3	5.47	5.65	2.77	16.4	1.63
Purchased options OTC (% of IRDC)	5.53	0.23	3.89	1.19	3.32	0
Swaps (% of IRDC)	68.9	80.4	75.8	88.7	62.1	84.0
Cleared IRDC (% of IRDC)	10.2	0	50.1	46.3	1.56	0
Derivatives' Credit Risk:						
Credit Risk (% of TA)	0.16	0.10	0.31	0.19	0.058	0.0073
Size:						
Total assets (log)	17.0	17.0	17.6	17.7	14.4	14.3
Observations	972	972	936	936	9144	9144

Note: The period covered is 2010q1-2018q4. IRDC represents the notional amount of Interest Rate Derivative Contracts. TA is total assets. GH is the gross hedging ratio defined in equation (6). GT is the ratio of the notional amount of derivatives held for trading purpose divided by total assets. Trading IRDC is the notional amount of derivatives held for trading purpose as a share of total interest rate derivatives. ET stands for exchange-traded contracts and OTC for over-the-counter contracts. Cleared IRDC is the share of the notional amount centrally cleared. Credit risk is the weighted credit equivalent amount of banks complete derivatives portfolio divided by total assets (see Section 6). *LC* and *HC* banks are institutions of the treatment group with low and high clearing levels, respectively. IRDC, GH, GT and Credit Risk are winsorized at the 99th percentile.

Table A2: **Portfolio Composition Dynamics of *LC* Banks Relative to *HC* Banks**

	Baseline Model				Fractional Logit			
	Swaps		Options		Swaps		Options	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2010 × Group	-0.025		0.044		-0.043		0.34	
	(0.044)		(0.040)		(0.19)		(0.30)	
2011 × Group	0.0051		0.026		0.047		0.23	
	(0.036)		(0.035)		(0.16)		(0.29)	
2012 × Group	/		/		/		/	
2013 × Group	-0.042	-0.035	0.047	0.023	-0.27	-0.27	0.53**	0.33
	(0.040)	(0.056)	(0.031)	(0.043)	(0.19)	(0.26)	(0.26)	(0.37)
2014 × Group	-0.051	-0.044	0.055	0.032	-0.36	-0.36	0.72**	0.52
	(0.049)	(0.062)	(0.035)	(0.046)	(0.25)	(0.30)	(0.29)	(0.38)
2015 × Group	-0.071	-0.064	0.088*	0.064	-0.38	-0.38	0.92**	0.71
	(0.064)	(0.075)	(0.045)	(0.054)	(0.32)	(0.37)	(0.38)	(0.45)
2016 × Group	-0.12*	-0.11	0.13**	0.11*	-0.62*	-0.62	1.36***	1.15***
	(0.071)	(0.081)	(0.050)	(0.058)	(0.34)	(0.38)	(0.36)	(0.43)
2017 × Group	-0.15*	-0.15*	0.14**	0.12*	-0.96**	-0.96**	1.63***	1.42***
	(0.079)	(0.088)	(0.054)	(0.061)	(0.42)	(0.45)	(0.43)	(0.49)
2018 × Group	-0.17**	-0.16*	0.13**	0.11*	-0.95**	-0.95**	1.48***	1.28***
	(0.083)	(0.090)	(0.055)	(0.059)	(0.46)	(0.48)	(0.47)	(0.49)
Bank FE	Yes	Yes	Yes	Yes	No	No	No	No
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1794	1794	1794	1794	1794	1794	1794	1794

Note: Estimates of selected parameters of model (1) in columns 1-4 and model (2) in columns 5-8. *Group* is a dummy variable that takes value 1 for banks with low clearing levels (i.e. *LC* banks) and 0 for banks with high clearing levels (i.e. *HC* banks). Omitted base year indicated by /. Standard errors clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table A3: **Portfolio Composition Dynamics of *HC* Banks Relative to Control Group**

	Baseline Model		Fractional Logit	
	Swaps	Options	Swaps	Options
	(1)	(2)	(3)	(4)
2010 × Group	0.015	-0.029	0.061	-0.13
	(0.035)	(0.024)	(0.15)	(0.16)
2011 × Group	-0.030	-0.0088	-0.098	-0.053
	(0.024)	(0.012)	(0.11)	(0.074)
2012 × Group	/	/	/	/
2013 × Group	0.015	0.0058	0.089	-0.12
	(0.032)	(0.026)	(0.16)	(0.21)
2014 × Group	0.025	-0.0024	0.19	-0.25
	(0.040)	(0.031)	(0.21)	(0.23)
2015 × Group	-0.0010	0.0057	0.0018	-0.14
	(0.052)	(0.039)	(0.27)	(0.32)
2016 × Group	-0.016	-0.0041	-0.0061	-0.40
	(0.057)	(0.039)	(0.28)	(0.31)
2017 × Group	-0.010	0.0035	0.12	-0.44
	(0.068)	(0.042)	(0.37)	(0.36)
2018 × Group	-0.032	0.022	0.031	-0.26
	(0.070)	(0.044)	(0.37)	(0.40)
Bank FE	Yes	Yes	No	No
Time FE	Yes	Yes	Yes	Yes
N	8151	8151	8151	8151

Note: Estimates of selected parameters of model (1) in columns 1-2 and model (2) in columns 3-4. *Group* is a dummy variable that takes value 1 for banks with high clearing levels (i.e. *HC* banks) in treatment group and 0 for banks in control group. Omitted base year indicated by /. Standard errors clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table A4: **Portfolio Composition Dynamics of *LC* Banks Relative to Control Group**

	Baseline Model		Fractional Logit	
	Swaps	Options	Swaps	Options
	(1)	(2)	(3)	(4)
2010 × Group	-0.0096	0.015	0.018	0.21
	(0.038)	(0.040)	(0.16)	(0.28)
2011 × Group	-0.025	0.017	-0.051	0.18
	(0.031)	(0.035)	(0.14)	(0.29)
2012 × Group	/	/	/	/
2013 × Group	-0.026	0.053**	-0.18	0.41**
	(0.031)	(0.024)	(0.15)	(0.19)
2014 × Group	-0.026	0.053*	-0.17	0.47**
	(0.040)	(0.030)	(0.19)	(0.23)
2015 × Group	-0.072	0.093**	-0.38*	0.78***
	(0.048)	(0.036)	(0.23)	(0.26)
2016 × Group	-0.13**	0.13***	-0.62**	0.95***
	(0.054)	(0.043)	(0.25)	(0.27)
2017 × Group	-0.16***	0.15***	-0.85***	1.19***
	(0.055)	(0.047)	(0.27)	(0.30)
2018 × Group	-0.20***	0.15***	-0.92***	1.22***
	(0.060)	(0.047)	(0.32)	(0.32)
Bank FE	Yes	Yes	No	No
Time FE	Yes	Yes	Yes	Yes
N	8155	8155	8155	8155

Note: Estimates of selected parameters of model (1) in columns 1-2 and model (2) in columns 3-4. *Group* is a dummy variable that takes value 1 for banks with low clearing levels (i.e. *LC* banks) in treatment group and 0 for banks in control group. Omitted base year indicated by /. Standard errors clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

B Netting benefits

Table B1: **Derivatives Portfolio of *HC* and *LC* banks over 2010-2012**

	HC Banks		*LC* Banks		
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean Diff.
Interest Rate Derivatives:					
IRDC (% of TA)	29.6	15.6	15.3	7.4	-14.3*
GH (% of TA)	9.9	4.7	5.5	1.8	-4.4
GT (% of TA)	19.2	5.3	9.7	1.9	-9.5
Trading IRDC (% of IRDC)	49.8	62.6	50.8	69.9	1.0
Futures (% of IRDC)	4.4	0.0	3.7	0.0	-0.7
Forwards (% of IRDC)	14.9	2.3	15.1	3.5	0.1
Written options ET (% of IRDC)	0.1	0.0	0.3	0.0	0.2
Purchased options ET (% of IRDC)	0.4	0.0	0.1	0.0	-0.3
Written options OTC (% of IRDC)	8.0	3.4	10.3	5.0	2.3
Purchased options OTC (% of IRDC)	6.5	1.4	4.6	0.0	-1.9
Swaps (% of IRDC)	65.7	78.9	66.0	80.5	0.3
Derivatives' Credit Risk:					
Gross positive FV (% of TA)	0.8	0.6	0.4	0.3	-0.4*
NCCE (% of TA)	0.6	0.5	0.3	0.2	-0.2
MNO (%)	30.5	5.7	10.0	0.3	-20.5**

Note: Mean and median of selected portfolio parameters for *HC* and *LC* banks over the period 2010-2012 (i.e. before the clearing requirement). IRDC represents the notional amount of Interest Rate Derivative Contracts. TA is total assets. GH is the gross hedging ratio defined in equation (6). GT is the ratio of the notional amount of derivatives held for trading purpose divided by total assets. Trading IRDC is the notional amount of derivatives held for trading purpose as a share of total interest rate derivatives. ET stands for exchange-traded contracts and OTC for over-the-counter contracts. FV means fair value and NCCE is net current credit exposures. Bilateral Netting is defined in equation (5). The last column gives the mean difference between the two subgroups. It corresponds to the coefficients obtained when regressing the variable on a dummy variable equal to 1 for *LC* banks and 0 for *HC* banks. Standard errors are clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table B2: **Financial Ratios of *HC* and *LC* banks over 2010-2012**

	HC Banks		*LC* Banks		Difference
	Mean	Median	Mean	Median	Mean
	(1)	(2)	(3)	(4)	(5)
Assets:					
Loans & leases (% of TA)	62.7	65.2	61.7	66.2	-1.0
Non-performing assets (% of TA)	1.6	1.5	2.4	1.7	0.8
Liquid assets (% of TA)	29.5	23.8	29.4	25.0	-0.1
Trading assets (% of TA)	0.7	0.5	0.8	0.2	0.1
Total assets (log)	17.3	17.2	16.8	16.7	-0.5*
Mean quarterly growth rate (%)	4.7	1.4	3.3	1.5	-1.4
Liabilities:					
Core deposits (% of TL)	63.7	66.8	59.6	64.9	-4.1
Time deposits (% of TL)	17.9	16.3	22.1	21.2	4.2
Trading liabilities (% of TL)	0.5	0.4	0.3	0.0	-0.2
Non-deposit liabilities (% of TL)	18.4	14.8	18.3	14.8	-0.1
Capital:					
Equity (% of TA)	10.9	10.3	12.8	12.3	1.9*
Tiers 1 RBC (%)	12.3	12.0	14.4	13.9	2.1*
Income:					
Net income (% of TA)	0.2	0.2	0.2	0.2	0.0
non-IR (% of TA)	-0.4	-0.4	-0.3	-0.4	0.1

Note: Mean and median of selected financial ratios for *HC* and *LC* banks over the period 2010-2012 (i.e. before the clearing requirement). See Table E1 for for the definitions of variables. The last column gives the mean difference between the two subgroups. It corresponds to the coefficients obtained when regressing the financial ratio on a dummy variable equal to 1 for *LC* banks and 0 for *HC* banks. Standard errors are clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

C Basel III capital buffers

Table C1: **Dynamics of Regulatory Credit Risk of LC Banks Relative to HC Banks**

	Weighted CEA Ratio		W_{it}	
	(1)	(2)	(3)	(4)
2010 × Group	-0.0016		0.35	
	(0.052)		(2.16)	
2011 × Group	-0.0056		1.94	
	(0.048)		(2.04)	
2012 × Group	0.0017		3.00	
	(0.044)		(1.93)	
2013 × Group	0.00038		3.33**	
	(0.016)		(1.37)	
2014 × Group	/		/	
2015 × Group	-0.077**	-0.076*	-1.74	-3.44
	(0.035)	(0.043)	(6.16)	(6.49)
2016 × Group	-0.037	-0.036	5.06	3.36
	(0.039)	(0.050)	(7.18)	(7.49)
2017 × Group	-0.013	-0.012	4.56	2.86
	(0.025)	(0.041)	(6.81)	(7.06)
2018 × Group	0.0041	0.0051	0.77	-0.93
	(0.030)	(0.048)	(6.90)	(7.23)
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
N	1908	1908	1761	1761

Note: Estimates of selected parameters of model (**??**) when the dependent variable is the weighted credit equivalent amount ratio (columns 1-2) and W_{it} (columns 3-4). *Group* is a dummy variable that takes value 1 for banks with low clearing levels (i.e. LC banks) and 0 for banks with high clearing levels (i.e. HC banks) in treatment group. Omitted base year indicated by /. Standard errors clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

D Impact of the clearing requirement on banks' hedging

Table D1: **Hedging portfolio dynamics of *LC* banks relative to *HC* banks**

	(1) Gross Hedging	(2) Gross Hedging
2010 × Group	-0.93	
	(1.82)	
2011 × Group	0.37	
	(1.31)	
2012 × Group	/	
2013 × Group	-0.97	-0.78
	(1.04)	(1.80)
2014 × Group	-1.19	-1.00
	(1.09)	(1.80)
2015 × Group	-1.78	-1.60
	(1.16)	(1.84)
2016 × Group	-1.48	-1.29
	(1.46)	(2.08)
2017 × Group	0.21	0.40
	(2.23)	(2.67)
2018 × Group	2.83	3.02
	(2.82)	(3.15)
Bank FE	Yes	Yes
Time FE	Yes	Yes
N	1908	1908

Note: Estimates of selected parameters of model (**??**) when the dependent portfolio is the gross hedging ratio defined in equation (6). *Group* is a dummy variable that takes value 1 for banks with low clearing levels (i.e. *LC* banks) and 0 for banks with high clearing levels (i.e. *HC* banks) in treatment group. Omitted base year indicated by /. Standard errors clustered at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

E Variable definitions

Table E1: **Variable Definitions**

Variables	Definition
Assets	
Loans & leases (% of TA)	Loans and leases held for sale and investment over total assets

Non-performing assets (% of TA)	Non-performing assets over total assets (loans over 90 days late plus loans not accruing scaled by total assets)
Liquid assets (% of TA)	Liquid assets (cash and balances due from depository institutions + held-to-maturity securities + available-for-sale securities + federal funds sold and securities purchased under agreements to resell) over total assets
Trading assets (% of TA)	Trading assets over total assets. This represents mostly assets held with a view to selling in the short-term and benefiting from price movements. Also include derivatives held for trading purpose with a positive fair value
Total assets (log)	Logarithm of total assets
Mean quarterly growth rate (%)	Average quarterly growth rate of total assets over the last 4 quarters
Liabilities	
Core deposits (% of TL)	Savings deposits (i.e. money market deposit and other savings deposits) + Transaction accounts (including demand deposits), over total liabilities
Time deposits (% of TL)	Time deposits over total liabilities
Trading liabilities (% of TL)	Trading liabilities over total liabilities. Includes liabilities resulting from sales of assets that the reporting bank does not own and derivatives held for trading purpose with a negative fair value
Non-deposit liabilities (% of TL)	Non-deposit liabilities over total liabilities (total liabilities - total deposits)
Capital	
Equity (% of TA)	Bank equity capital end of current period over total assets
Tiers 1 RBC (%)	Tier 1 capital over total risk-weighted assets
Income	
NI (% of TA)	Net income over total assets
Non-IR (% of /TA)	Net non-interest income (gross non interest income - gross non interest expense) over total assets