Mandatory Clearing of Derivatives and Systemic Risk of Bank Holding Companies♣

Shaofang Li* and **Matej Marinč****

January 13, 2017

Abstract

This paper investigates systemic risk of bank holding companies (BHCs) following the enactment of mandatory clearing of derivatives by the Dodd–Frank Act. We find that BHCs that were bigger users of derivatives experienced a larger drop in systemic risk contributions after mandatory clearing, all else being equal. This relationship holds across different measures of systemic risk and across several robustness checks that account for potential endogeneity and self-selection bias, including data mining through high-dimensional methods. Overall, our results suggest that derivatives clearing can curtail systemic risk in the banking system.

Keywords: Clearing, Derivatives, Systemic Risk, Bank Holding Companies, Dodd–Frank

JEL Classification: G01, G21, G28

♣ The authors would like to thank Alberto Bisin, Eddie Gerba, Barbara Guardabascio, Robin Lumsdaine, Mojca Marc, Esen Onur, Otto Randl, Vasja Rant, and Miroslav Verbič for their valuable comments and suggestions. All errors remain our own.

* Faculty of Economics & Management, Southeast University, 211189 Nanjing, China, e-mail: shaofangli2003@gmail.com.

** Faculty of Economics, University of Ljubljana, Kardeljeva pl. 17, 1000 Ljubljana, Slovenia, e-mail: matej.marinc@ef.uni-lj.si.

1 Introduction

A consensus among policymakers, academics, and practitioners has emerged that one of the major drivers of the 2008-2009 financial crisis was the wide net of linkages among financial institutions in the over-the-counter derivatives market. Counterparty risk was exacerbated by financial innovations, increased complexity, opaque interconnections, and failure of diversification (Kroszner and Strahan (2011), Thakor (2015)). The Financial Crisis Inquiry Commission (2011) stated that "[t]he scale and nature of the over-the-counter (OTC) derivatives market created significant systemic risk throughout the financial system and helped fuel the panic in the fall of 2008: millions of contracts in this opaque and deregulated market created interconnections among a vast web of financial institutions through counterparty credit risk, thus exposing the system to a contagion of spreading losses and defaults."

The notional amounts of financial derivatives expose the dangers lurking in the opaque OTC markets. At the end of 2014, bank holding companies (BHCs) in the United States held $270 trillion of derivatives which amounted to 17.3 times the value of their total assets. Even though derivatives enjoy super senior status in bankruptcy (Bliss and Kaufman (2006), Bolton and Oehmke (2015)), a failure of a large counterparty on the OTC market can trickle down the chain of large users of derivatives, predominantly large BHCs, exacerbating systemic risk in the banking system. For example, McDonald and Paulson (2015) estimate that a potential default of AIG might erase up to 10 % of equity capital of its six large derivatives counterparties—Goldman Sachs, Société Générale, Merrill, DZ Bank, UBS, and Rabobank—and create substantial stress in the financial system at large.

Central clearing of derivatives is seen as a cure for excessive interconnectedness in the opaque OTC derivatives market (FSB (2015)). A derivatives clearing organization subsumes counterparty risks by stepping in between the two counterparties, involved in a derivatives contract, which should in principle lower systemic risk in the banking system. In the words of

Federal Reserve Chair Janet Yellen, "[g]lobal policymakers and the Dodd–Frank Act have sought to reduce systemic risk in derivatives markets by moving standardized derivatives into central clearing".[1] In a survey published on a webpage of one of the clearing houses, 80% of institutional investors on the global fixed-income market stated that they believe systemic risk has decreased since the financial crisis, and 40% of them indicate clearing as a primary cause for this.[2] However, there is little robust empirical evidence to support such claims.

This paper analyzes whether derivatives clearing curtails systemic risk of BHCs in the United States. Our empirical strategy exploits the enactment of mandatory clearing requirements as an exogenous shock that simultaneously affected a large cross-section of BHCs. More specifically, Title VII of the Dodd–Frank Act required derivatives to be cleared through a derivatives clearing organization. For large swap users, mandatory clearing requirements became effective on March 11, 2013 for the majority of newly-entered interest rate derivatives and selected credit derivatives. We hypothesize that, following the enactment of the mandatory clearing requirements, BHCs experience a larger drop in systemic risk contributions if they hold a substantial amount of derivatives, to which mandatory clearing applies.

We focus on five measures of systemic risk. We compute two measures of delta-conditional value at risk ($\Delta CoVaR$) at 5% and at 1% risk levels following Adrian and Brunnermeier (2014), marginal expected shortfall (*MES*) following Acharya et al. (2010), long-run marginal expected shortfall (*LRMES*), and *SRISK* following Acharya et al. (2012) and Brownless and Engle (2015), using the daily stock price of each BHC from the CRSP.[3] We construct a quarterly panel data set combining time varying systemic risk measures, BHC reporting data from the FR Y-9C reports,

---

[1] Opening Statement by Chair Janet L. Yellen, Press Release—Federal banking regulators finalize liquidity coverage ratio—September 3, 2014. http://www.federalreserve.gov/newsevents/press/bcreg/yellen-statement-20140903.htm.
[2] Greenwich associates, 2015, http://www.lchclearnet.com/greenwich-associates-study.
[3] The literature on systemic risk has proliferated after the start of the financial crisis; see Billio, Getmansky, Lo, and Pelizzon (2012), Huang, Zhou, and Zhu (2012), Laeven, Ratnovski, and Tong (2014), Benoit et al. (2015), Engle, Jondeau, and Rockinger (2015), Hovakimian, Kane, and Laeven (2015), and Giglio, Kelly, and Pruitt (2015). Mutu and Ongena (2015) analyze the impact of policy intervention on systemic risk across European banks.

data on the proportion of derivatives cleared from the Depository Trust & Clearing Corporation (DTCC) and Trioptima, and hand-collected data from the SEC 10-Q reports.

Figure 1 presents the preliminary evaluation of the hypothesized negative relationship between clearing and systemic risk. The difference in five systemic risk measures (Δ*CoVaR* (5%), Δ*CoVaR* (1%), *MES*, *LRMES*, and *SRISK*) across users and non-users of interest rate derivatives, normalized to 1 at the start of the period, is plotted across time and shown on the left axis. We plot the proportion of interest rate derivatives cleared on the right axis. The vertical line presents the time of enactment of mandatory clearing requirements. We note that the difference in systemic risk among users and non-users of derivatives decreases with higher clearing of derivatives and it stays at low levels after the enactment of the mandatory clearing requirements.

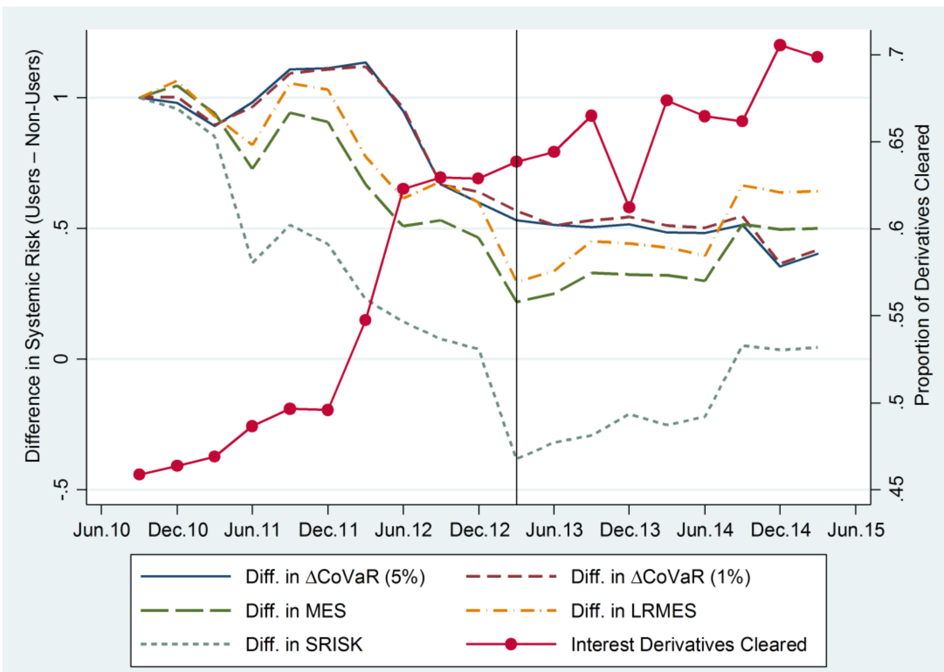


Figure 1: Difference in systemic risk measures among users and non-users of derivatives (interest rate swaps) across time, normalized to 1 at the beginning of the period, is shown on the left axis. Systemic risk measures are computed on a time-centered one-year rolling window. The proportion of interest rate derivatives cleared is shown on the right axis. The vertical line presents the time of enactment of mandatory clearing for large users of derivatives, so called Category 1 entities. Source: Our own computation based on CRSP, DTCC, and Trioptima.

Our empirical strategy is to employ the interaction term between the derivatives position of a BHC and the clearing indicator as a treatment and to analyze the treatment effect on the systemic risk contribution of a BHC in a difference-in-differences estimation. We use various variables to capture derivatives exposures and clearing intensity. We focus on interest rate derivatives for which mandatory clearing requirements apply and use fair values, notional amounts of swaps, and notional amounts of forward agreements and swaps. As a clearing indicator, we use a clearing dummy variable that equals 0 before and 1 after the enactment of mandatory clearing requirements.

Our findings support the notion that mandatory clearing requirements for financial derivatives decrease the systemic risk of BHCs. We find that BHCs that were greater users of interest rate derivatives experienced a larger drop in systemic risk contributions following the enactment of mandatory clearing requirements. This finding is economically and statistically significant across all measures of systemic risk and robust across many specifications and across different econometric models. We apply an instrumental variable analysis and Heckman's self-selection model to panel data to account for potential endogeneity and self-selection bias. We also provide robustness checks on the cross-section data using the standard treatment effect methodology, including propensity score matching, nearest neighbor matching, inverse probability weighting, and endogenous treatment-effect estimation.

Although mandatory clearing requirements applied only to newly entered swaps, BHCs, anticipating regulatory pressure, started to clear derivatives already before the enactment of mandatory clearing requirements. We use two measures to capture these clearing dynamics: the proportion of interest rate derivatives cleared on the total market and hand-collected data on the proportion of interest rate derivatives cleared for an individual BHC. We confirm that increased clearing of interest rate derivatives leads to a drop in systemic risk that is more pronounced for BHCs with high positions in interest rate derivatives.

We continue our analysis by examining additional risk indicators of BHCs to identify channels through which clearing of derivatives affects systemic risk. We find that, following mandatory clearing requirements, idiosyncratic risk dropped significantly more for BHCs with high derivative positions than for BHCs with low derivative positions. This supports the *idiosyncratic risk* channel in which derivatives clearing curtails systemic risk by decreasing the idiosyncratic risk of BHCs that hold financial derivatives. Our results do not support the *counterparty risk* channel, in which clearing would curtail systemic risk by lowering counterparty risk, the *efficiency* channel, in which clearing would increase the efficiency of derivatives operations, strengthening BHCs and curtailing systemic risk, or the *inefficiency* channel, in which the use of derivatives would decline due to clearing requirements, which would curtail systemic risk.

We also exploit the variation in mandatory clearing requirements across the cross-section of BHCs. In the so-called End-User Exception, small financial companies, including banks under $10 billion in total assets, were exempted from mandatory clearing of financial derivatives used for hedging purposes but not from mandatory clearing of financial derivatives used for trading purposes. We show that our results continue to hold when employing interest rate derivatives used for trading purposes.

Next, we examine whether systemic risk contributions became concentrated in remaining financial derivatives that are not required to be cleared. We find some evidence that, following mandatory clearing requirements, systemic risk was to a greater extent driven by other derivatives such as interest rate options, for which clearing requirements did not apply. In the case of credit derivative swaps (CDSs), clearing requirements apply only to the selected index-based CDSs under the regulatory authority of the CFTC, but not to security-based CDSs, which are regulated by the SEC. We show that, after mandatory clearing requirements, systemic risk was related to CDS positions to a greater extent than before. These results point to the possibility that systemic risk contributions can move across derivatives and indicate the potential for regulatory arbitrage, which calls for harmonized clearing requirements for derivatives across different types and across regulators (complementing the findings of Agarwal, Lucca, Seru, and Trebbi (2014)).

Our paper makes the following contributions. First, our paper is the first to employ enactment of mandatory clearing requirements under the Dodd–Frank Act as an event study. With this we add to the stream of papers that apply recent developments in program evaluation literature (see Imbens and Wooldridge (2009) and An and Winship (2015)) to analyze the effectiveness of bank regulation in a difference-in-differences framework (Berger and Roman (2015), Berger, Makaew, and Roman (2015), Duchin and Sosyura (2012, 2014), Beck, Levine, and Levkov (2010), Schaeck, Cihak, Maechler, and Stolz (2012), Hasan, Massoud, Saunders, and Song (2015)). Our findings relate to and mostly complement the existing literature that observes how BHCs weathered the recent financial crisis (Erel, Nadauld, and Stulz (2014), Ellul and Yerramilli (2013), Berger and Roman (2015), Berger, Bouwman, Kick, and Schaeck (2016), Fahlenbrach and Stulz (2011)). Our focus, however, is on the period after the crisis and on the effectiveness of post-crisis bank regulation on mandatory clearing, complementing growing but currently still limited research on the effectiveness of the Dodd–Frank Act (Acharya, Cooley, Richardson, and Walter (2010), Skeel (2010), Acharya, Anginer, and Warburton (2015)).

Second, we provide robust support for the statement that clearing of derivatives decreases systemic risk contributions of BHCs as major derivative users. This empirical finding is important for the ongoing theoretical discourse over the benefits of derivatives central clearing for systemic risk. The majority of theoretical papers suggest that systemic risk decreases if over-the-counter derivatives are cleared at the derivatives clearing organization rather than bilaterally (Acharya, Engle, Figlewski, Lynch, and Subrahmanyam (2009), Cont and Kokholm (2014), Zawadowski (2013), Acharya and Bisin (2014)). However, a few have argued that the reverse is true and that central clearing, if not carefully designed, might even increase risks (Biais, Heider, and Hoerova (2015), Duffie and Zhu (2011)).

Third, methodologically, we employ data mining techniques to guard against false discovery and overfitting. To the best of our knowledge, we are the first to apply high-dimensional methods as developed by Belloni, Chernozhukov, and Hansen (2014a, 2014b) to the vast regulatory data of BHCs. We employ a post-double-selection method to select a limited number of the most important controls out of 1,277 variables constructed from the vast array of data available in the regulatory reports of BHCs.[4] Our results remain robust.

The remainder of the article is organized as follows. Section 2 reviews the current literature, discusses the regulatory overhaul by the Dodd–Frank Act with a focus on mandatory clearing of derivatives, and builds hypotheses. Section 3 describes the data and methodology, including systemic risk measures, data statistics, and our research design. Section 4 contains the main analysis of the relationship between clearing of financial derivatives and systemic risk of BHCs. Section 5 provides several robustness checks. Section 6 presents the results of the post-double-selection method. Section 7 concludes the article. All tables are in the appendix and supplementary appendix.

2 Literature Review, Hypothesis Formation, and Regulatory Overview

2.1 Review of the Literature and Hypotheses

Our main hypothesis is that BHCs that were bigger derivatives users experienced a larger drop in systemic risk contributions following the enactment of mandatory clearing requirements. Derivatives clearing might affect systemic risk through several channels. In the first channel, which we call an *idiosyncratic risk* channel, derivatives clearing may lower the idiosyncratic risk of BHCs. Acharya and Bisin (2014) argue that central clearing increases transparency compared

---

[4] Whereas we use high dimensional methods to confirm robustness of inference, Bonaldi, Hortaçsu, and Kastl (2015) and Demirer, Diebold, Liu, and Yılmaz (2015) apply the adaptive elastic net to estimate systemic risk of the euro-zone and global banks, respectively.

to the otherwise opaque OTC markets. Because positions in derivatives are now better seen, BHCs refrain from overleveraging which brings the default risk of BHCs down to optimal levels. An additional argument supporting the *idiosyncratic risk* channel is that central clearing would improve the incentives of BHCs to hedge. More specifically, banks engaged in the OTC market would hedge insufficiently because they would not internalize the positive externality of hedging for other banks in the OTC market (Zawadowski (2013)).

However, Biais, Heider, and Hoerova (2015) are more reserved and warn that central clearing may actually increase idiosyncratic risk if not carefully designed. In their view, central clearing can destroy incentives for risk prevention and may bring additional risks even though it may lower counterparty risk.

In the second channel, which we call a *counterparty risk* channel, derivatives clearing organizations effectively cut direct interconnectedness among BHCs and cushion counterparty risk by demanding strict margin requirements and collateral for cleared derivatives (Singh (2010)). Central clearing also changes the configuration of the network of derivatives exposures through which BHCs are interconnected. A network of exposures, which is highly dispersed in the OTC market, becomes centralized with the clearing organization at its core. The initial literature on financial network resilience by Allen and Gale (2000) and Freixas, Parigi, and Rochet (2000) argues that a better-connected network is also a more stable one. In this view, centralization of a network through central clearing may be seen detrimental for its stability. More recently, Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) argue that a densely connected financial network deals well with small shocks but is not capable of handling large negative shocks. Following this view, a densely connected OTC market might be less resilient to large shocks than a centralized network created by central clearing (see also Nier, Yang, Yorulmazer, and Alentorn (2007), Haldane and May (2011), Allen, Babus, and Carletti (2012), Battiston, Delli Gatti, Gallegati, Greenwald, and Stiglitz (2012), and Elliott, Golub, and Jackson (2014)).

Clearing may also curtail counterparty risk if clearing organizations are more prudent, subjugated to more stringent regulatory standards, or simply enjoy greater implicit government guarantees than BHCs. Kelly, Lustig, and Van Nieuwerburgh (2015) and Veronesi and Zingales (2010) provide evidence that BHCs were too-systemic-to-default during the recent financial crisis. If clearing organizations become even more systemically important than BHCs, they may enjoy stronger government backing. However, if the reverse is true and clearing organizations are left unprotected in potential distress, counterparty risk may increase (Roe (2013)).

In the third channel, which we call an *efficiency* channel, central clearing might yield efficiency improvements that would result in additional profits of BHCs, increasing their resilience and lowering their systemic risk contributions. In line with the argument of Duffie and Zhu (2011), central clearing would only be efficient if multilateral netting benefits across BHCs are more important than cross-product netting benefits within a single BHC. Bolton and Oehmke (2015) argue that cross-netting gauges the benefits of a derivative counterparty when basis risk is idiosyncratic but cash flow risk is systematic. BHCs decided to clear some of their derivatives at derivatives clearing organizations even before the enactment of mandatory clearing. This is in line with the efficiency channel and is supported by Duffie, Scheicher, and Vuillemey's (2015) analysis, which predicts that central clearing will reduce the system-wide need for collateral.

In the fourth channel, which we call an *inefficiency channel*, mandatory clearing might make derivatives more costly to use for BHCs due to additional transaction costs, higher margin requirements, or due to increased transparency. Clearing would have an effect similar to a tax on derivatives. BHCs would then respond to mandatory clearing by a lower use of derivatives decreasing their systemic risk contributions.

Empirical literature on the impact of central clearing is scant. Loon and Zhong (2014) show that voluntary central clearing of CDS contracts reduces the CDS spreads. They argue that this is consistent with lower counterparty risk after central clearing. Whereas they focus on risks in individual CDS contracts, we directly measure systemic risk contributions of BHCs after the introduction of mandatory clearing requirements. Arora, Gandhi, and Longstaff (2012) provide evidence that prices of CDS contracts reflect counterparty credit risk. However, they find that economically this effect is so small that there exists little need for central clearing.[5]

2.2 Mandatory Clearing of Derivatives after the Dodd–Frank Act

Title VII of the Dodd–Frank Act provides the basis for regulation of the previously unregulated OTC derivatives market with the aim of increasing transparency and lowering counterparty risk, leading to lower systemic risk. Section 723 of the Dodd–Frank Act requires mandatory clearing of swaps: "It shall be unlawful for any person to engage in a swap unless that person submits such swap for clearing to a derivatives clearing organization . . . if the swap is required to be cleared" (see H.R. 4173-301). The implementation of mandatory clearing requirements is delegated to two regulatory authorities: the CFTC and the SEC.[6]

The Dodd–Frank Act envisioned that swap regulations would take effect 360 days after the date of enactment of the Dodd–Frank Act unless additional rulemaking was needed. This date was July 16, 2011. The wide regulatory framework for mandatory clearing requirements required several rounds of public consultations and postponed the enactment of mandatory clearing requirements until the end of 2012.[7]

Mandatory clearing requirements became effective on March 11, 2013 for swaps between two large swap users, so-called Category 1 Entities (i.e., swap dealers, security-based swap dealers, major swap participants, major security-based swap participants, or active funds). Swaps

---

[5] Our article is related to the literature on the use of derivatives and systemic risks of BHCs. Mayordomo, Rodriguez-Moreno, and Peña (2014) provide evidence that derivatives increase systemic risk of BHCs. Minton, Stulz, and Williamson (2009) analyze the use of credit derivatives.

[6] See the CFTC's and the SEC's Final Rule, Further Definition of "Swap," "Security-Based Swap," and "Security-Based Swap Agreement"; Mixed Swaps; Security-Based Swap Agreement Recordkeeping, FR 77(156), August 13, 2012, p. 48208.

[7] See the CFTC's Clearing Requirement Determination under Section 2(h) of the CEA, FR 77(240), December 13, 2012, p.74284.

between a Category 2 Entity and a Category 1 Entity, another Category 2 Entity, or any other party that wishes to clear the transaction need to be cleared from June 10, 2013 onwards. Other swaps are required to be cleared from September 9, 2013 onwards. Large swap users are responsible for a vast majority of derivatives holdings.[8] Therefore, our empirical strategy distinguishes between the period before and after the date of enactment of mandatory clearing requirements for Category 1 Entities.

Mandatory clearing requirements apply to the majority of interest rate swaps (the majority of fixed-to-floating swaps, basis swaps, forward rate agreements, and overnight index swaps in four currencies: the dollar, pound, yen, and euro) and selected index-based credit default swaps (CDX North America, and iTraxx Europe).[9] However, several exceptions to mandatory clearing exist. First, swaps entered into before the application of mandatory clearing requirements are exempt from the clearing determination.

Second, the End-User Exception to the Clearing Requirement for Swaps enacted by the CFTC (see FR 77(139), July 19, 2012, p. 42560) exempts non-financial companies from mandatory clearing requirements if they use derivatives for hedging purposes. In addition to non-financial companies, small banks with assets lower than $10 billion also qualify for the End-User Exception. Although BHCs were not allowed to employ the End-User Exception (until the acceptance of the Commodity End-User Relief Act of 2015, H.R. 2289, in August, 2015), small BHCs could move at least some derivatives to a subsidiary bank company and subsequently employ the End-User Exception indirectly.

---

[8] In the second quarter of 2015, the swap dealers in our sample held $2.53 trillion of derivatives, which accounts for 97.7% of the $2.59 trillion of derivatives held by all BHCs in our sample.

[9] See 77 FR 74284, December 13, 2012, http://www.cftc.gov/LawRegulation/FederalRegister/FinalRules/2012-29211a.

Third, mandatory clearing requirements are not yet enacted for security based swaps, which are under the SEC's regulatory authority.[10] This might result in substantial distortions to the equal-level playing field in derivatives markets and create a potential for regulatory arbitrage. For example, CDSs are required to be cleared only if they are based on a broad-based security index but not if they are based on an individual security or on a narrow-based security index.[11]

Whereas standardization of cleared derivatives contracts can decrease systemic risks, it can go against the needs of market participants and might suppress innovations, as predicted by Thakor (2012). Derivatives activity can then move to less regulated markets.[12] Giancarlo (2015) argues that trading regulations of OTC derivatives as enacted by the CFTC are ill designed and excessively intrusive. In his view, the CFTC's misguided regulations of the Dodd–Frank Act will actually increase systemic risk stemming from the OTC derivatives markets. Hence, our additional hypothesis is that mandatory clearing requirements will lead to a shift of systemic risk to derivatives contracts, for which mandatory clearing does not apply.

3 Estimation Methodology and Data

3.1 Systemic Risk Measures

In our analysis, we employ the following time varying measures of systemic risk contributions of BHCs: 1) $\Delta CoVaR_t^i(5\%)$, 2) $\Delta CoVaR_t^i(1\%)$, 3) MES_t^i, 4) $LRMES_t^i$, and 5) $SRISK_t^i$. First, we

---

[10] The SEC regulates "security-based swaps" and the CFTC regulates all other "swaps," where "swaps" are derivatives based on interest or other monetary rates and "security-based swaps" are derivatives based on the yield or value of a single security, loan or narrow-based security index. See the CFTC's and the SEC's Final Rule, Further Definition of ''Swap,'' ''Security-Based Swap,'' and ''Security-Based Swap Agreement''; Mixed Swaps; Security-Based Swap Agreement Recordkeeping, FR 77(156), 8.13.2012, p. 48208.

[11] One of the conditions for an index to be classified as a narrow-based security index is that it must have nine or fewer component securities (see the Commodity Exchange Act, 7 USC 1a(25)). If an index cannot be classified as narrow-based, it is a broad-based index.

[12] An alternative explanation for lower activity in cleared derivatives is that the activity on the OTC market was excessive before clearing. Atkeson, Eisfeldt, and Weill (2015) argue that dealer banks provide excessive levels of intermediation services on the OTC market because they are lured into entering due to a business stealing motive.

follow Adrian and Brunnermeier (2014) to estimate the time-varying $\Delta CoVaR_t^i(5\%)$ and $\Delta CoVaR_t^i(1\%)$ for BHC i. We employ the quantile regression on daily data

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i \tag{1}$$
$$X_t^{system} = \alpha^{system|i} + \beta^{system|i} X_t^i + \gamma^{system|i} M_{t-1} + \varepsilon_t^{system|i} \tag{2}$$

where X_t^i is the growth rate of the market-valued total assets of BHC *i* at time *t*; and X_t^{system} is the daily return on the market value of total assets of the financial system, which is measured by the average market-valued total assets returns weighed by the market-valued total assets of each BHC. M_{t-1} is a set of state variables including: *VIX*, which captures the implied volatility of the stock market tracked by the Chicago Board Options Exchanges; *Liquidity Spread*, which represents the difference between the three-month repo rate, obtained from Bloomberg, and the three-month bill rate, obtained from the Federal Reserve of New York; *Changes of Three-Month Treasury Bill Rate*, obtained from the Federal Reserve Board's H.15; *Changes in the Slope of the Yield Curve*, measured by the yield spread between the ten-year treasury rate and the three-month bill rate; *Changes in the Credit Spread*, measured by the credit spread between ten-year BAA-rated bonds and the ten-year treasury rate; *Return of the S&P 500 Index*; and *Real Estate Sector Return in Excess of the Market Return*.

We obtain

$$VaR_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \tag{3}$$

$$CoVaR_t^i(q) = \hat{\alpha}_q^{system|i} + \hat{\beta}_q^{system|i} VaR_t^i(q) + \hat{\gamma}_q^{system|i} M_{t-1} \tag{4}$$

where $\hat{\alpha}_q^i$, $\hat{\gamma}_q^i$, $\hat{\alpha}_q^{system|i}$, $\hat{\beta}_q^{system|i}$, and $\hat{\gamma}_q^{system|i}$ are the coefficients estimated through quantile regression in (1) and (2), based on q = 1% and q = 5% confidence levels. $\Delta CoVaR_t^i(q)$, which indicates the marginal contribution of BHC *i* to the overall systemic risk at time *t*, is calculated as the difference between $CoVaR_t^i(q)$ conditional on the distress of the bank (i.e., q = 0.01 or q = 0.05) and $CoVaR_t^i(50\%)$, conditional on the "normal" state of the bank (i.e., q = 0.5).

$$\Delta CoVaR_t^i(q) = CoVaR_t^i(q) - CoVaR_t^i(50\%) = \hat{\beta}_q^{system|i}\,(VaR_t^i(q) - VaR_t^i(50\%)) \tag{5}$$

Based on the quantile regressions performed on each BHC i, we generate daily $\Delta CoVaR_t^i$(q). Because we have the quarterly financial data for each BHC obtained from the FR Y-9C report, we construct the quarterly time-series $\Delta CoVaR_t^i$(q) and VaR_t^i(q) by using the mean of $\Delta CoVaR_t^i$(q) and VaR_t^i (q) within each quarter for each BHC i. For consistency with other systemic risk measures, we multiply $\Delta CoVaR_t^i$(q) and VaR_t^i(q) by –1 to obtain generally positive values of systemic risk, such that higher values of $-\Delta \mathrm{CoVaR}_t^i$(q) and $-VaR_t^i$(q) indicate greater levels of systemic risk.

The Marginal Expected Shortfall, MES_t^i, is a measure of the marginal contribution of BHC *i* to systemic risk, which is measured by expected shortfall. Following Acharya et al. (2010), we estimate

$$MES_t^i = -E[R_t^i | R_t^m \leq q_\alpha] \tag{6}$$

where R_t^i denotes the daily stock return of BHC *i* at time *t*; R_t^m denotes the daily market return at time *t*; and q_α is the α quantile of market return. We set $\alpha = 5\%$ and estimate MES_t^i based on a forward-looking one-year rolling window. That is, MES_t^i is measured as the mean return of BHC *i* on the days when the market return R_t^m is among the 5% worst values in a one-year period starting at time *t*.

We compute another measure of systemic risk, Long Run Marginal Expected Shortfall ($LRMES_t^i$), defined as the expected loss of an equity value of a BHC *i* in the case of a financial crisis in a one-year period starting at time *t*. In Acharya et al. (2012), $LRMES_t^i$ is approximated by

$$LRMES_t^i = 1 - exp(-18 \times MES_t^i) \tag{7}$$

where MES_t^i is the expected one-day loss if market returns are less than –2%. That is, MES_t^i is estimated for each BHC *i* in a period of one year following time *t* based on the daily stock return as $MES_t^i = -E[R_t^i | R_t^m \leq -2\%]$.

Another measure of systemic risk, $SRISK_t^i$, is defined as capital that BHC *i* needs to weather a financial crisis (i.e., to have more than the regulatory prescribed level of capital) in a one-year period following time *t*. From $SRISK_t^i = E[k(Debt + Equity) - Equity) | Crisis]$, we obtain

$$SRISK_t^i = kDebt_t^i - (1-k)(1 - LRMES_t^i) \times Equity_t^i \quad (8)$$

where k is a prudential capital ratio which is taken as 8%; $Debt_t^i$ is the debt of BHC *i* at time *t*; $LRMES_t^i$ is the long run marginal expected shortfall when the market returns are less than –2%, as given in (7); and $Equity_t^i$ is the equity capital of BHC *i* at time *t*.

We also estimate several measures of non-systemic risk. For clarity, we suppress subscripts *i*, and *t* from now on in the text. $VaR(5\%)$ is estimated based on equation (3) with α = 5%. Based on (1), we perform the quantile regression on the daily stock price of each BHC at each quarter and generate *Market Risk Beta* (the regression coefficient of *Return of the S&P 500 Index*) and *Idiosyncratic Risk*, unexplained by the market factor, defined as 1 minus R^2 from the quantile regression. Given the bounded nature of *Idiosyncratic Risk*, we use its logistic transformation (i.e., $\log \frac{(1-R^2)}{R^2}$). This yields quarterly-varying *Market Risk Beta* and *Idiosyncratic Risk* for each BHC.

3.2 Data Sources and Sample Selection

We collect data from several sources. We obtain the consolidated financial data of BHCs from the Consolidated Financial Statements for Holding Companies; the so-called FR Y-9C reports. The FR Y-9C report includes detailed information of a BHC's income statement, the consolidated balance sheet, and off-balance sheet items, including a wide range of data on the use of financial derivatives.

For the construction of systemic risk measures, we obtain the data for the daily stock price of each BHC from the Center for Research in Security Prices (CRSP). We match the measures of systemic risk of each BHC by PERMCO in CRSP with its corresponding RSSD9001 in the FR Y-9C reports.[13] We focus on the period following the enactment of the Dodd–Frank Act, from the third quarter of 2010 to the second quarter of 2015. In this way, our sample includes the BHCs that are publicly listed and required to file the FR Y-9C report between the third quarter of 2010 and the second quarter of 2015.[14]

We collect the data on the proportion of interest rate derivatives cleared from the DTCC's Global Trade Repository Reports from the first quarter of 2012 to the second quarter of 2015 and from Trioptima's Interest Rate Trade Repository Reports from the third quarter of 2010 to the fourth quarter of 2011. We also hand-collect individual BHC data on the proportion of interest rate derivatives cleared from the quarterly 10-Q statements filed with the SEC (see Table 1A).

<Insert Table 1A here>

3.3 Construction of Main Independent and Control Variables

We construct three clearing indicators—*Clearing Dummy*, *Ratio of Interest Rate Derivatives Cleared*, and *Individual Cleared Ratio*—to evaluate the impact of mandatory clearing requirements and the proportion of derivatives cleared on systemic risk. The variable *Clearing Dummy* equals 0 before and 1 after March 11, 2013, when the mandatory clearing requirements became effective for the majority of newly entered interest rate derivatives on the market. The variable *Ratio of Interest Rate Derivatives Cleared* is defined as the proportion of all interest rate

[13] The PERMCO-RSSD links can be found at "Federal Reserve Bank of New York. 2014. CRSP-FRB Link."
[14] The asset-size threshold for filing the FR Y-9C report became $500 million in March 2006 and was changed to $1 billion in March 2015.

derivatives on the market that are cleared by derivatives clearing organizations in a given quarter. We use quarter means based on weekly reports of the DTCC and Trioptima. The variable *Individual Cleared Ratio* is constructed as the proportion of a BHC's interest rate derivatives that are cleared in a given quarter. If the information on clearing of interest rate derivatives is not available, we use the proportion of a BHC's total financial derivatives that are cleared in a given quarter.

We use different proxies for the value of interest rate derivatives of a BHC. We employ *Fair Value of Interest Rate Derivatives*, defined as the sum of the gross positive and gross negative fair value of interest rate derivatives, divided by the gross total assets of a BHC. Fair values might better reflect real exposures of BHCs through the derivatives market but are not available across different types of interest rate contracts. Because mandatory clearing requirements apply only to interest rate swaps and interest rate forward agreements, we also use *Interest Rate Swaps*, which denotes the notional values of interest rate swaps divided by the gross total assets, and *Interest Rate Forwards and Swaps*, which denotes the notional values of interest rate forward agreements and interest rate swaps divided by the gross total assets.

We use several variables to control for bank-specific time-varying effects on systemic risk that are unrelated to derivatives. We employ proxies for CAMELS, which represent the financial criteria used by regulators for evaluating banks (following Berger, Makaew, and Roman (2015) and Duchin and Sosyura (2014)). We define *Capital Ratio* as the equity capital of a BHC scaled by its gross total assets. *ROA* is used to control for the profitability of a BHC. We define *Liquidity* as the ratio of cash to total deposits, *Asset Quality* as the ratio of non-performing loans to total loans, *Management Quality* as the ratio of total personnel expenses to gross total assets, and *GAP Ratio* as the ratio of the absolute difference between short-term assets and short-term liabilities to gross total assets. We use *log (GTA)*, defined as the logarithm of gross total assets,[15] to control for bank size, and *log (GTA)* squared to control for size anomalies in banking as documented by Gandhi and Lustig (2015).

3.4 Summary Statistics

Table 1B presents the summary statistics of systemic risk measures and financial variables for BHCs in our sample. We report the means, medians, standard deviations, and minimum and maximum values.

The mean of $-\Delta CoVaR(5\%)$ indicates that on average a distress of a BHC (i.e., the 5% worst-case scenario) leads to a 0.46% decline of the system VaR. As depicted in $-\Delta CoVaR(1\%)$, we note that on average, an even larger distress of a BHC (i.e., the 1% worst case scenario) leads to a 0.73% decline of the system VaR. As depicted in *MES*, the mean stock return of a BHC on the days when the S&P 500 return is among the 5% worst returns in a year is –1.39%. Looking at *LRMES*, the mean expected loss of equity value of a BHC in the crisis scenario is 20.18%. The mean of *SRISK* indicates that the equity value of an average BHC in the crisis scenario drops $0.2593 billion below the level of regulatory prescribed capital requirements at the prudential capital ratio of 8%.[16] Individual risks of BHCs measured by *Market Risk Beta* and *Idiosyncratic Risk* are 0.6693 and 1.6279, respectively.

The notional amounts of financial derivatives are comparable to a sizeable proportion of the gross total assets of BHCs. The mean of *Interest Rate Forwards and Swaps* is 0.4079. The largest proportion of derivatives are interest rate swaps, followed by interest rate forwards,

---

[15] To obtain the full value of the assets financed, we follow Berger, Makaew, and Roman (2015) and compute gross total assets (*GTA*) by summing together total assets, allowance for loan and lease losses, and the allocated transfer risk reserve.

[16] We have double-checked and confirmed that all our measures of systemic risk are positively and highly statistically significantly related to other systemic risk indicators, such as the National Financial Conditions Index of the Chicago Fed and the Composite Index of Systemic Stress, developed by Hollo, Kremer and Lo Duca (2012).

interest rate options, credit default swaps, and other swaps (i.e., foreign exchange swaps, equity swaps, and commodity and other swaps). Fair values of financial derivatives are substantially lower. The mean of *Fair Value of Interest Rate Derivatives* is 0.017. The median BHC uses interest rate forwards and swaps in a notional amount of only 0.008 of gross total assets, and does not hold interest rate swaps, credit default swaps, interest rate options, and other swaps. However, a few BHCs hold a large amount of financial derivatives.

The mean of *Ratio of Interest Rate Derivatives Cleared* is 60.11% and increased from the lowest value of 45.9% at the beginning of our period to the highest value of 70.6% in the fourth quarter of 2014. The hand-collected data on interest derivatives cleared per BHC, depicted by variable *Individual Cleared Ratio*, has a mean of 41.74% and ranges from a minimum of 1.3% to a maximum of 91.8%.

<Insert Table 1B here>

BHCs are substantially heterogeneous in their use of derivatives. At the end of our sample period, the five biggest users of interest rate swaps were Goldman Sachs Group, Citigroup, JPMorgan Chase & Co., Bank of America Corporation, and Morgan Stanley. They cover 95.41% of the total notional value of interest rate swaps and 95.62% of the total fair value of interest rate derivatives in our sample.

BHCs that use interest rate swaps are substantially different in their characteristics from non-users of interest rate swaps (see Panel B of Table 1B). They have higher $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES*, *LRMES*, *SRISK*, *Market Risk Beta*, and *Idiosyncratic Risk*, but lower $-VaR(5\%)$ compared to non-users. BHCs that use interest rate swaps have also higher *Capital Ratio*, *ROA*, and *log (GTA)*, and lower *Liquidity* and *GAP ratio*. They hold higher levels of CDSs, interest rate options, and other swaps.

3.5 Difference-in-Differences Estimator

To examine the impact of mandatory clearing requirements on systemic risk, we employ a difference-in-differences (DID) estimator, for which the first difference is in the level of interest rate derivatives that BHCs hold and the second difference is in the proportion of interest rate derivatives cleared. We employ the following DID regression model for BHC *i* at time *t*.

$$Systemic\ Risk_{i,t} = \beta_1 Clearing\ Indicator_{i,t-1} + \beta_2 Derivatives_{i,t-1} + \\ +\beta_3 Clearing\ Indicator_{i,t-1} * \ Derivatives_{i,t-1} + \sum_{n=1}^{N} \alpha_n X_{n,i,t-1} + \nu_i + \mu_t + \varepsilon_{i,t} \quad (9)$$

The dependent variable $Systemic\ Risk$ is one of the five systemic risk variables: $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES*, *LRMES*, or *SRISK*, and captures the systemic risk contribution of a BHC. The independent variable *Derivatives* denotes proxies for the value of interest rate derivatives of a given BHC, *Fair Value of Interest Rate Derivatives*, *Interest Rate Swaps*, or *Interest Rate Forwards and Swaps*. *Clearing Indicator* depicts the level of derivatives clearing through one of the three proxies: *Clearing Dummy*,[17] *Ratio of Interest Rate Derivatives Cleared*, or *Individual Cleared Ratio*. The vector variable X includes variables that control for bank characteristics, including *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, *GAP Ratio*, *log (GTA)*, and *log(GTA)* squared (see Table 1A). We include lagged independent variables because BHC's reporting data only become available with a two-month lag and only then affect stock prices. In addition, systemic risk variables are based on quarter means whereas balance sheet data present the end-quarter values. ε represents an error term. Standard errors are heteroskedasticity-consistent and are clustered at the individual BHC level. We follow Gormley and Matsa (2014) and employ bank-specific fixed effects to control for unobserved time-invariant heterogeneity across BHCs that might affect systemic risk.

[17] We set β_1 to 0 when using *Clearing Dummy* as a clearing indicator to prevent collinearity with quarter fixed effects.

Regressions include quarter fixed effects to control for macroeconomic factors that may vary over time.

To identify the channels through which mandatory derivatives clearing affects systemic risk, we use additional regression equations in which we replace systemic risk measures with other indicators of risks ($-VaR(5\%)$ and *Idiosyncratic Risk*), indicators of interconnectedness (*Market Risk Beta* and *Counterparty Revenue*), and efficiency indicators (*ROA*, *Trading Revenue*, *Trading Revenue from Interest Rate Exposures*, and *Trading Revenue from FX Exposures*).

4 Empirical Results

4.1 Main Results

Now, we examine whether BHCs with larger positions in interest rate forwards and swaps experience a larger drop in systemic risk contributions after the introduction of mandatory clearing requirements. In Table 2A, we estimate the regression in (9) based on five different measures of systemic risk: $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES*, *LRMES*, and *SRISK*. All measures of systemic risk are negatively and statistically significantly related to the interaction term between *Fair Value of Interest Rate Derivatives* and *Clearing Dummy*. The regression coefficients of the interaction term are –0.00178 for $-\Delta CoVaR(5\%)$, –0.00147 for $-\Delta CoVaR(1\%)$, –0.00412 for *MES*, –0.0467 for *LRMES*, and –18.42 for *SRISK*. This confirms our prediction that mandatory clearing of interest rate derivatives is associated with a larger drop in systemic risk contributions for BHCs that have greater exposures to interest rate derivatives.

<Insert Table 2A here>

Our results are also economically significant. The regression coefficient –0.00178 in the regression of $-\Delta CoVaR(5\%)$ in Table 2A indicates that one standard deviation higher position in *Fair Value of Interest Rate Derivatives* leads to a drop in $-\Delta CoVaR(5\%)$ of 6.15% of its standard deviations after mandatory clearing, all else being equal. The coefficient –0.00147 in the regression of $-\Delta CoVaR(1\%)$ indicates that one standard deviation higher position in *Fair Value of Interest Rate Derivatives* leads to a drop in $-\Delta CoVaR(1\%)$ of 3.29% of its standard deviations after mandatory clearing, all else being equal. The coefficient –0.00412 in the regression of *MES* indicates that one standard deviation higher position in *Fair Value of Interest Rate Derivatives* leads to a drop in *MES* of 4.54% of its standard deviations after mandatory clearing, all being else equal. The coefficient –0.0467 in the regression of *LRMES* indicates that one standard deviation higher position in *Fair Value of Interest Rate Derivatives* leads to a drop in *LRMES* of 2.48% of its standard deviations after mandatory clearing, all else being equal. The coefficient –18.42 in the regression of *SRISK* indicates that one standard deviation higher position in *Fair Value of Interest Rate Derivatives* leads to a drop in *SRISK* of 59.9% of its standard deviations, all else being equal. In short, mandatory clearing leads to a statistically and economically larger drop in systemic risk contributions for BHCs that are larger users of derivatives.

4.2 Alternative Measures of Derivative Clearing

BHCs voluntarily cleared a proportion of derivatives already before the enactment of mandatory clearing requirements. In addition, mandatory clearing requirements were effective only for the newly entered swaps but not for the swaps that were concluded before the effectiveness of mandatory clearing requirements. To account for this, we employ two alternative clearing proxies. First, we employ the ratio of interest derivatives cleared on the market, *Ratio of Interest Rate Derivatives Cleared*, based on reporting data from the DTCC and Trioptima. The results in Table 2B show that *Ratio of Interest Rate Derivatives Cleared * Fair Value* of *Interest Rate Derivatives* is significantly and negatively related to $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES, LRMES,* and *SRISK*. This confirms that BHCs with higher interest rate derivatives positions experience a larger drop in systemic risk contributions when more interest rate derivatives are cleared on the market.

Second, we compute *Individual Cleared Ratio*, which denotes the proportion of derivatives cleared by a given BHC. Because only a limited number of BHCs report the percentage of derivatives cleared and the reporting started only as late as in the last quarter of 2012, we use contemporaneous rather than lagged independent variables to prevent a further drop in the sample size. The results in Table 2C show that *Individual Cleared Ratio * Fair Value of Interest Rate Derivatives* is significantly and negatively related to $-\Delta\text{CoVaR}(5\%)$, $-\Delta\text{CoVaR}(1\%)$, *MES, LRMES,* and *SRISK*. In brief, our results confirm that derivatives clearing decreases the systemic risk contributions of BHCs stemming from their derivatives positions.

<Insert Table 2B & Table 2C here>

4.3 Instrumental Variable (IV) Analysis

Now, we employ an instrumental analysis (IV) regression approach to account for the potential endogeneity of our interest rate derivatives (instead of using lagged independent variables as in (9)). As an instrument for a BHC's interest rate derivatives position, we use an increase in its competitors' predicted fair value of interest rate derivatives. The intuition here is that competitive pressure would force BHCs to use derivatives more intensively if other BHCs (and especially ones of similar size) increase their derivatives positions.

Building on the treatment approach of Ellul and Yerramilli (2013), we construct the instrumental variable *Predicted Fair Value of Interest Rate Derivatives* by employing the following regression. For each BHC *i* at each quarter, we regress the variable *Fair Value of Interest Rate Derivatives* on *log (GTA)*, excluding individual BHC *i* from the regression. Based on the estimated regression, we compute the predicted value of *Fair Value of Interest Rate Derivatives* at the size of BHC *i* to obtain the value of the newly constructed variable *Predicted Fair Value of Interest Rate Derivatives* for BHC *i* at a given quarter. We employ the IV regression approach by using the two-stage least squares (2SLS) estimator. We instrument *Fair Value of Interest Rate Derivatives* and *Clearing Dummy * Fair Value of Interest Rate Derivatives* by the first difference in *Predicted Fair Value of Interest Rate Derivatives*, and by the first difference in *Clearing Dummy * Predicted Fair Value of Interest Rate Derivatives*.

The results of the IV regression are reported in Table 2D. First-stage regressions are in columns (1) and (2). Sanderson and Windmeijer (2016) tests of underidentification (SW χ^2 Wald test) and weak identification (SW F test) reject the null hypotheses that our endogenous regressors are unidentified or weakly identified. Second stage regressions are in columns (3) to (7). The results are qualitatively similar to the ones in Table 2A and they show that, after controlling for the endogeneity problem of interest rate derivatives, the treatment variable *Clearing Dummy * Fair Value of Interest Rate Derivatives* is significantly and negatively related to all five measures of systemic risk. This confirms our main hypothesis that clearing of interest rate derivatives reduces BHCs' contributions towards systemic risk.

<Insert Table 2D here>

4.4 Alternative Measures of Financial Derivatives

We continue by exploiting the differences in clearing requirements for BHCs in a cross section. In particular, the End-User Exception allows for an exemption from mandatory clearing for small banks with total assets below \$10 billion. Even though BHCs with total assets below \$10 billion could not invoke the End-User Exception directly, they could use it for derivatives held by its bank subsidiaries. We conjecture that the End-User Exception could cloud the treatment effect of mandatory clearing requirements.

To discard the effect of the End-User Exception and better isolate the treatment effect, we focus now only on derivatives for trading purposes, for which the End-User Exception cannot be invoked.[18] For brevity, we focus on three measures of systemic risk: $-\Delta CoVaR(5\%)$, MES, and

---

[18] The End-User Exception can only be applied for derivatives used for hedging purposes but not for derivatives used for trading purposes.

SRISK. The results in columns 1–3 of Table 3A confirm that greater use of interest rate derivatives for trading is associated with a larger drop in BHCs' systemic risk contributions after the introduction of mandatory clearing requirements. Columns 4–6 of Table 3A confirm that our results are statistically significantly when considering $-\Delta CoVaR(5\%)$ and $SRISK$ but not for *MES* when considering derivatives used for hedging purposes.

Looking at derivatives for hedging purposes, we predict that mandatory clearing would especially have an impact in the case of large BHCs for which the End-User Exception would not be applicable. We identify large BHCs with GTA larger than $10 billion with the dummy variable *Large Dummy* set to 1 and all other BHCs with *Large Dummy* set to 0. The interaction terms *Clearing Dummy * Large Dummy* Interest Rate Derivatives for Hedging* in columns 7–9 of Table 3A are significantly and negatively related to *MES*, and *SRISK*, respectively (but insignificantly to $-\Delta CoVaR(5\%)$). This provides additional evidence that mandatory clearing lowers BHC systemic risk contributions that stem from derivatives exposures.

<Insert Table 3A here>

Another approach to improve the precision of our treatment is to focus only on the type of derivatives for which mandatory clearing requirements apply. In the case of interest rate derivatives, mandatory clearing requirements apply to the large majority of interest rate swaps and interest rate forward agreements, but not to interest rate options and futures contracts. Hence, for this we use the interaction term *Clearing Dummy * Interest Rate Swaps* and *Clearing Dummy * Interest Rate Forwards and Swaps* as treatment.[19]

In Tables 3B and 3C, we investigate how the use of interest rate forwards and interest rate swaps affects a BHC's contribution towards systemic risk after the introduction of mandatory clearing

---

[19] On the one hand, our treatment improves because we now focus on the type of derivatives to which mandatory clearing applies. On the other hand, *Interest Rate Swaps* and *Interest Rate Forwards and Swaps* are computed based on notional values (BHCs do not report fair values of interest rate derivatives according to their types), which may reflect the derivatives exposures less precisely than fair values used in *Fair Value of Interest Rate Derivatives*.

requirements. The interaction term *Clearing Dummy * Interest Rate Swaps* is negatively and significantly related to $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES*, *LRMES*, and *SRISK*. In addition, the interaction term *Clearing Dummy * Interest Rate Forwards and Swaps* is negatively and significantly related to $-\Delta CoVaR(5\%)$, $-\Delta CoVaR(1\%)$, *MES*, *LRMES*, and *SRISK*. The results confirm that greater use of interest rate swaps and interest rate forward agreements is associated with a larger drop in systemic risk contributions after mandatory clearing requirements are enacted.

<Insert Table 3B & Table 3C here>

In Table 4A, we examine the contributions to systemic risk stemming from interest rate options and other derivatives (including foreign exchange derivatives, equity derivatives, and commodity and other derivatives), for which mandatory clearing requirements do not apply, while controlling for the effect of interest rate forwards and interest rate swaps. Columns 1–3 show that the interaction term *Clearing Dummy * Interest Rate Forwards and Swaps* is still negatively related, whereas *Clearing Dummy * Interest Rate Options* is positively and significantly related to the systemic risk measures $-\Delta CoVaR(5\%)$, *MES*, and *SRISK*. This indicates that systemic risk contributions might have moved away from interest rate forwards and swaps, which are required to be cleared, to interest rate options, which are still exempted from mandatory clearing.

When adding *Other Derivatives* and their interaction with *Clearing Dummy* as control variables in the regression equation in columns 4–6, we see that the interaction term *Clearing Dummy * Interest Rate Forwards and Swaps* is still negatively and statistically significantly related to systemic risk measures. The interaction term *Clearing Dummy * Other Derivatives* is not unequivocally related to systemic risk.

Mandatory clearing requirements were also enacted for credit derivatives but only for the selected CDSs, and broad-based index CDSs under the authority of the CFTC and not for narrow-based index CDSs under the authority of the SEC. In order to control for the effect of CDSs on systemic risk, we include the variables *Credit Default Swaps* and *Clearing Dummy **

Credit Default Swaps in our regression. Our main effect is unchanged, as shown in Table 4B. That is, the interaction variables *Clearing Dummy * Interest Rate Swaps* and *Clearing Dummy * Interest Rate Forwards and Swaps* are significantly and negatively related to $-\Delta CoVaR(5\%)$, *MES*, and *SRISK*.

<Insert Table 4A & Table 4B here>

Table 4B shows that the use of credit default swaps is associated with lower systemic risk before the introduction of mandatory clearing requirements. However, this relationship becomes less pronounced after the introduction of mandatory clearing requirements. One explanation for this is that systemic risk contributions may move from interest rate derivatives, for which clearing determination holds for the majority of interest rate swaps, to credit derivatives, for which clearing determination holds only for the broad-based index CDSs. This calls for a uniform regulatory framework for mandatory clearing of derivatives.

4.5 The Channels through Which Clearing Affects Systemic Risk

Now, we identify the channels through which clearing of derivatives affects systemic risk contributions that stem from derivatives. First, we analyze the impact of derivative clearing requirements on stand-alone risk of BHCs, measured by $-VaR(5\%)$ and *Idiosyncratic Risk*. Table 4C shows that mandatory clearing requirements reduce stand-alone risks of BHCs more if BHCs hold larger positions in interest rate derivatives. This is consistent with the *idiosyncratic risk* channel, in which mandatory clearing reduces systemic risk by lowering individual risk exposures of BHCs.

Second, Table 4D shows that *Market Risk Beta*, which serves as a proxy for interconnectedness and a co-movement of a BHC with the market, increases more for a BHC with larger interest rate derivatives exposures after mandatory clearing requirements are enacted. *Counterparty Revenue* is insignificantly related to the interaction term *Clearing Dummy * Fair Value of Interest Rate Derivatives*. These findings do not support the *counterparty risk* channel, in which systemic risk associated with derivatives decreases after clearing due to lower counterparty risk and lower interconnectedness of BHCs.

Third, Table 4D shows that measures of profitability, such as *Trading Revenue*, and *Trading Revenue from Interest Rate Exposures*, are negatively and significantly (also *ROA*, but insignificantly) related to the interaction term *Clearing Dummy * Fair Value of Interest Rate Derivatives*. In stark contrast, *Trading Revenue from Exchange Rate Exposures* is positively and significantly related to the interaction term *Clearing Dummy * Fair Value of Interest Rate Derivatives*. This indicates that profitability from interest rate derivative operations decreased after clearing requirements, whereas profitability increased for exchange rate derivatives, which are exempted from clearing requirements. Therefore, our findings do not support the *efficiency* channel, in which systemic risk decreases after derivatives clearing due to the associated efficiency improvements.

<Insert Table 4C & Table 4D here>

Now, we add the change in derivatives values as an additional control variable to our estimation in (9) to analyze the conjecture that the decline in systemic risk after mandatory clearing is a consequence of a lower use of derivatives rather than a consequence of central clearing. The results in Table 4E show that the interaction terms between the use of derivatives and the clearing indicator retain a negative and significant sign for all three measures of systemic risk (i.e., $-\Delta CoVaR(5\%)$, *MES*, and *SRISK*) as well as for both measures of idiosyncratic risk ($-VaR(5\%)$ and *Idiosyncratic Risk*). Therefore, our findings do not support the *inefficiency* channel, in which systemic risk (and idiosyncratic risk) would decrease predominantly because BHCs would use derivatives less after mandatory clearing.[20]

---

[20] We have also analyzed whether BHCs' use of derivatives declines after the enactment of mandatory clearing requirements. We cannot find statistically significant decline in the use of interest rate derivatives measured by several proxies, including *Fair Value of Interest Rate Derivatives*, *Interest Rate Swaps*, and *Interest Rate Forwards and Swaps*. The results are shown in Table SA1 in the supplementary appendix.

<Insert Table 4E here>

A potential explanation for decreased idiosyncratic risk and decreased profitability from interest rate derivative operations after mandatory clearing might be that BHCs took less risky positions in derivatives and this lowered idiosyncratic risk and consequently systemic risk. Acharya and Bisin (2014) show that, if the clearinghouse provides information about BHCs' aggregate positions, then it is optimal for the BHCs to reduce derivatives positions otherwise they would face an increase in price (or collateral requirement), something which does not happen if the aggregate position of the BHC is not revealed (e.g., in the case of bilateral contracts). Our data indicates that derivatives positions were not reduced in quantity but became less risky after mandatory clearing. The role of the clearing organization might then be in verifying aggregate risk exposures of BHCs stemming from derivatives contracts.

5 Robustness Checks

Now, we provide several robustness checks to support the consistency of our findings across different subsamples, time periods, and several controls for size. We also estimate alternative econometric models, including a Heckman two-stage estimation model, and present cross-section treatment analysis.

5.1 Subsample Analysis

Now, we replicate our analysis across different subsamples. For each control variable, gross total assets (*GTA*), *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, and *GAP Ratio*, we form two subsamples: one in which a control variable is below median and one in which it is above median (see Table SA2 in the supplementary appendix). We note that the regression coefficients are largely statistically significant and negative across subsamples, consistent with our main analysis.

Although our sample period starts with the third quarter of 2010—the first quarter after the enactment of the Dodd–Frank Act—several of the provisions of the Dodd–Frank Act only became effective one year later. To assure that our results are not driven by other provisions of the Dodd–Frank Act, we redo our analysis on a subsample starting with the third quarter of 2011. The results, reported in Table SA3 in the supplementary appendix, confirm our main results. We also extend our sample period to the period between the first quarter of 2008 and the second quarter of 2015, which covers the period of the financial crisis. The results, reported in Table SA4 in the supplementary appendix confirm our main results although with lower significance.

Our concern is that the results are driven by some other derivatives regulations and not by the enactment of mandatory clearing requirements. For example, the Dodd-Frank Act stipulated enhanced reporting of derivatives to increase transparency in the OTC derivatives markets. To alleviate this concern, we repeat our analysis on the pretreatment period, from the third quarter of 2010 to the second quarter of 2012, using *Ratio of Interest Rate Derivatives Cleared* times proxies for derivatives as our treatment variable. The results become insignificant (or significant only at 10% level, see Table SA5 in the supplementary appendix). This provides additional confirmation that mandatory clearing requirements are driving our results.

5.2 Controlling for Size Effects

Up until now, we have included *log (GTA)* and *log (GTA) * log (GTA)* as control variables to account for size effects and for non-linearities in size effects. In Table SA6 in the supplementary appendix, we include only *log (GTA)* as a control variable (but not *log (GTA) * log (GTA)* as before). In Table SA7 in the supplementary appendix, we control for size by including the fixed effects of 10 quantiles of *log (GTA)*, instead of *log (GTA)*. The results in Table SA6 and Table SA7 confirm our main findings. Our results continue to hold also if we winsorize at 0.5% all the variables in the regression analysis.

5.3 Alternative Econometric Models

In Table SA8 in the supplementary appendix, we report our basic regressions using heteroskedasticity and autocorrelation robust standard errors. The results confirm our basic findings. In Table SA9 in the supplementary appendix, we employ an alternative econometric model that excludes bank fixed effects. The results show that the variables *Interest Rate Swaps*, *Interest Rate Forwards and Swaps*, and *Fair Value of Interest Rate Derivatives* are significantly and positively related to systemic risk. After the introduction of mandatory clearing requirements, the positive relationship becomes less pronounced because *Clearing Dummy * Interest Rate Swaps*, *Clearing Dummy * Interest Rate Forwards and Swaps*, and *Clearing Dummy * Fair Value of Interest Rate Derivatives* are negatively related to systemic risk.

Our next concern is that treatment might be endogenous because BHCs voluntarily decide whether they use derivatives or not and our treatment variable is the interaction term between *Clearing Dummy* and the use of interest rate derivatives of a BHC. To avoid potential self-selection bias, we employ Heckman's (1979) two-step procedure. Following Wooldridge (2010, p. 835), we perform the probit model on each quarter and regress *Interest Rate Swaps Dummy*, *Interest Rate Forwards and Swaps Dummy*, and *Fair Value of Interest Rate Derivatives Dummy*,[21] respectively, on the individual BHC level means of all lagged control variables, the first difference in *Predicted Fair Value of Interest Rate Derivatives* defined in section 4.3, and the variable *Clearing Dummy*. In this way, we construct the quarterly self-selection parameters, inverse Mills ratios, *Lambda Interest Rate Swaps*, *Lambda Interest Rate Forwards and Swaps*, and *Lambda Fair Value of Interest Rate Derivatives*, respectively. In the next step (i.e., in the outcome equation), we use the systemic risk variables $-\Delta CoVaR\ (5\%)$, *MES*, and *SRISK* as dependent variables, and we include the quarterly inverse Mills ratios and the individual BHC

---

[21] We define the dummy variable *Interest Rate Swaps Dummy*, which equals 1 if *Interest Rate Swaps* > 0 and 0 otherwise, the dummy variable *Interest Rate Forwards and Swaps Dummy*, which equals 1 if *Interest Rate Forwards and Swaps* > 0 and 0 otherwise; and the dummy variable *Fair Value of Interest Rate Derivatives Dummy*, which equals 1 if *Fair Value of Interest Rate Derivatives* > 0 and 0 otherwise.

level means of independent variables and run the pooled OLS regression. We account for general heteroskedasticity and serial correlation by reporting the heteroskedasticity and autocorrelation consistent standard errors.

The results of the Heckman two-stage estimation model reported in Table 5A are consistent with our main findings. That is, mandatory clearing reduces systemic risk contributions that stem from derivatives positions of BHCs, even after controlling for potential self-selection bias.

<Insert Table 5A here>

5.4 Cross-Section Analysis

To ensure that our results are not driven by non-linear behavior in time and in derivatives values, we construct cross-section data with dummy variables denoting the use of derivatives. In particular, we employ the cross-section dummy variable *Interest Rate Swaps Dummy*, defined as 1 if a BHC uses interest rate swaps before the enactment of mandatory clearing requirements, and 0 otherwise, as a treatment variable. We also compute time averages of our control variables before the mandatory clearing requirements. As dependent variables, we compute the difference in the means of systemic risk measures $-\Delta\mathrm{CoVaR}\ (5\%)$, *MES*, and *SRISK* between two periods, before and after the enactment of mandatory clearing requirements, to obtain *Difference in* $-\Delta CoVaR(5\%)$, *Difference in MES*, and *Difference in SRISK* for each BHC.

First, we assume that outcomes are conditionally independent of the treatment (i.e., all variables that affect systemic risk and treatment assignment are observable). Following Abadie et al. (2004) and Abadie and Imbens (2012), we estimate the treatment effect using three matching methods: nearest-neighbor matching method (nnmatch), propensity-score matching method (psmatch), and inverse-probability weighting method (ipw). Matching methods are less prone to model specification errors, compared to parametric models, and may allow for better inference of the treatment effects by balancing distributions of control variables across treatment groups (An and Winship (2015)). With these approaches we compare how systemic risk contributions change after mandatory clearing for BHCs that have as similar control variables as possible, except for their treatment status (i.e., their use of interest rate swaps).

The results in Table 5B confirm that changes in systemic risk contributions, *Difference in* $-\Delta CoVaR(5\%)$, *Difference in MES*, and *Difference in SRISK* are negatively related to *Interest Rate Swaps Dummy*. That is, BHCs that used *Interest Rate Swaps* experienced a larger drop in systemic risk contributions following mandatory clearing compared to BHCs that did not employ *Interest Rate Swaps*, all else being equal. This confirms our main findings.

<Insert Table 5B here>

Second, we allow for endogenous treatment. That is, we drop the assumption that treatment assignment is conditionally independent of outcomes and allow for unobservable variables that affect treatment assignment and outcome. Following Wooldridge (2010), we use a control-function RA estimator, which includes residuals from the treatment model in the models for the potential outcomes. We believe that systemic risk contributions and the probability of using interest rate swaps are both influenced by the size of BHCs and by the maturity mismatch of bank assets and liabilities (*GAP Ratio*). Hence, we condition on *log (GTA)* and *GAP Ratio* in the probit model for *Interest Rate Swaps Dummy*.

The results in Table 5B indicate that, all else being equal, the drop in systemic risk contributions after mandatory clearing is significantly more pronounced for the average user of interest rate swaps compared to non-users of interest rate swaps. The average treatment effects on the treated (ATET) for *Difference in* $-\Delta CoVaR(5\%)$, *Difference in MES*, and *Difference in SRISK* are –0.0102, –0.0832, and –5.810, respectively. See Table SA10 in the supplementary appendix for the full estimation.

We also analyze whether larger use of interest rate swaps affects systemic risk contributions in a non-linear manner. Following Hirano and Imbens (2004) and Guardabascio and Ventura (2013), we use the generalized propensity score matching method and allow for continuous treatment. In

Figure 2, we estimate dose-response functions that identify systemic risk measures as functions of *Interest Rate Swaps Intensity* of a BHC (defined as the value of *Interest Rate Swaps* divided by the maximal value of *Interest Rate Swaps* of any BHC). Following mandatory clearing requirements, systemic risk contributions $-\Delta CoVaR(5\%)$ decreases for BHCs that use interest rate swaps (i.e., *Difference in* $-\Delta CoVaR(5\%)$ is always negative). A decrease in systemic risk contributions initially becomes more pronounced with more intensive use of interest rate swaps. However, this trend later reverses, resulting in a U-shaped curve of the change in systemic risk contributions as a function of interest rate derivatives (the results for *Difference in MES* are similar; *Difference in SRISK* is always negative and downwards sloping in *Interest Rate Swaps Intensity*). This gives some indication that the reduction in systemic risk contributions following mandatory clearing is the most pronounced for the intermediate use of interest rate derivatives.

<Insert Figure 2 here>

6 High Dimensional Methods

We are concerned with whether choosing a limited set of standard control variables (as in Berger, Makaew, and Roman (2015) and Duchin and Sosyura (2014)) is sufficient to account for unobservable factors that might affect systemic risk. We employ multidimensional methods to select the most important control variables out of the vast array of BHC reporting data.

We construct an initial set of control variables by combining 116 variables from BHCs' consolidated balance sheets as reported in Schedule HC, Schedule HC-B, Schedule HC-C, and Schedule HC-E, and 131 variables from consolidated income statement Schedule HI, Schedule HI-A, and Schedule HI-B in the FR Y-9C reports. We compute logarithms of control variables. We scale control variables by gross total assets (*GTA*). We compute squares of control variables, scaled by the *GTA*. We interact control variables scaled by the *GTA* with time trend. We also compute the initial values of control variables. We also add six proxies for CAMELS (including *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, and *GAP Ratio*), and two bank size variables, *log (GTA)* and *log (GTA) * log (GTA)*. We also compute their initial values, their interaction with time trend and their values squared. For each systemic risk measure, we also compute the initial value of the interest rate derivatives variable and its interaction with time trend. All dependent and independent variables (except the initial values of control variables), including quarter dummies, are time centered to remove fixed effects. We combine all of these lists in a set of 1,277 control variables.

We employ the post-double Lasso estimator developed by Belloni et al. (2014a, 2014b) and select the most relevant control variables, which are subsequently included in the final regressions as depicted in Table 6. Note that systemic risk measures, control variables, interest rate derivative variables, and their interaction terms with *Clearing Dummy* are all time centered to control for the fixed effects. For each regression, we report the number of selected control variables. For brevity, we only report the regression coefficients on interest rate derivatives and the interaction term between interest rate derivatives and *Clearing Dummy*.

<Insert Table 6 here>

The results in Table 6 show that the variables *Clearing Dummy * Fair Value of Interest Rate Derivatives*, *Clearing Dummy * Interest Rate Swaps*, and *Clearing Dummy * Interest Rate Forwards and Swaps* are negatively and significantly related to systemic risk measures, $-\Delta CoVaR(5\%)$, *MES*, and *SRISK*. This confirms that mandatory clearing requirements decrease a BHC's systemic risk contributions that stem from the use of interest rate derivatives.

7 Conclusion

This paper analyzes how derivatives clearing affects systemic risk of BHCs. Using the enactment of mandatory clearing requirements under the Dodd–Frank Act as an event study, we find evidence that derivatives clearing decreases BHCs' systemic risk contributions. In particular, BHCs with larger positions in interest rate derivatives experienced a larger drop in systemic risk contributions after the introduction of mandatory clearing requirements for interest rate derivatives.

We seek to distinguish between four channels through which derivatives clearing might affect systemic risk. Through the *idiosyncratic risk* channel, derivatives clearing would lower idiosyncratic risk of BHCs. Through the *counterparty risk* channel, derivatives clearing would lower risks stemming from counterparty exposures. Through the *efficiency* channel, derivatives clearing would increase the efficiency of derivatives operations, generating additional profits for BHCs, which would decrease systemic risks. Through the *inefficiency* channel, clearing would make derivatives more costly for BHCs, and the ensuing lower use of derivatives would decrease systemic risk. We show that derivatives clearing decreases idiosyncratic risks of BHCs, which supports the *idiosyncratic risk* channel. Our evidence is consistent with the notion that a derivatives clearing organization verifies a BHC's aggregate risk exposures stemming from derivatives, which puts the BHC under pressure to take less risky positions in derivatives.

We employ numerous robustness checks. Our findings are robust across different measures of systemic risk and across several specifications that account for potential endogeneity, self-selection bias, and arbitrary selection of control variables, including data mining through high dimensional methods. Overall, our results suggest that derivatives clearing can curtail systemic risk in the banking system.

References

Abadie, A., Drukker, D., Herr, J. L., and Imbens, G. (2004). Implementing matching estimators for average treatment effects in Stata. *Stata Journal, 4*, 290–311.

Abadie, A., and Imbens, G. W. (2012). *Matching on the estimated propensity score*. Harvard University and National Bureau of Economic Research. Retrieved from http://www.hks.harvard.edu/fs/aabadie/pscore.pdf.

Acemoglu, D., Ozdaglar, A., and Tahbaz-Salehi, A. (2015). Systemic risk and stability in financial networks. *American Economic Review, 105*(2), 564–608.

Acharya, V. V., Anginer, D., and Warburton, A. J. (2015). The end of market discipline? investor expectations of implicit government guarantees. Working paper. March 1, 2015.

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

Acharya, V. V., Cooley, T. F., Richardson, M. P., and Walter, I. (2010). *Regulating Wall Street: The Dodd-Frank Act and the new architecture of global finance*. Hoboken, N.J.: John Wiley & Sons.

Acharya, V. V., Engle, R. F., Figlewski, S., Lynch, A. W., and Subrahmanyam, M. G. (2009). Centralized clearing for credit derivatives. In V. Acharya. & M. Richardson (eds.), *Restoring Financial Stability: How to Repair a Failed System* (pp. 251–268). Hoboken, NJ: John Wiley and Sons, Inc.

Acharya, V. V., Engle, R. F., and Richardson, M. (2012). Capital shortfall: A new approach to ranking and regulating systemic risks. *American Economic Review, 102*(3), 59–64.

Acharya, V. V., Pedersen, L. H., Philippon, T., and Richardson, M. (2010). Measuring systemic risk. New York University Working Paper. May 2010.

Adrian, T., and Brunnermeier, M. K. (2014). CoVaR. Working paper, September 10, 2014.

Agarwal, S., Lucca, D., Seru, A., and Trebbi, F. (2014). Inconsistent regulators: Evidence from banking. *Quarterly Journal of Economics, 129*(2), 889–938.

Allen, F., Babus, A., and Carletti, E. (2012). Asset commonality, debt maturity and systemic risk. *Journal of Financial Economics, 104*(3), 519–534.

Allen, F., and Gale, D. (2000). Financial contagion. *Journal of Political Economy, 108*(1), 1–33.

An, W., and Winship, C. (2015). Causal inference in panel data with application to estimating race-of-interviewer effects in the general social survey. *Sociological Methods & Research*. Forthcoming.

Arora, N., Gandhi, P., and Longstaff, F. A. (2012). Counterparty credit risk and the credit default swap market. *Journal of Financial Economics, 103*(2), 280–293.

Atkeson, A. G., Eisfeldt, A. L., and Weill, P.-O. (2015). Entry and exit in OTC derivatives markets. *Econometrica, 83*(6), 2231–2292.

Battiston, S., Delli Gatti, D., Gallegati, M., Greenwald, B., and Stiglitz, J. E. (2012). Liaisons dangereuses: Increasing connectivity, risk sharing, and systemic risk. *Journal of Economic Dynamics and Control*, *36*(8), 1121–1141.

Beck, T., Levine, R., and Levkov, A. (2010). Big bad banks? The winners and losers from bank deregulation in the United States. *Journal of Finance, 65*(5), 1637–1667.

Belloni, A., Chernozhukov, V., and Hansen, C. (2014a). High-dimensional methods and inference on structural and treatment effects. *Journal of Economic Perspectives, 28*(2), 29–50.

Belloni, A., Chernozhukov, V., and Hansen, C. (2014b). Inference on treatment effects after selection among high-dimensional controls. *Review of Economic Studies, 81*(2), 608–650.

Benoit, S., Colliard, J.-E., Hurlin, C., and Pérignon, C. (2015). Where the risks lie: A survey on systemic risk. *Review of Finance*. Forthcoming.

Berger, A. N., Bouwman, C. H., Kick, T. K., and Schaeck, K. (2016). Bank risk taking and liquidity creation following regulatory interventions and capital support. *Journal of Financial Intermediation*. Forthcoming.

Berger, A. N., Makaew, T., and Roman, R. (2015). Did bank borrowers benefit from the TARP program? The effects of TARP on loan contract terms. *Journal of Financial and Quantitative Analysis*. Forthcoming.

Berger, A. N., and Roman, R. (2015). Did TARP banks get competitive advantages? *Journal of Financial and Quantitative Analysis*. Forthcoming.

Biais, B., Heider, F., and Hoerova, M. (2015). Risk-sharing or risk-taking? Counterparty-risk, incentives and margins. *Journal of Finance*. Forthcoming.

Billio, M., Getmansky, M., Lo, A. W., and Pelizzon, L. (2012). Econometric measures of connectedness and systemic risk in the finance and insurance sectors. *Journal of Financial Economics, 104*(3), 535–559.

Bliss, R. R., and Kaufman, G. G. (2006). Derivatives and systemic risk: Netting, collateral, and closeout. *Journal of Financial Stability, 2*(1), 55–70.

Bolton, P., and Oehmke, M. (2015). Should derivatives be privileged in bankruptcy? *Journal of Finance, 70*(6), 2352–2394.

Bonaldi, P., Hortaçsu, A., and Kastl, J. (2015). An empirical analysis of funding costs spillovers in the EURO-zone with application to systemic risk. August 2015, NBER Working Paper No. 21462.

Brownlees, T., and Engle, R. (2015). SRISK: A conditional capital shortfall index for systemic risk measurement. Working paper, October 2015.

Cont, R., and Kokholm, T. (2014). Central clearing of OTC derivatives: Bilateral vs multilateral netting. *Statistics & Risk Modeling, 31*(1), 3–22.

Demirer, M., Diebold, F. X., Liu, L., and Yilmaz, K. (2015). Estimating global bank network connectedness. July 14, 2015, PIER Working Paper No. 15–025.

Duchin, R., and Sosyura, D. (2012). The politics of government investment. *Journal of Financial Economics, 106*(1), 24–48.

Duchin, R., and Sosyura, D. (2014). Safer ratios, riskier portfolios: Banks' response to government aid. *Journal of Financial Economics, 113*(1), 1–28.

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.

Elliott, M., Golub, B., and Jackson, M. O. (2014). Financial networks and contagion. *American Economic Review, 104*(10), 3115–3153.

Ellul, A., and Yerramilli, V. (2013). Stronger risk controls, lower risk: Evidence from US bank holding companies. *Journal of Finance, 68*(5), 1757–1803.

Engle, R., Jondeau, E., and Rockinger, M. (2015). Systemic risk in Europe. *Review of Finance, 19*(1), 145–190.

Erel, I., Nadauld, T., and Stulz, R. M. (2014). Why did holdings of highly rated securitization tranches differ so much across banks? *Review of Financial Studies, 27*(2), 404–453.

Fahlenbrach, R., and Stulz, R. M. (2011). Bank CEO incentives and the credit crisis. *Journal of Financial Economics, 99*(1), 11–26.

Financial Crisis Inquiry Commission. (2011). The Financial Crisis Inquiry Report, Final Report of the National Commission on the Causes of the Financial and Economic Crisis in the United States, January, http://www.gpo.gov/fdsys/pkg/GPO-FCIC/pdf/GPOFCIC.pdf.

Financial Stability Board (FSB) (2015). OTC Derivatives Market Reforms. Ninth Progress Report on Implementation, 24 July 2015.

Freixas, X., Parigi, B. M., and Rochet, J.-C. (2000). Systemic risk, interbank relations, and liquidity provision by the central bank. *Journal of Money, Credit and Banking, 32*(3), 611–638.

Gandhi, P., and Lustig, H. (2015). Size anomalies in U.S. bank stock returns. *Journal of Finance, 70*(2), 733–768.

Giancarlo, J. C. (2015). Pro-reform reconsideration of the CFTC swaps trading rules: Return to Dodd-Frank, White paper, January 29, 2015.

Giglio, S., Kelly, B. T., and Pruitt, S. (2015). Systemic risk and the macroeconomy: An empirical evaluation. *Journal of Financial Economics*. Forthcoming.

Gormley, T. A., and Matsa, D. A. (2014). Common errors: How to (and not to) control for unobserved heterogeneity. *Review of Financial Studies, 27*(2), 617–661.

Guardabascio, B., and Ventura, M. (2013). Estimating the dose-response function through the GLM approach. MPRA Paper No. 45013.

Haldane, A. G., and May, R. M. (2011). Systemic risk in banking ecosystems. [10.1038/nature09659]. *Nature, 469*(7330), 351–355.

Hasan, I., Massoud, N., Saunders, A., and Song, K. (2015). Which financial stocks did short sellers target in the subprime crisis? *Journal of Banking & Finance, 54*, 87–103.

Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica, 47*(1), 153–161.

Hirano, K., and Imbens, G. (2004). The propensity score with continuous treatments. In A. Gelman & X.-L. Meng (eds.), *Applied Bayesian Modeling and Causal Inference from Incomplete-Data Perspectives* (pp. 73–84). New York: John Wiley & Sons.

Hollo, D., Kremer, M., and Lo Duca, M. (2012). CISS - a Composite Indicator of Systemic Stress in the Financial System. European Central Bank (ECB) Working Paper No. 1426.

Hovakimian, A., Kane, E., and Laeven, L. (2015). Tracking variation in systemic risk at US banks during 1974–2013. Working paper, August 3, 2015.

Huang, X., Zhou, H., and Zhu, H. (2012). Assessing the systemic risk of a heterogeneous portfolio of banks during the recent financial crisis. *Journal of Financial Stability, 8*(3), 193–205.

Imbens, G. W., and Wooldridge, J. M. (2009). Recent developments in the econometrics of program evaluation. *Journal of Economic Literature, 47*(1), 5–86.

Kelly, B. T., Lustig, H., and Van Nieuwerburgh, S. (2015). Too-systemic-to-fail: What option markets imply about sector-wide government guarantees. *American Economic Review.* Forthcoming.

Kroszner, R. S., and Strahan, P. E. (2011). Financial regulatory reform: Challenges ahead. *American Economic Review, 101*(3), 242–246.

Laeven, L., Ratnovski, L., and Tong, H. (2014). Bank size, capital, and systemic risk: Some international evidence. Available at SSRN: http://ssrn.com/abstract=2508910.

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.

Mayordomo, S., Rodriguez-Moreno, M., and Peña, J. I. (2014). Derivatives holdings and systemic risk in the US banking sector. *Journal of Banking & Finance, 45*, 84–104.

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

Minton, B. A., Stulz, R., and Williamson, R. (2009). How much do banks use credit derivatives to hedge loans? *Journal of Financial Services Research, 35*(1), 1–31.

Mutu, S., and Ongena, S. (2015). The impact of policy interventions on systemic risk across banks. Working paper, April 10, 2015.

Nier, E., Yang, J., Yorulmazer, T., and Alentorn, A. (2007). Network models and financial stability. *Journal of Economic Dynamics and Control, 31*(6), 2033–2060.

Roe, M. J. (2013). Clearinghouse overconfidence. *California Law Review, 101*(6), 1641–1703.

Sanderson, E. and Windmeijer, F. (2016). A weak instrument F-test in linear IV models with multiple endogenous variables. *Journal of Econometrics, 190*(2), 212–221.

Schaeck, K., Cihak, M., Maechler, A., and Stolz, S. (2012). Who disciplines bank managers? *Review of Finance, 16*, 197–243.

Singh, M. M. (2010). Collateral, netting and systemic risk in the OTC derivatives market. IMF Working Paper WP/10/99.

Skeel, D. (2010). *The New Financial Deal: Understanding the Dodd-Frank Act and Its (Unintended) Consequences*. Hoboken, NJ: John Wiley & Sons.

Thakor, A. V. (2012). Incentives to innovate and financial crises. *Journal of Financial Economics, 103*(1), 130–148.

Thakor, A. V. (2015). The financial crisis of 2007–2009: Why did it happen and what did we learn? *Review of Corporate Finance Studies, 4*(2), 155–205.

Veronesi, P., and Zingales, L. (2010). Paulson's gift. *Journal of Financial Economics, 97*(3), 339–368.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT Press.

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

Appendix

Table 1A: Variable Names, Construction, and Data Sources

Variables	Definition	Data Source
Dependent Variables		
ΔCoVaR	Measures the marginal contribution of bank *i* to the overall systemic risk. It is calculated as the negative value of the difference between $CoVaR_i$ conditional on the distress of bank *i* (α = 5% or α = 1%) and $CoVaR_i$ conditional on the "normal" state of bank *i* (i.e., α = 0.5). See Adrian and Brunnermeier (2014).	Self-calculation
MES	Indicates Market Expected Shortfall (*MES*) of each BHC, calculated as the negative average return of each BHC on the 5% worst days of the market during each year. See Acharya et al. (2012). The estimation of 5% worst days is performed using a one-year rolling window to estimate quarterly-varying *MES* for each BHC.	Self-calculation
LRMES	Indicates the Long Run Marginal Expected Shortfall (*LRMES*). See Acharya et al. (2012).	Self-calculation
SRISK	Defined as the additional capital that a BHC is expected to need to fulfill capital requirements if there is another financial crisis. See Acharya et al (2012).	Self-calculation
VaR	Value at Risk, the most that the bank loses with confidence 1 – α, where α is taken to be 5%. See Adrian and Brunnermeier (2014).	Self-calculation
Market Risk Beta	Market risk of a BCH at each quarter, measured by the regression coefficient of *Market Return* in the quantile regression of the CAPM model for each BHC at each quarter.	Self-calculation
Idiosyncratic Risk	Idiosyncratic risk of a BHC at each quarter, measured by $1 - R^2$, where R^2 is obtained from the quantile regression of the CAPM model for each BHC at each quarter. Given the bounded nature of idiosyncratic risk ($1-R^2$), we use its logistic transformation risk (i.e., $\log(\frac{1-R^2}{R^2})$).	Self-calculation
Explanatory Variables		
GTA	Gross total assets equal to total assets plus the allowance for loan and lease losses and the allocated transfer risk reserve (a reserve for certain foreign loans) as in Berger et al. (2015).	FR Y-9C, BHCK2170+BHCK3123+BHCKC435
log (GTA)	The natural logarithm of gross total assets (*GTA*) of the BHCs.	FR Y-9C, log(BHCK2170+BHCK3123+BHCKC435)
Capital Ratio	Capitalization ratio, defined as equity capital divided by *GTA*.	FR Y-9C, BHCKG105/GTA
ROA	Return on assets (*ROA*), measured as the ratio of the annualized net income to *GTA*.	FR Y-9C, 4*BHCK4340/ GTA
Liquidity	Cash divided by gross total assets (*GTA*).	FR Y-9C, (BHCK0081+BHCK0395+BHCK0397/GTA
Asset Quality	Asset quality evaluates the overall condition of a BHC's portfolio, measured as the non-performing loans to total loans.	FR Y-9C, BHCK3123/BHCKB528
Management Quality	Proxy for a BHC's management quality computed as the ratio of personnel expenses to GTA.	FR Y-9C, BHCK4135/BHCK3210
GAP Ratio	Sensitivity to interest rate risk, defined as the ratio of the absolute difference (gap) between short-term assets and short-term liabilities to *GTA*.	FR Y-9C, abs (BHCK0081+BHCK0395+BHCK0397 +BHCK1773+BHDMB987+BHCKB989–BHDM6631–BHDM6636–BHFN6631–BHFN6636–BHDMB993–BHCKB995)/GTA
Interest Rate Swaps	Notional amount of interest rate swap contracts divided by gross total assets (*GTA*).	FR Y-9C, BHCK3450/GTA
Interest Rate Forwards and Swaps	Sum of notional amount of interest rate forward agreement contracts and interest rate swap contracts divided by gross total assets (*GTA*).	FR Y-9C, (BHCK8697+BHCK3450)/GTA
Large Dummy	Dummy variable that equals 1 if GTA > \$10 billion, and 0 otherwise.	

Foreign Exchange Derivatives	Notional amount of foreign exchange derivatives divided by gross total assets (*GTA*).	FR Y-9C, (BHCK8694 + BHCK8698 + BHCK8702 + BHCK8706 + BHCK8710 + BHCK8714 + BHCK3826)/GTA
Credit Default Swaps	Notional amount of credit default swaps divided by gross total assets (*GTA*).	FR Y-9C, (BHCKC968+BHCKC969)/GTA
Interest Options	Notional amount of OTC interest rate options (written options and purchased options) scaled by *GTA*.	FR Y-9C, (BHCK8709 + BHCK8713)/GTA
Other Derivatives	Notional amount of other swaps (foreign exchange swaps, equity swaps, and commodity and other swaps) plus notional amount of other forwards contracts (foreign exchange forwards contracts, equity forwards contracts, and commodity and other forwards contracts) plus notional amount of OTC option contracts (interest rate options, foreign exchange options, equity options, and commodity and other options) scaled by *GTA*.	FR Y-9C, (BHCK3826+BHCK8719+BHCK8720+BHCK8698+ BHCK8699+BHCK8700+BHCK8709 + BHCK8710 + BHCK8711 + BHCK8712 + BHCK8713+ BHCK8714 + BHCK8715+ BHCK8716)/GTA
Fair Value of Interest Rate Derivatives	Fair values of interest rate derivatives scaled by gross total assets (*GTA*).	FR- Y-9C, (BHCK8733 + BHCK8737+BHCK8741+BHCK8745)/GTA
Fair Value of Credit Default Swaps	Fair values of Credit Default Swaps scaled by gross total assets (*GTA*).	FR Y-9C, (BHCKC219+BHCKC220+BHCKC221 +BHCKC222)/GTA
Interest Rate Derivatives for Trading	Notional amount of interest rate derivatives held for trading scaled by gross total assets (*GTA*).	FR Y-9C, BHCKA126/GTA
Interest Rate Derivatives for Hedging	Notional amount of interest rate derivatives held for hedging scaled by gross total assets (*GTA*).	FR Y-9C, BHCK8725/GTA
Counterparty Revenue	Sum of the impact on trading revenue of changes in the creditworthiness of the BHC's derivatives counterparties on the BHC’s derivative assets and liabilities scaled by *GTA*.	FR Y-9C, (BHCKK090+BHCKK094)/GTA
Trading Revenue	Trading revenue scaled by gross total assets (*GTA*).	FR Y-9C, BHCKA220/GTA
Trading Revenue from Interest Rate Exposures	Trading revenue from interest rate exposures scaled by gross total assets (*GTA*).	FR Y-9C, BHCK8757/GTA
Trading Revenue from FX Exposures	Trading revenue from foreign exchange exposures scaled by gross total assets (*GTA*).	FR Y-9C, BHCK8758/GTA
Interest Rate Swaps Dummy	Dummy variable that equals 1 if *Interest Rate Swaps* > 0, and 0 otherwise.	
Interest Rate Forwards and Swaps Dummy	Dummy variable that equals 1 if the notional amount of interest rate forwards and swaps is higher than 0, and 0 otherwise.	
Fair Value of Interest Rate Derivatives Dummy	Dummy variable that equals 1 if the fair value of interest rate derivatives is higher than 0, and 0 otherwise.	
Clearing Dummy	Equals 0 before 2013 and 1 in the first quarter of 2013 and thereafter.	
Ratio of Interest Rate Derivatives Cleared	Proportion of a notional value of interest derivatives cleared by the derivatives clearing organization in the market. We compute the proportion of interest rate swaps and interest rate forward agreements cleared in the case of the DTCC. Such detailed data is unavailable in the case of Trioptima, where we use the proportion of interest rate derivatives cleared.	Trioptima, http://www.trioptima.com/resource-center/historical-reports.html Depository Trust & Clearing Corporation (DTCC), http://www.dtcc.com/repository-otc-data#rates
Individual Cleared Ratio	Proportion of interest rate derivatives cleared for a BHC at a given quarter. We use fair values or, if not available, gross notional amounts.	U.S. Securities and Exchange Commission, 10-Q form
Time Trend	Linear time trend variable.	

Table 1B: Summary Statistics and Group Differences between BHCs That Use Interest Rate Swaps (Users) and BHCs That Do Not (Non-Users)

	Panel A: Total Sample						Panel B:						
							Subgroup: Users (U)		Subgroup: Non-Users (N)		Group Mean Difference (U - N)		
Variables	*N*	Mean	Median	Std.dev.	Min	Max	Mean	Std.dev.	Mean	Std.dev.	U - N	*t* - Statistic	*p*-value
–ΔCoVaR (5%)	7918	0.0046	0.004	0.004	–0.005	0.021	0.0051	0.004	0.0035	0.004	0.0016	17.92***	0.0000
–ΔCoVaR (1%)	7918	0.0073	0.007	0.006	–0.005	0.035	0.0082	0.006	0.0056	0.005	0.0025	18.96***	0.0000
MES	7918	0.0139	0.014	0.012	–0.156	0.116	0.0150	0.012	0.0116	0.013	0.0034	11.53***	0.0000
LRMES	7918	0.2018	0.217	0.251	–15.595	0.877	0.2202	0.159	0.1643	0.372	0.0558	7.34***	0.0000
SRISK ($ billion)	7218	0.2593	–0.006	4.101	–40.161	80.635	0.4266	5.118	–0.0372	0.237	0.4638	6.14***	0.0000
–VaR (5%)	7918	0.0350	–0.029	0.022	0.006	0.306	0.0345	0.023	0.0359	0.020	–0.00144	–2.67***	0.0077
Market Risk Beta	7918	0.6693	0.700	0.878	–10.227	6.269	0.7596	0.849	0.4852	0.906	0.2744	12.92***	0.0000
Idiosyncratic Risk	7916	1.6279	1.565	1.006	–0.962	7.379	1.4793	1.004	1.9312	0.942	–0.4520	19.62***	0.0000
Capital Ratio	7570	0.1093	0.104	0.055	–0.155	0.915	0.1080	0.045	0.1117	0.069	–0.0037	2.48**	0.0131
ROA	7570	0.0165	0.016	0.040	–0.388	0.841	0.0178	0.037	0.0143	0.046	0.0035	3.38***	0.0007
Liquidity	7570	0.0593	0.043	0.053	0.001	0.574	0.0570	0.053	0.0635	0.052	–0.0065	–5.16***	0.0000
Asset Quality	7556	0.0179	0.016	0.010	0.000	0.092	0.0177	0.010	0.0181	0.010	–0.0004	–1.69*	0.0918
Management Quality	7570	0.0108	0.009	0.012	0.001	0.257	0.0108	0.010	0.0108	0.015	0.0000	–0.08	0.9385
GAP Ratio	7570	0.3057	0.303	0.167	0.000	1.431	0.2922	0.159	0.3295	0.177	–0.0373	–9.13***	0.0000
Gross Total Assets (GTA) ($ billion)	7570	40.5	2.147	221	0.503	2590	62.6	3.318	2.193	0.056	60.4	14.86***	0.0000
log (GTA)	7570	15.04	14.58	1.635	13.129	21.675	15.5454	1.766	14.1495	0.809	1.3958	46.93***	0.0000
Interest Rate Swaps	7570	0.3358	0.000	2.694	0.000	41.808	0.5270	3.360	0.0000	0.000	0.5270	10.89***	0.0000
Interest Rate Forwards and Swaps	7570	0.4079	0.008	3.178	0.000	49.627	0.6402	3.963	0.0000	0.000	0.6402	11.22***	0.0000
Credit Default Swaps	7570	0.0352	0.000	0.348	0.000	6.999	0.0553	0.434	0.0000	0.000	0.0553	8.85***	0.0000
Interest Rate Options	7570	0.0692	0.000	0.526	0.000	7.814	0.1073	0.656	0.0023	0.012	0.1049	11.10***	0.0000
Other Derivatives	7570	0.1567	0.000	1.088	0.000	14.9	0.2445	1.355	0.0027	0.0123	0.2417	9.35***	0.0000
Fair Value of Interest Rate Derivatives	7570	0.0174	0.000	0.133	0.000	2.393	0.0272	0.166	0.0000	0.000	0.0272	11.37***	0.0000
Fair Value of Credit Default Swaps	7570	0.0016	0.000	0.016	0.000	0.414	0.0024	0.020	0.0000	0.000	0.0024	8.41***	0.0000
Interest Rate Derivatives for Trading	7570	0.4602	0.000	3.868	0.000	56.168	0.7223	4.827	0.0002	0.0017	0.7221	7.84***	0.0000
Interest Rate Derivatives for Hedging	7570	0.0443	0.007	0.102	0.000	1.225	0.0682	0.1217	0.0022	0.0118	0.0660	28.36***	0.0000
Counterparty Revenue	1492	0.0000	0.0000	0.000	- 0.0004	0.005	0.0000	0.0002	0.0000	0.0000	0.0000	1.077	0.2816
Trading Revenue	7570	0.0002	0.000	0.001	0.0000	0.022	0.0003	0.0013	0.0000	0.0005	0.0002	9.87***	0.0000
Trading Revenue from Interest Rate Exposures	4674	0.0001	0.0000	0.0008	- 0.0003	0.016	0.0002	0.0010	0.0000	0.0004	0.0002	6.441***	0.0000
Trading Revenue from FX Exposures	4660	0.0000	0.0000	0.0003	- 0.003	0.008	0.0000	0.0004	0.0000	0.0000	0.0000	8.29***	0.0000
Clearing Dummy	8476	0.5031	1	0.500	0	1	0.5315	0.499	0.4438	0.4969	0.0877	7.59***	0.0000
Ratio of Interest Rate Derivatives Cleared	8476	0.6011	0.629	0.083	0.459	0.706	0.6061	0.083	0.5907	0.083	0.0155	8.02***	0.0000
Individual Cleared Ratio	130	0.4174	0.4174	0.2139	0.0126	0.9184	0.4174	0.2139					

Note: The sample period starts in the third quarter of 2010 and lasts to the second quarter of 2015. Variables are described in Table 1A. *MES*, *LRMES*, and *SRISK* are computed based on a forward-looking one-year rolling window. The subgroup "Users" denotes BHCs that use interest rate swaps; the subgroup "Non-Users" denotes BHCs that do not use interest rate swaps. *t*-statistics are based on unequal group variances. * $p < 0.10$ ** $p < 0.05$, *** $p < 0.01$.

Table 2A: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs

	(1)	(2)	(3)	(4)	(5)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	$-\Delta CoVaR$ (1%)$_t$	MES_t	$LRMES_t$	$SRISK_t$
Capital Ratio$_{t-1}$	0.00162	0.00228	0.0352**	0.436**	–2.740
	(0.69)	(0.62)	(2.21)	(1.97)	(–1.37)
ROA$_{t-1}$	0.000737	0.000346	0.00469	0.0853	5.492**
	(0.74)	(0.22)	(0.91)	(1.24)	(2.14)
Liquidity$_{t-1}$	–0.00011	–0.000293	–0.0000318	–0.00182	–1.274
	(–0.12)	(–0.19)	(–0.00)	(–0.02)	(–0.90)
Asset Quality$_{t-1}$	0.0216***	0.0327**	0.0322	–0.0194	82.90**
	(2.94)	(2.57)	(0.68)	(–0.03)	(2.21)
Management Quality$_{t-1}$	–0.00267*	–0.00129	0.0015	–0.0304	–2.062
	(–1.70)	(–0.43)	(0.20)	(–0.30)	(–0.68)
GAP Ratio$_{t-1}$	–0.000168	–0.00038	–0.00215	–0.038	–1.180*
	(–0.39)	(–0.57)	(–0.71)	(–0.93)	(–1.86)
log (GTA)$_{t-1}$	0.0182***	0.0226***	–0.0235	–0.337	–1.568
	(7.60)	(5.97)	(–1.57)	(–1.64)	(–0.15)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000625***	–0.000776***	0.000893*	0.0128*	0.0731
	(–7.81)	(–6.12)	(1.83)	(1.93)	(0.20)
Fair Value of Interest Rate Derivatives$_{t-1}$	0.000598	0.00218	–0.00295	–0.0324	–7.634
	(0.71)	(1.43)	(–1.32)	(–1.22)	(–0.90)
Clearing Dummy$_{t-1}$ * *Fair Value of*	–0.00178***	–0.00147*	–0.00412***	–0.0467**	–18.42***
Interest Rate Derivatives$_{t-1}$	(–5.01)	(–1.72)	(–3.01)	(–2.53)	(–2.74)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6760	6760	6750
R^2	0.574	0.518	0.167	0.121	0.233

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2B: Impact of *Ratio of Interest Rate Derivatives Cleared* on Systemic Risk of BHCs

	(1)	(2)	(3)	(4)	(5)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	$-\Delta CoVaR$ (1%)$_t$	MES_t	$LRMES_t$	$SRISK_t$
Capital Ratio$_{t-1}$	0.00158	0.00231	0.0349**	0.433*	–3.104*
	(0.68)	(0.63)	(2.20)	(1.96)	(–1.67)
ROA$_{t-1}$	0.000612	0.000182	0.00454	0.0841	4.152**
	(0.62)	(0.12)	(0.88)	(1.22)	(2.12)
Liquidity$_{t-1}$	–0.0000392	–0.000138	–0.000102	–0.00338	–0.490
	(–0.04)	(–0.09)	(–0.01)	(–0.04)	(–0.34)
Asset Quality$_{t-1}$	0.0205***	0.0314**	0.0309	–0.0308	71.74**
	(2.83)	(2.51)	(0.65)	(–0.04)	(2.25)
Management Quality$_{t-1}$	–0.00267*	–0.00132	0.00159	–0.0291	–2.058
	(–1.71)	(–0.44)	(0.22)	(–0.29)	(–0.73)
GAP Ratio$_{t-1}$	–0.000125	–0.000311	–0.00213	–0.0381	–0.721
	(–0.29)	(–0.46)	(–0.71)	(–0.93)	(–1.53)
log (GTA)$_{t-1}$	0.0182***	0.0227***	–0.0237	–0.340*	–1.138
	(7.63)	(6.09)	(–1.58)	(–1.65)	(–0.13)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000627***	–0.000782***	0.000900*	0.0129*	0.0516
	(–7.85)	(–6.26)	(1.85)	(1.94)	(0.17)
Ratio of Interest Rate Derivatives Cleared$_{t-1}$	– 0.00209	– 0.00445	– 0.00232	0.0323	2.145
	(– 0.54)	(– 0.67)	(– 0.11)	(0.11)	(0.21)
Fair Value of Interest Rate Derivatives$_{t-1}$	0.00686***	0.00889***	0.00786*	0.0782	58.10**
	(5.49)	(2.61)	(1.77)	(1.55)	(2.42)
Ratio of Interest Rate Derivatives Cleared$_{t-1}$	–0.0106***	–0.0118***	–0.0172***	–0.171**	–111.2***
* *Fair Value of Interest Rate Derivatives*$_{t-1}$	(–6.03)	(–2.66)	(–2.59)	(–2.12)	(–2.67)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6760	6760	6750
R^2	0.575	0.519	0.167	0.121	0.309

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2C: Impact of Derivatives Clearing, Measured by *Individual Cleared Ratio*, on Systemic Risk of BHCs

	(1)	(2)	(3)	(4)	(5)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	$-\Delta CoVaR$ (1%)$_t$	MES_t	$LRMES_t$	$SRISK_t$
Capital Ratio$_t$	–0.00362	–0.0470	0.00314	0.0490	–64.33
	(–0.19)	(–1.36)	(0.05)	(0.05)	(–0.51)
ROA$_t$	0.00467	0.0112	–0.00819	–0.0663	–42.64
	(0.53)	(0.75)	(–0.40)	(–0.22)	(–0.70)
Liquidity$_t$	0.00849	0.0185	0.00508	0.0870	17.05
	(0.97)	(1.46)	(0.24)	(0.29)	(0.39)
Asset Quality$_t$	0.228***	0.354***	0.167	1.855	199.4
	(3.10)	(4.44)	(0.94)	(0.79)	(0.58)
Management Quality$_t$	0.0123	–0.0173	0.110*	1.356	225.8
	(0.60)	(–0.49)	(1.76)	(1.58)	(1.35)
GAP Ratio$_t$	0.00796**	0.0124**	0.0248	0.341	49.80
	(2.34)	(2.01)	(1.55)	(1.57)	(1.34)
Time Trend$_t$	0.000282***	0.000437***	0.00109***	0.0143***	0.768
	(3.86)	(6.74)	(4.13)	(3.93)	(1.01)
log (GTA)$_t$	–0.0241	–0.0164	–0.548***	–7.656***	–1141.3***
	(–0.68)	(–0.25)	(–4.42)	(–4.39)	(–3.09)
log (GTA)$_t$ * *log (GTA)*$_t$	0.000395	0.0000732	0.0138***	0.194***	29.57***
	(0.43)	(0.04)	(4.49)	(4.47)	(3.26)
Individual Cleared Ratio$_t$	0.00154	0.00457*	–0.00379	–0.0390	3.292
	(1.29)	(1.83)	(–0.92)	(–0.62)	(0.31)
Fair Value of Interest Rate	0.0109***	0.0122***	0.0310***	0.428***	50.63*
Derivatives$_t$	(4.89)	(4.78)	(3.83)	(3.52)	(1.77)
Individual Cleared Ratio$_t$ * *Fair Value*	–0.0152***	–0.0152***	–0.0445***	–0.601***	–71.67*
of Interest Rate Derivatives$_t$	(–4.58)	(–3.99)	(–3.74)	(–3.46)	(–1.83)
Bank Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	130	130	130	130	130
R^2	0.291	0.346	0.466	0.456	0.318

Note: The regressions include bank-specific fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a time-centered one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2D: Impact of Mandatory Clearing on Systemic Risk. Instrumental Variable Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable =	*Fair Value of Interest Rate Derivatives*$_t$	*Clearing Dummy*$_t$* *Fair Value of Interest Rate Derivatives*$_t$	–Δ*CoVaR* (5%)$_t$	–Δ*CoVaR* (1%)$_t$	*MES*$_t$	*LRMES*$_t$	*SRISK*$_t$
Δ Predicted Fair Value of Interest Rate Derivatives$_t$	0.388944***	–0.081851**					
	(2.73)	(–2.17)					
Δ (Clearing Dummy$_t$ * *Predicted Fair Value of Interest Rate Derivatives*$_t$*)*	0.085675**	0.490744***					
	(2.20)	(2.66)					
Capital Ratio$_t$	0.048506	0.140247	0.000275	–0.000227	0.0297*	0.289	–3.748
	(1.05)	(1.07)	(0.08)	(–0.05)	(1.74)	(1.19)	(–1.12)
ROA$_t$	0.008460	–0.033874	0.00193	0.00289	0.00403	0.0524	5.720*
	(0.32)	(–0.91)	(0.75)	(0.87)	(0.35)	(0.33)	(1.83)
Liquidity$_t$	–0.111913*	0.21129**	0.0124**	0.0159**	0.0266**	0.292**	3.102
	(–1.66)	(2.00)	(2.57)	(2.42)	(2.37)	(1.97)	(0.75)
Asset Quality$_t$	0.677105	–0.451031	–0.0294	–0.0281	–0.0236	–0.626	78.50*
	(1.32)	(–0.53)	(–0.67)	(–0.49)	(–0.24)	(–0.50)	(1.73)
Management Quality$_t$	0.040536	–0.098878	–0.00173	–0.00204	–0.0693**	–0.762*	–4.399
	(0.64)	(–1.04)	(–0.34)	(–0.30)	(–2.14)	(–1.93)	(–1.11)
GAP Ratio$_t$	–0.013751	0.048887*	0.00226*	0.00277*	0.00477	0.0326	0.262
	(–0.90)	(1.82)	(1.84)	(1.65)	(1.20)	(0.61)	(0.19)
log (GTA)$_t$	0.225661	0.078087	0.00797	0.00991	–0.0105	–0.0424	–3.821
	(1.32)	(0.30)	(0.54)	(0.54)	(–0.34)	(–0.11)	(–0.25)
log (GTA)$_t$ * *log (GTA)*$_t$	–0.007165	–0.003907	–0.00035	–0.000436	0.000258	0.000519	0.121
	(–1.25)	(–0.43)	(–0.71)	(–0.71)	(0.25)	(0.04)	(0.23)
Fair Value of Interest Rate Derivatives$_t$			0.0649***	0.0828**	0.0811***	0.634	42.10***
			(2.64)	(2.58)	(2.63)	(1.34)	(3.72)
Clearing Dummy$_t$ * *Fair Value of Interest Rate Derivatives*$_t$			–0.0289**	–0.0363**	–0.0782**	–1.003**	–32.56**
			(–2.54)	(–2.51)	(–2.31)	(–2.21)	(–2.33)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	7081	7081	7081	7081	7055	7055	7055
R^2	0.0404	0.044					
SW χ^2 Wald test	7.77***	7.77***					
SW χ^2 Wald test (*p* value)	0.0053	0.0057					
SW F test	7.72***	7.59***					
SW F test (*p* value)	0.0057	0.0061					

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a time-centered one-year rolling window. We instrument *Fair Value of Interest Rate Derivatives* and *Clearing Dummy * Fair Value of Interest Rate Derivatives* by the first difference in the fitted value *Predicted Fair Value of Interest Rate Derivatives*, and by the first difference in *Clearing Dummy * Predicted Fair Value of Interest Rate Derivatives*. We report Sanderson and Windmeijer (2016) tests of underidentification (SW χ^2 Wald-test) and weak identification (SW *F* test) for each endogenous regressor separately. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3A: Interest Rate Derivatives for Trading, Interest Rate Derivatives for Hedging, and Systemic Risk. Accounting for End-User Exception

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR(5\%)_t$	MES_t	$SRISK_t$	$-\Delta CoVaR\ (5\%)_t$	MES_t	$SRISK_t$	$-\Delta CoVaR\ (5\%)_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00152	0.0349**	–3.811**	0.00177	0.0350**	–4.160	0.00166	0.0337**	–5.605**
	(0.65)	(2.19)	(–2.03)	(0.76)	(2.20)	(–1.45)	(0.75)	(2.13)	(–2.37)
ROA$_{t-1}$	0.000733	0.00470	5.497**	0.000679	0.00450	6.062*	0.000199	0.00437	5.578**
	(0.73)	(0.91)	(2.12)	(0.68)	(0.87)	(1.90)	(0.22)	(0.85)	(2.02)
Liquidity$_{t-1}$	–0.0000542	0.0000222	–0.967	–0.000115	0.0000606	–3.033	0.000481	0.000883	–1.889
	(–0.06)	(0.00)	(–0.68)	(–0.12)	(0.01)	(–1.34)	(0.55)	(0.13)	(–1.01)
Asset Quality$_{t-1}$	0.0215***	0.0314	80.55**	0.0210***	0.0299	83.63*	0.0180***	0.0239	74.49*
	(2.93)	(0.66)	(2.16)	(2.80)	(0.63)	(1.83)	(2.72)	(0.51)	(1.86)
Management Quality$_{t-1}$	–0.00268*	0.00149	–2.190	–0.00286*	0.000784	–1.149	–0.00230	–0.000619	–2.584
	(–1.73)	(0.20)	(–0.69)	(–1.74)	(0.11)	(–0.35)	(–1.61)	(–0.09)	(–0.61)
GAP Ratio$_{t-1}$	–0.000149	–0.00218	–1.219*	–0.000234	–0.00232	–1.853*	0.0000195	–0.00230	–1.530*
	(–0.35)	(–0.72)	(–1.86)	(–0.55)	(–0.77)	(–1.93)	(0.05)	(–0.77)	(–1.90)
log (GTA)$_{t-1}$	0.0179***	–0.0244	–4.358	0.0174***	–0.0258*	–6.854	0.00894***	–0.0285	–12.68
	(7.41)	(–1.62)	(–0.42)	(7.35)	(–1.72)	(–0.58)	(3.60)	(–1.64)	(–0.84)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000616***	0.000922*	0.167	–0.000599***	0.000972*	0.270	–0.000319***	0.00106*	0.455
	(–7.63)	(1.89)	(0.46)	(–7.55)	(1.99)	(0.65)	(–3.85)	(1.86)	(0.87)
Interest Rate Derivatives for Trading$_{t-1}$	0.0000988**	0.0000149	0.189						
	(2.22)	(0.13)	(0.30)						
Clearing Dummy$_{t-1}$ * *Interest Rate Derivatives for Trading*$_{t-1}$	–0.0000615***	–0.0000905***	–0.486**						
	(–4.65)	(–3.45)	(–2.53)						
Interest Rate Derivatives for Hedging$_{t-1}$				0.000839	0.00399	–1.197	–0.000146	0.00700	–1.055
				(1.48)	(0.97)	(–0.31)	(–0.23)	(1.53)	(–0.60)
Clearing Dummy$_{t-1}$ * *Interest Rate Derivatives for Hedging*$_{t-1}$				–0.00217***	–0.00128	–9.055*	–0.000560	0.000832	–0.505
				(–3.77)	(–0.50)	(–1.95)	(–1.43)	(0.33)	(–0.24)
Large Dummy$_{t-1}$							0.000747**	0.000214	0.404
							(2.31)	(0.12)	(0.84)
Clearing Dummy$_{t-1}$ * *Large Dummy*$_{t-1}$							–0.00132***	–0.000199	–0.482
							(–9.33)	(–0.23)	(–0.63)
Large Dummy$_{t-1}$ * *Interest Rate Derivatives for Hedging*$_{t-1}$							0.00122**	–0.00584	–0.200
							(1.96)	(–1.27)	(–0.05)
Clearing Dummy$_{t-1}$ * *Large Dummy*$_{t-1}$ * *Interest Rate Derivatives for Hedging*$_{t-1}$							–0.0170	–0.153**	–485.2***
							(–1.31)	(–2.28)	(–4.44)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750	6760	6760	6750
R^2	0.575	0.167	0.209	0.573	0.167	0.0777	0.592	0.168	0.148

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3B: Impact of Mandatory Clearing on Systemic Risk. Notional Value of Interest Rate Swaps

Dependent Variable =	(1) $-\Delta CoVaR$ (5%)$_t$	(2) $-\Delta CoVaR$ (1%)$_t$	(3) MES_t	(4) $LRMES_t$	(5) $SRISK_t$
Capital Ratio$_{t-1}$	0.00156	0.00225	0.0349**	0.433*	–3.924**
	(0.67)	(0.61)	(2.19)	(1.96)	(–2.07)
ROA$_{t-1}$	0.000733	0.000346	0.00470	0.0855	5.492**
	(0.73)	(0.22)	(0.91)	(1.24)	(2.13)
Liquidity$_{t-1}$	–0.0000792	–0.000264	–0.0000175	–0.00206	–1.003
	(–0.08)	(–0.17)	(–0.00)	(–0.02)	(–0.68)
Asset Quality$_{t-1}$	0.0216***	0.0332***	0.0315	–0.0266	80.04**
	(2.95)	(2.59)	(0.66)	(–0.04)	(2.16)
Management Quality$_{t-1}$	–0.00271*	–0.00132	0.00146	–0.0307	–2.325
	(–1.74)	(–0.44)	(0.20)	(–0.30)	(–0.73)
GAP Ratio$_{t-1}$	–0.000153	–0.000344	–0.00218	–0.0385	–1.225*
	(–0.36)	(–0.51)	(–0.73)	(–0.94)	(–1.83)
log (GTA)$_{t-1}$	0.0180***	0.0225***	–0.0242	–0.344*	–4.465
	(7.55)	(5.96)	(–1.61)	(–1.67)	(–0.44)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000621***	–0.000775***	0.000917*	0.0130**	0.171
	(–7.77)	(–6.12)	(1.88)	(1.96)	(0.49)
Interest Rate Swaps$_{t-1}$	0.0000849	0.000174	–0.0000158	–0.000315	0.290
	(1.54)	(1.26)	(–0.13)	(–0.23)	(0.40)
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.0000885***	–0.0000918*	–0.000135***	–0.00149***	–0.706**
	(–4.50)	(–1.88)	(–3.56)	(–2.90)	(–2.54)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6760	6760	6750
R^2	0.575	0.518	0.167	0.121	0.211

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3C: Impact of Mandatory Clearing on Systemic Risk. Notional Value of Interest Rate Forwards and Interest Rate Swaps

Dependent Variable =	(1) $-\Delta CoVaR$ (5%)$_t$	(2) $-\Delta CoVaR$ (1%)$_t$	(3) MES_t	(4) $LRMES_t$	(5) $SRISK_t$
Capital Ratio$_{t-1}$	0.00155	0.00226	0.0349**	0.433*	–3.580*
	(0.67)	(0.62)	(2.20)	(1.96)	(–1.91)
ROA$_{t-1}$	0.000727	0.000338	0.00469	0.0854	5.426**
	(0.73)	(0.22)	(0.91)	(1.24)	(2.14)
Liquidity$_{t-1}$	–0.0000615	–0.000262	0.0000174	–0.00163	–1.031
	(–0.07)	(–0.17)	(0.00)	(–0.02)	(–0.72)
Asset Quality$_{t-1}$	0.0215***	0.0332***	0.0313	–0.0290	80.00**
	(2.94)	(2.59)	(0.66)	(–0.04)	(2.19)
Management Quality$_{t-1}$	–0.00270*	–0.00133	0.00148	–0.0305	–2.277
	(–1.74)	(–0.44)	(0.20)	(–0.30)	(–0.73)
GAP Ratio$_{t-1}$	–0.000153	–0.000350	–0.00218	–0.0384	–1.232*
	(–0.36)	(–0.52)	(–0.72)	(–0.94)	(–1.86)
log (GTA)$_{t-1}$	0.0180***	0.0225***	–0.0242	–0.344*	–3.555
	(7.52)	(5.97)	(–1.61)	(–1.67)	(–0.36)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000620***	–0.000775***	0.000917*	0.0130**	0.140
	(–7.74)	(–6.13)	(1.88)	(1.96)	(0.41)
Interest Rate Forwards and Swaps$_{t-1}$	0.0000804*	0.000149	–0.0000207	–0.000354	0.00682
	(1.68)	(1.19)	(–0.19)	(–0.28)	(0.01)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$	–0.0000751***	–0.0000784*	–0.000115***	–0.00128***	–0.609***
	(–4.48)	(–1.90)	(–3.63)	(–2.96)	(–2.64)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6760	6760	6750
R^2	0.575	0.518	0.167	0.121	0.214

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES*, *LRMES*, and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4A: Mandatory Clearing and Systemic Risk. Interest Rate Options and Other Derivatives

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable =	*–ΔCoVaR*	MES_t	$SRISK_t$	*–ΔCoVaR* (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00138	0.0344**	–4.791***	0.00128	0.0349**	–2.971
	(0.59)	(2.17)	(–2.60)	(0.55)	(2.19)	(–1.61)
ROA$_{t-1}$	0.000655	0.00449	5.004**	0.00078	0.00477	5.087**
	(0.66)	(0.87)	(2.14)	(0.78)	(0.92)	(2.37)
Liquidity$_{t-1}$	–0.0000929	–0.0000689	–1.237	0.000111	–0.00015	–0.994
	(–0.10)	(–0.01)	(–0.81)	(0.12)	(–0.02)	(–0.90)
Asset Quality$_{t-1}$	0.0201***	0.0273	69.48**	0.0221***	0.0323	76.07**
	(2.79)	(0.58)	(2.15)	(2.99)	(0.68)	(2.36)
Management Quality$_{t-1}$	–0.00278*	0.00129	–2.419	–0.00280*	0.0014	–1.859
	(–1.79)	(0.17)	(–0.79)	(–1.87)	(0.19)	(–0.67)
GAP Ratio$_{t-1}$	–0.000162	–0.0022	–1.214*	–0.00013	–0.00225	–1.098**
	(–0.38)	(–0.73)	(–1.73)	(–0.29)	(–0.75)	(–2.00)
log (GTA)$_{t-1}$	0.0178***	–0.0247*	–3.302	0.0164***	–0.0244	0.735
	(7.32)	(–1.67)	(–0.38)	(6.14)	(–1.59)	(0.09)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.000614***	0.000932*	0.13	–0.000566***	0.000927*	–0.00861
	(–7.54)	(1.95)	(0.44)	(–6.33)	(1.86)	(–0.03)
Interest Rate Forwards and Swaps$_{t-1}$	0.0000557	–0.0000817	0.0534	–5.4E–06	–0.00012	0.464
	(1.57)	(–1.11)	(0.12)	(–0.10)	(–0.76)	(0.61)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$	–0.000229***	–0.000546***	–1.857***	–0.0000486**	–0.000186***	–0.486**
	(–8.51)	(–4.40)	(–2.65)	(–2.24)	(–3.22)	(–2.02)
Interest Rate Options$_{t-1}$	0.000868***	0.00226	1.718**			
	(3.51)	(1.42)	(2.14)			
Clearing Dummy$_{t-1}$ * *Interest Rate Options*$_{t-1}$	0.000999***	0.00279***	7.896**			
	(7.00)	(3.92)	(2.34)			
Other Derivatives$_{t-1}$				0.000717***	0.00121	–4.808
				(3.20)	(1.11)	(–1.52)
Clearing Dummy$_{t-1}$ * *Other Derivatives*$_{t-1}$				–0.000340**	0.000364	–0.161
				(–2.12)	(0.79)	(–0.15)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750
R^2	0.577	0.168	0.249	0.577	0.167	0.241

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4B: Impact of Mandatory Clearing on Systemic Risk of BHCs. Comparing the Effect of Interest Rate Derivatives and Credit Default Swaps

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable =	$-\Delta CoVaR$ $(5\%)_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ $(5\%)_t$	MES_t	$SRISK_t$
$Capital\ Ratio_{t-1}$	0.00149	0.0345**	–5.425***	0.0015	0.0345**	–4.757**
	(0.64)	(2.17)	(–2.86)	(0.65)	(2.17)	(–2.57)
ROA_{t-1}	0.000665	0.00449	4.452**	0.000639	0.00445	4.315**
	(0.67)	(0.87)	(2.23)	(0.64)	(0.87)	(2.19)
$Liquidity_{t-1}$	–0.0000271	0.000327	0.216	1.88E–05	0.000392	0.263
	(–0.03)	(0.05)	(0.16)	(0.02)	(0.06)	(0.20)
$Asset\ Quality_{t-1}$	0.0200***	0.0247	50.83**	0.0196***	0.0242	52.39**
	(2.72)	(0.51)	(2.16)	(2.70)	(0.50)	(2.16)
$Management\ Quality_{t-1}$	–0.00275*	0.00164	–2.284	–0.00274*	0.00165	–2.24
	(–1.75)	(0.22)	(–0.90)	(–1.74)	(0.22)	(–0.90)
$GAP\ Ratio_{t-1}$	–0.000136	–0.00208	–0.856	–0.00014	–0.00209	–0.934*
	(–0.32)	(–0.69)	(–1.49)	(–0.32)	(–0.69)	(–1.65)
$log\ (GTA)_{t-1}$	0.0179***	–0.0251*	–7.755	0.0178***	–0.0252*	–6.465
	(7.49)	(–1.68)	(–0.93)	(7.46)	(–1.69)	(–0.80)
$log\ (GTA)_{t-1}*\ log\ (GTA)_{t-1}$	–0.000617***	0.000947*	0.274	–0.000616***	0.000949**	0.23
	(–7.72)	(1.95)	(0.96)	(–7.69)	(1.96)	(0.83)
$Interest\ Rate\ Swaps_{t-1}$	0.000232	0.000458***	2.571***			
	(1.54)	(2.71)	(3.70)			
$Clearing\ Dummy_{t-1}$ * $Interest\ Rate\ Swaps_{t-1}$	–0.000291**	–0.000468**	–3.098***			
	(–2.13)	(–2.17)	(–5.05)			
$Interest\ Rate\ Forwards\ and\ Swaps_{t-1}$				0.000202**	0.000399***	1.697***
				(2.14)	(2.70)	(3.97)
$Clearing\ Dummy_{t-1}$ * $Interest\ Rate\ Forwards\ and\ Swaps_{t-1}$				–0.000254***	–0.000405**	–2.488***
				(–2.70)	(–2.14)	(–5.57)
$Credit\ Default\ Swaps_{t-1}$	–0.000874	–0.00447***	–17.43***	–0.00094	–0.00458***	–15.53***
	(–1.10)	(–4.67)	(–3.67)	(–1.58)	(–4.52)	(–3.51)
$Clearing\ Dummy_{t-1}$ * $Credit\ Default\ Swaps_{t-1}$	0.00163*	0.00116	15.70***	0.00168**	0.00119	14.80***
	(1.72)	(0.64)	(4.14)	(2.16)	(0.65)	(4.81)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750
R^2	0.576	0.168	0.314	0.576	0.168	0.301

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4C: Impact of Mandatory Clearing Requirements on the Idiosyncratic Risk Measures

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable =	*–VaR* (5%)$_t$	*–VaR* (5%)$_t$	*–VaR* (5%)$_t$	*Idiosyncratic Risk*$_t$	*Idiosyncratic Risk*$_t$	*Idiosyncratic Risk*$_t$
Capital Ratio$_{t-1}$	–0.0425***	–0.0424***	–0.0425***	–3.569***	–3.607***	–3.607***
	(–3.59)	(–3.58)	(–3.59)	(–4.32)	(–4.37)	(–4.37)
ROA$_{t-1}$	–0.0203***	–0.0203***	–0.0203***	–0.516	–0.515	–0.517
	(–3.34)	(–3.34)	(–3.34)	(–1.39)	(–1.38)	(–1.39)
Liquidity$_{t-1}$	–0.0037	–0.00369	–0.00363	–0.492	–0.472	–0.472
	(–0.70)	(–0.70)	(–0.69)	(–1.37)	(–1.31)	(–1.31)
Asset Quality$_{t-1}$	0.185***	0.186***	0.185***	6.533***	6.414***	6.413***
	(4.92)	(4.96)	(4.95)	(3.02)	(2.98)	(2.98)
Management Quality$_{t-1}$	–0.00385	–0.0039	–0.00391	2.384**	2.381**	2.380**
	(–0.37)	(–0.38)	(–0.38)	(2.19)	(2.18)	(2.18)
GAP Ratio$_{t-1}$	0.00326*	0.00331*	0.00332*	0.268*	0.270*	0.269*
	(1.80)	(1.83)	(1.83)	(1.75)	(1.76)	(1.76)
log (GTA)$_{t-1}$	–0.0282**	–0.0279**	–0.0283**	–0.848	–0.964	–0.965
	(–2.21)	(–2.19)	(–2.22)	(–0.90)	(–1.02)	(–1.02)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	0.000972**	0.000964**	0.000974**	0.0289	0.0327	0.0327
	(2.37)	(2.34)	(2.37)	(0.97)	(1.08)	(1.09)
Fair Value of Interest Rate Derivatives$_{t-1}$	0.00374**			–0.128		
	(2.33)			(–1.60)		
Clearing Dummy $_{t-1}$ **Fair Value of Interest Rate Derivatives*$_{t-1}$	–0.00174			–0.303***		
	(–1.38)			(–7.15)		
Interest Rate Swaps$_{t-1}$		0.000212			0.0222***	
		(1.41)			(3.62)	
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$		–0.000129**			–0.0114***	
		(–2.01)			(–4.03)	
Interest Rate Forwards and Swaps$_{t-1}$			0.000251*			0.0192***
			(1.96)			(3.07)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$			–0.000108**			–0.00973***
			(–2.24)			(–3.80)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6760	6760	6760	6760
R^2	0.705	0.705	0.705	0.142	0.143	0.143

Note: The regressions include bank-specific fixed effects and quarter fixed effects. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4D: Impact of Mandatory Clearing Requirements on Counterparty Risk and Efficiency Indicators

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable =	*Market Risk Beta*$_t$	*Counterparty Revenue*$_t$	*ROA*$_t$	*Trading Revenue*$_t$	*Trading Revenue from Interest Rate Exposures*$_t$	*Trading Revenue from FX Exposures*$_t$
Capital Ratio$_{t-1}$	2.149**	0.0000503	0.0701	0.000903	0.000696	0.000246
	(2.37)	(0.17)	(0.96)	(1.51)	(0.61)	(1.22)
ROA$_{t-1}$	0.768					
	(0.92)					
Liquidity$_{t-1}$	0.482	–0.000125	–0.0620***	–0.00120*	–0.00213*	–0.0000829
	(1.23)	(–0.99)	(–3.05)	(–1.77)	(–1.85)	(–0.52)
Asset Quality$_{t-1}$	–4.667	–0.00472*	–1.054***	–0.00157	–0.00391	0.00118
	(–1.55)	(–1.71)	(–5.35)	(–0.60)	(–1.03)	(0.81)
Management Quality$_{t-1}$	–2.321**	0.0000656	–0.0993	0.00372	0.00843**	–0.0000435
	(–1.97)	(1.12)	(–1.53)	(1.32)	(2.30)	(–0.21)
GAP Ratio$_{t-1}$	–0.243	0.000117	–0.0182***	0.0000733	0.000131	–0.000114
	(–1.55)	(1.38)	(–2.68)	(0.49)	(0.51)	(–1.26)
log (GTA)$_{t-1}$	0.584	–0.000182	–0.0037	0.000398	–0.000704	0.00118**
	(0.79)	(–0.39)	(–0.11)	(0.53)	(–0.93)	(2.24)
log (GTA)$_{t-1}$* *log (GTA)*$_{t-1}$	–0.0103	0.00000709	–0.000605	–0.0000106	0.0000254	–0.0000404**
	(–0.43)	(0.43)	(–0.58)	(–0.40)	(0.92)	(–2.26)
Fair Value of Interest Rate	0.558***	0.000025	0.00348	–0.000157	–0.000872	0.00151***
Derivatives$_{t-1}$	(6.96)	(0.23)	(0.35)	(–1.23)	(–1.30)	(3.23)
Clearing Dummy$_{t-1}$ * *Fair Value*	0.183***	0.0000439	–0.00468	–0.000550**	–0.00135***	0.00109**
of Interest Rate Derivatives$_{t-1}$	(3.61)	(0.46)	(–1.07)	(–2.51)	(–2.79)	(2.05)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	1397	7065	7065	4145	4132
*R*²	0.0501	0.0341	0.182	0.0296	0.0695	0.18

Note: The regressions include bank-specific fixed effects and quarter fixed effects. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4E: Impact of Derivatives Clearing on Systemic Risk of BHCs. Accounting for Changes of Fair Value of Interest Rate Derivatives

	(1)	(2)	(3)	(4)	(5)
Dependent Variable =	$-VaR$ (5%)$_t$	*Idiosyncratic Risk*$_t$	$-\Delta CoVaR$ (5%)$_t$	*MES*$_t$	*SRISK*$_t$
Capital Ratio$_{t-1}$	–0.0425***	–3.666***	0.00177	0.0325**	–2.709
	(–3.57)	(–4.46)	(0.75)	(2.03)	(–1.34)
ROA$_{t-1}$	–0.0203***	–0.529	0.000780	0.00415	5.536**
	(–3.34)	(–1.40)	(0.77)	(0.78)	(2.14)
Liquidity$_{t-1}$	–0.00285	–0.549	–0.0000836	–0.000339	–0.955
	(–0.53)	(–1.53)	(–0.09)	(–0.05)	(–0.70)
Asset Quality$_{t-1}$	0.183***	6.048***	0.0224***	0.0247	83.62**
	(4.89)	(2.76)	(3.02)	(0.52)	(2.20)
Management Quality$_{t-1}$	0.000279	2.738**	–0.00150	0.00297	–1.828
	(0.02)	(2.50)	(–0.67)	(0.38)	(–0.60)
GAP Ratio$_{t-1}$	0.00291	0.244	–0.000237	–0.00235	–1.106*
	(1.63)	(1.56)	(–0.55)	(–0.77)	(–1.83)
log (GTA)$_{t-1}$	–0.0262**	–0.666	0.0182***	–0.0236	–2.163
	(–2.16)	(–0.70)	(7.47)	(–1.56)	(–0.20)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	0.000910**	0.0236	–0.000625***	0.000899*	0.0922
	(2.32)	(0.78)	(–7.69)	(1.83)	(0.24)
Δ *Fair Value of Interest Rate*	0.0109***	–0.380***	0.00478***	–0.00517***	–9.929**
Derivatives$_{t-1}$	(3.53)	(–2.90)	(7.78)	(–4.84)	(–2.18)
Fair Value of Interest Rate	0.000745	–0.0267	–0.000734	–0.00145	–4.835
Derivatives$_{t-1}$	(0.37)	(–0.31)	(–0.80)	(–0.58)	(–0.52)
Clearing Dummy$_{t-1}$ * *Fair Value of*	–0.00209*	–0.287***	–0.00192***	–0.00381***	–18.12***
Interest Rate Derivatives$_{t-1}$	(–1.69)	(–5.96)	(–5.60)	(–2.82)	(–2.72)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**
N	6651	6651	6651	6651	6641
R^2	0.708	0.142	0.580	0.169	0.243

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Variable Δ *Fair Value of Interest Rate Derivatives*$_{t-1}$ is defined as *Fair Value of Interest Rate Derivatives*$_{t-1}$ – *Fair Value of Interest Rate Derivatives*$_{t-2}$. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5A: Impact of Derivatives Clearing on Systemic Risk of BHCs. Heckman's (1979) Selection Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
***Dependent Variable* =**	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00548	0.0328*	−2.944	0.00458	0.0320*	−4.483**	0.00587	0.0339*	−3.673*
	(1.44)	(1.86)	(−1.54)	(1.19)	(1.82)	(−2.16)	(1.55)	(1.96)	(−1.85)
ROA$_{t-1}$	−0.00604***	−0.00625	3.420**	−0.00617***	−0.00468	2.976**	−0.00585***	−0.0067	3.273**
	(−3.37)	(−0.95)	(2.12)	(−3.44)	(−0.72)	(1.96)	(−3.21)	(−1.01)	(2.11)
Liquidity$_{t-1}$	0.00174	0.00107	−1.396	0.00208	0.00157	−0.81	0.00176	0.00084	−1.265
	(1.13)	(0.15)	(−0.49)	(1.35)	(0.21)	(−0.29)	(1.13)	(0.12)	(−0.42)
Asset Quality$_{t-1}$	0.0199*	0.0792	85.97***	0.0222**	0.0765	85.56***	0.0205*	0.078	83.89***
	(1.86)	(1.55)	(2.63)	(2.06)	(1.49)	(2.63)	(1.90)	(1.53)	(2.59)
Management Quality$_{t-1}$	−0.0041	−0.00197	−5.300	−0.00583	−0.00427	−5.927	−0.00421	−0.00127	−4.392
	(−0.96)	(−0.11)	(−1.12)	(−1.48)	(−0.25)	(−1.18)	(−1.09)	(−0.07)	(−1.01)
GAP Ratio$_{t-1}$	0.000134	0.000911	−0.481	0.000282	0.000639	−0.424	0.000162	0.000782	−0.478
	(0.19)	(0.28)	(−0.59)	(0.39)	(0.20)	(−0.51)	(0.23)	(0.25)	(−0.55)
log (GTA)$_{t-1}$	0.00970**	−0.00605	−8.093	0.00608	−0.00821	−12.97	0.00969**	−0.00298	−9.065
	(2.01)	(−0.28)	(−0.70)	(1.24)	(−0.37)	(−1.11)	(2.02)	(−0.14)	(−0.80)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	−0.000340**	0.000278	0.286	−0.000227	0.000351	0.438	−0.000346**	0.000178	0.315
	(−2.16)	(0.39)	(0.73)	(−1.42)	(0.48)	(1.12)	(−2.20)	(0.25)	(0.82)
Clearing Dummy$_{t-1}$	−0.00232***	−0.00174**	−0.197	−0.00263***	−0.00151*	−0.272	−0.00220***	−0.00120	0.0000182
	(−11.51)	(−2.38)	(−0.89)	(−11.71)	(−1.86)	(−1.01)	(−10.89)	(−1.57)	(0.00)
Fair Value of Interest Rate Derivatives$_{t-1}$	−0.0000101	−0.00731**	−8.659						
	(−0.01)	(−2.08)	(−1.14)						
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00112*	−0.00578**	−18.50***						
	(−1.90)	(−2.57)	(−2.95)						
Interest Rate Swaps$_{t-1}$				0.000120	0.0000811	0.243			
				(1.00)	(0.32)	(0.29)			
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$				−0.0000415	−0.000186***	−0.727***			
				(−1.27)	(−3.23)	(−2.68)			
Interest Rate Forwards and Swaps$_{t-1}$							0.000110	0.0000176	−0.0336
							(1.08)	(0.09)	(−0.05)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$							−0.0000478	−0.000169***	−0.626***
							(−1.60)	(−3.47)	(−2.75)
Constant	−0.0779***	−0.157***	51.04	−0.0891***	−0.224***	103.2*	−0.0964***	−0.136***	41.41
	(−4.96)	(−3.64)	(1.13)	(−4.33)	(−3.36)	(1.72)	(−6.89)	(−3.74)	(1.13)
***Lambda Interest Rate Swaps* Quarterly Fixed Effects**	**YES**	**YES**	**YES**						
***Lambda Interest Rate Forwards and Swaps* Quarterly Fixed Effects**				**YES**	**YES**	**YES**			
***Lambda Fair Value of Interest Rate Derivatives* Quarterly Fixed Effects**							**YES**	**YES**	**YES**
Individual BHC Mean of Indep. Var.	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6766	6766	6757	6766	6766	6757	6766	6766	6757
R^2	0.634	0.298	0.497	0.634	0.299	0.469	0.635	0.299	0.465

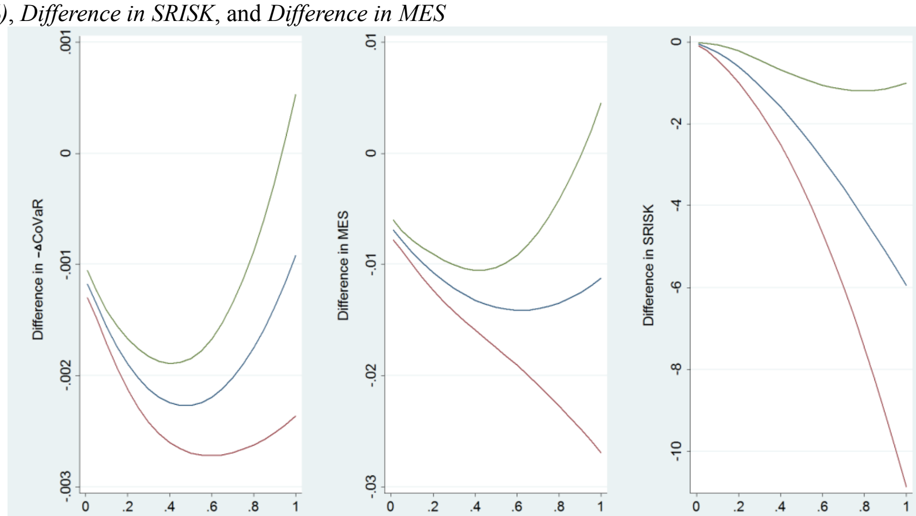
Note: The regressions include quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. *Lambda Interest Rate Swaps* is the self-selection parameter estimated from the probit model on each quarter that regresses *Interest Rate Swaps Dummy* on all control variables from the main specification based on each quarter. *Lambda Interest Rate Forwards and Swaps* is the self-selection parameter estimated from the probit model on each quarter that regresses *Interest Rate Forwards and Swaps Dummy* on all control variables from the main specification based on each quarter. *Lambda Fair Value of Interest Rate Derivatives* is the self-selection parameter estimated from the probit model on each quarter that regresses *Fair Value of Interest Rate Derivatives Dummy* on all control variables from the main specification based on each quarter. Standard errors are heteroskedasticity and autocorrelation consistent (HAC) and robust to both arbitrary heteroskedasticity and arbitrary autocorrelation. t statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5B: Cross-Section Treatment Effect Estimation

	(1)	(2)	(3)
Dependent Variable =	*Difference in –ΔCoVaR (5%)*	*Difference in MES*	*Difference in SRISK*
ATET (nnmatch)			
Interest Rate Swaps Dummy (1 vs 0)	–0.000457***	–0.00332**	–1.507***
	(–2.82)	(–2.53)	(–2.76)
ATET (psmatch)			
Interest Rate Swaps Dummy (1 vs 0)	–0.000380**	–0.00549***	–1.471**
	(–2.22)	(–3.61)	(–2.48)
ATET (ipw)			
Interest Rate Swaps Dummy (1 vs 0)	–0.000246*	–0.00534***	–1.637***
	(–1.76)	(–3.26)	(–2.76)
ATET (endogenous treatment)			
Interest Swap Dummy (1 vs 0)	–0.0102***	–0.0832***	–5.810**
	(–3.21)	(–3.25)	(–2.07)
N	387	387	367

Notes: (1) The estimation method is treatment-effects estimation of average treatment effect on the treated (ATET); nnmatch indicates nearest-neighbor matching, psmatch indicates propensity-score matching, ipw indicates inverse-probability weighting, where treatment is assumed to be independent of outcome and covariates. Endogenous treatment indicates control-function RA estimator, where treatment is assumed to be endogenous. (2) The covariates in the outcome model include means of the control variables (*Capital Ratio*, *ROA*, *Liquidity*, *Assets Quality*, *Management Quality*, *GAP Ratio*, *log (GTA)*, *log (GTA) * log (GTA))* before the introduction of mandatory clearing requirements. We do not include log (GTA) squared as a control variable in endogenous treatment estimation to assure convergence of the estimation. The results are very similar if we drop *log (GTA) * log (GTA)* from the list of our covariates. (3) *Difference in –ΔCoVaR (5%)*, *Difference in MES*, and *Difference in SRISK* are defined as the difference between the means of the –*ΔCoVaR (5%)*, *MES*, and *SRISK*, respectively, after the implementation of mandatory clearing and the means before the implementation of mandatory clearing in the first quarter of 2013 for each BHC. *Interest Rate Swaps Dummy* is a dummy variable that equals 1 if *Interest Rate Swaps* > 0 before the implementation of mandatory clearing, and 0 otherwise. *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, *GAP Ratio*, *log (GTA)*, and *log (GTA) * log (GTA)* are computed in the total period before the implementation of the mandatory clearing requirements. (4) Standard errors are heteroskedasticity-consistent. *t* statistics are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Figure 2: Estimated Dose-Response Functions based on *Interest Rate Swaps Intensity* as Treatment on *Difference in –ΔCoVaR (5%)*, *Difference in SRISK*, and *Difference in MES*



Interest Rate Swaps Intensity

Note: Difference in systemic risk measures before and after mandatory clearing is plotted against *Interest Rate Swaps Intensity*, computed as *Interest Rate Swaps* of a BHC divided by the maximum value of *Interest Rate Swaps* in our sample. To obtain convergence, the mean values of *Interest Rate Swaps* are winsorized at 0.05. For each share of *Interest Rate Swaps Intensity*, the blue solid line indicates the estimated conditional expectation of *Difference in –ΔCoVaR* (5%) on the left, of *Difference in MES* in the middle, and of *Difference in SRISK* on the right after the enactment of mandatory clearing given the estimated generalized propensity score (GPS). The covariates in the outcome model include means of control variables (*Capital Ratio*, *ROA*, *Liquidity*, *Assets Quality*, *Management Quality*, *GAP Ratio*, *log (GTA)*, *log (GTA) * log (GTA))* before the introduction of mandatory clearing requirements. Confidence bounds at 90% are plotted as green and red lines.

Table 6: Impact of Mandatory Clearing Requirements on Systemic Risk Using Post-double-Lasso Estimator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Fair Value of Interest Rate Derivatives$_{t-1}$	0.00131	–0.00336	–7.637						
	(1.57)	(–1.27)	(–0.94)						
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	–0.00165***	–0.00472***	–18.65***						
	(–3.08)	(–2.97)	(–2.60)						
Interest Rate Swaps$_{t-1}$				0.000127**	0.000000363	0.332			
				(2.39)	(0.00)	(0.44)			
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$				–0.0000771***	–0.000160***	–0.730**			
				(–3.90)	(–2.82)	(–2.46)			
Interest Rate Forwards and Swaps$_{t-1}$							0.000120**	0.00000644	0.0410
							(2.53)	(0.05)	(0.07)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$							–0.0000675***	–0.000147***	–0.627**
							(–3.88)	(–2.99)	(–2.53)
N. of Time-Centered Control Variables	**6**	**6**	**10**	**6**	**6**	**8**	**7**	**7**	**9**
N. of Initial Values of Control Variables	**0**	**0**	**0**	**4**	**4**	**4**	**0**	**0**	**0**
N. of Log of Control Variables	**2**	**2**	**2**	**5**	**5**	**5**	**5**	**5**	**5**
N. of Control Variable(s) Squared	**1**	**0**	**2**	**4**	**3**	**3**	**5**	**4**	**4**
N. of Control Variables Times Time Trend	**1**	**1**	**4**	**4**	**4**	**5**	**4**	**4**	**5**
Time-Centered Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6731	6731	6722	6604	6604	6595	6731	6731	6722
R^2	0.552	0.169	0.233	0.566	0.168	0.216	0.564	0.164	0.221

Note: (1) *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. (2) All dependent and independent variables (except the initial values of control variables) are time centered to remove fixed effects. (3) The total list of control variables is constructed as follows. We combine 116 variables from BHCs' consolidated balance sheets as reported in Schedule HC, Schedule HC-B, Schedule HC-C, and Schedule HC-E, 131 variables from consolidated income statement Schedule HI, Schedule HI-A, and Schedule HI-B in FR Y-9C, six proxies for CAMELS (including *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, *GAP Ratio*), and two bank size variables (*log (GTA)* and *log (GTA)* * *log (GTA)*). *Time-Centered Control Variables* are control variables scaled by the GTA and time centered. *Log of Control Variables* are time-centered logarithms of control variables. Instead of simple logarithms, we compute transformation (log(1 + abs(x)) – 1) * sign(x) of control variables x to remove singularities. *Control Variable(s) Squared* are time-centered squares of control variables scaled by the GTA. *Control Variables Times Time Trend* are control variables scaled by the GTA, interacted with time trend, and time centered. We also compute the initial values of centered variables. For each systemic risk measure, we also compute the initial value of the interest rate derivative variable and its interaction with time trend. We combine all of these lists in a set of 1,277 control variables. Using a post-double-Lasso estimator, developed by Belloni et al. (2014a, 2014b), we select the most important control variables, which are then included in the final regression. To conserve the space, the numbers of the selected variables are reported in the table but not the regression coefficients. (4) The regressions include quarter fixed effects. (5) Heteroskedasticity-constistent standard errors are clustered at bank level. t statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Supplementary Appendix

Table SA1: Impact of Derivatives Clearing on the Use of Derivatives of BHCs

Dependent Variable =	(1) *Fair Value of Interest Rate Derivatives*$_t$	(2) *Interest Rate Swaps*$_t$	(3) *Interest Rate Forwards and Swaps*$_t$	(4) *Fair Value of Interest Rate Derivatives*$_t$	(5) *Interest Rate Swaps*$_t$	(6) *Interest Rate Forwards and Swaps*$_t$	(7) *Fair Value of Interest Rate Derivatives*$_t$	(8) *Interest Rate Swaps*$_t$	(9) *Interest Rate Forwards and Swaps*$_t$
Capital Ratio$_{t–1}$	0.0440	0.511	0.655	0.0435	0.581	0.716	0.0453	0.567	0.708
	(1.21)	(0.94)	(0.99)	(1.22)	(1.12)	(1.15)	(1.26)	(1.11)	(1.16)
ROA$_{t–1}$	0.0192	0.135	0.139	0.0214	0.174	0.178	0.0222	0.165	0.171
	(1.00)	(0.60)	(0.54)	(1.13)	(0.74)	(0.67)	(1.19)	(0.72)	(0.66)
Liquidity$_{t–1}$	–0.0690	–0.919	–0.951	–0.0634	–0.941	–0.960	–0.0661	–0.956	–0.979
	(–1.56)	(–1.23)	(–1.23)	(–1.47)	(–1.26)	(–1.25)	(–1.49)	(–1.25)	(–1.24)
Asset Quality$_{t–1}$	0.468	5.301	4.955	0.600	4.371	4.358	0.530	4.138	3.993
	(1.13)	(0.94)	(0.79)	(1.47)	(0.83)	(0.73)	(1.26)	(0.73)	(0.62)
Management Quality$_{t–1}$	–0.0451**	–0.439	–0.568	–0.0205	–0.537	–0.612	–0.0175	–0.443	–0.522
	(–1.99)	(–0.95)	(–1.16)	(–1.09)	(–1.26)	(–1.39)	(–0.95)	(–1.31)	(–1.48)
GAP Ratio$_{t–1}$	–0.00695	–0.204	–0.185	–0.00366	–0.246	–0.216	–0.00570	–0.246	–0.221
	(–0.63)	(–0.98)	(–0.88)	(–0.32)	(–1.11)	(–0.97)	(–0.49)	(–1.08)	(–0.94)
log (GTA)$_{t–1}$	0.174	2.591	2.989	0.175	2.545	2.950	0.173	2.548	2.949
	(1.21)	(1.27)	(1.35)	(1.21)	(1.25)	(1.33)	(1.20)	(1.25)	(1.33)
log (GTA)$_{t–1}$ * *log (GTA)*$_{t–1}$	–0.00547	–0.0851	–0.0980	–0.00563	–0.0824	–0.0959	–0.00548	–0.0822	–0.0954
	(–1.12)	(–1.24)	(–1.30)	(–1.14)	(–1.20)	(–1.27)	(–1.12)	(–1.19)	(–1.26)
Clearing Dummy$_{t–1}$	–0.00555	–0.00638	–0.0160						
	(–1.54)	(–0.12)	(–0.24)						
Ratio of Interest Rate Derivatives Cleared$_{t–1}$				–0.0113	–0.224	–0.223			
				(–0.64)	(–0.67)	(–0.55)			
Time Trend$_{t–1}$							–0.000341	–0.00368	–0.00402
							(–0.86)	(–0.51)	(–0.46)
Bank Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	7065	7065	7065	7065	7065	7065	7065	7065	7065
*R*²	0.015	0.0094	0.0084	0.0119	0.0102	0.0089	0.0127	0.0101	0.0090

Note: The regressions include bank-specific fixed effects. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA2: Subsample Analysis: Regression coefficients on the interaction term between *Clearing Dummy* and *Fair Value of Interest Rate Derivatives*

	Subsamples Below the Medium of the Indicator			Subsamples Above the Medium of the Indicator		
	(1)	(2)	(3)	(1)	(2)	(3)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
	Subsample: *GTA* <= $2.147 billion (Median)			**Subsample: *GTA* > $2.147 billion (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00118***	−0.0167***	−0.00191	−0.000776***	−0.00296***	−18.28***
	(−2.69)	(−3.07)	(−0.13)	(−2.60)	(−3.44)	(−2.78)
	Subsample: *Capital Ratio* <= 0.1036 (Median)			**Subsample: *Capital Ratio* > 0.1036 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00176***	−0.00400**	−13.51***	−0.00109**	−0.00745	−14.63
	(−8.04)	(−2.29)	(−3.17)	(−2.52)	(−1.53)	(−1.48)
	Subsample: *Liquidity* <= 0.0432 (Median)			**Subsample: *Liquidity* > 0.0432 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00426	−0.0194***	−1.094	−0.00187***	−0.00448***	−18.06***
	(−1.17)	(−2.97)	(−0.19)	(−4.90)	(−3.01)	(−2.79)
	Subsample: *GAP Ratio* <= 0. 3029 (Median)			**Subsample: *GAP Ratio* > 0.3029 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00159***	−0.00287***	−18.12***	−0.00195	−0.0211***	4.481
	(−4.71)	(−2.69)	(−2.81)	(−1.36)	(−4.66)	(1.04)
	Subsample: *ROA* <= 0.0156 (Median)			**Subsample: *ROA* > 0.0156 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00221***	−0.00482***	−18.23***	−0.00100***	−0.00231	−18.70*
	(−6.05)	(−5.17)	(−2.74)	(−3.23)	(−1.07)	(−1.96)
	Subsample: *Asset Quality* <= 0.0157 (Median)			**Subsample: *Asset Quality* > 0.0157 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00119***	−0.00211**	−8.720***	−0.00303**	−0.00914***	−51.43***
	(−5.49)	(−2.14)	(−36.76)	(−2.52)	(−4.27)	(−6.58)
	Subsample: *Management Quality* <= 0.0091 (Median)			**Subsample: *Management Quality* > 0.0091 (Median)**		
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	−0.00205***	−0.00631***	−24.47***	−0.00163***	−0.00271**	−13.67***
	(−3.47)	(−4.68)	(−3.00)	(−3.28)	(−2.28)	(−3.00)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Notes: (1) The variables *Capital Ratio* $_{t-1}$, *ROA* $_{t-1}$, *Liquidity* $_{t-1}$, *Asset Quality* $_{t-1}$, *Management Quality* $_{t-1}$, *GAP Ratio* $_{t-1}$, *log (GTA)* $_{t-1}$, *log (GTA)* $_{t-1}$ * *log (GTA)* $_{t-1}$, *and Fair Value of Interest Rate Derivatives* $_{t-1}$ are also included in each regression but their regression coefficients are not reported for brevity. (2) The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA3: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Subsample Period from the Third Quarter of 2011 to the Second Quarter of 2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00218	0.0404***	–7.288***	0.00218	0.0404***	–6.970***	0.00213	0.0406***	-6.740***
	(0.96)	(3.04)	(–3.64)	(0.96)	(3.04)	(–3.52)	(0.94)	(3.06)	(-3.33)
ROA$_{t-1}$	0.00205**	0.0015	1.700**	0.00204**	0.00149	1.678**	0.00203**	0.00151	1.741**
	(2.19)	(0.24)	(2.20)	(2.19)	(0.24)	(2.21)	(2.18)	(0.24)	(2.19)
Liquidity$_{t-1}$	–0.00104	0.00533	0.178	–0.00102	0.00536	0.243	–0.00097	0.00543	0.405
	(–1.11)	(0.88)	(0.14)	(–1.09)	(0.89)	(0.19)	(–1.03)	(0.90)	(0.32)
Asset Quality$_{t-1}$	0.0164*	0.0109	35.10**	0.0163*	0.0108	34.76**	0.0153*	0.0108	34.53**
	(1.87)	(0.22)	(2.28)	(1.86)	(0.22)	(2.32)	(1.77)	(0.22)	(2.18)
Management Quality$_{t-1}$	–0.00106	–0.00284	–1.195	–0.00106	–0.00283	–1.106	–0.00109	–0.00277	-0.932
	(–0.59)	(–0.35)	(–0.91)	(–0.59)	(–0.35)	(–0.87)	(–0.61)	(–0.34)	(-0.76)
GAP Ratio$_{t-1}$	–0.000615	0.00141	–0.802**	–0.000614	0.00142	–0.774**	–0.00062	0.00143	-0.757**
	(–1.35)	(0.48)	(–2.18)	(–1.34)	(0.48)	(–2.18)	(–1.34)	(0.48)	(-2.19)
log (GTA)$_{t-1}$	0.0186***	–0.0647***	–15.41**	0.0185***	–0.0647***	–14.62**	0.0183***	–0.0644***	-14.84**
	(7.62)	(–4.59)	(–2.36)	(7.59)	(–4.59)	(–2.22)	(7.45)	(–4.57)	(-2.27)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	–0.000639***	0.00235***	0.523**	–0.000637***	0.00235***	0.497**	–0.000629***	0.00234***	0.502**
	(–7.79)	(5.01)	(2.37)	(–7.77)	(5.00)	(2.23)	(–7.63)	(4.98)	(2.27)
Interest Rate Swaps$_{t-1}$	0.0000739	0.00000906	–0.0707						
	(0.99)	(0.06)	(–0.19)						
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.0000807***	–0.000134***	–0.463***						
	(–3.55)	(–4.00)	(–2.61)						
Interest Rate Forwards and Swaps$_{t-1}$				0.0000682	–0.0000083	–0.224			
				(1.06)	(–0.07)	(–0.78)			
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				–0.0000683***	–0.000115***	–0.398***			
				(–3.63)	(–3.94)	(–2.81)			
Fair Value of Interest Rate Derivatives$_{t-1}$							0.00169*	–0.00077	–2.225
							(1.72)	(–0.33)	(–0.45)
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$							–0.00118***	–0.00377**	–
							(–4.84)	(–2.56)	(–3.29)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	5458	5458	5455	5458	5458	5455	5458	5458	5455
R^2	0.562	0.0912	0.172	0.562	0.0912	0.181	0.562	0.0915	0.191

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA4: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Extended Sample Period from the First Quarter of 2008 to the Second Quarter of 2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	–0.0224***	–0.0168	–3.344**	–0.0223***	–0.0168	–3.085*	–0.0224***	–0.0164	–2.485
	(–5.10)	(–1.43)	(–2.07)	(–5.10)	(–1.42)	(–1.94)	(–5.09)	(–1.39)	(–1.42)
ROA$_{t-1}$	–0.00111	0.0124	2.711*	–0.00111	0.0124	2.700*	–0.0011	0.0124	2.906**
	(–0.80)	(1.44)	(1.87)	(–0.80)	(1.44)	(1.87)	(–0.80)	(1.45)	(2.01)
Liquidity$_{t-1}$	0.00337**	0.00745	–2.178	0.00336**	0.00738	–2.434	0.00344**	0.00691	–2.918
	(2.27)	(0.99)	(–1.12)	(2.27)	(0.98)	(–1.33)	(2.32)	(0.92)	(–1.57)
Asset Quality$_{t-1}$	0.0330***	0.143**	59.90**	0.0330***	0.143**	60.12**	0.0330***	0.145**	65.43***
	(3.71)	(2.29)	(2.37)	(3.71)	(2.30)	(2.45)	(3.71)	(2.33)	(2.63)
Management Quality$_{t-1}$	0.000386	–0.0162	–8.303	0.000417	–0.0163	–8.266	0.000449	–0.0163	–8.239
	(0.12)	(–0.96)	(–1.24)	(0.13)	(–0.96)	(–1.25)	(0.14)	(–0.97)	(–1.30)
GAP Ratio$_{t-1}$	–0.00012	–0.00283	–0.671	–0.000122	–0.00286	–0.756	–0.0000989	–0.00297	–0.822
	(–0.17)	(–0.85)	(–0.98)	(–0.17)	(–0.86)	(–1.10)	(–0.14)	(–0.90)	(–1.08)
log (GTA)$_{t-1}$	0.0283***	0.0330*	21.21**	0.0284***	0.0333*	22.54**	0.0281***	0.0348*	23.83**
	(7.11)	(1.68)	(2.39)	(7.13)	(1.69)	(2.48)	(7.09)	(1.75)	(2.14)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	–0.000988***	–0.00101	–0.680**	–0.000991***	–0.00102	–0.725**	–0.000981***	–0.00107	–0.768**
	(–7.42)	(–1.56)	(–2.28)	(–7.45)	(–1.57)	(–2.37)	(–7.40)	(–1.63)	(–2.05)
Interest Rate Swaps$_{t-1}$	–0.0000676	0.000571	0.777						
	(–0.47)	(1.46)	(0.61)						
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.000127***	–0.0000687	–1.019**						
	(–3.00)	(–1.48)	(–2.23)						
Interest Rate Forwards and Swaps$_{t-1}$				–0.000108	0.000471	0.254			
				(–0.74)	(1.31)	(0.21)			
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				–0.000108***	–0.0000669	–0.894**			
				(–3.10)	(–1.57)	(–2.28)			
Fair Value of Interest Rate Derivatives$_{t-1}$							–0.000879	–0.0021	–13.67
							(–0.54)	(–0.50)	(–1.20)
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$							–0.00297***	–0.00260	–27.38**
							(–2.83)	(–0.96)	(–2.15)
Bank and Quarter FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	10222	10222	10210	10222	10222	10210	10222	10222	10210
R^2	0.622	0.216	0.199	0.622	0.216	0.196	0.622	0.215	0.219

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA5: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Sample Period from the Third Quarter of 2010 to the Second Quarter of 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
***Dependent Variable* =**	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	-0.00239	0.0186	0.713	-0.00243	0.0186	1.064	-0.00205	0.0187	1.298
	(-0.64)	(0.63)	(0.37)	(-0.65)	(0.63)	(0.53)	(-0.55)	(0.64)	(0.56)
ROA$_{t-1}$	-0.00169*	-0.00530	2.508**	-0.00169*	-0.00530	2.394**	-0.00180*	-0.00530	2.392**
	(-1.72)	(-1.11)	(2.05)	(-1.72)	(-1.11)	(1.99)	(-1.82)	(-1.11)	(2.07)
Liquidity$_{t-1}$	0.0000604	-0.000733	2.082	0.0000605	-0.000728	2.128	0.0000752	-0.000808	1.987
	(0.05)	(-0.07)	(1.04)	(0.05)	(-0.07)	(1.08)	(0.06)	(-0.08)	(1.05)
Asset Quality$_{t-1}$	0.0137*	-0.000658	51.17**	0.0137*	-0.000703	50.20**	0.0133*	-0.0000709	50.25**
	(1.70)	(-0.01)	(1.98)	(1.71)	(-0.01)	(1.98)	(1.65)	(-0.00)	(2.14)
Management Quality$_{t-1}$	-0.00693***	0.00712	-4.842	-0.00696***	0.00713	-4.749	-0.00686***	0.00704	-4.626
	(-3.59)	(0.64)	(-1.26)	(-3.62)	(0.64)	(-1.28)	(-3.40)	(0.63)	(-1.26)
GAP Ratio$_{t-1}$	0.000458	-0.00916*	-0.301	0.000445	-0.00915*	-0.205	0.000487	-0.00902*	0.106
	(0.73)	(-1.95)	(-0.39)	(0.71)	(-1.95)	(-0.27)	(0.77)	(-1.92)	(0.12)
log (GTA)$_{t-1}$	-0.00519	0.0637*	32.16	-0.00544	0.0638*	34.21*	-0.00332	0.0652**	37.63*
	(-1.02)	(1.91)	(1.60)	(-1.07)	(1.92)	(1.80)	(-0.68)	(1.97)	(1.90)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	0.000206	-0.00230**	-1.070	0.000214	-0.00230**	-1.139*	0.000143	-0.00235**	-1.258*
	(1.20)	(-2.24)	(-1.57)	(1.26)	(-2.25)	(-1.76)	(0.87)	(-2.30)	(-1.87)
Ratio of Interest Rate Derivatives Cleared$_{t-1}$	-0.0129***	-0.0329***	-3.319***	-0.0129***	-0.0329***	-3.188***	-0.0129***	-0.0328***	-2.544**
	(-20.81)	(-7.50)	(-2.81)	(-20.81)	(-7.50)	(-2.74)	(-20.63)	(-7.45)	(-2.25)
Interest Rate Swaps$_{t-1}$	0.000461***	-0.000192	2.135*						
	(3.55)	(-0.46)	(1.79)						
Ratio of Interest Rate Derivatives Cleared$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	-0.000104	-0.000168	-5.084*						
	(-0.46)	(-0.27)	(-1.96)						
Interest Rate Forwards and Swaps$_{t-1}$				0.000454***	-0.000188	1.575*			
				(4.34)	(-0.48)	(1.83)			
Ratio of Interest Rate Derivatives Cleared$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				-0.000108	-0.000139	-4.430*			
				(-0.61)	(-0.27)	(-1.96)			
Fair Value of Interest Rate Derivatives$_{t-1}$							0.00307***	-0.0118	12.58
							(2.98)	(-0.98)	(0.50)
Ratio of Interest Rate Derivatives Cleared$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$							-0.00456*	0.00610	-67.68
							(-1.75)	(0.38)	(-1.45)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	2713	2713	2706	2713	2713	2706	2713	2713	2706
R^2	0.532	0.182	0.137	0.533	0.182	0.148	0.529	0.183	0.222

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA6: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Without Quadratic Term of *log (GTA)*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$	MES_t	$SRISK_t$	$-\Delta CoVaR$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.000159	0.0370**	–3.537*	0.000152	0.0370**	–3.262*	0.00021	0.0372**	–2.575
	(0.06)	(2.28)	(–1.91)	(0.06)	(2.28)	(–1.76)	(0.08)	(2.30)	(–1.30)
ROA$_{t-1}$	0.000949	0.00438	5.435**	0.000941	0.00437	5.379**	0.000952	0.00438	5.467**
	(0.95)	(0.85)	(2.17)	(0.94)	(0.84)	(2.18)	(0.95)	(0.85)	(2.18)
Liquidity$_{t-1}$	–0.00091	0.00121	–0.774	–0.000894	0.00125	–0.841	–0.00096	0.00118	–1.175
	(–0.93)	(0.18)	(–0.51)	(–0.92)	(0.18)	(–0.57)	(–0.98)	(0.17)	(–0.78)
Asset Quality$_{t-1}$	0.0245***	0.0272	79.25**	0.0245***	0.0269	79.35**	0.0245***	0.0281	82.57**
	(3.22)	(0.57)	(2.19)	(3.21)	(0.57)	(2.23)	(3.20)	(0.59)	(2.26)
Management Quality$_{t-1}$	–0.00184	0.000176	–2.565	–0.00184	0.000201	–2.473	–0.0018	0.000257	–2.164
	(–1.28)	(0.02)	(–0.83)	(–1.29)	(0.03)	(–0.81)	(–1.26)	(0.03)	(–0.72)
GAP Ratio$_{t-1}$	–0.000332	–0.00192	–1.176*	–0.000334	–0.00191	–1.190*	–0.00036	–0.00188	–1.157*
	(–0.72)	(–0.64)	(–1.85)	(–0.72)	(–0.64)	(–1.90)	(–0.77)	(–0.63)	(–1.93)
log (GTA)$_{t-1}$	–0.000673***	0.00340*	0.671	–0.000675***	0.00339*	0.666	–0.000667***	0.00337*	0.631
	(–2.83)	(1.94)	(1.43)	(–2.84)	(1.94)	(1.43)	(–2.80)	(1.93)	(1.34)
Interest Rate Swaps$_{t-1}$	0.000121**	–0.0000693	0.28						
	(2.29)	(–0.59)	(0.39)						
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.0000859***	–0.000138***	–0.707**						
	(–4.93)	(–3.50)	(–2.54)						
Interest Rate Forwards and				0.000113**	–0.0000695	–0.000641			
				(2.53)	(–0.65)	(–0.00)			
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				–0.0000729***	–0.000118***	–0.609***			
				(–4.89)	(–3.55)	(–2.63)			
Fair Value of Interest Rate Derivatives$_{t-1}$							0.00103	–0.00357	–7.685
							(1.47)	(–1.49)	(–0.92)
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$							–0.00163***	–0.00433***	–18.44***
							(–4.88)	(–3.27)	(–2.73)
Bank and Quarter FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750	6760	6760	6750
R^2	0.561	0.166	0.21	0.561	0.166	0.214	0.56	0.166	0.233

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA7: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Controlling BHCs' Size in 10 Quantiles of *log (GTA)*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00181	0.0308**	–4.070**	0.00181	0.0308**	–3.759**	0.00187	0.0310**	–2.993
	(0.73)	(2.10)	(–2.19)	(0.73)	(2.10)	(–2.03)	(0.75)	(2.12)	(–1.52)
ROA$_{t-1}$	0.00121	0.00269	5.223**	0.00121	0.00268	5.178**	0.00122	0.0027	5.288**
	(1.19)	(0.54)	(2.22)	(1.18)	(0.54)	(2.24)	(1.19)	(0.54)	(2.25)
Liquidity$_{t-1}$	–0.000955	0.00185	–0.708	–0.00094	0.00189	–0.775	–0.001	0.00182	–1.108
	(–0.98)	(0.27)	(–0.46)	(–0.97)	(0.28)	(–0.53)	(–1.03)	(0.27)	(–0.73)
Asset Quality$_{t-1}$	0.0250***	0.0196	78.50**	0.0250***	0.0193	78.65**	0.0249***	0.0206	82.01**
	(3.26)	(0.42)	(2.21)	(3.25)	(0.42)	(2.25)	(3.25)	(0.44)	(2.28)
Management Quality$_{t-1}$	–0.00108	0.000456	–3.208	–0.00109	0.000484	–3.098	–0.00105	0.000579	–2.711
	(–0.66)	(0.06)	(–0.98)	(–0.67)	(0.06)	(–0.96)	(–0.64)	(0.08)	(–0.86)
GAP Ratio$_{t-1}$	–0.000415	–0.00166	–1.142*	–0.000416	–0.00164	–1.158*	–0.00044	–0.00161	–1.130*
	(–0.93)	(–0.56)	(–1.84)	(–0.94)	(–0.56)	(–1.89)	(–0.99)	(–0.55)	(–1.93)
Interest Rate Swaps$_{t-1}$	0.000120**	–0.0000677	0.280						
	(2.27)	(–0.55)	(0.38)						
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.0000830***	–0.000149***	–0.709**						
	(–4.90)	(–3.65)	(–2.54)						
Interest Rate Forwards and Swaps$_{t-1}$				0.000112**	–0.0000696	–0.00146			
				(2.52)	(–0.63)	(–0.00)			
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				–0.0000704***	–0.000127***	–0.611***			
				(–4.87)	(–3.72)	(–2.63)			
Fair Value of Interest Rate Derivatives$_{t-1}$							0.00103	–0.0036	–7.705
							(1.51)	(–1.46)	(–0.92)
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate*							–0.00156***	–0.00459***	–18.48***
							(–4.69)	(–3.51)	(–2.73)
10-Quantiles of *log (GTA)* Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750	6760	6760	6750
*R*²	0.564	0.171	0.21	0.564	0.171	0.214	0.563	0.171	0.233

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Size dummy variables, defined according to 10 quantiles of *log (GTA)*, are also included but not reported in the table. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA8: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Heteroskedastic and Autocorrelation Consistent (HAC) Standard Errors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00156	0.0349**	–3.924**	0.00155	0.0349**	–3.580**	0.00162	0.0352**	-2.740
	(0.74)	(2.43)	(–2.24)	(0.73)	(2.43)	(–2.06)	(0.76)	(2.45)	(-1.50)
ROA$_{t-1}$	0.000733	0.00470	5.492**	0.000727	0.00469	5.426**	0.000737	0.00469	5.492**
	(0.78)	(0.96)	(2.48)	(0.78)	(0.96)	(2.49)	(0.79)	(0.96)	(2.51)
Liquidity$_{t-1}$	–0.0000792	–0.0000175	–1.003	–0.0000615	0.0000174	–1.031	–0.000110	-0.0000318	-1.274
	(–0.09)	(–0.00)	(–0.71)	(–0.07)	(0.00)	(–0.74)	(–0.13)	(-0.00)	(-0.91)
Asset Quality$_{t-1}$	0.0216***	0.0315	80.04**	0.0215***	0.0313	80.00***	0.0216***	0.0322	82.90***
	(3.29)	(0.73)	(2.55)	(3.28)	(0.72)	(2.59)	(3.28)	(0.75)	(2.63)
Management Quality$_{t-1}$	–0.00271	0.00146	–2.325	–0.00270	0.00148	–2.277	–0.00267	0.00150	-2.062
	(–1.16)	(0.19)	(–0.82)	(–1.16)	(0.19)	(–0.82)	(–1.14)	(0.20)	(-0.76)
GAP Ratio$_{t-1}$	–0.000153	–0.00218	–1.225**	–0.000153	–0.00218	–1.232**	–0.000168	-0.00215	-1.180**
	(–0.39)	(–0.79)	(–1.98)	(–0.39)	(–0.79)	(–2.01)	(–0.43)	(-0.78)	(-2.02)
log (GTA)$_{t-1}$	0.0180***	–0.0242*	–4.465	0.0180***	–0.0242*	–3.555	0.0182***	-0.0235*	-1.568
	(8.16)	(–1.76)	(–0.49)	(8.12)	(–1.76)	(–0.39)	(8.25)	(-1.71)	(-0.16)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	–0.000621***	0.000917**	0.171	–0.000620***	0.000917**	0.140	–	0.000893**	0.0731
	(–8.35)	(2.05)	(0.54)	(–8.32)	(2.05)	(0.45)	(–8.43)	(2.00)	(0.22)
Interest Rate Swaps$_{t-1}$	0.0000849	–0.0000158	0.290						
	(1.29)	(–0.12)	(0.47)						
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$	–0.0000885***	–0.000135***	–0.706***						
	(–4.86)	(–3.76)	(–2.95)						
Interest Rate Forwards and Swaps$_{t-1}$				0.0000804	–0.0000207	0.00682			
				(1.32)	(–0.18)	(0.01)			
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$				–0.0000751***	–0.000115***	–0.609***			
				(–4.88)	(–3.80)	(–3.07)			
Fair Value of Interest Rate Derivatives$_{t-1}$							0.000598	–0.00295	-7.634
							(0.74)	(-1.43)	(-1.06)
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$							–0.00178***	–	–
							(–4.78)	(–3.49)	(–3.23)
Bank and Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6760	6760	6750	6760	6760	6750	6760	6760	6750
R^2	0.575	0.167	0.211	0.575	0.167	0.214	0.574	0.167	0.233

Note: The regressions include bank-specific fixed effects and quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Standard errors are heteroskedasticity and autocorrelation consistent (HAC). *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA9: Impact of Mandatory Clearing Requirements on Systemic Risk of BHCs. Using Alternative Econometric Model without Bank Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(7)
Dependent Variable =	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$	$-\Delta CoVaR$ (5%)$_t$	MES_t	$SRISK_t$
Capital Ratio$_{t-1}$	0.00996***	0.00916	–	0.00998***	0.0093	–	0.0100***	0.00932	–7.552***
	(3.37)	(1.15)	(–5.58)	(3.38)	(1.17)	(–5.19)	(3.38)	(1.17)	(–5.17)
ROA$_{t-1}$	0.00253	0.00335	1.391	0.00251	0.00341	1.529	0.0025	0.00339	1.48
	(1.00)	(0.46)	(0.82)	(0.99)	(0.47)	(0.90)	(0.98)	(0.47)	(0.87)
Liquidity$_{t-1}$	0.00237	0.00661	1.586	0.00228	0.00657	1.417	0.0023	0.00659	1.510
	(1.43)	(1.64)	(0.87)	(1.37)	(1.63)	(0.80)	(1.38)	(1.64)	(0.84)
Asset Quality$_{t-1}$	–0.0383***	0.0839***	–0.103	–0.0375***	0.0861***	6.279	–0.0376***	0.0857***	5.598
	(–3.96)	(2.77)	(–0.01)	(–3.85)	(2.81)	(0.45)	(–3.85)	(2.80)	(0.40)
Management Quality$_{t-1}$	–0.00108	0.0243	–1.846	–0.000781	0.0244	–1.883	–0.0009	0.0242	–2.364
	(–0.11)	(0.64)	(–0.34)	(–0.08)	(0.64)	(–0.37)	(–0.09)	(0.64)	(–0.45)
GAP Ratio$_{t-1}$	–0.00192***	–0.00352**	–0.0101	–0.00192***	–0.00350**	0.0357	–0.00192***	–0.00350**	0.0363
	(–3.39)	(–2.12)	(–0.03)	(–3.38)	(–2.10)	(0.09)	(–3.38)	(–2.10)	(0.09)
log (GTA)$_{t-1}$	0.0145***	0.0239***	–2.701	0.0142***	0.0238***	–2.804	0.0143***	0.0239***	–2.589
	(15.62)	(11.98)	(–0.69)	(15.39)	(12.04)	(–0.71)	(15.51)	(11.95)	(–0.66)
log (GTA)$_{t-1}$ * *log (GTA)*$_{t-1}$	–0.000409***	–	0.086	–0.000400***	–0.000661***	0.089	–0.000402***	–0.000662***	0.082
	(–13.88)	(–10.40)	(0.67)	(–13.65)	(–10.48)	(0.69)	(–13.77)	(–10.38)	(0.64)
Fair Value of Interest Rate Derivatives$_{t-1}$	0.00362***	0.00553***	18.44***						
	(2.99)	(2.92)	(3.44)						
Clearing Dummy$_{t-1}$ * *Fair Value of Interest Rate Derivatives*$_{t-1}$	–0.000904*	–0.000791	–10.65*						
	(–1.72)	(–0.69)	(–1.77)						
Interest Rate Swaps$_{t-1}$				0.000182***	0.000312***	1.050***			
				(3.06)	(3.32)	(3.41)			
Clearing Dummy$_{t-1}$ * *Interest Rate Swaps*$_{t-1}$				–0.0000875***	–0.000105**	–0.732**			
				(–2.85)	(–2.05)	(–2.12)			
Interest Rate Forwards and Swaps$_{t-1}$							0.000157***	0.000265***	0.894***
							(3.03)	(3.18)	(3.34)
Clearing Dummy$_{t-1}$ * *Interest Rate Forwards and Swaps*$_{t-1}$							–0.0000727***	–0.0000887**	–0.608**
							(–2.78)	(–1.99)	(–2.08)
Constant	–0.121***	–0.196***	21.69	–0.118***	–0.196***	22.46	–0.119***	–0.196***	20.81
	(–16.54)	(–12.44)	(0.73)	(–16.28)	(–12.48)	(0.74)	(–16.42)	(–12.40)	(0.70)
Quarter Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
N	6766	6766	6757	6766	6766	6757	6766	6766	6757
R^2	0.647	0.334	0.417	0.645	0.334	0.439	0.645	0.334	0.439

Note: The regressions include quarter fixed effects. *MES* and *SRISK* are computed based on a forward-looking one-year rolling window. Heteroskedasticity-consistent standard errors are clustered at bank level. *t* statistics are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table SA10: Cross-Section Treatment Effects Analysis under Endogenous Treatment-Effects Estimation

		(1)	(2)	(3)
	Dependent Variable = *Difference in –ΔCoVaR (5%)*	*Difference in MES*	*Difference in SRISK*	
ATET	*Interest Swap Dummy* (1 vs 0)	–0.0102***	–0.0832***	–5.810**
		(–3.21)	(–3.25)	(–2.07)
POmean	*Interest Swap Dummy* (0)	0.00800**	0.0711***	4.166
		(2.53)	(2.80)	(1.50)
TME1	*log (GTA)*	0.578***	0.578***	0.562***
		(7.50)	(7.50)	(7.22)
	GAP Ratio	–0.545	–0.545	–0.586
		(–1.22)	(–1.22)	(–1.27)
	Constant	–8.429***	–8.429***	–8.161***
		(–7.38)	(–7.38)	(–7.09)
OME0	*Capital Ratio*	–0.00237	–0.0141	–0.0905
		(–1.10)	(–0.84)	(–0.24)
	ROA	–0.00388**	–0.0153	0.315
		(–2.51)	(–0.59)	(0.66)
	Liquidity	0.000231	0.0116	0.766**
		(0.16)	(0.69)	(2.48)
	Asset Quality	–0.00566	–0.0615	–1.021
		(–0.82)	(–0.70)	(–0.84)
	Management Quality	–0.00253	0.0491	3.276***
		(–0.35)	–0.86	–3.33
	GAP Ratio	–0.000968	–0.0132	–0.935
		(–0.66)	(–1.11)	(–1.22)
	log (GTA)	0.00110**	0.0123***	0.714
		(2.37)	(3.30)	(1.55)
	Constant	–0.0124**	–0.147***	–8.432
		(–2.24)	(–3.29)	(–1.54)
OME1	*Capital Ratio*	–0.00712**	–0.0569**	–15.68
		(–2.31)	(–2.15)	(–1.52)
	ROA	–0.0111***	–0.0026	9.286
		(–3.25)	(–0.06)	(0.72)
	Liquidity	0.000212	0.0128	13.53**
		(0.14)	(1.30)	(1.97)
	Asset Quality	–0.0115	–0.156*	–133.7**
		(–1.20)	(–1.96)	(–2.35)
	Management Quality	0.00537	0.0858	–3.886
		(0.89)	(1.59)	(–0.24)
	GAP Ratio	–0.000876	0.00285	10.01
		(–1.37)	–0.56	–1.5
	log (GTA)	–0.000169*	–0.00048	–8.062***
		(–1.84)	(–0.70)	(–5.02)
	Constant	0.000953	–0.0024	143.1***
		(0.53)	(–0.18)	(4.65)
TEOM0	Constant	0.00984***	0.0780***	4.153
		(3.13)	(3.12)	(1.55)
TEOM1	Constant	0.00228***	0.0121**	–45.70***
		(3.05)	(2.19)	(–3.69)
	N	387	387	367

Notes: (1) The estimation method is endogenous treatment-effects estimation of average treatment effect on the treated (ATET). (2) The covariates in the outcome model include means of the control variables (*Capital Ratio, ROA, Liquidity, Assets Quality, Management Quality, GAP Ratio, and log (GTA))* before the introduction of mandatory clearing requirements. (3) *Difference in –ΔCoVaR (5%)*, *Difference in MES*, and *Difference in SRISK* are defined as the difference between the means of the –*ΔCoVaR (5%)*, *MES*, and *SRISK*, respectively, after the implementation of mandatory clearing and the means before the implementation of mandatory clearing in the first quarter of 2013 for each BHC. *Interest Rate Swaps Dummy* is a dummy variable that equals 1 if *Interest Rate Swaps* > 0 before the implementation of mandatory clearing, and 0 otherwise. *Capital Ratio*, *ROA*, *Liquidity*, *Asset Quality*, *Management Quality*, *GAP Ratio*, and *log (GTA)* are computed in the total period before the implementation of the mandatory clearing requirements. We do not include *log (GTA)* squared as a control variable to assure convergence of the estimation. (4) Standard errors are heteroskedasticity-consistent. *t* statistics are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.