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Essays on

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Contents

1 Introduction **1**

2 Macroprudential Policy and Intra-Group Dynamics **7**
- 2.1 Introduction . . . 7
- 2.2 Reserve Requirements in Brazil . . . 12
- 2.3 Data and Descriptive Statistics . . . 15
  - 2.3.1 Bank-level data . . . 15
  - 2.3.2 Country-level data . . . 17
- 2.4 Estimation Approach . . . 19
  - 2.4.1 Identification . . . 19
  - 2.4.2 Reserve requirements and credit supply . . . 22
  - 2.4.3 Robustness tests . . . 27
  - 2.4.4 The anatomy of reserve requirements' transmission . . . 30
  - 2.4.5 Effect on total credit . . . 35
- 2.5 Conclusion . . . 37
- Appendix A . . . 52

3 Ownership Structure and Default Resource Composition of CCPs **61**
- 3.1 Introduction . . . 61
- 3.2 Central Clearing in the EU . . . 65
  - 3.2.1 CCP Risk and Regulation . . . 67
- 3.3 Data . . . 71
- 3.4 Ownership Structure and Risk Governance . . . 73
- 3.5 Empirical Strategy . . . 76
- 3.6 Empirical Findings . . . 77
  - 3.6.1 Ownership and Margin Setting . . . 77
  - 3.6.2 Ownership and Capital Adequacy . . . 82
  - 3.6.3 Ownership and Default Loss Mutualization . . . 84
  - 3.6.4 Ownership and Collateral Quality . . . 87
- 3.7 Conclusion . . . 90

4 Bank Risk and Central Clearing Networks in Europe **121**
- 4.1 Introduction . . . 121
- 4.2 Data . . . 126
- 4.3 Clearing Member Network . . . 128
- 4.4 Clearing Connections and Bank Risk . . . 130
- 4.5 Peer Effects in Central Clearing . . . 135
- 4.6 Conclusion . . . 139

5 Conclusion **159**

Bibliography **163**

List of Tables

2.1 Summary Statistics . . . 42
2.2 Deposit Ratio of Parent Banks for Sub-Samples . . . 43
2.3 Baseline Results . . . 44
2.4 Robustness – Credit Demand & Response over Time . . . 45
2.5 Robustness – Monetary Policy . . . 46
2.6 Robustness – Macro and Political Confounders . . . 47
2.7 Periods . . . 48
2.8 Ownership . . . 49
2.9 Dynamics within State-Owned Banks during the Crisis Period . . . 50
2.10 Total Effect on Credit at the Municipality Level . . . 51
A.I Variables Definitions . . . 53
A.I Variables Definitions (continued) . . . 54
A.II Correlations . . . 55
A.III Credit Demand Proxies by Deposit Ratio . . . 57
A.IV Branch and Parent Characteristics . . . 58

3.1 Countries and Competent Authorities of European CCPs . . . 94
3.2 Availability of CPMI-IOSCO Quantitative Disclosures by CCP . . . 95
3.3 Data Sources . . . 96
3.4 Summary Statistics . . . 97
3.5 Ownership Structure of European Central Clearing Counterparties . 98
3.6 Groups of CCPs by Ownership Model . . . 99
3.7 Relative Size of Initial Margin by Ownership Model . . . 100
3.8 Mean Difference Tests for the Relative Size of Initial Margin . . . 101
3.9 Maximum Variation Margin Size in Relation to Subsequent Default Resources . . . 101
3.10 Mean Difference Tests for the Relative Size of Variation Margin Calls 102
3.11 Relative Amount of Pre-funded Capital by Ownership Model . . . 103
3.12 Mean Difference Tests for the Relative Size of the Capital Buffer . . 104
3.13 Mutualization by Ownership Model . . . 104
3.14 Mean Difference Tests for the Mutualization . . . 105
3.15 Haircut by Ownership Model . . . 105
3.16 Mean Difference Tests for the Average Haircut Applied to Margin and Default Fund Assets . . . 106

4.1 Summary Statistics of the Panel Regression Sample . . . 142
4.2 Summary Statistics of the Cross-section Regression Sample . . . 143
4.3 Summary Statistics for the Panel Regression of the Single-connection Subnetwork . . . 144
4.4 List of Clearing Members with the most Connections . . . 145
4.5 List of Clearing Members in Network by CCP . . . 146
4.6 Direct clearing memebers of CCPs by quarter . . . 146
4.7 Cross-section Regression Results for 2017 . . . 147

4.8 Cross-section Regression Results for the Collapsed Period of 2016 and 2017 . . . 148
4.9 Peer Effects Regression Results . . . 149
4.10 Marginal Peer Effect . . . 150
4.11 Peer Effects Regression Results for the Single-connection Subnetwork 151

List of Figures

2.1 Reserve Requirements and Cross-Border Banking Claims 39
2.2 Reserve Requirements and Monetary Policy Rate 39
2.3 Reserve Requirements and Average Credit Supply (Quarterly Change) 40
2.4 Municipality Coverage 40
2.5 Marginal Effect of Reserve Requirements on Credit Supply 41

3.1 Map of Authorized CCPs under EMIR 107
3.2 Notional Amount Covered by CCPs 107
3.3 Average Variation Margin as Share of Total Initial Margin Held by Ownership Type 108
3.4 Distribution of Average Variation Margin as Share of Total Initial Margin Held by Ownership Type 108
3.5 Maximum Variation Margin as Share of Total Initial Margin Held by Ownership Type 109
3.6 Distribution of the Maximum Variation Margin as Share of Total Initial Margin Held by Ownership Type 109
3.7 Share of Notional Amount Covered by Initial Margin 110
3.8 Distribution of the Notional Amount that is Covered by Initial Margin 110
3.9 Maximum Variation Margin Calls as Share of CCP's Own Capital by Ownership Type 111
3.10 Maximum Variation Margin Calls as Share of Total Default Fund Resources by Ownership Type 111
3.11 Distribution of the Maximum Variation Margin Calls as Share of Total Default Fund Resources by Ownership Type 112
3.12 Distribution of Maximum Variation Margin Calls as Share of CCP's Own Capital by Ownership Type 112
3.13 Share of Notional Amount Covered by CCP's Capital 113
3.14 Distribution of Notional Amount Covered by CCP's Capital by Ownership Type 113
3.15 Size of Capital Buffer in Terms of Initial Margin Held 114
3.16 Distribution of Capital Buffer Size in Terms of Initial Margin Held . 114
3.17 Share of Loss Given Default that is Covered by CCP's own Prefunded Capital 115
3.18 Distribution of Loss Given Default that is Covered by CCP's own Pre-funded Capital 115
3.19 Default Fund Size in Terms of Initial Margin Held 116
3.20 Default Fund Size in Terms of Initial Margin Held 116
3.21 Density of the Haircut Applied to Initial Margin by Ownership Type 117
3.22 Average Haircut Applied to Initial Margin by Ownership Type . . . 117
3.23 Average Haircut Applied to the Default Fund Contributions by Ownership Type 118
3.24 Distribution of Average Haircut Applied to the Default Fund Contributions by Ownership Type 118

4.1 Distribution of Members' Clearing Connections in Network 152
4.2 Distribution of Members' Clearing Connections in Sample 152
4.3 Clearing Member and Counterparty Network 153
4.4 Subgraphs of Clearing Network 154
4.5 Bank subset of the Clearing Network 155
4.6 Mean of Members' Zscore by CCP 156
4.7 Closed Neighborhood subset of the Clearing Network 157

Chapter 1

Introduction

> *"We regulate finance over and above the way we regulate other industries because finance exhibits market failures that can have devastating consequences"*

– Mark Taylor

The Warwick Commission on International Financial Reform. (2009), p.9.

Finance has seen a spectacular growth in innovation and internationalization during the 20^{th} century (Lane and Milesi-Ferretti, 2008; Shiller, 2013), resulting in a complex and highly interconnected network of financial entities spanning across jurisdictions (Allen and Gale, 1994; Popov and Udell, 2012). Meanwhile the challenges grow for policymakers to provide a framework which allows for the operation of a stable financial system within their jurisdiction (Merton, 1995; Allen and Gale, 2000; Morrison and White, 2009; Ongena et al., 2013). The global financial crisis highlights that severe disruptions in the financial sector spread across jurisdictions (Wiggins and Metrick, 2015) and can have large negative effects on the real economy (Chodorow-Reich, 2013). To contain systemic risk and contagion in the globalized financial system, several changes have been applied to the regulatory framework of international financial markets (G20, 2009). Regulatory efforts encompass among others the implementation of macroprudential policies and the introduction of mandatory central clearing of derivatives. This thesis aims to contribute to the understanding of differential effects of financial policy reforms depending on the characteristics of the regulated financial entities and networks.

First, this thesis aims to contribute to the knowledge about the effectiveness of macroprudential policies to steer the cycle of banks' credit supply. Macroprudential policies affect the banks' funding constraints, which is why an understanding of how banks' funding structures shape the effect of macroprudential policies is important to evaluate their effectiveness. The existing literature points to bank funding structures and internal capital as important transmission channels of monetary policy to credit supply (Campello, 2002; Kishan and Opiela, 2000; Holod and Peek, 2010), but lacks the evidence of whether they affect the effectiveness of macroprudential policies, as well. This thesis contributes to previous studies analyzing the functioning of macroprudential policies (Aiyar et al., 2014; Claessens et al., 2013) by analyzing the importance of banking group characteristics for the effectiveness of such policies. The analysis shows that parent banks' funding structure and branch profitability matter for the transmission of the policy to affect credit supply. This is, to the best of my knowledge, the first evidence on how bank-specific regulatory exposures affect the transmission of macroprudential policies to credit supply within banking groups.

Second, I contribute to the literature on the effects of the central clearing reform on the risk governance of central clearing counterparties (CCPs) and the correlation of risk within the network of derivative clearing banks. The literature suggests that the characteristics of CCPs such as ownership and business models may cause the CCPs' risk taking incentives to be misaligned with the goals of the central clearing policy reform (BIS, 2010), this thesis provides empirical evidence on the relationship between ownership types and the structuring of the loss absorbing capacities of CCPs. Furthermore, I contribute to the literature on the transmission of distress within financial networks (Allen and Gale, 2000) for the case of bank clearing networks and the effects of clearing connections on bank risk (Duffie and Zhu, 2011).

This thesis aims to expand the understanding of the differential effects of financial interventions, which aim to contain systemic imbalances, to create a more resilient derivative clearing network and to decrease the correlation of risk between bank counterparties of derivative trades, in three main chapters. Chapter 2 aims to demonstrate the importance of intra-group dynamics for the transmission of macroprudential policy.[1] Using bank-level data on the Brazilian banking system, the analysis investigates

[1] Chapter 2 is co-authored with *Lena Tonzer* and *Matias Ossandon Busch*.

the effect of reserve requirements targeting headquarter banks' deposit ratio on credit supply by their municipal branches. Exploiting this matched bank-branch data for identification purposes, the analysis finds a lending channel of reserve requirements for branches whose parent banks are more exposed to targeted deposits. The findings reveal limitations in current macroprudential policy frameworks.

Chapter 3 confirms the idea that ownership and business models directly affect the outcome of financial regulation at the level of the regulated entities. I look at the introduction of mandatory central clearing in the European Union, which created a set of diversely configured institutions with diverging characteristics regarding business models and strategic incentives. I examine the composition of default resources across ownership models of central clearing counterparties and find that CCPs held by a central bank compared to CCPs under different ownership models show persistently higher initial margin requirements, lower variation margin calls relative to subsequent layers of the default resources, accept collateral to which lower haircuts are applied and provide more own pre-funded capital relative to member provided default resources.

Chapter 4 sheds light on how the European central clearing reform affected the network structure and risk correlation among derivative clearing banks in Europe. European regulatory efforts to disentangle the opaque and complex liability structures of bilateral over-the-counter derivative trading led to the increased importance of central clearing counterparties (CCPs) now posing systemic nodes in the financial markets network. In this paper I analyze the network structure of the European central clearing market. I find that the European clearing sector is highly interconnected, that banks with more clearing memberships are less risky, and that the correlation between the risk of a bank and that of its peers has declined significantly since the introduction of central clearing. These findings speak in favor of the shock absorbing capability of central clearing counterparties in relatively stable times.

The findings in this thesis show that the outcome of financial regulation depends on the characteristics of the concerned entities and their interconnectedness. Overall this thesis contains three highly policy relevant findings. First, the aggregate outcome of reserve requirements is driven by the heterogeneity of banks' responses to macro-prudential policies and dynamics within a banking group. Second, the composition of default loss absorbing resources of CCPs differs significantly and persistently across ownership models, potentially due to misaligned incentives in the provision of clearing services, between the regulatory and individual for-profit perspective. Third, within group correlation of bank health, as indicated by the Zscore, decreased significantly after the implementation of mandatory central clearing. This may speak in favor of CCPs acting as buffers to absorb shocks and successfully shield their members from contagion of distress.

The remainder of the thesis is structured as follows. Chapters 2 to 4 present the three research papers that constitute the main contribution of this thesis. Each chapter discusses its individual contribution to the literature in detail, as outlined in this introduction. A general conclusion is drawn in Chapter 5.

Chapter 2

Macroprudential Policy and Intra-Group Dynamics: The Effects of Reserve Requirements in Brazil

Abstract: *This paper examines whether intra-group dynamics matter for the transmission of macroprudential policy. Using bank-level data on the Brazilian banking system, we investigate the effect of reserve requirements targeting headquarter banks' deposit ratio on credit supply by their municipal branches. Exploiting this matched bank-branch data for identification purposes, we find a lending channel of reserve requirements for branches whose parent banks are more exposed to targeted deposits. The result is driven by the crisis period and state-owned banks, which also adjust the transmission of the policy depending on branches' traits. Our findings reveal limitations in current macroprudential policy frameworks.*[*]

2.1 Introduction

> *"[T]he so-called developed world ... has reserve ratios of less than 10 percent, and we here have [a reserve ratio] of 53 percent on our demand deposits. What was in the past a defect has turned into an advantage for us..."*

– Guido Mantega, Brazilian Minister of Finance,

quoted from an interview in Folha de São Paulo, October 19, 2008.

[*]This chapter is co-authored with *Lena Tonzer* and *Matias Ossandon-Busch* from the Halle Institute for Economic Research, Member of the Leibniz Association. Contact:*lena.tonzer@iwh-halle.de*, *matias.ossandonbusch@iwh-halle.de*. A version of this chapter has been published in the IWH Discussion Papers as Becker, Chris, Matias Ossandon Busch and Lena Tonzer (2017): Macroprudential Policy and Intra-group Dynamics: The Effects of Reserve Requirements in Brazil. IWH Discussion Papers, No. 21, 2017.

The global financial crisis highlighted that disruptions in the financial sector can have large negative effects on the real economy. To reduce systemic risk in financial markets, several changes in the regulatory framework of the banking system have been made. This policy consensus about the reform of banking supervision and regulation has been characterized by the introduction of macroprudential policies, a combination of policy tools aimed at reducing the risk of systemic imbalances by steering the cycle of banks' credit supply. One necessary condition for macroprudential policies to be effective is in such a context their capacity to tighten or loosen banks' funding constraints (Aiyar et al., 2014). Understanding how banks' funding structures influence the effectiveness of macroprudential policies is therefore crucial to assess their functioning and limitations.

Using data on the Brazilian banking system with granular information on bank holding companies, this paper assesses the link between macroprudential policies, banks' funding structures and credit supply within banking groups. The analysis focuses on a macroprudential policy that has been introduced in several countries worldwide and targets the funding side of the balance sheet, namely reserve requirements for demand (short-term) deposits. Exploiting rich regional banking data for identification purposes, we explore the effect of reserve requirements targeting headquarter banks' deposit ratio on credit supply by their municipal bank branches. Our results reveal a higher sensitivity of credit supply to reserve requirements for branches whose headquarter banks are more exposed to targeted deposits. Branch ownership and the stage of the economic cycle are central in explaining the result.

Although the literature suggests that bank funding structures and internal capital markets are important for the transmission of monetary policy to credit supply e.g., Campello, 2002; Kishan and Opiela, 2000; Holod and Peek, 2010, there is limited evidence of whether a similar rationale applies to macroprudential policies. We thus contribute to previous studies analyzing the functioning of macroprudential policies (e.g., Aiyar et al., 2014; Claessens et al., 2013) by looking at a novel transmission mechanism of macroprudential policies, in our case reserve requirements, imposed on banks' headquarters (or parent banks) to credit supply by their regional bank branches.[1] Our analysis suggests that it is not only parent banks' funding structure that matters for transmitting the policy but also the profitability of the branch. By

[1] Hereafter, we refer to banks' headquarters as parent banks.

exploring these channels, our paper contributes to the literature by providing, to the best of our knowledge, first evidence of how bank-specific regulatory exposures affect the transmission of macroprudential policies to credit supply within banking groups.

We follow an identification strategy based on three main building blocks. First, we rely on data for the Brazilian banking system that include the network of regional bank branches of every banking conglomerate operating in the country. This reduces concerns about reverse causality by separating the corporate level at which reserve requirements are imposed from the level at which the credit supply is realized. This point is strengthened considering that reserve requirements are actively used by the Brazilian Central Bank to steer the local credit cycle when foreign capital shocks hit. Hence, changes in reserve requirements are likely to be exogenous from the perspective of regional bank branches, the level at which the analysis is performed. Second, we identify the effect of reserve requirements on branches' credit supply by making use of the fact that parent banks vary in their reliance on targeted demand deposits. Following similar approaches by Rajan and Zingales, 1998 and Manganelli and Popov, 2015, we argue that the heterogeneous effect of reserve requirements along the distribution of banks' demand deposit ratios can provide a proper identification of changes in credit supply triggered by reserve requirements. Third, we exploit the branch-level structure in the data to isolate credit supply from credit demand. We follow the literature (Carlson et al., 2013; Neef, 2018) by including quarter-municipality fixed effects in a panel model that absorb time-varying and municipality-specific changes in credit demand to which branches in a given region are commonly exposed.

We implement this research design on hand-collected data for the Brazilian banking system covering balance-sheet information for every active bank in the country between 2008 and 2014. These data allow us to link individual parent banks with their regional branches aggregated at the level of Brazilian municipalities. In addition to providing the setting for our identification strategy, there are several advantages to relying on these data. The high reporting frequency of the data (compared to alternative data sources such as Orbis Bank Focus) allows us to properly track changes in banks' credit induced by adjustments in reserve requirements. Additionally, our analysis benefits from the fact that Brazil follows a floating exchange-rate regime with an inflation-targeting policy framework. This enables us to differentiate the effect of reserve requirements from monetary policy. Finally, we can exploit the large presence of foreign and state-owned banks in Brazil to explore whether results differ depending on banks' ownership structure, similar to Aiyar et al., 2014 and Coleman and Feler, 2015. In this way, our study contributes to the scarce literature using bank-level data to identify the lending channel of macroprudential policies in emerging countries.

Our results are threefold and can be summarized as follows. First, we find robust evidence that reserve requirements targeting parent banks' funding side are transmitted into their affiliated branches' credit supply, whereas the effect of reserve requirements becomes stronger for banks largely exposed to demand deposits. These baseline results remain robust when controlling for monetary policy and a large range of other confounding factors. Branches' lending sensitivity to reserve requirements pertains at the aggregate level and is not netted out by borrowers' substituting credit between banks. Second, the result depends crucially on the stage of the economic cycle and bank ownership. It is driven by periods of economic downturns when reserve requirements are loosened and by branches belonging to state-owned parent banks. Third, for the sample of state-owned banking groups and the crisis period, we find that the loosening of the policy has contributed to the maintenance of credit supply by branches with low profitability. Hence, as concerns intra-group dynamics, the results show that both parent banks' exposure but also branch characteristics matter for the transmission of a policy change.

This paper contributes to three main strands of literature. First, there is an evolving literature on the effectiveness of macroprudential policies (see e.g., Claessens et al. (2013), Haldane et al. (2014)). A few papers have studied the heterogeneous effects of macroprudential policy by relying on bank-level data (Acharya et al., 2018; Barbone Gonzalez et al., 2018; Buch and Goldberg, 2017; Epure et al., 2017). For instance, Aiyar et al. (2014) use a sample of domestically-owned banks and foreign-owned branches and subsidiaries in the UK from 1998 to 2007 and find that stricter bank-specific capital regulation of domestic banks and foreign subsidiaries leaks to unregulated foreign branches, which increase their lending. The differential responses to home regulation of foreign branches versus subsidiaries located in the UK are found by Danisewicz et al. (2017).[2] Two main contributions differentiate our paper from these studies. First, we look at a different instrument of macroprudential policy — reserve requirements for demand deposits— in the context of an emerging country that uses this tool to steer the transmission of cycles of capital flows from abroad. Second, we analyze how the characteristics of banks' funding structures drive the effectiveness of reserve requirements within a banking group.

Second, our focus on banks' intra-group dynamics adds to the literature on the transmission of liquidity shocks via internal capital markets. Early literature on internal capital markets discussed the role of banking groups' strength for affiliates' lending and the internal transmission of monetary policy (see, e.g., Ashcraft, 2008; Campello, 2002; Dahl et al., 2002; Houston et al., 1997; Houston and James, 1998). More recent studies have analyzed the cross-border transmission of liquidity or regulatory shocks within international bank holding companies (e.g., Aiyar et al., 2014; Buch and Goldberg, 2015; Cetorelli and Goldberg, 2012a; Cetorelli and Goldberg, 2012b; Danisewicz et al., 2017; De Haas and Lelyveld, 2010; Frey and Kerl, 2015). Using also Brazilian branch-level data, Coleman et al., 2017 show that banks make use of internal liquidity management after liquidity shocks to support their branches' lending. We contribute to this literature by examining the transmission of macroprudential regulation within a banking group.

Finally, we add to a new strand of literature focused on understanding the interactions between macroprudential policy and monetary policy (Agur and Demertzis, 2015; Cecchetti, 2016; Gourinchas et al., 2012; IMF, 2011; IMF, 2013; Leduc and Natal, 2017; Tressel and Zhang, 2016; Zdzienicka et al., 2015). Our paper directly analyzes the effect of a macroprudential policy instrument on credit supply while controlling for monetary policy.

The paper is structured as follows. Section 2.2 discusses the use of reserve requirements in Brazil as a macroprudential tool. Section 2.3 describes the data and shows

[2]Other studies have relied on country-level data or descriptive analysis to evaluate the functioning of reserve requirements in Latin America (Montoro and Moreno (2011), Da Silva and Harris (2012)). Glocker and Towbin (2015) estimate structural VAR models to analyze the effect of monetary policy and reserve requirement on aggregate credit growth in Brazil. Tovar Mora et al. (2012) follow a similar approach with a sample of four Latin American countries. Dassatti Camors et al., 2015 study one increase in reserve requirements in Uruguay using credit register data and find evidence for a contraction of the loan supply. In contrast, our paper analyzes the effect of reserve requirements on intra-group dynamics for several changes in reserve requirements and using bank-level data.

descriptive statistics. Section 2.4 explains the empirical estimation approach, discusses our identification scheme, and presents regression results. Section 2.5 concludes.

2.2 Reserve Requirements in Brazil

Reserve requirements are used as an important part of the macroprudential toolbox in Brazil and aim at maintaining overall financial stability (Da Silva and Harris, 2012).[3] In technical terms, reserve requirements define the ratio of the deposit base that must be held as reserves at the central bank.

These requirements serve to control two dimensions of systemic risk. First, a cross-sectional dimension is related to the availability of bank funding at one point in time. Banks' liquidity may be managed in case of a shock to a common funding source or sudden capital outflows. Given liquidity constraints, easing reserve requirements can free liquidity from banks' own balance sheets. This can mitigate a potential economic downturn caused by a shortage of credit supply as a response to funding squeezes. Second, reserve requirements also target a time dimension of systemic risk by steering the pro-cyclicality of credit growth over time. The higher the requirements, the more reserves domestic banks must hold at the central bank. On the one hand, this limits the amount of available funds that can be intermediated into loans, potentially dampening credit growth and thus economic overheating during a boom period. On the other hand, unremunerated reserve requirements act as a tax on financial intermediation in the form of forgone interest. This increases the marginal funding costs of deposits and may thus have negative effects on banks' credit supply.

One important aspect of reserve requirements is that their use relates to a traditional policy dilemma faced by monetary policy in emerging countries. In times of a credit boom, a typical recommendation implies implementing a counter-cyclical monetary policy by raising interest rates and thus lowering demand for credit. However, historically, this has not been a feasible option in emerging countries facing credit booms financed by capital inflows. The reason is that increased interest rates attract even more capital inflows, triggering a vicious circle of further increases in both local

[3] "In Brazil, the percentage of financial assets that must be held as reserve requirements has been defined by the BCB [Banco Central do Brasil] with the aim of preserving the stability and soundness of the financial system, therefore allowing the sustained growth of credit." (Central Bank of Brazil, 2016).

credit supply and asset prices (Glocker and Towbin, 2015; Montoro and Moreno, 2011). In such a context, the imposition of higher reserve requirements limits the amount of banks' liquidity that can be transformed into loans without attracting more capital inflows. This can be accompanied by an expansionary monetary policy that depresses interest rates and thus restricts incentives for capital inflows. This illustrates how the restrictions of monetary policy in emerging countries can provide a reasoning to explain the use of reserve requirements as a macroprudential tool.

In the context of a global financial crisis with large capital outflows and high local inflation, the aforementioned restrictions on monetary policy are even stronger. This was the case for Brazil during the 2008-2009 global financial crisis. In this scenario, reducing the interest rate of monetary policy to boost local credit may induce further capital outflows, depressing local investment, depreciating the local currency, worsening inflation and increasing the risk of a balance-of-payments crisis (Joyce and Nabar, 2009). Again, reserve requirements provide policy-makers with an alternative to increase market liquidity, to decrease lending rates and to support domestic credit demand without inducing further capital outflows. This rationale for relying on reserve requirements to steer credit cycles when facing reversals in capital flows is in line with the behavior of Brazilian reserve requirements both during and after the global financial crisis.

The Central Bank of Brazil changed its reserve requirements on numerous occasions around the global financial crisis. This setting offers a high degree of variation in the level of reserve requirements and allows us investigating whether symmetric effects of reserve requirements arise in the context of booms and busts in capital flows. Although we remain agnostic about the potential asymmetric effects of reserve requirements along the credit cycle, the discussion above tends to suggest that their effect could be stronger in periods of crisis when monetary policy faces stronger restrictions. This question is relevant given that our sample period includes the global financial crisis, during which several emerging countries such as Brazil changed reserve requirements to limit the risk of liquidity dry-ups in banking markets (see Montoro and Moreno, 2011). We thus address the differential effects of reserve requirements at different stages of the economic cycle in Section 2.4.4.

Figure 2.1 provides a general picture of the pattern of reserve requirements for short-term demand deposits and cross-border exposure in the Brazilian banking system. Before the global financial crisis, Brazil experienced a surge in capital inflows. Thus, reserve requirements were at elevated levels to limit the risk of the potential overheating effect on local credit markets (Montoro and Moreno, 2011). This trend changed after the 2008 collapse of Lehman Brothers, which induced a large contraction in global capital flows. The Brazilian central bank reacted by decreasing reserve requirements with the objective of decreasing liquidity shortages and supporting credit supply when the external shock represented by the crisis was at its height.[4] [5]

This strategy was reversed when expansionary monetary policy in advanced countries —leading to excessive global liquidity— and the European sovereign debt crisis caused large capital inflows into Brazil (Da Silva and Harris, 2012). The reason for these capital inflows were the favorable return possibilities given spreads between advanced economies' low interest rates and Brazil's interest rates, which were among the highest in the world. High inflation rates attributable to, inter alia, high food prices, restricted the scope for lower interest rates. This fueled an increase in local credit provision. The Central Bank of Brazil increased reserve requirements as a response to this expansion in credit (Da Silva and Harris, 2012; Tovar Mora et al., 2012).

These dynamics of reserve requirements contain two features that are beneficial for identifying a credit supply channel of the policy tool. First, reserve requirements co-move with the global cycle of cross-border capital flows. Especially the loosening of reserve requirements during the global financial crisis and the tightening following the surge in capital flows to emerging markets are arguably driven by global factors. Second, reserve requirements are implemented in a counter-cyclical way to target credit supply. As credit demand operates in a pro-cyclical fashion, concerns that results merely reflect unobserved credit demand are reduced. We discuss the implications of the functioning of reserve requirements for our identification in Section 2.4.1.

[4]The Brazilian Central Bank states that "In the case of Brazil, the measures adopted by the Government and by the BCB to mitigate the effects of the crisis on the domestic banking system aimed primarily to offset the significant decline in financial markets liquidity [...]." (Central Bank of Brazil, 2016); see also Da Silva and Harris, 2012.

[5]The decline in reserve requirements in October 2008 (July 2012) by 6 (11) percentage points corresponds to approximately 3800 (8400) millions of USD of aggregate demand deposits in our sample.

2.3 Data and Descriptive Statistics

2.3.1 Bank-level data

We obtain parent bank and branch-level data from the IWH Latin American Banking Database to create an empirical setting that allows us to investigate our research question.[6] This data set contains micro-level data on balance sheet and income statements for domestic banks and foreign subsidiaries located in Brazil. All bank-related information is collected by the Central Bank of Brazil as regulatory data with mandatory reporting. We use the granularity of the data and combine data at the level of the parent bank and regional branches, as well as we aggregate the monthly data to the quarterly frequency. Overall, our sample comprises 6081 domestic branches for the period from 2008Q1 to 2014Q1.[7] The branches are owned by 56 domestic and foreign-owned parent banks and operate in 1678 Brazilian municipalities (out of 3122 municipalities in which some banking activity is reported). Figure 2.4 shows the coverage of municipalities in the estimation sample. In the Data Appendix A, we provide a description of data sources and procedures used to construct the database.

To clean the bank-level data from outliers and unreasonable values, we conduct the following adjustments. First, we restrict the sample to branches reporting over the whole sample period to properly gauge the intensive margin of the effect of reserve requirements on credit supply. Second, we correct for outliers by winsorizing all parent- and branch-level variables at the one and ninety-nine percentiles. Finally, we only keep municipalities in which at least two different parent banks are represented via branches. This filter is important to control for time-varying common market or credit demand shocks affecting all branches operating in a single municipality (see

[6]The data have been used in Noth and Ossandon Busch (2016) as well as Noth and Ossandon Busch (2017). In addition, Coleman and Feler, 2015 use the availability of bank and branch-level data to study government banks' lending behavior in Brazil during the financial crisis. Coleman et al., 2017 study internal liquidity management by parent banks and lending responses by branches after liquidity shocks.

[7]Note that balance sheet data for multiple branches operated by the same parent bank within a given municipality are summed to represent one entity in the sample, which we refer to as a "branch" throughout the paper.

Carlson et al., 2013; Neef, 2018).[8] Despite these restrictions, our sample still represents a reasonable share of the Brazilian credit market. On average, we observe 89.2 percent of total outstanding credit and 79.6 percent of total bank assets. Summary statistics are provided in Table 2.1. A detailed list of variables and correlation tables can be found in the Data Appendix A.

As noted above, one important feature of the data is that it allows us to link individual parent banks with their regional branches aggregated at the level of Brazilian municipalities. We exploit this parent bank-branch setting to study how intra-group dynamics affect the transmission of reserve requirements targeting parent banks to branches' credit supply. The fact that there is a large variation in the number of branches owned by different types of parent banks (e.g. state-owned versus private, foreign versus domestic banks) ensures sufficient variation to identify effects and we explore the implications of banks' ownership in Section 2.4.4.[9]

The large presence of branches of foreign-owned parent banks allows us to explore whether reserve requirements are equally transmitted to the credit supply of branches owned by domestic banks versus foreign banks.[10] Foreign parent banks may differ in their funding structure with implications for the exposure to reserve requirements. Previous evidence suggests that macroprudential policies affect banks differently depending on their ownership with consequences for the effect of macroprudential policies on aggregate changes in credit supply (Aiyar et al., 2014). Heterogeneous responses of domestic and foreign banks would highlight the importance of the cross-country coordination of macroprudential policies. Another dimension of ownership that may result in differential responses across banks is state versus private ownership. This is a relevant issue in the case of Brazil. In our final estimation sample, 52.9 percent of branch-level observations stem from 9 state-owned parent banks (16 percent of parent

[8]Because we restricted our sample to municipalities in which at least two parent banks operate via their branches, we lose approximately 19.1 percent of our original branch-time observations. On average, the branches remaining in the sample are larger, most likely because we drop smaller municipalities with a less dense branch presence.

[9]E.g., Banco do Brasil, a domestic and state-owned bank, dominates in terms of the number of branches owned (1628). The foreign bank with the largest number of branches (171) is Banco Santander, the Brazilian subsidiary of a Spanish-owned bank.

[10]Approximately one-third of parent banks in the sample are foreign banks (15 out of 56), whereas 11.8 percent of branch-level observations stem from the branches of foreign parent banks (717 out of 6081 branches are operated by foreign banks). On average, foreign parent banks manage 35 percent of total assets over the sample period, whereas the average municipality has 2.9 percent of its assets managed by a branch operated by a foreign parent bank. The definition of foreign banks is partially based on Claessens and van Horen, 2015.

banks), which operate 3220 out of 6081 branches. State-owned parent banks manage an average of 35.6 percent of total assets over time. The average municipality has three quarters of its assets managed by a state-owned bank, revealing state-owned banks' relevance to the Brazilian banking system.

Branch-level data are complemented with quarterly information on parent banks' balance-sheet characteristics. In our empirical model, we exploit parent banks' reliance on demand deposit funding —the item of the balance sheet targeted with the highest rate by reserve requirements— to assess whether increased funding constraints attributable to tighter reserve requirements can explain the pass-through of this policy to credit supply. Since we observe outstanding credit balances at the branch level, we use this data structure to ask whether branches adapt their credit supply differently as a response to reserve requirements and depending on their parent banks' funding structure. If the final outcome of reserve requirements depends on parent banks' funding structure, then macroprudential policies should be considered within a more general policy framework addressing the heterogeneous effect of these interventions. Keeping in mind that macroprudential policies aim at affecting aggregate developments that depend on individual banks' adjustments, this seems a relevant consideration.

The analysis below also sheds light on potential heterogeneous effects of reserve requirements conditional on parent bank characteristics, which might determine access to alternative funding sources. Table 2.2 reports summary statistics of the deposit ratio by different sub-samples. Differences arise when comparing domestic and foreign parent banks: foreign parent banks have a lower average demand deposit ratio, most likely because they find it more difficult to raise domestic demand deposits. Pronounced differences are revealed for state-owned versus private banks, with state-owned banks showing a higher average demand deposit ratio. In addition, parent banks with a lower liquid asset ratio and a higher capital ratio have, on average, a lower deposit ratio targeted by reserve requirements.

2.3.2 Country-level data

Information on reserve requirements —that is, the share of deposits that parent banks must hold as reserves at the central bank— is provided by the Central Bank of Brazil. Depending on redeemability, different types of deposits are subject to individual rates.

Similar to the study on reserve requirements in Uruguay by Dassatti Camors et al., 2015, we focus exclusively on non-remunerated reserve requirements for short-term funding targeting banks' demand deposits. The reason for this choice is that reserve requirements for demand deposits aim to affect short-term funding, that is, the part of funding that is the most volatile and thus is the most likely to cause systemic disruptions. This is also mirrored by the fact that reserve requirements for demand deposits show the highest reserve ratios compared to reserve requirements for term deposits.

We complement the data set by adding variables for monetary policy, including data on the policy rate (SELIC) and the monetary base. The SELIC rate is used as the main policy instrument by the central bank to maintain the inflation target of approximately 4.5 percent. Figure 2.2 shows the pattern of reserve requirements (solid line) and the policy rate (dashed line). There is a large fluctuation in the rates of both monetary policy and reserve requirements: For the sample period starting in 2008Q1, reserve requirements range from 44 to 55 percent and the SELIC rate ranges from 7.1 to 13.7 percent.[11] Some periods are characterized by similar patterns of tightening or loosening the relevant instrument (for example, the period between 2010 and 2013). In the following analysis, we thus verify that our results obtained for reserve requirements are neither driven by changes in monetary policy nor other macroeconomic developments.

Graphically, the relationship between reserve requirements and branches' credit supply is shown in Figure 2.3. Reserve requirements (solid line) are depicted on the left axis. The right axis shows the average quarterly change in credit supply by branches. The figure shows that, in general, changes in reserve requirements occur with a lag to changing trends in credit supply induced by reversals in capital flows. For example, because of the financial crisis and capital outflows, the decline in credit growth at the end of 2008 has been followed by a loosening of reserve requirements. Whereas credit growth increased during 2009, a tightening in reserve requirements only occurred in 2010. Finally, during the European sovereign debt crisis and globally depressed growth patterns, quarterly credit growth in Brazil showed a downward trend

[11] Additionally, it is noteworthy that compared to, e.g., the Euro Area, which recently had reserve requirements of one percent on deposits with a maturity shorter than 2 years, reserve ratios on short-term deposits are quite high in Brazil.

until the end of 2012 and stagnated. Reserve requirements nevertheless remained at elevated levels until mid-2012 because of elevated capital inflows.

2.4 Estimation Approach

We proceed as follows to test the predictions made in the previous sections. First, we estimate the effect of reserve requirements on branches' credit supply conditional on parent banks' reliance on demand deposits, that is, their exposure to the policy. This provides insights into whether macroprudential policies result in dynamics within a banking group that affect branches' credit supply. Second, we conduct extensive robustness tests to address identifications concerns related to credit demand shocks, anticipation effects, and confounding events. Third, we extend our baseline model to test for asymmetric effects of reserve requirements and the relevance of bank ownership.

2.4.1 Identification

Our identification strategy is based on three considerations related to (i) the counter-cyclicality of reserve requirements, (ii) the heterogeneous impact of this macroprudential policy across banks, and (iii) the disentangling of credit supply from credit demand.

(i) Counter-cyclicality of reserve requirements Section 2.2 has revealed a co-movement between reserve requirements and cross-border capital flows. The reason is that the central bank makes use of reserve requirements to respond to changes in foreign capital flows such as the capital outflow due to the collapse of Lehman Brothers or the inflow following the European sovereign debt crisis. Adjustments in reserve requirements are hence critically influenced by major economic events triggered outside Brazil, which reduces concerns about reverse causality between single banks' credit supply and the level of reserve requirements.[12] Furthermore, we estimate credit

[12]The importance of external factors driving capital flows to emerging economies has been shown by e.g. Calvo et al., 1993; Gavin et al., 1995; Kim, 2000 next to country-specific determinants (Papaioannou, 2009). Forbes and Warnock, 2012 show that reversals in capital movements are not significantly related to local economic conditions but to global factors such as risk aversion or global growth. Amiti et al., 2017 confirm that, during crisis times, idiosyncratic factors hitting the creditor country determine capital flows to borrower countries rather than local demand effects. Also, Jara

supply at the level of individual bank branches. Narrowing down the organizational level at which credit supply is estimated dissociates the decision level between the policy-maker and banks even further.

(ii) Heterogeneous impact across banks A second pillar of our identification strategy is that reserve requirements are likely to affect banks conditional on the exposure of their balance sheet to the targeted demand deposits. Therefore, our analysis is based on exploring the effect of reserve requirements along the distribution of banks' demand deposits to total assets ratio. The idea of identifying the effect of an aggregate variation by focusing on heterogeneous responses at a narrower level of observation resembles the approach by Rajan and Zingales, 1998, more recently applied by Klapper et al., 2006, Manganelli and Popov, 2015, and Heider et al., 2018. In addition to its methodological advantages, this type of identification adds to the understanding of how banks' funding restrictions influence the effectiveness of macroprudential regulation.

(iii) Disentangling credit supply from demand Central for our identification is disentangling credit supply effects from credit demand shocks. Even if we observe an effect of reserve requirements on credit growth, unobserved demand shocks may provide an alternative explanation for this relationship. For instance, branches from banks that are relatively more exposed to a macroprudential policy may be simultaneously more affected by demand shocks that then explain the observed changes in credit growth. Since we aim at interpreting our results as supply-driven, we have to address this concern.

An omitted variable bias due to unobserved credit demand shocks becomes a problem if two conditions hold: First, since we identify the effect of reserve requirements along the distribution of parent banks' deposit ratio, there would need to be a systematic correlation between this ratio and credit demand. To preliminarily investigate the presence of this type of systematic correlation, we collect different proxies for credit demand at the municipality-level and analyze whether it varies across branches owned

et al., 2009 write that "[...] the shock originated in the financial sector of advanced economies rather than in Latin America or another emerging market region."

by parent banks in different quartiles of the deposit ratio distribution. For this purpose, we compute quarterly growth rates in total bank assets, job creation (i.e. new contracts signed), and GDP.[13] We then take the average of these demand proxies across municipalities in which branches owned by parent banks that have e.g. a deposit ratio in the 25th percentile of the distribution are located. The results from this exercise are reported in Table A.III in Data Appendix A and show that the average trends in credit demand do not significantly differ between branches owned by parent banks with different deposit ratios. This evidence indicates that if credit demand plays a role, it does not work via banks' exposure to deposits targeted by reserve requirements.

Second, credit demand shocks would pose a problem if they are positively correlated with the credit supply effect that we attempt to identify. In this case, any estimated coefficients would be potentially upward biased, inflating our results (see a similar discussion in Khwaja and Mian, 2008). To shield against this concern, out setting exploits the fact that reserve requirements operate in a counter-cyclical fashion, meaning that we expect a negative effect on credit supply in a period when total credit supply and demand go up (or vice versa). This feature of reserve requirements reduces concerns that significant effects on credit growth only reflect unobserved credit demand, as credit demand moves in the opposite direction and works against the effect we aim at identifying. In other words, the credit demand bias would in our setting reduce the size and statistical significance of the estimated effect of reserve requirements.

These considerations reduce concerns that results will merely reflect unobserved credit demand shocks. In the empirical estimation, we go one step further to separate credit supply and demand. Making use of the matched parent banks-branches data, we estimate credit growth by simultaneously controlling for time-varying municipality fixed effects in a within-region panel regression (see Section 2.4.2). This identification approach is similar to studies by Carlson et al., 2013 and Neef, 2018 for the US with branches operating in metropolitan statistical areas (MSAs). It allows comparing the reaction of two or more branches that operate in the same municipality such that

[13] Total bank claims are computed by aggregating the bank-level data. Information on job creation and GDP comes from different administrative records (see Data Appendix A for detailed information on the construction of the variables).

local demand effects are controlled for. Furthermore, it rules out that our estimation of credit supply reflects economy-wide fluctuations or regional time-invariant characteristics. In Section 2.4.3, we explore the validity of the assumptions behind this approach and re-conduct the analysis with alternative controls for credit demand.

2.4.2 Reserve requirements and credit supply

We begin by analyzing the effect of reserve requirements on branch-level credit supply. For this purpose, we compute quarterly changes in outstanding credit as follows:

$$\text{Credit Growth}_{b,m,t} = \frac{\text{credit}_{b,m,t} - \text{credit}_{b,m,t-1}}{\text{credit}_{b,m,t-1}} \tag{2.1}$$

Credit $\text{Growth}_{b,m,t}$ is defined as the quarterly growth rate of outstanding credit of branch b in municipality m and quarter t.[14] The effect of macroprudential regulation on quarterly credit growth has also been analyzed by Buch and Goldberg (2017) and Ohls et al. (2017). This allows exploiting the high reporting frequency of the data while taking into account that balance sheet items may not change instantaneously.

The baseline regression equation is then specified as follows:

$$\begin{aligned}\text{Credit Growth}_{b,m,t} = \beta_1 \left(\text{dep.ratio}_{p,t-1}\right) + \beta_2 \left(\text{dep.ratio}_{p,t-1} \times \text{RR}_{t-1}\right) \\ + \gamma_1 X_{b,m,t-1} + \mu_{b,m} + \nu_{t,m} + \varepsilon_{b,m,t}\end{aligned} \tag{2.2}$$

where $\text{dep.ratio}_{p,t-1}$ is the one quarter lagged ratio of demand deposits to total assets of parent bank p that owns branch b, which measures the relative exposure to the precise item in the balance sheet targeted by reserve requirements. This variable is additionally interacted with the level of reserve requirements RR_{t-1} of the previous quarter. Time-varying branch and parent bank characteristics are controlled for by $X_{b,m,t-1}$. We lag all explanatory variables by one quarter to reduce simultaneity concerns (in Section 2.4.3 we allow for alternative lag structures.).

Structural and time-invariant differences in branches and parent banks' balance-sheet characteristics are captured by branch-level fixed effects ($\mu_{b,m}$). As previously

[14] Outstanding credit corresponds to total credit operations subtracting agricultural credit. The reason is that the central bank specifies separate rules for the intermediation of demand deposits into agricultural credit.

discussed, we introduce quarter-municipality fixed effects ($\nu_{t,m}$) to control for credit demand in a municipality. Quarter fixed effects, that is, a proxy for macroeconomic developments affecting all banks in Brazil, are implicitly captured by $\nu_{t,m}$. Standard errors are clustered by parent bank and quarter, which reduces concerns about serial correlation within a banking group and over time. To facilitate the interpretation of the coefficient of the interaction term, we standardize the bank-level control variables.[15]

The main underlying assumption behind the fixed effects approach to control for credit demand is that local economic conditions in a small geographic area like the municipalities in our sample affect homogeneously the different branches operating in that region. However, since credit demand remains unobserved, a natural concern would be that branches operate, for example, in different credit market segments so that $\nu_{t,m}$ does not fully absorb a demand-bias. To account for this concern, we implement several empirical tests that are discussed in Section 2.4.3. For example, we compute a branch-level credit demand proxy following Aiyar, 2012 that accounts for branches' individual exposure to specific segments of the credit market in each municipality. We also run Eq. 2.2 for a sub-sample of banks that we expect to face similar demand. Moreover, and as discussed in Section 2.4.1, we preliminary test in Table A.III whether municipality-level demand trends differ for branches of parent banks with a differential exposure to demand deposits.

Because of the fixed-effects structure introduced in the model, the direct effect of reserve requirements is not measurable as such. The reason is that the reserve ratio is equal to all banks and therefore captured by quarter-municipality fixed effects ($\nu_{t,m}$) together with any other macroeconomic factors. The effect of reserve requirements on credit supply is therefore identified by the coefficient of the interaction term ($\text{dep.ratio}_{p,t-1} \times \text{RR}_{t-1}$). A negative and statistically significant coefficient β_2 would reveal that, if reserve requirements tighten, branches' credit supply declines by more given the parent bank is funded to a relatively larger extent by demand deposits and thus more affected by the reserve policy. To better assess the functional form of the coefficient of the interaction term, we report estimates without quarter-municipality

[15]Coefficients of standardized variables represent the marginal effect of a one standard deviation increase from the mean in the predictor.

fixed effects so that the baseline coefficient of RR_{t-1} becomes visible.

As concerns the variables included in $X_{b,m,t-1}$, we control for the parent banks' capital and funding structure. This is important given that the exposure to reserve requirements depends on the structure of the liability side of parent banks' balance sheet. The relevance of banks' capital ratio is highlighted by papers studying the transmission of monetary policy. For example, Kishan and Opiela, 2000 find that lending by well-capitalized banks is less sensitive to changes in monetary policy, an argument that may also apply to reserve requirements. Thus, we include the capital ratio capturing parent banks' ability to offset the effect of reserve requirements by tapping non-deposit funding. It should be noted that in our sample, only parent banks hold capital in their balance sheet, whereas branches are funded by a combination of deposit and interbank liabilities. Further controls include parent banks' size (log of total assets), the liquid assets ratio and a proxy for cost efficiency (administrative costs / total costs). Also, we control for the size of branches as well as branches' liquidity ratio and demand deposit ratio. Branches' return on assets (RoA) proxies for the profitability of the asset portfolio, considering that more profitable branches may also have more market power and lending capacities.

Our baseline results are reported in Table 2.3. In Column (1), we only include reserve requirements as the explanatory variable. This regression, included for completeness, shows a negative association between reserve requirements and branch-level credit growth, which is in line with theoretical considerations. In Column (2), we add the interaction with the parent bank's demand deposit ratio. The coefficient of the interaction term ($\text{dep.ratio}_{p,t-1} \times \text{RR}_{t-1}$) directly addresses our research question by shedding light on whether heterogeneous effects of reserve requirements exist alongside the distribution of parent banks' demand deposit ratio. The regression in Column (3) includes branch and quarter fixed effects. Due to the latter, the reserve requirements rate can no longer be included in the model. To rule out the possibility that parent bank or branch characteristics drive the results, in Columns (4) and (5), controls are added. In Column (6), we estimate our preferred model as described in Eq. 2.2, which includes quarter-municipality fixed effects to control for local demand conditions.

We find the coefficient of the interaction term to be negative and statistically significant. Thus, branches from parent banks with a higher reliance on demand deposits are significantly more responsive to reserve requirements: the negative sign of the interaction coefficient implies that compared to branches owned by parent banks with a lower demand deposit ratio, these branches are more likely to adjust credit supply downwards given a tighter reserve policy.[16] While this result is obtained when considering the entire regulatory cycle, in Section 2.4.4, we assess whether results differ when looking at periods of increases or decreases in reserve requirements. Furthermore, we test in Section 2.4.5 whether effects are also present at the municipality level and do not cancel out due to borrowers substituting credit from more to less affected branches.

Graphically, our main finding is depicted in Figure 2.5, which shows the marginal effect of a unit change in the level of reserve requirements on branches' credit growth depending on parent banks' demand deposit ratio. The increase in the absolute value of the marginal effect confirms our hypothesis that the parent bank's exposure to macroprudential regulation is significant for the transmission of macroprudential policies to regional branches' credit growth.[17]

Finally, in Column (7), we test the alternative hypothesis of branch-level demand deposit ratios driving the results. Testing for this alternative explanation is important because we have argued that intra-group dynamics between a parent bank and its network of regional branches transmit macroprudential policies. This would not be the case if the individual branch exposure to demand deposit funding were to drive the results. Indeed, this would reflect that local conditions in branches' deposit base channel the effects of reserve requirements to branches' credit supply. Alternatively, it may capture the fact that parent banks allocate the burden of reserve requirements to branches, depending on their share of demand deposit funding.

Therefore, we perform a regression in which reserve requirements are interacted with the demand deposit ratio at the branch level. If the effects of reserve requirements

[16] The effect is also of economic significance: Comparing two branches that differ by one standard deviation in their parent banks' deposit ratio, an average increase in reserve requirements by 8 percentage points implies that the sensitivity of those branches to adjust credit growth differs by $-0.192 * 0.08 = -0.015$ (or -1.5 percentage points). This differential effect corresponds to 50 percent of the average credit growth rate and 8.67 percent of the standard deviation of the credit growth rate.

[17] For example, in the case of a parent bank with approximately 6 percent demand deposit funding, an increase of reserve requirements by one percentage point reduces the credit growth rate at the branch level by more than 0.293 percentage points. For the average increase of reserve requirements by 8 percentage points, this translates into a decline of the credit growth rate by more than 2.34 percentage points.

are transmitted within a banking group depending on the aggregate exposure of the parent bank and independent of the funding structure of single branches, we should expect the coefficient on this interaction term to be not statistically significant. The results reported in Column (7) show that this is indeed the case. Consequently, the result is similar to findings on the internal capital market, for example, Houston and James, 1998 find that lending of banks affiliated with a larger group is less responsive to the bank's own balance sheet compared to standalone banks. Instead, it is the group's positions that matter (Dahl et al., 2002; Houston et al., 1997).[18]

In sum, these results support the conclusion that macroprudential policies targeting parent banks can translate into adjustments in credit supply by bank branches. Provided parent banks report a relatively large exposure to demand deposits funding and thus to reserve requirements, regulatory decisions are transmitted to branches' credit supply. To the best of our knowledge, this is the first evidence on how dynamics in a banking group affect the transmission of macroprudential policies.[19]

At least three implications can be derived from our analysis. First, we find that reserve requirements can be a successful tool in influencing credit growth. Hence, when applied in a counter-cyclical way, this policy tool can be useful in steering the occurrence of credit cycles in emerging countries caused by capital waves attributable to globally changing conditions. Second, our results show that funding structure, and thus banks' differential exposure to the policy, is significant for the transmission of macroprudential policies. This implies that countries may benefit from a more general framework of macroprudential policies in which different tools are used to influence the behavior of different banks. Finally, the finding suggests that to assess macroprudential policies it is not sufficient to look at the behavior of parent banks as standalone entities; instead responses within the whole banking group must be considered to trace out aggregate effects.

[18] The results of Table 2.3 remain robust when excluding the capital regions Sao Paulo and Rio de Janeiro where most of the parent banks are located.

[19] With respect to the transmission of monetary policy or dynamics within multinational banks, the importance of internal capital markets has been shown by e.g. Campello, 2002, De Haas and Lelyveld, 2010, and Cetorelli and Goldberg, 2012b.

2.4.3 Robustness tests

In this section, we explore the sensitivity of our baseline findings along three dimensions, which include possible estimation biases arising (i) from credit demand shocks, (ii) from banks delaying or anticipating the response to reserve requirements, and (iii) from banks' exposure to other macroeconomic shocks.

Credit demand shocks We first examine whether our baseline results are biased by not properly accounting for the role of credit demand in branches' adjustment to reserve requirements. Our approach of saturating Eq. 2.2 with quarter-municipality fixed effects to control for demand shocks assumes that credit demand is homogeneously distributed across branches within a municipality. This assumption can be challenged if, for example, certain branches focus on specific credit segments, such as commercial or mortgage loans, which experience specific credit demand dynamics. It becomes a concern in our setting if a systematic correlation between parent banks' deposit ratio and credit demand exists. Moreover, demand shocks would need to be positively correlated with the identified effect to inflate our results. However, since reserve requirements are implemented in a counter-cyclical fashion, (pro-cyclical) credit demand shocks would lead to an upward bias in the coefficient β_2 (i.e. they would make β_2 "less negative"), making our results a rather conservative estimation of the true effect of the policy.

Even though these latter considerations make it less likely that Eq. 2.2 suffers from a credit demand bias, we implement several tests that shed light on the validity of the underlying assumptions. First, we compare our benchmark estimation with a regression that replaces the fixed effects structure by branch, municipality and quarter fixed effects. This result is reported in Column (2) in Panel A of Table 2.4 and it allows us to compare our coefficient of interest (replicated in Column (1)) once we exclude the credit demand control via quarter-municipality fixed effects. The estimated coefficient differs only marginally and a test of normalized differences (Imbens and Wooldridge, 2009) confirms that it is not statistically significantly different from our benchmark result. Hence, the credit demand bias if proxied by the difference between these coefficients seems not to be a reason of major concern.

Next, we compute a branch-level credit demand control following Aiyar, 2012, where market shares in specific credit market segments are used to pin-down banks' exposure to segment-specific credit demand shocks. For each branch (b, m), we compute the growth rate of credit demand in municipality m as $\Delta\text{Demand} = \sum_{j\varepsilon J} s_{b,m,j}\Delta TBC_j$, where ΔTBC is the quarterly growth rate in total bank credit in segment j by all branches but (b, m) at time t. The sectoral growth rates are weighted by the share of sector j in the credit portfolio of branch (b, m) which is expressed as $s_{b,m,j}$. The sectors j encompass commercial, consumer, and mortgage loans. Controlling for this credit-portfolio-weighted aggregate growth rate in credit in Columns (3) and (4) leaves our results robust. Finally, we perform a test by estimating the model within the sample of state-owned banks to look at a group of banks that share a similar type of borrowers. Column (5) shows that our main result holds also when looking at an estimation within a relatively homogeneous group of banks.

Response over time Our benchmark results could also be affected by banks delaying their response to reserve requirements over time or by anticipation effects. To account for longer-term adjustments to reserve requirements, we include not only the first lag of the interaction term but the first to fourth lag of reserve requirements interacted with the pre-determined deposit ratio in $t-5$ and report the sum and joint significance of $\sum_{k=1}^{4} \text{dep.ratio}_{p,t-5} \times \text{RR}_{t-k}$ (see also Kashyap and Stein, 2000 or Aiyar et al., 2014). This time structure also recognizes that credit supply adjustments may take place with a certain delay. The results from these regressions are reported in Columns (2) and (3) in Panel B of Table 2.4 and show that the cumulative effect does not differ much from the baseline results such that adjustments seem to take place rather quickly.[20] In case banks anticipate changes in reserve requirements and react ex ante, we would underestimate the full response. To account for this, we run regressions in which we replace either the reserve requirements variable or the complete interaction term by the respective value in $t+1$. The results in Columns (4) and (5) show that β_2 losses its explanatory power such that anticipation effects seem to be of minor concern.

[20] The estimated cumulative coefficient is not statistically significantly different from the benchmark estimate.

Confounding events A further concern relates to a potential correlation between adjustments in reserve requirements and other macroeconomic events if they are time-clustered with changes in the reserve policy and also impact on credit supply in a counter-cyclical fashion. The problem would be strengthened if banks' exposure to those alternative shocks is systematically correlated with the deposit ratio, which measures the exposure to reserve requirements. An example of the above could be monetary policy. If the monetary policy rate increases, banks whose balance sheets are more directly exposed to monetary policy might decrease lending. If this monetary policy shock is time-clustered with increases in reserve requirements and banks more exposed to monetary policy are also the ones with a high deposit ratio, then our results could be capturing a monetary policy shock.

To rule out the possibility that our results are driven by monetary policy, we extend the model to perform a "horse race" between our baseline interaction term $\left(\text{dep.ratio}_{p,t-1} \times \text{RR}_{t-1}\right)$ and the interaction between the deposit ratio and proxies for the stance of monetary policy. We obtained data on the monetary base (M0), which proxies for the change in the aggregate amount of circulating currency in the economy, and the SELIC rate, which is the overnight interest rate set by the Central Bank of Brazil for monetary policy purposes. The results in Column (2) of Table 2.5 show that the explanatory power of our coefficient of interest remains statistically significant, while the coefficient of the interaction term with the monetary policy control M0 is not significant. In Column (3), we use instead the quarterly change in the policy rate with our finding remaining again robust. Hence, controlling for changes in monetary policy, reserve requirements are still transmitted from parent banks' balance sheets to branches' credit supply. To test for interaction effects between macroprudential and monetary policy, in Columns (4) and (5), we study whether our results change when including a triple interaction between our interaction term of interest and one of the monetary policy measures. The triple interaction term shows an insignificant coefficient suggesting that the effectiveness of macroprudential policy does not depend on the stance of monetary policy.

We implement a series of further robustness tests to ensure that our benchmark estimates are not capturing the occurrence of other macro shocks that could affect bank behavior. We include interaction terms between banks' deposit ratio and variables capturing other macroeconomic shocks such as the Reais/ US dollars exchange rate, the sovereign yield, the sovereign spread vis-à-vis the US treasury bonds, and foreign funding to rule out that the interaction term of reserve requirements and the demand deposit ratio only captures the exposure of banks with a higher demand deposit ratio to foreign funding shocks such as reversals in capital flows.[21] While the exchange rate can affect capital inflows as well as Brazil's competitiveness, a higher sovereign yield and sovereign spread reveal potential distress within the government sector with potential implications for bank stability (see Aiyar et al., 2014; Gennaiolo et al., 2014). The results reported in Columns (2) to (5) in Panel A of Table 2.6 show that our benchmark estimates remain unaltered by the inclusion of these interaction terms.

Also political uncertainty and changes in policies that target capital flows may act as confounders. We thus add an interaction term between banks' deposit ratio and the quarterly political uncertainty index by Baker et al., 2016, finding that our results remain in place (Column (2) in Panel B). In Columns (3) and (4), we add an interaction between the deposit ratio and an indicator variable being one in periods in which other macroprudential interventions were implemented in Brazil. We thereby consider the introduction of reserve requirements on banks' foreign exchange (FX) positions and the implementation of a tax on banks' foreign borrowing, both in 2011. In Column (5), we finally control for banks' political connections by adding a competing interaction term between reserve requirements and parent banks' share of deposits from the public sector. Across all alternative specifications, the exposure of the parent bank to reserve requirements still matters but there is a weakening effect in case the parent bank holds more public sector deposits (Column (5)).

2.4.4 The anatomy of reserve requirements' transmission

Having established the robustness of our main result, we extend the analysis to gain a deeper understanding of the underlying mechanisms. Understanding the financial

[21] We compute the aggregate growth rate in foreign funding by aggregating the bank-level data on banks' interbank borrowing from non-residents.

market structures that affect the transmission of macroprudential policies is of utmost importance when it comes to the derivation of policy implications.

Asymmetric effects across periods We first investigate whether our baseline results vary across time. Even though one important contribution of our analysis is that we look at the complete cycle of increases and decreases in reserve requirements, we aim at shedding light on the differential effects of reserve requirements across the cycle. We divide the sample period into three sub-periods and run separate regressions based on our preferred specification. The first period covers 2008Q1 to 2010Q1, including the decrease in reserve requirements aimed at unfreezing liquidity during the global financial crisis (Column (2)). The second period, from 2010Q2 to 2011Q1, captures the tightening of reserve requirements as a reaction to foreign capital inflows in the search for yield after the global financial crisis (Column (3)). The third period (2011Q2 to 2014Q1) relates to the loosening of reserve requirements given a stagnation of capital inflows, in part driven by the end of the commodities super cycle combined with depressed economic growth (Column (4)).

Table 2.7 reveals that the baseline results (Column (1)) are primarily driven by the periods in which reserve requirements are loosened. The absolute size of the coefficient of the interaction term is largest during the global financial crisis. In contrast, the coefficient of the interaction term becomes statistically insignificant during the period of capital inflows that followed the global financial crisis revealing a limited effectiveness of the policy tool in periods of credit expansion and large capital inflows. This result is in line with findings by Bhaumik et al., 2011 on the asymmetric transmission of monetary policy across the economic cycle. Similar asymmetries seem to prevail for macroprudential policies, a result also found by Jiménez et al., 2017 studying dynamic provisioning and credit supply in Spain and by Barroso et al., 2017 analyzing the functioning of reserve requirements based on Brazilian credit registry data.[22]

How can we explain the insignificant result for the period characterized by capital inflows and economic boom? Our analysis has consistently shown that the transmission of reserve requirements to credit supply operates via banks' funding structure and in particular via banks' reliance on targeted deposits. This test delves further

[22]The result also confirms the findings by Vegh and Vuletin, 2014 that Latin American countries have been successful to move from pro-cyclical to counter-cyclical policy responses following crises.

into this important aspect of macroprudential policies. In periods of capital inflows, banks may have easier access to alternative funding sources that allow them to circumvent tighter reserve requirements. In addition, the result may hide the fact that the increase in reserve requirements has simply been too low compared to the wave of inflowing capital. Alternatively, policy-makers may want to consider the implementation of complementary policy tools. Counter-cyclical capital buffers and regulatory caps on banks' foreign funding can be considered as a potential alternative to enhance policy-makers' ability to steer credit growth in times of boom.

Bank ownership Previous studies provide evidence that the transmission of monetary policy depends on banks' liquidity and balance-sheet management. To the extent that similar arguments may apply to the transmission of macroprudential policies, our results could also be weakened or strengthened depending on bank traits. For example, we saw in Table 2.2 that demand deposit ratios differ depending on bank ownership.

We first address the question of whether the effect of reserve requirements conditional on parent banks' funding structure depends on whether branches belong todomestic or foreign parent banks. Previous evidence suggests that differential effects can occur. Jeon and Wu, 2014 show at the country level that foreign bank penetration was associated with a weaker transmission of monetary policy during the crisis. Wu et al., 2011 provide bank-level evidence pointing in the same direction. These findings may be well explained by internal capital markets providing alternative funding sources to foreign banks' subsidiaries located in Brazil, which help circumvent local policy shocks (see De Haas and Lelyveld, 2010). Moreover, global banks' role in transmitting monetary policy actions across countries may lead foreign banks' subsidiaries to be less sensitive to local macroprudential policies (see Rajan, 2014; Rey, 2016). In line with this, Aiyar et al., 2014 find that foreign-owned banks located in the UK are less responsive to local macroprudential policies compared to domestic banks.

In Table 2.8, Column (2), we show that branches' credit supply sensitivity increases (in absolute terms) when foreign banks are excluded from the sample. This finding suggests that foreign banks may indeed have access to alternative funding and be less affected by reserve policies. This is confirmed in Column (3) showing that the effect of reserve requirements is insignificant in case a branch is owned by a foreign bank.

Second, we differentiate between branches of state-owned versus private banks. The theoretical analysis by Andries and Billon, 2010 finds that state-owned banks are likely to be less responsive to changes in monetary policy because of their better capacity to obtain additional (government-sponsored) deposit funding than private banks. Empirical evidence also suggests that state-owned banks could react less to changes in monetary policy because of a generally less pro-cyclical credit supply (Ferri et al., 2014) and differences in their corporate governance compared to private banks (Bhaumik et al., 2011). The role of state-owned banks can be especially relevant in our setting considering their large presence in Brazil. In addition, previous findings show that state-owned banks in Brazil are less likely to transmit funding shocks to the regions in which they operate (see Coleman and Feler, 2015).

We conduct the analysis for the sample of state-owned versus private banks and results are reported in Columns (4) and (5). The coefficient of the interaction term is significant and larger in absolute terms for branches of state-owned banks, however, insignificant in case of private ownership revealing that our results are driven by state-owned banks. This contrasts with the aforementioned findings of state-owned banks being less responsive to changes in monetary policy. Following Coleman and Feler, 2015 studying government banks' lending behavior in Brazil during the financial crisis, we can also rule out the possibility that the results are driven by branches of state-owned banks being located in regions with, e.g., more favorable economic conditions.

Two arguments may explain that the responsiveness to reserve requirements seems to be driven by branches of state-owned parent banks. First, state-owned banks' larger reliance on demand deposits (see Table 2.2) implies that reserve requirements are more likely to affect them than other banks. In other words, by restricting the analysis to state-owned banks, we look exclusively at the right-hand side of the deposit ratio distribution from which our baseline results originate. Second, the political economy of credit supply by state-owned banks is likely to play a role. In particular, a political decision that pushes state-owned banks to act counter-cyclically may reinforce the effect of their exposure to demand deposits. This is supported by the fact that, as shown in Table (2.7), our results are stronger during the global financial crisis. Therefore, a counter-cyclical policy action via state-owned banks may lead these institutions to transmit the effects of reserve requirements to their branches' credit supply more emphatically than other banks. This interpretation would be in line with the finding of Coleman and Feler, 2015 that regions in Brazil with a large share of government banks benefited from increased loan supply, weakening the effects of the financial crisis.

One could still argue that the government induces changes in the lending policy of state-owned banks at the same time when reserve requirements are changed. However, it should be noted that when estimating Eq. 2.2 within the sample of state-owned banks the heterogeneous effect of reserve requirements along the deposit ratio distribution remains in place (see Table 2.4, Panel A). This approach allows identifying heterogeneous responses to reserve requirements within state-owned banks when controlling for political influence within the municipality. Furthermore, we have tested whether reserve policies matter less for branches with stronger political ties approximated by the parent bank's public sector deposit ratio (Table 2.6, Panel B), finding that our baseline conclusions remain unaltered.[23]

Dynamics within state-owned banks during the crisis Previous tests have shown that the baseline effect is driven by the financial crisis period and the response of branches of state-owned parent banks. Next, we are interested in the intra-group dynamics taking place within a state-owned banking group during crisis times. We first restrict the sample accordingly and Column (1) in Table 2.9 shows that during crisis times — when reserve requirements are loosened — branches of state-owned banks that are more exposed to the policy are more likely to increase credit supply. Second, we ask which branches are particularly affected by the transmission of reserve requirements within a banking group. For example, following the literature on internal capital markets, one may expect that parent banks loosen liquidity constraints for profitable branches to ensure a positive revenue stream for the whole group (Cetorelli and Goldberg, 2012b).

We thus test whether branches sensitivity to the reserve policy depending on the parent's exposure differs by branch profitability (Columns (2) and (3)). To do so,

[23] In Table A.IV, we split the sample depending on branches' liquid assets ratio (Columns (1)-(2)) and internal funding ratio (Columns (3)-(4)) as well as parent banks' liquid assets ratio (Columns (5)-(6)) and capital ratio (Columns (7)-(8)). The cut point for the sample split is the 75th percentile of the respective variable in 2008Q1. Across all sample splits, a consistent result emerges, namely that reserve requirements transmit through the demand deposit ratio in particular in the presence of liquidity or capital constraints.

we run the estimations for sub-samples of branches with high versus low profitability whereas the branch indicator that determines the sample split takes a value of one for branches with an average profitability above the sample median and zero otherwise. Again, branches owned by more exposed parents are more sensitive to the reserve policy. However, the effect is much stronger (in absolute terms) for branches with a low profitability.[24] Hence, given a loosening in the reserve policy, less profitable branches show a stronger and significant sensitivity towards increasing credit supply. For the US, Nguyen, 2019 shows that closures of bank branches reduce local credit supply, in particular during the recent financial crisis. Our results lead to the conclusion that the loosening of reserve requirements during the financial crisis period has induced parent banks to allocate freed-up liquidity to less profitable branches such that those branches could maintain credit supply within their municipality, potentially reducing the widening of regional disparities. The finding is in contrast to Cetorelli and Goldberg, 2012b but might be explained by state-ownership of branches.

In Columns (4) and (5), we differentiate by the importance of the branch for the banking group and split the sample across branches with an average asset share in group assets above the group's median and those below the median. Branches' sensitivity is stronger (in absolute terms) in case the sub-sample with relatively less important branches within banking groups are considered. This fits together with the results on profitability and indicates that banking groups exploit the loosening of the reserve policy to stabilize smaller group members during crisis times.

2.4.5 Effect on total credit

The previous sections contribute to the understanding of how reserve requirements affect credit supply. However, macroprudential policies aim at affecting not only individual banks but rather aggregate credit supply. Therefore the question remains whether the identified effect at the bank level translates into adjustments in the aggregated supply of credit in those municipalities in which branches operate. Given higher reserve requirements, credit constraints and relationship banking may restrict borrowers' capacity to access liquidity in branches whose parent banks are targeted more by

[24] The coefficient of the interaction term takes a value of -0.109 for highly profitable compared to a value of -0.252 for weakly profitable branches.

the policy. However, if bank borrowers tap liquidity from less exposed branches, regulators' intended effect on aggregate credit supply can be netted out.

To address these concerns and to investigate whether reserve requirements affect aggregate credit supply, we replicate our baseline analysis based on data aggregated at the municipality level. Following Khwaja and Mian (2008), we therefore include all active branches in the 1678 municipalities of the baseline sample and compute credit growth as in Eq.2.1 but using the total outstanding credit of all branches in each municipality. Control variables are then computed by constructing a weighted average (based on branches' market shares in the municipality) of the bank-level variables. This procedure allows us to obtain a measure of each municipality's exposure to reserve requirements, which is increasing in the local market share of branches owned by parent banks with a higher reliance on targeted demand deposits.

We exploit this setting to estimate Eq.2.2 at the municipality level, including quarter and municipality fixed effects. As noted in studies proceeding similarly (Khwaja and Mian, 2008; Jiménez et al., 2017), we cannot longer include combined quarter-municipality fixed effects to rule-out credit demand considerations. However, it should be noted from Columns (1) and (2) in Table 2.4 that controlling for credit demand only marginally affects our estimated coefficients (point estimates change from -0.195 to -0.192 when quarter-municipality fixed effects are included). Hence, although the results at the municipality level should be interpreted with caution, Table 2.4 suggests that a credit demand bias should not be a large concern.

Results in Table 2.10 show that also at the aggregate level, we can confirm a significant sensitivity of credit growth to reserve requirements conditional on the weighted average of the demand deposit ratio. This result holds when including quarter or quarter and municipality fixed effects. To test the robustness of the results, we compute the municipality market shares using branches' total assets (Columns (1) and (2)) or total outstanding credit (Columns (3) and (4)), obtaining similar results. Our findings in Table 2.10 confirm that the sensitivity to the lending channel of reserve requirements is not netted out by borrowers' substituting credit between banks.

2.5 Conclusion

Reversals in global capital flows can threaten the stability of emerging countries. Macroprudential policies applied in a counter-cyclical manner can be a useful tool for protecting the domestic economy against global cycles. This paper documents how intra-group dynamics between a parent bank and its network of regional branches, combined with parent banks' funding structure, explain the transmission of macroprudential policies to credit supply. Using parent bank and branch-level data for the Brazilian banking system and the period from 2008 to 2014, we show that reserve requirements for demand deposits imposed on parent banks are transmitted to credit-supply responses by individual bank branches.

We rely on an identification strategy that is based on three main building blocks and carefully addresses numerous estimation concerns. First, policy changes in reserve requirements are triggered by external conditions in global capital markets and the policy targets the parent bank, while the analysis is performed at the branch level. Second, we exploit the fact that banks are differently exposed to reserve requirements depending on their reliance on demand deposits. This may lead to heterogeneous responses related to credit supply. Third, by observing multiple branches operating in Brazilian municipalities over time, we can control for quarter-municipality fixed effects to interpret our results as supply-driven.

By following this conservative estimation approach, we find that the effect of reserve requirements applied at the parent bank level is transmitted to branches' credit supply. However, the sensitivity of credit supply to reserve requirements is higher for branches whose parent banks are more exposed to targeted deposits. The result remains robust when controlling for simultaneous changes in monetary policy and a large range of potentially confounding factors. Extending the analysis, we can show that the result is driven by periods in which reserve requirements have been loosened and by branches of state-owned parent banks. For the latter sample of banks, we find evidence that during loosening period, reserve requirements help maintain credit supply by smaller branches with low profitability.

Our findings contribute to the literature by providing evidence that parent banks' exposure to macroprudential policies results in differential responses within a banking group. Two central policy implications of our analysis can be drawn. First, the aggregate outcome of reserve requirements is driven by the heterogeneity of banks' responses to macroprudential policies and dynamics within a banking group. Second, our results show that macroprudential regulation can be an effective tool for emerging economies to mitigate the negative effects of exogenously driven periods of capital outflows on credit growth. While the loosening of the policy can help maintaining credit supply by weaker branches of parent banks during crisis periods, analyzing the consequences for allocative efficiency is an interesting avenue for future research.

Tables and Figures

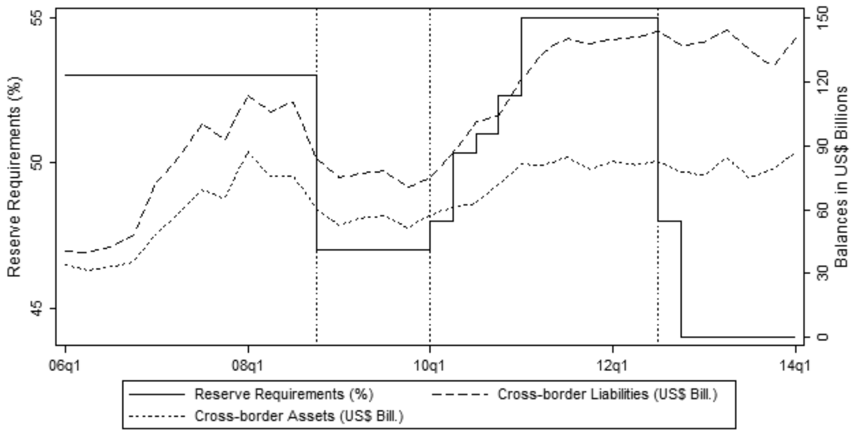

FIGURE 2.1: **Reserve Requirements and Cross-Border Banking Claims:** This graph describes the pattern of the reserve requirements for demand deposits (in %, solid line - left axis) as provided by the Central Bank of Brazil. The dashed (dotted) line describes the evolution of quarterly cross-border liabilities (assets) of the Brazilian banking system (in billions of USD), as obtained from the Locational Banking Statistics of the Bank for International Settlements.

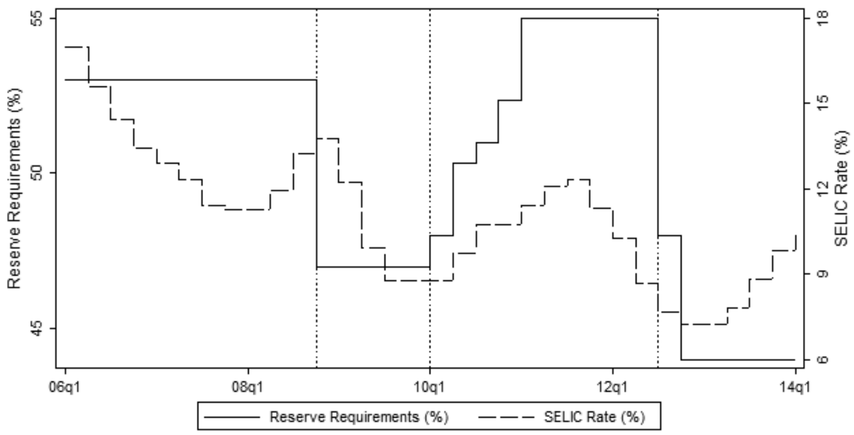

FIGURE 2.2: **Reserve Requirements and Monetary Policy Rate:** This graph describes the pattern of the reserve requirements for demand deposits (in %, solid line - left axis). The dashed line (right axis) describes the evolution of the SELIC rate (in %), which is the policy interest rate set by the Central Bank of Brazil. Data are obtained from the Central Bank of Brazil.

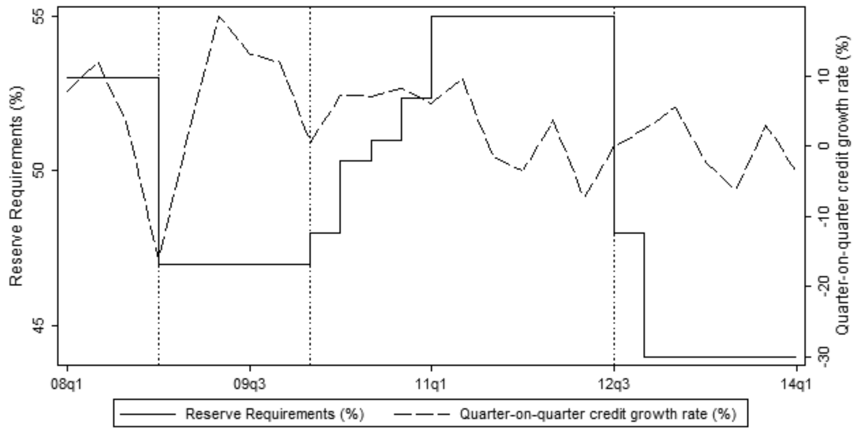

FIGURE 2.3: **Reserve Requirements and Average Credit Supply (Quarterly Change):** This graph shows the evolution of the quarterly growth rate of outstanding credit (in %, dashed line - right axis) averaged over all branches during the sample period together with the time series of the reserve requirements for demand deposits (in %, solid line - left axis).

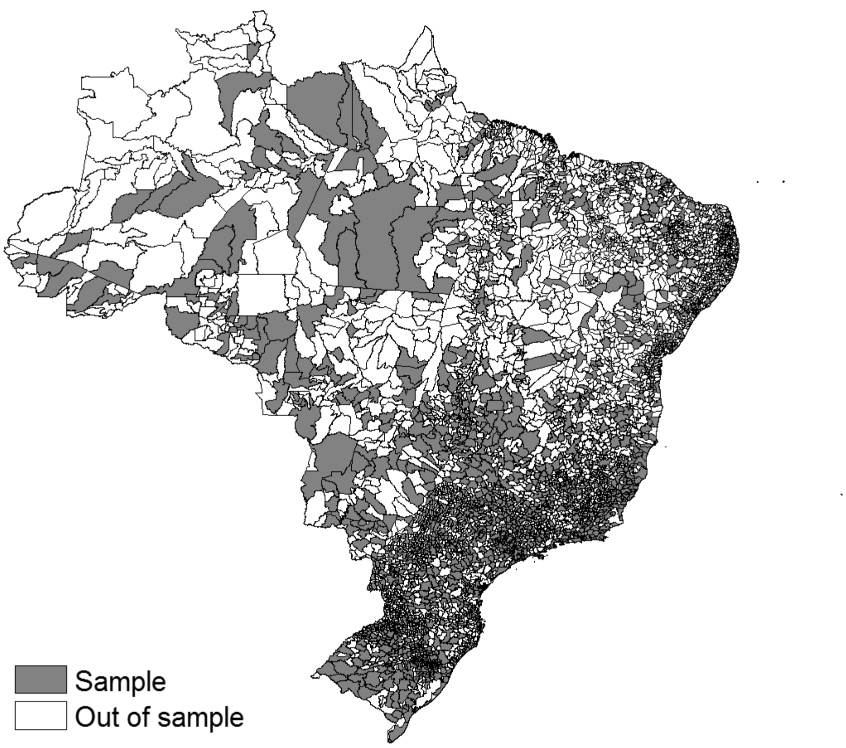

FIGURE 2.4: **Municipality Coverage:** This graph shows (in red) the municipalities in which at least two parent banks operate branches over the full sample period and that are therefore included in the sample.

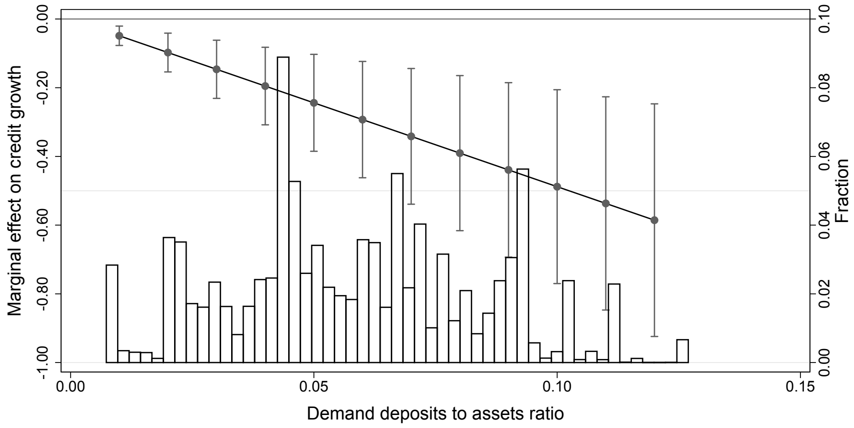

FIGURE 2.5: **Marginal Effect of Reserve Requirements on Credit Supply:** This graph shows the marginal effect of a unit change in the level of reserve requirements on branches' credit growth conditional on parent banks' demand deposit ratio surrounded by 95 percent confidence bands (solid line, left axis). On the right axis, the distribution of parent banks' demand deposit to assets ratio is depicted.

	Mean	**Median**	**SD**	**Min**	**Max**
Branch-level					
ΔCredit	0.030	0.022	0.130	-0.274	0.523
Log(Assets)	3.166	3.000	1.312	0.518	7.551
Liquidity ratio	0.015	0.009	0.015	0.000	0.084
Deposit ratio	0.137	0.120	0.086	0.006	0.440
RoA	0.009	0.008	0.007	-0.005	0.033
ΔDemand	0.027	0.021	0.077	-0.771	0.221
Parent-level					
Deposit ratio	0.035	0.017	0.046	0.000	0.236
Log(Assets)	7.798	7.712	2.290	3.641	12.919
Liquidity ratio	0.004	0.000	0.006	0.000	0.030
Capital ratio	0.156	0.136	0.096	0.023	0.499
Adm. cost / total cost	0.004	0.003	0.005	0.000	0.036
Public sector deposit ratio	0.003	0.000	0.016	0.000	0.192
Country-level					
Reserve requirements	0.497	0.492	0.042	0.440	0.550
Δ SELIC rate	-0.001	0.000	0.010	-0.023	0.013
Δ M0	0.022	0.017	0.040	-0.037	0.117
Exchange rate	1.896	1.801	0.226	1.594	2.316
Sovereign yield	0.120	0.123	0.014	0.093	0.156
Sovereign spread	2.338	2.206	0.680	1.638	4.243
Δ Foreign funding	0.014	-0.002	0.083	-0.170	0.204
Political uncertainty	131.261	133.567	45.553	62.962	275.073
Municipality-level					
Δ Agg. claims	0.024	0.029	0.090	-0.386	0.321
Δ Job creation	0.011	0.005	0.339	-1.394	1.557
Δ GDP	-0.067	0.006	0.248	-1.000	0.977
Observations	145,944				

TABLE 2.1: **Summary Statistics:** This table shows summary statistics of the variables used in the analysis. The variables are listed according to their entity level of observation. The table distinguishes between variables at the branch, parent bank, country and municipality level. The sample is based on quarterly data from 2008Q1 to 2014Q1. A detailed description of the variables can be found in the Data Appendix A.

Parent banks sub-samples	**mean**	**median**	**sd**	**min**	**max**
Foreign	0.022	0.013	0.028	0.000	0.126
Domestic	0.039	0.019	0.050	0.000	0.236
State-owned	0.095	0.086	0.061	0.005	0.236
Private	0.023	0.013	0.030	0.000	0.229
High liquid assets	0.129	0.097	0.069	0.041	0.236
Low liquid assets	0.028	0.015	0.034	0.000	0.229
High capital ratio	0.025	0.014	0.032	0.000	0.229
Low capital ratio	0.057	0.039	0.060	0.000	0.236
Total	0.035	0.017	0.046	0.000	0.236

Table 2.2: **Deposit Ratio of Parent Banks for Sub-Samples:** This table lists descriptive statistics for the ratio of parents' demand deposits to total assets. The descriptive statistics are presented by groups of parent banks divided into foreign and domestic as well as state-owned and private parent banks. The table also reports summary statistics for this variable for parent banks with a high or low liquidity ratio as well as a high or low capital ratio. In case of liquidity and capital, the sample is split for the respective variable by the 75th percentile of the parent banks' sample distribution in 2008Q1.

	Reserve requirements (1)	Dep. ratio interaction (2)	Branch and quarter FE (3)	Parent controls (4)	Branch controls (5)	Quarter X Mun. FE (6)	Branch dep. ratio (7)
Reserve requirements	-0.220***	-0.126***					
	(0.008)	(0.011)					
Deposit ratio		0.098***	0.052	0.094***	0.097***	0.099**	-0.014
		(0.007)	(0.036)	(0.006)	(0.006)	(0.039)	(0.130)
Deposit ratio X Reserve requirements		-0.181***	-0.114*	-0.180***	-0.195***	-0.192***	0.162
		(0.014)	(0.068)	(0.011)	(0.011)	(0.070)	(0.256)
Parent controls							
Log(Assets)				0.061***	0.125***	0.133***	0.112***
				(0.008)	(0.009)	(0.047)	(0.041)
Liquidity ratio				0.027***	0.025***	0.026***	0.026***
				(0.002)	(0.002)	(0.008)	(0.008)
Capital ratio				0.101***	0.101***	0.101***	0.098***
				(0.004)	(0.004)	(0.030)	(0.030)
Adm. costs / total costs				-0.033***	-0.028***	-0.030	-0.024
				(0.005)	(0.005)	(0.022)	(0.023)
Branch controls							
Log(Assets)					-0.058***	-0.061***	-0.060***
					(0.003)	(0.012)	(0.012)
Liquidity ratio					0.842***	0.877***	0.867***
					(0.053)	(0.082)	(0.082)
Deposit ratio					0.052***	0.066***	
					(0.007)	(0.019)	
RoA					-32.286***	-27.208**	-27.402**
					(12.379)	(13.688)	(13.597)
Branch FE	No	No	Yes	Yes	Yes	Yes	Yes
Quarter FE	No	No	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	No	No	No	No	No	Yes	Yes
Obs	145,944	145,944	145,944	145,944	145,944	145,944	145,944
R2	0.005	0.007	0.369	0.375	0.383	0.542	0.542

TABLE 2.3: **Baseline Results:** This table lists the regression results from estimating Eq.2.2. Column (1) presents the result when including only reserve requirements. The second column includes the interaction term of reserve requirements and the demand deposit ratio. Starting from Column (3), the model is estimated with branch and quarter fixed effects. Column (4) adds parent controls and Column (5) adds branch controls. Quarter-municipality fixed effects are included in Column (6). Column (7) replaces parent banks' demand deposit ratio with the demand deposit ratio at the branch level. The dependent variable is the quarter-to-quarter growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Panel A: Credit demand

	Baseline		Demand control		Within
	full FE	partial FE	partial FE	full FE	state banks
	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.099**	0.097***	0.097***	0.097***	0.148***
	(0.039)	(0.035)	(0.035)	(0.037)	(0.055)
Deposit ratio X	-0.192***	-0.195***	-0.196***	-0.178***	-0.243**
Reserve requirements	(0.070)	(0.061)	(0.062)	(0.069)	(0.098)
ΔDemand			0.020***	-0.331***	
			(0.007)	(0.042)	
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Mun. FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	No	No	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Obs	145,944	145,944	145,944	145,944	65,760
R2	0.542	0.383	0.383	0.605	0.652

Panel B: Cumulative/ anticipated effect

		Cumulative effect		Lead of reserve policy	
	Baseline	partial FE	full FE	RR_{t+1}	Int_{t+1}
	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.099**	0.112**	0.116**	0.093	0.067
	(0.039)	(0.046)	(0.055)	(0.066)	(0.065)
Deposit ratio X	-0.192***	-0.185**	-0.190**	-0.191	-0.173
Reserve requirements	(0.070)	(0.084)	(0.100)	(0.128)	(0.127)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Mun. FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	No	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Obs	145,944	145,944	145,944	139,863	139,863
R2	0.542	0.384	0.544	0.541	0.541

TABLE 2.4: **Robustness – Credit Demand & Response over Time:** Panel A shows robustness tests using alternative controls for credit demand. The baseline model is shown in Column (1). Column (2) re-estimates the baseline model without quarter-municipality fixed effects. In Columns (3) and (4), a demand control similar to Aiyar, 2012 is included. Column (5) estimates the baseline model only within branches of state-owned banks. Panel B shows robustness tests controlling for responses over time. In Columns (2) and (3), the cumulative effect of $\sum_{k=1}^{4}$ dep.ratio$_{p,t-5} \times \mathrm{RR}_{t-k}$ is reported including different fixed effects. In Column (4), the reserve requirements (RR_{t+1}) are included with a lead. In Column (5), the whole interaction term with the deposit ratio (Int_{t+1}) is included with a lead. The dependent variable is the quarter-to-quarter growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter if not indicated otherwise. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Type of model:		Horse race:		Triple interaction:	
	Baseline	M0	SELIC	M0	SELIC
	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.099**	0.098***	0.097***	0.077**	0.097***
	(0.039)	(0.038)	(0.038)	(0.037)	(0.037)
Deposit ratio X	-0.192***	-0.194***	-0.185***	-0.151**	-0.185***
Reserve requirements	(0.070)	(0.070)	(0.067)	(0.070)	(0.067)
Deposit ratio X		0.107	-0.563*	1.743	0.235
Monetary policy		(0.126)	(0.341)	(1.325)	(4.116)
Dep. ratio X				-3.300	-1.613
RR X MP				(2.564)	(8.163)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Obs	145,944	145,944	145,944	145,944	145,944
R2	0.542	0.543	0.543	0.543	0.543

TABLE 2.5: **Robustness – Monetary Policy:** This table shows robustness tests controlling for monetary policy by running a horse race with M0 and the SELIC rate (Columns (2)-(3)) and by including triple interactions with these monetary policy controls (Columns (4)-(5)). The dependent variable is the quarter-to-quarter growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Panel A: Macro confounders

	Baseline (1)	Ex. rate (2)	Sov. yield (3)	Sov. spread (4)	Foreign funding (5)
Deposit ratio	0.099**	0.103***	0.127***	0.119**	0.094**
	(0.039)	(0.038)	(0.046)	(0.046)	(0.037)
Deposit ratio X Reserve requirements	-0.192***	-0.200***	-0.174**	-0.210***	-0.182***
	(0.070)	(0.069)	(0.078)	(0.069)	(0.065)
Deposit ratio X Macro confounder		0.018	-0.275	-0.004	-0.024
		(0.027)	(0.325)	(0.006)	(0.046)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Obs	145,944	145,944	145,944	145,944	145,944
R2	0.542	0.543	0.543	0.543	0.543

Panel B: Political confounders

	Baseline (1)	Political uncertainty (2)	RR on foreign fund. (3)	Tax on foreign fun. (4)	Public dep. ratio (5)
Deposit ratio	0.099**	0.099**	0.099**	0.099**	0.096**
	(0.039)	(0.039)	(0.042)	(0.039)	(0.044)
Deposit ratio X Reserve requirements	-0.192***	-0.193***	-0.193**	-0.192***	-0.183**
	(0.070)	(0.070)	(0.077)	(0.070)	(0.083)
Deposit ratio X Political confounder		-0.000	0.000	-0.000	
		(0.000)	(0.005)	(0.004)	
Public dep. ratio X Reserve requirements					-0.013
					(0.060)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Obs	145,944	145,944	145,944	145,944	145,944
R2	0.542	0.542	0.542	0.542	0.543

Table 2.6: **Robustness – Macro and Political Confounders:** Panel A shows robustness tests controlling for macroeconomic confounders (exchange rate, sovereign yield, sovereign spread, foreign funding). Panel B shows robustness tests controlling for political confounders. These variables include the political uncertainty index of Baker et al., 2016, reserve requirements on foreign funding (RR on foreign fund.) and a tax on foreign funding (Tax on foreign fund.). Column (5) in Panel B differs from the other exercises in that it adds to Eq. 2.2 an interaction term between reserve requirements and the ratio of public sector to total deposits at the bank level (Public dep. ratio). The dependent variable is the quarter-to-quarter growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Fixed effects include branch fixed effects and quarter-municipality fixed effects if not indicated otherwise. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

	Sub-sample period:			
	Baseline (1)	Crisis (2)	Tightening (3)	Loosening (4)
Deposit ratio	0.099**	0.155	-0.140	0.149***
	(0.039)	(0.101)	(0.157)	(0.045)
Deposit ratio X Reserve requirements	-0.192***	-0.367*	0.155	-0.201***
	(0.070)	(0.187)	(0.290)	(0.068)
Parent controls				
Log(Assets)	0.133***	-0.073	-0.137	0.352***
	(0.047)	(0.096)	(0.329)	(0.117)
Liquidity ratio	0.026***	0.009	-0.043	0.014
	(0.008)	(0.013)	(0.031)	(0.012)
Capital ratio	0.101***	0.166***	-0.271***	-0.032
	(0.030)	(0.051)	(0.097)	(0.039)
Adm. costs / total costs	-0.030	0.004	0.030	-0.030
	(0.022)	(0.039)	(0.085)	(0.024)
Branch controls				
Log(Assets)	-0.061***	-0.064**	-0.095**	-0.073***
	(0.012)	(0.025)	(0.040)	(0.010)
Liquidity ratio	0.877***	1.637***	2.090***	1.300***
	(0.082)	(0.189)	(0.335)	(0.133)
Deposit ratio	0.066***	0.107***	0.104**	0.101***
	(0.019)	(0.033)	(0.042)	(0.026)
RoA	-27.208**	-129.887***	-104.342***	-1.921
	(13.688)	(46.916)	(39.075)	(6.057)
Branch FE	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes
Obs	145,944	48,648	24,324	72,972
R2	0.542	0.639	0.508	0.535

TABLE 2.7: **Periods:** This table lists results from various sub-periods from our baseline model (Column (1)). In Column (2), the period spans 2008Q1-2010Q1. In Column (3), the period from 2010Q2 until 2011Q1 is covered. In Column (4), the sample spans 2011Q2-2014Q1. The dependent variable is the quarter-to-quarter growth rate of outstanding credit. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

		Ownership sub-sample:			
	Baseline	Domestic	Foreign	State-owned	Private
	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.099**	0.158***	0.008	0.148***	-0.073
	(0.039)	(0.049)	(0.074)	(0.055)	(0.055)
Deposit ratio X Reserve requirements	-0.192***	-0.281***	-0.213	-0.243**	0.177
	(0.070)	(0.083)	(0.152)	(0.098)	(0.134)
Parent controls					
Log(Assets)	0.133***	0.201***	-0.031	0.216***	-0.018
	(0.047)	(0.059)	(0.068)	(0.062)	(0.059)
Liquidity ratio	0.026***	0.027***	0.019	0.020**	0.015
	(0.008)	(0.008)	(0.021)	(0.009)	(0.012)
Capital ratio	0.101***	0.129***	0.122**	0.126***	0.118***
	(0.030)	(0.045)	(0.052)	(0.039)	(0.039)
Adm. costs / total costs	-0.030	-0.033	-0.061	-0.002	-0.020
	(0.022)	(0.026)	(0.079)	(0.033)	(0.022)
Branch controls					
Log(Assets)	-0.061***	-0.077***	-0.023*	-0.078***	-0.058***
	(0.012)	(0.018)	(0.013)	(0.022)	(0.012)
Liquidity ratio	0.877***	0.842***	1.020	2.462***	1.326***
	(0.082)	(0.082)	(0.720)	(0.490)	(0.120)
Deposit ratio	0.066***	0.071***	0.071	0.022	0.071***
	(0.019)	(0.021)	(0.050)	(0.023)	(0.024)
RoA	-27.208**	-47.694**	-10.501	38.509*	-50.899*
	(13.688)	(22.490)	(7.752)	(20.544)	(26.513)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes
Obs	145,944	128,280	7,296	65,760	53,424
R2	0.542	0.566	0.641	0.652	0.598

TABLE 2.8: **Ownership:** This table lists results from various sub-samples from our baseline model (Column (1)). In Column (2), the sample covers only domestic banks. In Column (3), only branches of foreign parent banks are included. In Column (4), branches of state-owned parent banks and in Column (5) branches of private parent banks are included. The dependent variable is the quarterly growth rate of outstanding credit. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Branch indicator:		RoA		Share in group assets	
	Baseline	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.103	0.073	0.031	-0.020	0.629***
	(0.084)	(0.094)	(0.080)	(0.113)	(0.046)
Deposit ratio X Reserve requirements	-0.307**	-0.109	-0.252*	-0.099	-0.992***
	(0.141)	(0.161)	(0.132)	(0.190)	(0.064)
Parent controls					
Log(Assets)	0.654***	0.448**	0.568*	1.045***	0.870***
	(0.235)	(0.209)	(0.287)	(0.325)	(0.110)
Liquidity ratio	-0.028**	0.006	0.040*	-0.037**	-0.013
	(0.013)	(0.012)	(0.023)	(0.014)	(0.014)
Capital ratio	0.588***	0.145	1.021***	0.743***	1.337***
	(0.166)	(0.107)	(0.202)	(0.190)	(0.054)
Adm. costs / total costs	0.038	0.084**	-0.019	0.021	0.012
	(0.056)	(0.035)	(0.062)	(0.094)	(0.017)
Branch controls					
Log(Assets)	-0.078	-0.151***	-0.023	-0.173**	-0.028
	(0.069)	(0.044)	(0.101)	(0.078)	(0.086)
Liquidity ratio	5.687***	2.391	5.649**	7.151**	5.882**
	(1.506)	(1.488)	(2.814)	(2.731)	(2.734)
Deposit ratio	0.070	0.071	0.084	0.135**	-0.047
	(0.045)	(0.049)	(0.083)	(0.064)	(0.082)
RoA	9.534	-12.262	-183.920*	21.258	-24.603
	(56.662)	(32.276)	(102.086)	(81.996)	(84.488)
Branch FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Mun. FE	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes
Obs	21,920	5,264	8,728	9,320	2,480
R2	0.731	0.800	0.735	0.690	0.855

TABLE 2.9: **Dynamics within State-Owned Banks during the Crisis Period:** This table lists results when focusing on the role of branch characteristics for the transmission process. The baseline model is shown in Column (1) for the sample of branches of state-owned parent banks and the crisis period 2008Q1-2010Q1. In Columns (2) and (3), results are shown for the sub-sample of high versus low profitability branches. *Branch indicator* : *RoA* takes a value of one for branches with an average profitability exceeding the sample median and zero otherwise. In Columns (4) and (5), results are shown for the sub-sample of branches with a high versus low share of group assets. *Branch indicator* : *Share in group assets* takes a value of one for branches with an average share in group assets exceeding the group's median and zero otherwise. The dependent variable is the quarterly growth rate of outstanding credit. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Fixed effects include branch fixed effects and quarter-municipality fixed effects if not indicated otherwise. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

	Asset-based market shares		Credit-based market shares	
	Quarter FE	Time & Mun. FE	Quarter FE	Time & Mun. FE
	(1)	(2)	(3)	(4)
Deposit ratio	0.112***	0.019	0.105***	0.015
	(0.023)	(0.029)	(0.021)	(0.027)
Deposit ratio X Reserve requirements	-0.245***	-0.139***	-0.224***	-0.129***
	(0.046)	(0.052)	(0.042)	(0.048)
Parent controls				
Log(Assets)	-0.009**	-0.077***	-0.001	-0.056***
	(0.004)	(0.015)	(0.003)	(0.012)
Liquidity ratio	0.053***	0.049***	0.045***	0.039***
	(0.014)	(0.015)	(0.014)	(0.015)
Capital ratio	-0.023**	-0.030	-0.005	0.024
	(0.010)	(0.038)	(0.009)	(0.033)
Adm. costs / total costs	0.051***	0.018	0.058***	0.018
	(0.012)	(0.022)	(0.012)	(0.022)
Branch controls				
Log(Assets)	0.007***	-0.069***	0.006**	-0.072***
	(0.003)	(0.013)	(0.003)	(0.013)
Liquidity ratio	0.012***	0.003	0.013***	0.004
	(0.002)	(0.005)	(0.002)	(0.005)
Deposit ratio	0.005**	0.003	0.004**	0.005
	(0.002)	(0.005)	(0.002)	(0.005)
RoA	-0.007**	-0.023***	-0.008**	-0.023***
	(0.003)	(0.007)	(0.003)	(0.007)
Quarter FE	Yes	Yes	Yes	Yes
Municipality FE	No	Yes	No	Yes
Obs	38,615	38,615	38,615	38,615
R2	0.651	0.670	0.651	0.671

TABLE 2.10: **Total Effect on Credit at the Municipality Level:** This table lists results of our baseline model when accounting for aggregated effects at the municipality level. The dependent variable is the quarterly growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. The standardized and lagged explanatory variables at the branch and parent level are weighted by asset- or credit-based market shares of branches to aggregate data to the municipality level. Fixed effects include municipality fixed effects and quarter fixed effects. Standard errors are clustered by municipality. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Appendix A

Summary of data construction

To construct the dataset used in the analysis, we downloaded the balance sheets and income statements of banks and branches from the website of the Brazilian Central Bank (BCB) (https://www.bcb.gov.br/) These data were retrieved from two sources. For parent banks, we used the "Balancetes e Balanos Patrimoniais" (Bank Balances and Equity) database collected and publicly reported by the BCB. The data on branches comes from the "ESTBAN - Estadistica Bancaria Mensal por Municipio" (Monthly Banking Statistics by Municipality) database. In this latter database, the information is aggregated at the bank-municipality level, so that all individual municipal branches report as a single municipal entity. The definition of variables comes from the "Manual de Normas do Sistema Financeiro" (Manual of Financial System's Norms or COSIF), also available through the website of the BCB. To ensure the correct match between parent banks and branches, we relied on an identifier assigned by the BCB to all institutions. We also manually checked that the names of banks and branches correspond to the same institution. The BCB collects these data for regulatory purposes. Therefore all institutions with a banking license are mandated to report the respective information on a monthly basis. The data is reported in nominal Brazilian Reais, which we adjusted in order to work with millions of Brazilian Reais. We added to the main dataset information on banks' ownership status. For this purpose, we relied on banks' websites and on the Claessens and van Horen, 2015 Bank Ownership Database.

Variable	Definition	Unit	Source
Branch-level			
ΔCredit	Quarter-to-quarter growth rate of outstanding total credit (excl. rural credit).	Growth rate	BCB
Deposit ratio	Ratio of demand deposits to total assets.	Fraction	BCB
Log(Assets)	Log of total branch-level assets in millions of Brazilian Reais.	Log	BCB
Liquidity ratio	Ratio of liquid assets (cash, gold and interbank deposits) to total assets.	Fraction	BCB
RoA	Ratio of net returns (total income - total costs) to total assets.	Fraction	BCB
Internal funding ratio	Ratio of intra-bank assets minus intra-bank liabilities to total branch assets.	Fraction	BCB
ΔDemand	Sum of quarter-to-quarter growth rates in segment-specific credit weighted by the share of each segment in a branch credit portfolio. The variable is computed using data on consumer, commercial and mortgage loans.	Growth rate	BCB
Branch indicator: RoA	Indicator equal to 1 if a branch reports a sample average of return on assets above the sample median and 0 otherwise.	1/0	BCB
Branch indicator: Share in group assets	Indicator equal to 1 if a branch reports a sample average of the share in group assets above the group's median and 0 otherwise.	1/0	BCB
Parent-level			
Deposit ratio	Ratio of demand (sight) deposits to total assets.	Fraction	BCB
Log(Assets)	Log of total (conglomerate-level) assets in millions of Brazilian Reais.	Log	BCB
Liquidity ratio	Ratio of liquid assets (cash, gold and interbank deposits) to total assets.	Fraction	BCB
Capital ratio	Ratio of total equity to total assets.	Fraction	BCB
Adm./total costs	Ratio of administrative expenses to total expenses.	Fraction	BCB
Foreign	Dummy equal to 1 for foreign-owned banks and 0 otherwise.	1/0	Claessens & van Horen (2015)
State-owned	Dummy equal to 1 for state-owned banks and 0 otherwise.	1/0	BCB
Public sector deposit ratio	Ratio of public sector deposits to total deposits.	Fraction	BCB

Table A.I: **Variables Definitions:** This table reports the definitions and sources of the variables used in the analysis. The variables are grouped by the respective entity-level of observation. These groups include branch, parent bank, municipality, and country level variables. BCB stands for Brazilian Central Bank, IBGE for the Brazilian Institute of Geography and Statistics and Brazilian ML for the Brazilian Ministry of Labor.

Variable	Definition	Unit	Source
Municipality-level			
Δ Agg. claims	Quarter-to-quarter growth rate of outstanding assets by all branches per municipality.	Growth rate	BCB
Δ Jobs	Quarter-to-quarter growth rate of new job contracts signed per municipality and quarter.	Growth rate	Brazilian ML
Δ GDP	Quarter-to-quarter growth rate of municipal GDP. Variable computed from end-of-year data. We assign a weight of 0.25 to the end-of-year GDP of the last three quarters per period and a weight of 0.25 to the GPD of the year of the corresponding quarter. The variable corresponds to the growth rate of the volume resulting from adding up the weighted GDP data. Quarters between Q2 2012 and Q1 2014 dropped because of missing GDP data for 2013.	Growth rate	IBGE
Country-level			
Reserve requirements	Regulatory fraction of demand deposits to be held as reserves at the Brazilian Central Bank.	Fraction	BCB
Δ M0	Quarterly change in monetary base (total physical paper money and coins, in millions of Brazilian Reais).	Log difference	BCB
Δ SELIC rate	Quarterly change in the monetary policy rate set by the Brazilian Central Bank.	Percentage points	BCB
Exchange rate	Nominal exchange rate Brazilian Reais (BRL)/ US Dollars (USD).	Fraction	St. Louis Fed
Sovereign yield	Interest rate paid on sovereign bonds issued by the Brazilian government.	Rate	Datastream
Sovereign spread	Difference between the Brazilian and US sovereign bond yields.	Percentage points	Datastream
Δ Foreign funding	Quarterly change in aggregate foreign funding of banks (in millions of Brazilian Reais).	Log difference	BCB
Political uncertainty	Quarterly average of the Economic Policy Uncertainty Index for Brazil.	Index	Baker et al., 2016
RR on FX positions	Dummy equal to 1 for the period between 2011Q1 and 2012Q4 in which a reserve requirement on banks' foreign exchange (FX) positions was introduced in Brazil. The variable equals 0 outside this period.	1/0	BCB
Foreign funding tax	Dummy equal to 1 for the period between 2011Q1 and 2014Q1 in which a tax on banks' volumes borrowed abroad was introduced in Brazil. The variable equals 0 outside this period.	1/0	BCB

TABLE A.I: **Variables Definitions (continued):** This table reports the definitions and sources of the variables used in the analysis. The variables are grouped by the respective entity-level of observation. These groups include branch, parent bank, municipality, and country level variables. BCB stands for Brazilian Central Bank, IBGE for the Brazilian Institute of Geography and Statistics and Brazilian ML for the Brazilian Ministry of Labor.

	Branch-level						Parent-level		
	ΔCredit	Size (log Assets)	Liquidity ratio	Deposit ratio	RoA	ΔDemand	Deposit ratio	Size (log Assets)	Liquidity ratio
Branch-level									
ΔCredit	1.000								
Size (log Assets)	-0.004	1.000							
Liquidity ratio	-0.007	-0.384*	1.000						
Deposit ratio	-0.001	-0.281*	0.310*	1.000					
RoA	0.023*	-0.236*	0.284*	0.144*	1.000				
ΔDemand	0.423*	-0.064*	0.071*	0.082*	0.090*	1.000			
Parent-level									
Deposit ratio	0.028*	-0.042*	-0.061*	0.441*	-0.100*	0.049*	1.000		
Size (log Assets)	-0.015*	0.129*	0.228*	-0.096*	0.081*	-0.053*	-0.117*	1.000	
Liquidity ratio	0.007*	-0.118*	0.050*	0.370*	-0.065*	0.040*	0.792*	0.021*	1.000
Capital ratio	-0.002	-0.095*	-0.056*	0.166*	0.024*	0.074*	0.022*	-0.546*	-0.178*
Adm. cost / total cost	0.073*	-0.110*	-0.320*	0.011*	-0.198*	0.065*	0.107*	-0.730*	0.064*
Public sector deposit ratio	0.053*	-0.026*	-0.062*	0.119*	-0.014*	0.019*	0.529*	-0.290*	0.442*
Country-/ municipality-level									
Reserve requirements	-0.070*	0.020*	0.011*	0.070*	0.030*	-0.126*	0.085*	0.014*	0.067*
Δ SELIC rate	-0.236*	0.021*	-0.002	0.039*	-0.037*	-0.372*	0.053*	0.016*	0.031*
Δ M0	-0.030*	0.022*	-0.007*	-0.012*	0.006	-0.052*	-0.007*	0.027*	0.027*
Exchange rate	0.101*	-0.035*	-0.018*	-0.092*	-0.043*	0.191*	-0.124*	-0.027*	-0.113*
Sov. yield	0.038*	-0.114*	0.027*	0.142*	0.037*	0.032*	0.204*	-0.126*	0.111*
Sov. spread	0.220*	-0.130*	0.015*	0.054*	0.028*	0.337*	0.076*	-0.133*	0.014*
Δ Foreign funding	0.005	0.043*	0.000	0.013*	0.006	-0.043*	0.025*	0.042*	0.020*
Volat. stock returns	0.099*	-0.094*	0.017*	0.069*	0.027*	0.138*	0.119*	-0.102*	0.058*
Uncertainty index	0.006	-0.081*	0.007*	0.014*	-0.014*	0.059*	0.010*	-0.084*	-0.027*
Δ Agg. claims	0.451*	-0.064*	0.032*	0.035*	0.066*	0.569*	0.019*	-0.002	0.020*
Δ Job creation	0.077*	0.001	0.003	-0.002	-0.006	0.099*	0.011*	-0.004	0.014*
Δ GDP	0.068*	-0.043*	0.031*	0.111*	0.035*	0.070*	0.150*	-0.044*	0.125*

TABLE A.II: **Correlations:** This table shows the correlation of the dependent and explanatory variables at the branch- and parent-level as well as the country- and municipality-level variables. The Bonferroni-adjusted significance levels are depicted with stars as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. See the data description in the Data Appendix A for more information on the variables.

	Parent-level		Country-/ municipality-level						
	Capital ratio	Adm. cost / total cost	Public sector deposit ratio	Reserve requirements	Δ SELIC rate	Δ M0	Exchange rate	Sov. yield	Sov. spread
Parent-level									
Capital ratio	1.000								
Adm. cost / total cost	0.356*	1.000							
Public sector deposit ratio	0.037*	0.165*	1.000						
Country-/ municipality-level									
Reserve requirements	0.016*	0.017*	0.041*	1.000					
Δ SELIC rate	-0.020*	-0.047*	-0.004	-0.010*	1.000				
ΔM0	-0.005	0.040*	-0.012*	-0.147*	0.088*	1.000			
Exchange rate	-0.015*	-0.051*	-0.047*	-0.755*	-0.218*	-0.008*	1.000		
Sov. yield	0.031*	0.121*	0.100*	0.195*	0.304*	0.057*	-0.124*	1.000	
Sov. spread	0.037*	0.089*	0.062*	-0.222*	-0.326*	0.005	0.564*	0.557*	1.000
Δ Foreign funding	-0.018*	0.020*	0.009*	0.184*	0.149*	-0.139*	-0.397*	-0.168*	-0.500*
Volat. stock returns	0.020*	0.081*	0.068*	0.028*	-0.153*	0.093*	0.203*	0.498*	0.611*
Uncertainty index	0.026*	-0.029*	0.026*	-0.098*	-0.128*	-0.406*	0.444*	0.320*	0.639*
Δ Agg. claims	-0.000	0.055*	0.020*	-0.163*	-0.342*	-0.029*	0.226*	-0.098*	0.231*
Δ Job creation	-0.000	0.019*	0.010*	-0.073*	-0.080*	0.140*	0.066*	0.021*	0.058*
Δ GDP	0.044*	0.091*	0.079*	0.595*	-0.129*	0.052*	-0.607*	0.354*	0.031*

	Country-/ municipality-level					
	Δ Foreign funding	Volat. stock returns	Uncertainty index	Δ Agg. claims	Δ Job creation	Δ GDP
Country-/ municipality-level						
Δ Foreign funding	1.000					
Volat. stock returns	-0.203*	1.000				
Uncertainty index	-0.515*	0.450*	1.000			
Δ Agg. Claims	-0.001	0.074*	0.005	1.000		
Δ Job creation	0.072*	0.153*	-0.042*	0.061*	1.000	
Δ GDP	0.330*	0.172*	-0.178*	-0.030*	0.090*	1

Correlations (*continued*). This table shows the correlation of the dependent and explanatory variables at the branch- and parent-level as well as the country- and municipality-level variables. The Bonferroni-adjusted significance levels are depicted with stars as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. See the data description in the Data Appendix A for more information on the variables.

Deposit ratio percentile:	<25th (1)	>25th & <50th (2)	>50th & <75th (3)	>75th (4)
Δ Agg. claims				
mean	-0.007	0.018	0.025	0.024
s.d.	0.160	0.121	0.087	0.089
diff.	-0.026	-0.007	0.001	0.032
test	-0.127	-0.045	0.006	0.172
Δ Job creation				
mean	0.012	0.019	0.010	0.011
s.d.	0.103	0.342	0.317	0.351
diff.	-0.007	0.009	-0.001	-0.001
test	-0.021	0.019	-0.001	-0.002
Δ GDP				
mean	-0.112	-0.100	-0.102	-0.100
s.d.	0.372	0.356	0.363	0.356
diff.	-0.011	0.002	-0.002	0.012
test	-0.022	0.004	-0.005	0.023
ΔDemand				
mean	0.020	0.032	0.020	0.030
s.d.	0.074	0.068	0.054	0.066
diff.	-0.012	0.012	-0.010	0.010
test	-0.119	0.134	-0.113	0.101

TABLE A.III: **Credit Demand Proxies by Deposit Ratio:** The table reports summary statistics for municipality-level credit demand proxies by quartiles of parent-banks' deposit ratio. The proxies for credit demand are represented by the municipal quarter-to-quarter growth rate in aggregate bank claims, in job creation (i.e. number of job contracts signed), GDP, and credit demand. This latter variable is computed from our branch-level data following Aiyar, 2012. For each quartile per variable the table reports its mean, standard deviation (s.d.), and difference in means with respect to the next upper quartile (diff.). The table also reports a test of normalized differences in means by Imbens and Wooldridge, 2009 (test). An absolute number of "test" above 0.25 means that demand proxies are statistically and significantly different across quartiles of deposit ratio. The test is conducted between a given quartile and the next upper one reported in the column on the right. For the last column, the test depicts the difference between the 75th and 25th percentile. The variables are defined in Table A.I in the Data Appendix A.

	Branches characteristics				Parent characteristics			
	Liquid assets ratio		Internal funding ratio		Liquid assets ratio		Capital ratio	
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Deposit ratio	0.058	0.127***	0.047	0.113**	0.053	0.155***	0.002	0.107**
	(0.049)	(0.041)	(0.037)	(0.046)	(0.084)	(0.052)	(0.055)	(0.048)
Deposit ratio X	-0.134	-0.234***	-0.121*	-0.225***	-0.021	-0.290***	0.028	-0.218**
Reserve requirements	(0.090)	(0.073)	(0.071)	(0.084)	(0.110)	(0.092)	(0.100)	(0.088)
Parent controls								
Log(Assets)	0.044	0.193***	-0.040	0.185***	0.325	0.120**	0.021	0.141***
	(0.060)	(0.048)	(0.049)	(0.050)	(0.265)	(0.050)	(0.074)	(0.054)
Liquidity ratio	0.041***	0.021***	0.032***	0.028***	-0.000	0.029***	0.004	0.042***
	(0.010)	(0.008)	(0.009)	(0.010)	(0.020)	(0.008)	(0.007)	(0.015)
Capital ratio	0.146***	0.076***	0.108***	0.114***	0.094	0.129***	0.081***	0.129***
	(0.049)	(0.021)	(0.030)	(0.036)	(0.103)	(0.035)	(0.027)	(0.047)
Adm. costs / total costs	-0.060**	-0.014	-0.007	-0.057*	0.054	-0.029	0.004	-0.062
	(0.026)	(0.022)	(0.021)	(0.032)	(0.043)	(0.022)	(0.015)	(0.046)
Branch controls								
Log(Assets)	-0.037***	-0.066***	-0.049***	-0.070***	-0.050***	-0.063***	-0.087***	-0.057***
	(0.011)	(0.013)	(0.012)	(0.020)	(0.010)	(0.013)	(0.017)	(0.013)
Liquidity ratio	1.024***	1.088***	0.876***	0.937***	1.320***	1.753***	0.900***	1.778***
	(0.086)	(0.133)	(0.301)	(0.090)	(0.152)	(0.249)	(0.117)	(0.281)
Deposit ratio	0.145***	0.044***	0.071**	0.071***	0.019	0.087***	0.058	0.064***
	(0.039)	(0.017)	(0.031)	(0.023)	(0.026)	(0.024)	(0.039)	(0.023)
RoA	-14.660	-36.863**	-27.494	-29.260*	-142.608***	0.261	-16.891	-23.165*
	(11.717)	(17.422)	(25.306)	(17.543)	(33.298)	(10.687)	(28.050)	(13.302)
Branch FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter X Mun. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	37,608	97,872	18,792	101,712	23,040	98,328	13,800	96,744
R2	0.578	0.588	0.595	0.552	0.678	0.589	0.612	0.571

TABLE A.IV: **Branch and Parent Characteristics:** This table lists results of our baseline model when accounting for branches' or parents' liquidity and capital constraints. Sample splits are conducted by branches' *Liquid assets ratio* (Columns (1)-(2)) and *Internal funding ratio* (Columns (3)-(4)) and parents' *Liquid assets ratio* (Columns (5)-(6)) and *Capital ratio* (Columns (7)-(8)). The sample is split for the respective variable being larger or equal to the 75th percentile of the branch or parent bank sample distribution in 2008Q1. The dependent variable is the quarterly growth rate of outstanding credit. The sample period spans 2008Q1-2014Q1. *Deposit ratio* abbreviates the demand deposit ratio of parent banks. *Reserve requirements* corresponds to the reserve requirements rate on demand deposits. For more information on the data definition, see the data description. Explanatory variables at the branch and parent level are standardized. All explanatory variables enter the model lagged by one quarter. Fixed effects include branch fixed effects and quarter-municipality fixed effects. Standard errors are clustered by parent bank and quarter. *** indicates significance at the 1% level; ** at the 5%; * at the 10%.

Chapter 3

Ownership Structure and Default Resource Composition of Central Clearing Counterparties in Europe

Abstract: *The introduction of mandatory central clearing in the European Union created a set of diversely configured institutions with diverging characteristics regarding business models and strategic incentives in a highly competitive environment. I examine the composition of default resources across ownership models of central clearing counterparties (CCPs) and find that CCPs held by a central bank compared to CCPs under different ownership models show persistently higher initial margin requirements, lower variation margin calls relative to subsequent layers of the default resources, accept collateral to which lower haircuts are applied and provide more own pre-funded capital relative to member provided default resources.*

3.1 Introduction

> *"I believe that the over-the-counter derivatives marketplace was in fact part and parcel to this crisis."*
>
> – Gary Gensler, Chairman of the Commodity Futures Trading Commission, Speech to the Council on Foreign Relations in New York, January 6, 2010.

The European Market Infrastructure Regulation (EMIR) enacted in 2012 to enforce central clearing of over-the-counter derivatives (OTCs) created a multitude of systemically important central clearing hubs in the European Union (EU)[1]. Heterogeneous

[1] "Since EMIR was first adopted in 2012, CCPs have become a systemically-important part of the financial sector and their importance is growing." (European Commission - Press release IP/19/1657, 13 March 2019). ESMA considers the systemically importance of CCPs since the amendments made in EMIR 2.2 as of May 2019.

implementations of the reform across countries led to a variety of differently organized actors and several forms of clearing entities now exist in parallel. Most importantly, the central clearing counterparties (CCPs) differ in their ownership structure. From the 16 European based CCPs authorized under EMIR, two CCPs are owned by the respective national central banks, ten belong to major stock exchanges, and four are in part owned by their users and an affiliated exchange. The ownership of CCPs and the respective business models may cause the CCP's risk taking incentives to be misaligned with the goals of the central clearing policy initiative (BIS, 2010).

The divergences in risk governance of different ownership models may have a bearing on financial stability. CCPs are of major concern regarding financial stability as they concentrate counterparty risk, are highly interlinked and deeply integrated in financial markets, but their resolution remains an unresolved problem (Singh and Turing, 2018). The CCP's risk to fail is largely determined by the resources it collects to absorb the losses of failing clearing members. The central importance of clearing houses for the stability of financial markets led regulators to require CCPs to be equipped with multiple layers of loss absorbing resources. This paper addresses the implications of the ownership structure of CCPs for the composition of these resources, which are referred to as the loss absorbing waterfall.

The required loss absorbing waterfall, as defined by EMIR (2012), applies to all CCPs authorized to operate in the EU and consists resources provided by the CCP, such as capital, and by its members, such as collateral in the form of margins and default fund contributions. The main contribution of this paper is to link the CCPs' ownership structure to differences in margin requirements, collateral quality and capital provision. To this end I combine hand collected data from regulatory reports for the years 2015 to 2018 with hand collected ownership information.

As a first line of defense, the CCP sets the required margin which is to be put down by each counterparty of a novated trade. The margin requirements directly affect the probability of the CCP to step in with its own capital to cover the losses caused by a default. Setting margins such that they positively affect the likelihood of touching the CCP's own capital is a form of risk taking behavior. In my analysis on the role of a firm's ownership structure on risk taking, I follow seminal work by Saunders et al. (1990), who find that shareholder owned listed banks take on more risk than privately owned non-listed banks. I discuss the risk taking of CCPs analogous to the findings in the banking literature. Risk taking preferences are affected by the stakes to which a party is involved in the profit generating activity (Saunders et al., 1990). This also holds true for CCPs in similar fashion. Both, owner and user contribute to the default resources of a CCP. Owners provide capital, which ranks higher in loss absorbing waterfall and members provide the downstream default fund. In combination with margin collateral they form the default waterfall resources covering the losses in the case of a member's default. As for banking activities Esty (1998) shows that the limited liability structure of banking positively influences bank risk taking. The limited liability nature of CCPs, where the CCP retains the profits and provides only a fraction of default resources as capital, skews the risk taking preferences of owners towards less prudency as compared to the user's preferences.

The risk assumed by the CCP is determined by the uncovered amount of the trade's replacement value and reduced by the collateralization in terms of initial margin. The initial margin setting is an important determinant for the risk taking incentives of the counterparties and contribute to the opportunity costs of the trade in term of forgone interest on the collateral assets. Increasing costs of trade collateralization in turn depress the volume that is novated by the CCP and therefore reduce profits. In order to increase profits limited liability CCP owners may want to drive down margins, which in turn would help to gain market share.

On the contrary, one would assume that Central bank owned CCPs operate in order to provide financial stability and do not aim to generate profits, that is they set margins in line with the objective of the clearing regulation. Exchange owned CCPs operate on a for profit basis and set margins according to the profit maximizing optimum, resulting in a possible misalignment with the objective of the central clearing regulation. Early concerns of the interference of the ownership structure and the alignment of individual CCP's profit maximizing and the policy's financial stability goals have been raised by BIS (2010).

The ownership structure defines the ability of the parties to affect the risk taking behavior in line with the incentives as defined by the operational objective, that is to set margins in line with the respective risk taking preferences (Jensen and Meckling, 1976). Limited liability owners of privately run CCPs would be expected to set the margin standards according to the profit maximizing optimum in line with the risk appetite of the owners. Hybrid CCPs, which are in part owned by the members, also generate profit but the members have the ability to steer the risk management towards a more prudent margin setting. Central banks operating a CCP have the direct control over the CCP's operations and would be expected to adjust margin setting standards according to the financial stability objective set by the clearing regulation.

The dynamics described above for the margin setting of CCPs also apply for the amount of pre-funded capital, the default fund size, the degree of loss mutualization. Fixed costs of clearing for example arise from the opportunity costs of default fund contributions. Margins are regained by the surviving members, both owners and members would therefore prefer a lower degree of mutualization.

Hence, I hypothesize that exchange run CCPs show the lowest margin coverage, mutualization, collateral quality and initial to variation margin ratio. This would match the risk preferences of limited liability capital providers, while the ownership structure provides them with the ability to set the risk profile of the CCP according to these preferences. Hybrid owned CCPs run in part by the users would be expected to show a higher level of margin coverage as compared to exchange run CCPs as the user owners gain the ability to shift the CCP risk profile further towards the users' preferences. Central bank run CCPs would be expected to show the most conservative risk profile, meaning high margin coverage and high loss mutualization, as the risk taking incentives are in line with the regulatory target of improving financial stability.

This paper aims to analyze the risk structure of central clearing counterparties depending on their ownership types in the following three dimensions. Credit risk addressed by the default fund adequacy, collateral quality and loss mutualization as an insurance against the counterparties default. To the best of my knowledge, this paper is the first to compare the composition of default resources across ownership types. I find that central bank owned CCPs demand more initial margin, call for less variation margin, provide more capital, have a stronger emphasis on loss mutualization and apply lower haircuts on assets accepted as collateral and default fund contributions in contrast to CCPs run by exchanges or in part by its members. The results are important for understanding the derivative clearing market structure in the EU, monitoring the risks associated with CCPs and identify best practices in the implementation of derivative clearing reforms.

Section 3.2 introduces the regulatory environment of central clearing in the European Union as well as the characteristics of CCPs as financial institutions, Section 3.3 presents the data, the European Central Counterparty landscape and regulatory reporting obligations, Section 3.4 highlights the differences in the ownership structures and derives hypotheses to be tested empirically, Section 3.5 describes the empirical strategy to test for differences in the composition of default resources between ownership types, Section 3.6 discusses the findings, and Section 3.7 concludes.

3.2 Central Clearing in the EU

Over the counter derivatives (OTCs) have been identified to be an important contagion mechanism of financial distress, which has facilitated the dissemination of a crisis of a local mortgage market to a global financial crisis severely affecting the European financial sector in 2008 (see for example Wiggins and Metrick (2015)). In response to their adverse potential, G20 leaders committed to reform the structure of OTC derivatives markets and to improve their transparency (G20, 2009, par. 13). Standardized OTC derivative contracts should be cleared through central clearing counterparties (CCPs) and OTC derivatives contracts should be centrally reported to trade repositories.

The EU implemented mandatory central clearing of OTC derivatives via the European Market Infrastructure Regulation (EMIR) in August 2012 (EMIR, 2012, par. 1). Since June 21, 2016, standardized derivatives must be cleared through central clearing counterparties authorized by the European Securities and Markets Authority (ESMA). Instead of OTCs to remain an individualized bilateral contract, derivatives ought to be standardized and become a contract involving the CCP placing itself between the buyer and seller of an original trade and serve as the buyer to every seller and the seller to every buyer, manages the collateral and steps in if either party fails to fulfill its obligations. This procedure is intended to contain bilateral counter-party credit risk exposures, reduce interconnectedness and limit the systemic risk posed by OTC derivatives.

Over the counter financial instruments classified as interest rate (IRS), foreign exchange (FX), equity, credit and commodity derivatives transactions need to be cleared through an authorized CCP. All EU-based financial counterparties (FCs), as well as non-financial firms (NFCs) with OTC positions exceeding EUR 1 billion in credit and equity derivative contracts or EUR 3 billion in IRS, FX and commodity derivative contracts are subject to the central clearing obligation. Exemption apply to some intra-group trades and trades involving pension funds until August 2018. Non-EU based counterparties may be obliged to hand over transactions to CCPs authorized under EMIR if the transaction involves an EU-based firm or implies a direct and substantial effect on EU markets.

Standardized contracts may not cover the full range of risk management requirements. There is a role for tailored OTC contracts that meet end-user risk management needs, but which are not suitable for clearing. Remaining customized, non-centrally-cleared trades are subject to mandatory reporting, and elevated margin requirements will be applied to mitigate other potential risks and incentivize centralized settlement (BCBS, 2015).

As CCPs now become the central figure in the transaction settlement of a large part of the international financial market[2] they themselves evolve into a major concern regarding systemic financial stability, with significant implications in the case of their default.

Mandatory central clearing of OTCs transformed the market structure of derivative trading from a network with a multitude of institutions with bilateral connections to few systemically important central hubs. As of the first quarter in 2017, 16 EU-based CCPs connect 1,184 unique clearing members. A list of authorized CCPs under EMIR according to ESMA (2018b) can be found in Table 3.1 with the respective host country. The list reveals that the UK is host to four CCPs, while two CCPs operate in Germany and the remaining countries only host one CCP each. Not every EU country hosts a CCP, only 13 out of 28 countries are home to a CCP headquarter.

The market of central clearing operations is served by a small number of market participants and characterized by high fix and low marginal costs, also further cost

[2]In the European Union, CCPs covered a notional amount of 293 trillion EUR in the first quarter of 2017. Globally, OTC derivatives covered a notional amount of 532 trillion USD in the second half of 2017 with a gross market value of 11 trillion USD (BIS, 2018).

reduction benefits from netting and compression increase with the volume of trades running through a single CCP (D'Errico and Roukny, 2017). The setting might encourage a dynamic of market concentration, where large participants naturally attract more volume. By merging, market participants may want to benefit from economies of scale. That a further concentration is feared by the market authorities may be drawn from the blocked merger of Eurex owner Deutsche Börse and London Stock Exchange, which owns LCH Clearnet (European Commission, 2017).

Two authorized CCPs have ceased operations during the observation period as a strategic decisions. In June 2017 ICE Clear Netherlands halted clearing after the wind down of its major client The Order Machine (TOM B.V.), but remains licensed as an authorized CCP under EMIR. CME London Clearing Europe stopped operating in Europe after the decision of CME Group to consolidate its business to its US infrastructure, while continuing to offer clearing services to its European clients, its license as an authorized CCP under EMIR has been revoked in October 2017. Also, recent changes of providers by large clearing members suggest that CCPs are substitutable and that clearing is transferable between them. Deutsche Bank for example, relocated its clearing of newly concluded contracts from LCH in London to Eurex in Frankfurt. LCH Clearnet allows its customers to clear with any of its two CCPs LCH Ltd. in London or LCH SA. in France while only being a member of one of them.

The large count of competitors, high profits from economies of scale in central clearing and a market that is just beginning to consolidate clearing providers create a setting that created incentives to aggressively increase market share (Krahnen and Pelizzon, 2016). This development could result in less prudent risk management, posing a threat on financial stability if CCPs respond with lowering the required initial margin rates, refrain from adapting margins throughout the life of a derivative contract by not issuing a margin call when actually necessary or accept lower quality securities as collateral implying the possibility of increased haircuts.

3.2.1 CCP Risk and Regulation

CCPs provide a monitoring and commitment mechanism to its members. The risks CCPs take on in doing so differ from the ones faced by similar financial institutions. This is why the instruments measuring the CCPs' risk profile are different from the ones analyzing banks and insurance companies. A first important step when assessing a CCP's health is to appreciate that a CCP is not a bank. A realization which alters the adequate tools and risks which needs to be assessed (Hughes and Manning, 2015). The just recently emerging literature on central clearing exposes that the common recognition of CCPs is potentially flawed by the view a CCP being a financial institution which provides services as a mixture of banks and insurances. The counterparty risk associated with contracts novated by the CCP are barely comparable to the credit risk taken by a bank. CCPs take on counterparty default risk in the process of novation. But compared to a bank, CCPs run matched books as they do not engage in maturity transformation. Every trade position is matched by an opposing position of the exact same size, underlying and termination date. Abstracting from client risk outstanding claims and liabilities are therefore perfectly symmetric in risk, size, and maturity. Although CCPs incorporate features of an insurance from the client point of view, the structure of risk from the CCP's point of view differs from that of an insurance as it does not engage in diversification and risk pooling[3].

Hughes and Manning (2015) describe CCPs as a provider of "commitment mechanisms", which need to be distinctly monitored and regulated and should not be regarded as to be equal to banks, insurance, depositories or payment systems. This way a CCP acts as a risk manager, but also takes on credit and liquidity risk by assuming the existing debt in the event of a member' default. Mandatory central clearing is a regulatory tool to contain network risk and mitigate contagion of distress between clearing members.

Therefore, risk taking incentives, regulations and monitoring instruments differ greatly for CCPs as compared to other financial agencies. A CCP is merely a risk manager and becomes a principal to the trades through counterparty substitution via the novation process, which eliminates the original counterparties' claims to each other. In addition to the enforcing mechanism central clearing counterparties implement when clearing, they are set in place as an insurance of both initial parties as the originator of a derivative trade against a participant's default. In order to cover potential losses associated with a member's insolvency, CCPs are required to

[3]Cox and Steigerwald (2017) provide a detailed description of the characteristics that distinguish CCPs from other financial market participants.

be equipped with adequate loss absorbing resources. The buffers against a default shock contain partitions of individual and collective loss bearing and involve margins, consisting of initial and variation margin, a mutual default fund, the CCPs' own capital and additional member commitments pledged in case the of to run out of the previous resource bins. The first segments aim at shielding other members from the repercussions of a single member's default as they draw on the defaulting member's margins and default fund contributions. If the defaulting member's funds are insufficient to cover the losses, the CCP additionally draws on its own capital. Only after these funds have been tabbed and also found to be insufficient, the CCP resorts to other members' mutual default fund contributions and may call for the requisition of additionally made commitments by the remaining clearing members.

One of the main regulatory efforts regarding banks focuses on banks' equity as a mechanism to absorb losses and incentivize the banks' owners to prudent risk behavior due to their skin in the game (BCBS, 2016). Capital adequacy is not the main focus in regulatory efforts concerning CCPs as capital is not the primary resource of the default loss absorbing cascade. According to Cox and Steigerwald (2017) it also should not be the main primary resource of loss absorbing capacity as this would create adverse incentives on the client side. Opinions diverge in the question of capitalization of CCPs, some argue that an increase in the capitalization drives incentives away from clearing members, increasing the riskiness of their trading behavior, others argue that CCPs need more skin in the game (Albuquerque et al., 2016). The composition of the default loss absorbing mechanism is multi leveled and creates incentives to prudent margin setting and trading behavior affecting the client and the novation side at the same time, as both sides have their skin in the game. The ratio of these involvements creates the driving factors making some incentives stronger than others. Margin setting will be affected by the relative share and position of the CCP's own capital compared to the member loaded default fund. Trading behavior will be affected by the size and composition of the default fund, and how much the individual member is bearing as compared to the degree of loss mutualization.

Adequacy of the default resources is not the focus of the paper, but merely their composition. It is not possible to calculate the replacement value of the trades from the regulatory data at hand. Trade values are also a factor which is shifting on a daily basis. Loss absorbing adequacy depends on predictions about the potentially adverse development of the trades through stress tests, which are conducted by ESMA (ESMA, 2018a).

Another focus of bank regulation is concerning the liquidity of assets as banks engage in liquidity transformation of short term liabilities into long term assets, resulting in mismatched books. CCPs do not engage in liquidity transformation. Every trade position corresponds to an offsetting position of the same amount opposite direction, creating a matched book with no maturity asymmetry. Risk regarding liquidity arise in the case that losses have to be compensated for by liquidating assets. As CCPs do not engage in maturity transformation, the liquidity risk faced by a CCP is not a structural risk, as compared to the liquidity risk stemming from a bank's mismatched books. CCPs only face liquidity risk in the case of a counterparty's default (Hughes and Manning, 2015).

A bank's balance sheet is an informative accounting tool in order to assess the health of a bank, especially in order to calculate the liability residual of the bank's capital. For instance, non-performing loans might be written off the balance sheet at some point by pricing the asset's value at zero, which in turn reduces the liability residual on the balance sheet, which is the capital. Losses are absorbed differently by CCPs. The most likely cause for a default is a member's inability to settle its variation margin. The outstanding variation margin is then covered by the default resources. The first three lines of defense are constructed by the principle of defaulter pay and consist of initial margin held at the CCP, variation margin paid out to the members at the end of the offsetting trades and the defaulting member's default fund contribution. The remaining losses will be covered by the survivors, with the CCP's capital first and its surviving member's default fund contributions and additional commitments second. The default resources therefore also include a bail-in clause via the unfunded commitments of its members, which is not a recapitalization as the members do not acquire additional claims vis-à-vis the CCP.

The loss absorbing capacity of a CCP includes all resources that are available to the CCP consisting of various layers each implementing its own risk related incentives. Their adequacy or the CCP's health cannot be judged from examining the CCP's balance sheet, which is an inadequate accounting instrument for this purpose. Balance sheets may be used to calculate the capital as a residual of assets and debt, but CCPs are not leveraged as they do not create and hold debt, which renders the tool of balance sheets inadequate to judge a CCP's state of health. The CCP's capital is used as an incentive mechanism for prudent margin setting and increasing the effort to sell on a defaulting members positions. The main role in the loss absorbing mechanism is played by the members' margins and default fund contributions.

The emphasize on the individual member's margins as compared to the CCP's own capital or the remaining members' default fund contributions increases the members' skin in the game. Margins are also directly linked to the risk associated with the participant's portfolio and set opportunity costs which are proportional to the risk involved in a trade (Carter and Cole, 2017; Krahnen and Pelizzon, 2016). The downside of the emphasis on margins is that they have been found to be pro-cyclical, causing asset price spirals and liquidity shortages in times of financial stress (Capponi and Cheng, 2018).

A CCP has a unique risk profile and loss absorbing mechanisms that differ from other financial institutions. The risk nexus arises from the interconnection of systemically important banks with the highly concentrated clearing market (Umar Faruqui and Takàts, 2018). The ability of CCPs to act as a buffer between banks connected through the same CCP is addressed in part three of this thesis.

3.3 Data

Data are collected at the CCP level covering the time period second quarter 2015 until the first quarter 2018 and comprises quarterly information on the clearing activity and default fund resources based on mandatory quarterly reports, as well as hand collected yearly balance sheet information taken from public statements, ownership information, and information on clearing members as published by the CCPs. The quarterly reports are structured according to the template of the disclosure framework based on a joint effort of CPMI[4] and IOSCO[5]. The resulting data set contains detailed information on

[4]Committee on Payments and Market Infrastructures, formerly known as CPSS, the Committee on Payment and Settlement Systems, a monitoring committee hosted at the Bank of International Settlements and member of the Financial Stability Board.

[5]International Organization of Securities Commissions, an association of securities regulating agencies based in Madrid.

the default bearing resources, liquidity risk, credit risk, position concentration and the storage and reinvestment of funds in 236 items. A list of authorized CCPs under EMIR according to ESMA (2018b) can be found in Table 3.1, together with the operating country, national competent authority in charge of supervision as well as the date of initial authorization. A map in Figure 3.1 depicts the location of the authorized CCPs across Europe. Tables 3.2 and 3.3 list the data availability and sources respectively.

Data on CCPs stems from their individual online resources pages and is compiled by a script that downloads the files at the end of each quarter, as previous dissembles and unifies the CPMI-IOSCO mandatory reporting files, automatically corrects common errors, converts all currencies to nominal Euro and builds a panel data set. The number of observations in each category varies across CCPs due to missings or ambiguous errors in the underlying reports.

The volume of the underlying that is encompassed in a trade is the notional amount, which may be an indicator for the market share of a CCP. This must not be equated with the value or replacement costs of the trade or the risk that is associated with the novated contracts. Figure 3.2 plots the notional amount covered by the European CCPs as of September 2017 and reveals a highly skewed power law distribution of notional amount across CCPs. The largest CCP in terms of notionals, the London based LCH Clearnet Ltd., covers four times the notional amount compared to the Frankfurt based Eurex, the second largest CCP in terms of the notional amount, followed by the Paris based LCH S.A. covering half the amount compared to Eurex. Both, LCH.Clearnet Ltd. and LCH.Clearnet S.A. are operated by LCH.Clearnet Group Limited, which is owned by the London Stock Exchange Group, demonstrating an already high market concentration. Two of the largest four CCPs are London based, which results in a growing share of 64 percent of the European notional amount that is cleared in the UK.

The loss absorbing capacities of CCPs differ in size and composition, but most notably their composion differs systematically across ownership models. In order to compare the different layers of the absorbing capacities across the ownership types I calculate ratios between the layers as to normalize and abstract from the differences in overall size. I then test for mean differences of the ratios between ownership types. Summary statistics of all measures tested for mean differences are listed in Table 3.4.

The measures are given in percentage terms, with the exception of Max. VM/capital and Max. VM/default which are given as ratios, and grouped into five categories.

The first category measures the relative size of initial margin held by the CCP. Avg. VM/IM is the relative size of initial margin compared to the average variation margin transferred during a quarter and the average variation margin call is two percent of the initial margin held. Max. VM/IM is the relative size of initial margin in terms of maximum variation margin and the maximum variation margin call is on average 7.3 percent of initial margin held. The notional covered by IM the initial margin divided by the notional amount novated by the CCP and is 0.5 percent on average. The next category measures the relative sizes of the maximum variation margin calls, where Max. VM/capital shows that the maximum variation margin call are 38.3 times the capital buffer on average and Max. VM/default fund shows that the maximum variation margin size is 0.8 times the size of the default fund volume.

The third category measures the relative size of the capital pre-funded by the CCP, where the Notional covered by capital is 0.015 percent on average, Capital/IM is the capital buffer size divided by initial margin and is 0.537 on average and the exposure amount at default (EAD) covered by Capital is 8.617 percent on average. The next category measures the degree to which a CCPs supplies an insurance mechanism as relative emphasize on individual member and CCP risk bearing, labeled Mutualization, which is the default fund size relative to initial required margin and roughly one quarter on average. The fifth and last category measures collateral valuation risk as perceived by the CCP in terms of the haircut applied to the assets accepted as collateral (3.7 percent on average) or as default fund contribution (two percent on average).

3.4 Ownership Structure and Risk Governance

Safely operating the amount of risk concentrated at CCPs requires not only a strong backbone of provisions and funds, but also a good governance oriented ownership structure in order to avoid conflicts of interest. Table 3.5 lists the ownership structures of the European central clearing counterparties. Most common ownership models are ownership by an exchange or by the same owner of the linked exchange[6], member owned or a combination thereof. Two CCPs, KDPW in Poland and Keler CCP in Hungary, are ultimately owned by the respective central bank, enabling them to directly supervise the CCPs' daily operations. Compared to the US-based National Securities Clearing Corporation (NSCC)[7] which is completely user-owned by its direct clearing members, no European CCP is held under such a model. Only the two LCH.Clearnet Group clearing houses (UK-based LCH.Clearnet Ltd and France-based LCH.Clearnet S.A.) and the European Central Counterparty are in part owned by its users.

The ownership structure may indicate whether the CCP operates on a profit or cost oriented business model and whether third parties have a way of pushing particular interests. The majority of CCPs being operated by non-users might induce the incentive to compete on pricing based on margin setting. Furthermore, the profit oriented business model brings about particular interests of service providers, which affect the CCP's risk management, e.g. with regard to quality of collateral requirements.

Both of these incentives driven by the for-profit interests of non-user owners raise concerns regarding financial stability. The non-involvement of most European central banks into its national CCP's operations besides the combined supervision process in conjunction with the ECB sets the local supervision further apart from the origin of the potential risk. The CPSS[8] Working Group on Post-Trade Services report (BIS, 2010) takes up the concerns and incentives arising with user and non-user owned CCPs.

The report emphasizes the different incentives following the ownership models. A user owned CCP operates towards the aim of cost reduction and internalizes all the CCP's choices affecting its users by which it is owned. A profit oriented non-user-owned CCP is subject to opposing incentives concerning the setting of margins and collateral quality requirements. In order to reduce the probability of resorting to the CCP's own capital, the non-user-owned CCPs have the incentive to *increase* margins, but at the same time the incentive to *reduce* margins in order to increase market

[6]BME Clearing S.A., CC&G, CME Clearing Europe, Eurex Clearing.

[7]The NSCC is a US-based CCP and a subsidiary of The Depository Trust & Clearing Corporation (DTCC).

[8]Renamed as the Committee on Payments and Market Infrastructures (CPMI) in 2014.

share and profitability. To the best of my knowledge, there is no description of the incentive structure implied by a hybrid model, where the CCP is operated by users and non-users. The majority of the European CCPs operates under such a hybrid model, with its implications to the well functioning of their risk management is not yet understood.

Governance structures which imply conflicts of interest may hamper the functioning of risk managing institutions. Ellul and Yerramilli (2013) emphasize the importance of a strong and independent risk management in financial institutions to its resilience in times of distress. EMIR sets in place such measures in order to prevent the ownership structure induced conflicts of interest to possibly hampering the well functioning of risk management. Following the BIS-proposed Principles for Financial Market Infrastructures (PFMI[9]), EMIR requires the establishment of a standing risk committee[10] in which representatives of members and clients exercise voting rights, while the CCP's employees (e.g. the CCP's own risk officers) and external independent experts (e.g. members of the national competent authorities) may attend in a non-voting capacity. The national competent authorities (NCAs) are in charge of supervising the authorized European CCPs' operations as found in Table 3.1, the NCA's supervision practices are peer reviewed under ESMA.

The ownership structure and the composition of the risk committee determine the ability of the involved parties to steer the CCP's risk profile according to their risk taking preferences. This would imply that the CCPs operated by central banks operate in line with the goals of the central clearing reform and set a conservative composition of default resources, while non central bank owned CCPs primarily operate to generate profits and apply a thinner, riskier default waterfall. Hence, I hypothesize that exchange run CCPs require the lowest initial margin (initially assumed risk) relative to variation margin (realized valuation risk) and overall novated notional amount, execute the highest variation margin calls in terms of subsequent default buffers such as capital and default fund size, provide the least amount of capital relative to overall novated notional amount, initial margin and exposure at default (expected loss given

[9]See BIS, 2012, 3.2.9. p. 28.

[10]Article 28(1): "A CCP shall establish a risk committee, which shall be composed of representatives of its clearing members, independent members of the board and representatives of its clients. The risk committee may invite employees of the CCP and external independent experts to attend risk-committee meetings in a non-voting capacity.[. . .]" (EMIR, 2012, p. 31).

members' default). I also expect non central bank operated CCPs to show the least amount of loss mutualization in terms of common default fund size in terms of individual members' total initial margin deposit and show the least collateral quality in terms of increased haircuts on assets accepted as initial margin deposits and default fund contributions.

The current implementation of central clearing may be jeopardizing the policy objective of enhancing financial stability as the profit oriented CCP's incentives may not be leading to prudent margin setting and sufficient capital provision. The non-excludable quality of financial stability is a public good, but the incentives of the for-profit clearing firm conflict with the provision of a public good. Clearing members pay a membership fee and can be excluded from trading with a CCP, giving the current implementation the characteristics of a club good (Lopez, Manning, et al., 2017).

Providing financial stability is therefore not the main objective of a profit oriented central clearing counterparty. The literature describes the misalignment of the individual and public goals of central clearing and that financial stability may not be provided by the commitment mechanism of central clearing if the main objective of the central counterparty is to maximize shareholder value by cutting risk prudence (Albuquerque et al., 2016). Operating central clearing according to the individual for profit incentives of non-user owners may not yield the socially desired improvement of financial stability that was intended by the regulatory efforts to reform the post-crisis derivative trading.

3.5 Empirical Strategy

In order to statistically test the mean differences between groups I estimate simple pooled cross section regression functions, which model the respective relationship as a function of the ownership type at each point in time as follows:

$$y_{i,t} = \alpha + \beta\, \mathrm{D}_{\text{exchange}} + \gamma\, \mathrm{D}_{\text{hybrid}} + \delta_t + \varepsilon_{i,t} \tag{3.1}$$

and

$$y_{i,t} = \alpha + \beta\, \mathrm{D}_{\text{central bank}} + \delta_t + \varepsilon_{i,t}, \tag{3.2}$$

where $\mathrm{D}_{\text{exchange}}$, $\mathrm{D}_{\text{hybrid}}$ and $\mathrm{D}_{\text{central bank}}$ are a set of binary variables, which take the value of one for CCPs owned by an exchange, in part by users or by a central bank, respectively and zero otherwise. The ownership groups are assigned to the CCPs according to the ownership models in Table 3.5, the group affiliation is listed in Table 3.6. In order to compare the differences at each point in time and to take level shifts of the whole sample over time into account the model includes quarterly time dummies represented by δ_t. Standard errors are clustered within the ownership groups. The time invariant nature of the ownership type does not allow the model to include entity fixed effects. Although the ratios to be tested are constraint to be non-negative or rely within a specific interval, I refrain from employing truncated models and rely instead on linear models due to the advantages in simplicity and reduced set of assumptions. In order to check the appropriateness of the model I report the range of the predicted dependent variable to see if the sample interval is matched. The estimated constant refers to the mean of the base group to which the mean of the groups represented by the ownership binaries are tested against after controlling for common level shifts.

The following sections inspect the differences in the default waterfall composition between the ownership groups.

3.6 Empirical Findings

3.6.1 Ownership and Margin Setting

At the time of novation, the CCP assesses the risk associated with the derivative contract and requires both parties to pledge collateral, the initial margin. Changes in the risk perceived by the CCP with respect to the contract over time must be offset daily by payments of the adjusted variation margin. Counterparties to derivative transactions are requested to settle their margin accounts by daily margin calls. If the performance of the underlying asset turns out to be more volatile than initially expected, the initial margin proves to be insufficiently low. In this case the margin account needs to be corrected by the demand for variation margin. On the other hand, a lower initial margin means lower costs of the derivative transaction for both counterparties. In order to assess the appropriateness of the margin setting, the initial margin is set in relation to the changes in valuation of trades indicated by the variation margin and to notional value of the trades.

The average variation margin that is collected from or paid to the CCP's members in a given quarter is an indicator for the average volatility of the value of trades held with the CCP. The volatility indicated by the variation margin are of special interest because the margin calls have to be met in cash and therefore pose a threat to the liquidity of the clearing members. Not being able to settle margin calls is a cause for declaring a member's insolvency. In order to assess the size of the variation margin it is set in relation to the initial margin held, that is the valuation risk initially assumed by the CCP. The sample mean of the average variation margin is at two percent of initial margin with a maximum of 10.8 percent[11] (Table 3.4), but the measure differs systematically between the ownership types of CCPs.

I find that non-central bank owned CCPs systematically and significantly call for higher variation margin (VM) relative to initial margin (IM). Table 3.7 Panel A shows that during the sample period the average central bank owned CCPs called for variation margin of about one percent of its initial margin compared to non-central bank owned CCPs which had to adjust their margins accounts by about twice that amount. Estimating the simple pooled cross-section regression models defined in Equations 3.1 and 3.2 explaining the ratio of initial with just the ownership types reveals that exchange owned and hybrid CCPs significantly call for 1.17 and 0.75 percentage points more variation margin relative to initial margin (Table 3.8 Column (1)) as compared to central bank owned CCPs, while central bank owned CCPs significantly call for one percentage point less variation margin relative to initial margin as compared to CCPs under a different ownership structure.

Figure 3.3 depicts the average margin calls over time and shows a persistent pattern. Central bank owned CCPs on average have to adjust their margin accounts on average less than CCPs with a different ownership structure. The density plotted in

[11] In the first quarter of 2017 CC&G had to adjust their members' margin accounts by ten percent of the initial margin on average.

Figure 3.4 shows for the exchange and hybrid owned CCPs a slight shift to right and long right tails, indicating large upper outliers, as compared to central bank owned CCPs.

The average variation margin in relation to initial margin already reveal structural differences between the ownership models. But loss absorbing mechanisms are not designed to withstand the average of losses that might occur. In the case of a member's default it is more testing to look at the maximum amount of variation margin that potentially needs to be covered by the CCP in the case of a client's default and if the layers of loss absorbing mechanism are able to prevent the CCP's default. To capture this, I calculate the group specific median of quarterly maximum variation margin calls in relation to the first three layers of the default waterfall. Figure 3.5 plots the group specific median of the quarterly maximum variation margin calls in relation to total initial margin held. Exchange and hybrid owned CCPs show a volatile evolution of the measure as compared to central bank owned CCPs until the first quarter 2017. From there on the time series stabilize and at roughly the same level for hybrid and central bank owned CCPs below 5 percent and a higher level for exchange owned CCPs at around 7.5 percent. The higher this ratio, the higher is the amount of financial resources that is needed to be held in cash by the affected client in order to be able to comply with the variation margin call and thus the probability of the client to strategically or actually default on the trade. The distribution plotted in Figure 3.6 again shows longer right tails for exchange and hybrid owned CCPs as compared to central bank owned CCPs.

A potential thread to a member's liquidity is posed by large margin calls that need to be met in cash. The maximum variation margin that is demanded by the CCPs from its members is on average 7.3 percent with a maximum of 55.1 percent of initial margin (Table 3.4).[12] Again, central bank owned CCPs call less variation compared to CCPs under different ownership models. The maximum variation margin that was demanded by central bank owned CCPs is 4.1 percent on average as compared to 8.15 percent for exchange owned CCPs (Table 3.7 Panel B). The estimates show that the difference is statistically significant (Table 3.8 Columns (3) and (4)).

[12] The largest margin call amounted to 55 percent of the total initial margin held and was issued by Eurex Clearing in the last quarter of 2015.

The volume of trades held by the CCP comprises the open interest positions and newly novated trades within the respective quarter. The share of the notional amount covered by the total initial margin held encompasses historic margin setting behavior. The notional amount of newly novated trades that is covered by the required margin within the respective quarter is depicted in Figure 3.7. This ratio covers newly novated trades and their required initial margin only and its evolution may be seen as an indicator of change in margin setting behavior. The share is highest for the central bank owned CCPs but decreasing beginning in the third quarter 2017. This may point into the direction of a more prudent margin setting for central bank owned CCPs, but this must be judged with caution as the risks associated with the trades may not be inferred from the notional value alone. The sample mean of the notional amount that is covered by the required margin is 0.5 percent wit a maximum of 3.1 percent (Table 3.4), but differs across the ownership types. The density depicted in Figure 3.8 shows a low variance distribution for hybrid owned CCPs and large variance and increased kurtosis for exchange owned and central bank owned CCPs, respectively. Newly novated trades by central bank owned CCPs are covered with 1.3 percent of required initial margin on average as compared to 0.13 and 0.46 percent for hybrid and exchange owned CCPs, respectively (Table 3.7 Panel C). The notional amount of the newly novated trades that is covered by the initially required margin is significantly one percentage point larger for central bank operated CCPs in each quarter as compared to other CCPs (Table 3.8 Columns (5) and (6)).

The findings so far speak in favor of the expectation that non-central bank owned CCPs aim on driving down the costs of trades and set lower initial margins in order to attract a higher volume of trades. Brigo and Pallavicini (2014) show for the case of interest rate derivatives, which make up 80 percent of the notional centrally cleared, that valuation risk increases volatility of margin account adjustments and therefore the amplitude of variation margin calls. Larger variation margins may therefore indicate higher valuation risk that is associated with the trade. In order to assess the evolution of the valuation risk in relation to the initially assumed risk the aggregate margin account changes may be scaled by the initial margin held. Doing so reveals the relative change in the valuation risk as perceived by the CCP compared to the initially assumed risk as estimated by the CCP.

If the variation margin is high relative to the initial margin held, this increases the likelihood of the member on the losing end of the adjustment not being able to comply with the margin call or to strategically default on the trade (Huang, 2019). The initial margin is the amount of risk coverage that is already provided by the counterparties, whereas the variation margin call exceeds that commitment. High variation margin changes relative to initial margin account increase the share of the loss that is uncovered in the case of a default and needs to be absorbed by the subsequent parts of the default waterfall (Capponi and Cheng, 2018).

These findings suggest that non-central bank led CCPs are systematically underestimating the risks associated with their novated trades. The descriptive evidence on the difference between margin calls among the ownership models points into the direction that non-central bank run CCPs follow a profit oriented business model keeping initial costs low and call for margins alongside the trade at the time when the collateral is really needed. This behavior is posing a threat to financial stability as high variation margins have been shown to not only adversely affect the counterparties directly involved in the trade but also bear the potential of negative externalities to securities markets, therefore spreading shocks to unrelated parties. Since the required margin is an important component of the non-mutualized loss absorbing capacity, lower margins come at the cost of increasing the likelihood that the CCP or its members will have to cover the losses in the event of a default by a member.[13] High variation margin calls force the affected members to abruptly adjust their margin accounts, which might severely draw on their liquidity. Bakoush et al. (2019) show that variation margins are pro-cyclical and Bruno Biais (2018) show that high variation margins have fire sale externalities, because even assets that would be eligible as initial margin payments need to be transferred into cash in order to cover variation margin calls.

If a member is unable to settle a margin call, the member is declared insolvent and subsequent layers of the default resources will have to be mobilized. After collecting on the defaulting member's initial margin, the CCP steps in with its own pre-funded capital before the mutual default fund is tabbed. The sample mean of the maximum

[13]On September 11, 2018 Nasdaq Clearing declared the depletion of two-thirds of its mutual default fund after a single member's default wiped out the defaulting member's margin account and default fund contributions, as well as Nasdaq's junior capital. Nasdaq Clearing called on its members for contributions to replenish its mutual default fund (see: `https://newsclient.omxgroup.com/cdsPublic/viewDisclosure.action?disclosureId=855085`).

variation margin call per quarter is 50 times larger than the CCPs own capital and 7 times larger than the mutual default fund. Maximum variation margin calls in relation to the CCP's own pre-funded capital and the post haircut total default fund resources are plotted in Figures 3.9 and 3.10 respectively and show a persistent pattern with central bank CCPs having the lowest margin calls in relation to subsequent default resource layers. The densities depicted in Figures 3.11 and 3.12 show a low variance distribution for central bank owned CCPs and long right tails for exchange and hybrid owned CCPs respectively, again revealing large upper outliers. CCPs operated by central banks issue margin calls 3.6 times the size of their pre-funded capital as compared to 36.58 times by exchange owned CCPs (Table 3.9 Panel A) and about 11 percent of their mutual default size as compared to 99 percent by exchange owned CCPs (Table 3.9 Panel B). Those differences are statistically significant as shown by the test result in Table 3.10.

3.6.2 Ownership and Capital Adequacy

Part of the loss absorbing capacity of a CCP consists of the capital provided by the CCP itself. So far, there is no official mandatory capital requirement which might be comparable to the regulatory capital requirement as it is present in banking regulation. The relative size of the capital buffer compared to the other components of the loss absorbing capacity of a CCP also implies very different risk incentives as compared to the cases in banking and insurance (Cox and Steigerwald, 2017). Huang (2019) presents a model of central clearing and shows that more capital provided by the CCP is associated with a more prudent margin setting, as the collected margin elleviates the pressure on the capital to eventually cover losses of a failing member. In a cross section analysis Huang (2019) shows that a higher capital stock provided by the CCP beforehand is infact associated with a higher amount of required margins. The model also suggests a crowding-out effect of trades being novated by the increase of required margin. This effect may dis-incentivize central clearing and may push more derivatives to be traded bilaterally.

Privately operated CCPs may want to maximize profits by acquiring a larger volume of trades, which are being novated. If the risk of a potential loss may be kept relatively low, margins may also be set less prudently, putting the CCP's own capital at risk. One would therefore expect privately run CCPs to be equipped with less capital than their public counterparts. The sample mean of the notional amount that is covered by the CCP's capital is at 0.015 percent (Table 3.4). Figure 3.13 shows the evolution of the median share of the notional amount which is covered by the CCP's own capital. The plot reveals a persistent pattern, where the central bank owned CCPs provide more capital to the default waterfall relative to the notional amount that is covered by the CCP compared to non-central bank owned CCPs. The density depicted in Figure 3.14 shows similarly narrow distributions for hybrid and exchange owned CCPs and a large variance for central bank owned CCPs. The notional amount that is covered by the CCP's own capital is 0.04 percent for central bank owned CCPs and 0.01 percent for exchange owned CCPs (Table 3.11 Panel A), that is significantly 2.8 basis points more for central bank owned CCPs as compared to the other ownership types (Table 3.12 Column (2)).

In order to see the relative importance of the CCP's capital for the loss absorbing mechanism I plot the capital buffer size in terms of the initial margin held by the CCP in Figure 3.15. This plot reveals a stronger emphasis on the loss absorbing capital buffer for central bank owned CCPs as compared to the other types of the ownership model. The density depicted in Figure 3.16 shows a right shifted distribution for central bank owned CCPs. The sample mean is at 0.54 percent (Table 3.4), with 1.2 percent for central bank owned CCPs and 0.39 and 0.48 for hybrid and exchange owned CCPs, respectively (Table 3.11 Panel B). That is significantly larger by about 0.74 percentage points for central bank owned CCPs in each reporting quarter as compared to other ownership types (Table 3.12 Column (4)).

As the notional of a derivative contract only refers to the volume of the underlying commodity or security the contract is based on, the notional amount covered by the CCP does not disclose the amount of risk assumed by the CCP upon novation of the contract. In order to evaluate the adequacy of a CCP's default fund, we need to compare it with the value of novated contracts and the risk of loss associated with them. The CCPs' reports disclose this information, to be used as a default fund counterpart, in the form of the hypothetical capital calculation,[14] which is set by the

[14]The hypothetical capital (K_{CCP}) is based on the capital requirements for bank exposures to central counterparties, see BCBS (2014, p. 12).

BCBS at eight percent of the risk weighted loss given default:

$$\mathrm{K_{CCP}} = \sum_{\mathrm{CM}_i} \mathrm{EAD}_i \times \mathrm{RW} \times \text{capital ratio}. \tag{3.3}$$

Where EAD_i is the exposure amount at default (loss given default) of the CCP to clearing member CM_i. This includes the total value of collateral pledged by the clearing member at the CCP held against all genuine member and client contracts guaranteed by the clearing member. The minimum risk weight (RW) and capital ratio is preset by the Basel Committee on Banking Supervision (BCBS) at 20 percent and eight percent, respectively.

The total risk that might be covered by the capital buffer is estimated by the relative size of the capital buffer in terms of the CCP's own estimated exposure given default, which is only computable for exchange and hybrid owned CCPs due to data availability. Figure 3.17 shows $\mathrm{K_{CCP}}$ and reveals that the loss given default that is covered by the CCPs capital is well below the regulatory set eight percent for most of the time and only occasionally jumps above this value in Q4 2015 and Q2 2017 for exchange owned CCPs. The density depicted in Figure 3.18 shows a narrow distribution for hybrid owned CCPs and a high variance for exchange owned CCPs. The sample mean of the exposure covered by capital is at 8.6 percent with a median of only 2 percent, with exchange owned CCPs providing nearly ten percentage points more capital as compared to hybrid owned CCPs (Table 3.11 Panel C), which is also statistically significantly different (Table 3.12 Column (5)). The low values of capital render the segment of the default waterfall relatively unimportant.

3.6.3 Ownership and Default Loss Mutualization

In case of a member's default the loss absorbing waterfall consists of several layers combining partitions with defaulters pay and survivors pay principles. The relative size of these partitions defines the degree of mutualization. In the degree of mutualization lies the trade-off between containing the risk on an individual level versus providing an insurance mechanism to the surviving members against a default of the clearing house. The defaulting members' pay principle is resource efficient as the margins is proportionate to the risk and paid for by the risk taking entity. The surviving members pay principle incentivizes the CCP to set the initial margins prudently and the remaining members to monitor the CCP. The quasi bail-in clause gives the remaining parties the opportunity to prevent the CCPs default in case of a defaulting member's loss is running through multiple layers of loss protection. This part of the waterfall provides the insurance part of central clearing. This is not claiming that a CCP is taking on risk comparable to an insurance, also CCPs do not engage in risk pooling or diversification.

A theoretical approach to the optimal relationship of individual liability and the insurance of surviving members against the CCP's default resulting from an insolvent member expressed by the ratio of margins value to the pre-funded default fund is provided by Haene and Sturm (2009). An increase in the default fund relative to the initial margin creates adverse incentives to take on more counterparty risk reducing screening and monitoring, which raises the potential of a moral hazard problem.

The increase in the relative importance also increases the probability of the fund being retained to cover defaults from the perspective of the non-defaulting members. An increase in the relative importance of margins therefore decreases the likelihood and size of a potential loss to the default resources in case of a participant's default. To decrease the potential loss and the moral hazard problem, the ratio of the default fund to the value of required margins should be relatively low. It is unclear what the optimal ratio is as the insurance characteristics of the default fund provides a backstop against the assumed risk by the CCP and protects the surviving members against the CCP's default.

The default fund provides a backstop against the counterparty risk assumed by the CCP and sets apart the individual (defaulting member's resources and CCPs own capital) and the collective loss bearing part of the CCP's loss absorbing capacity. Haene and Sturm (2009) find that an established collective risk bearing resource is always optimal and may prevent a clearing house from insolvency if sufficiently large. A large backstop in form of default funds would therefore increase financial stability, even when taking the changes in risk incentives through mutualization into account.

The default fund contribution causes fixed costs for the clients and increasing the collective loss absorbing buffer increases the opportunity costs of the assets bound with the default fund. Offering central clearing participation at lower fixed costs attracts more customers for the CCP. So there is a trade-off between improved resilience against default by increasing the default fund and losing customers with the increasing fixed costs and therefore lower profitability. As there is no legal requirement in the relative compositions of the loss absorbing elements of the CCP's waterfall, European CCPs differ in their degree of mutualization.

In order to assess the degree of mutualization at the level of the CCP, I calculate the relative size of the CCP's default fund in terms of the initial margin pledged with the CCP. This is the actually pledged default fund contributions, disregarding committed but not yet pledged funds, over the aggregated initial margin account at the CCP level, both in post haircut terms. Higher values indicate a larger share of mutualized losses as compared to the individual liabilities in form of margins. The sample mean of the default fund size in terms of aggregated margin account is at 23.2 percent (Table 3.4). The mean coverage of a central bank owned CCP's default fund is 41.75 percent of the aggregated margin accounts held with that CCP, whereas the mean default fund size of a CCP held by an exchange or a CCP jointly held by the exchange and the CCP's members is as low as 23.55 and 14.34 percent of their aggregated margin accounts, respectively (Table 3.13).

The densities of default fund sizes separated by ownership model are plotted in Figure 3.19 revealing a similar distribution for non central bank run CCPs and a distribution shifted to the right for CCPs operated by a central bank. The mean difference in each reporting period is also statistically different with the default fund being 24.36 percentage point larger in terms of initial margin held for central bank owned CCPs as compared to other ownership types (Table 3.14 Column (2)). Figure 3.20 plots the evolution of the median default fund size in terms of initial margin held over time for the three ownership groups and shows a persistent pattern over time. The median privately run CCP operated at a lower level of risk mutualization, with the median exchange owned CCP just below the level of median hybrid owned CCP. This shows that central bank owned CCPs implement larger default funds in terms of initial margins held and therefore show the largest degree of mutualization.

In order to test for the differences in the relative size of the default fund between the ownership groups, I estimate equations 3.1 and 3.2 with $y_{i,t}$ as the ratio measuring the post haircut default fund size in terms of total initial margin held post haircut.

Regression results are listed in Table 3.14 and show that the default fund size in terms of initial margin differs between the ownership groups. CCPs owned by an exchange or in part by their users have a default fund size in terms of total initial post haircut margin which is 21.7 and 29.7 percentage points lower, respectively, as compared to those of CCPs operated by a central bank. The average central bank operated CCP has a default fund in terms of initial margin which is 24.4 percentage points higher as compared to other CCPs, revealing a relative emphasis on the mutualization of potentially occurring loss.

3.6.4 Ownership and Collateral Quality

A haircut, as used in central clearing, is the relative amount by which the value of an asset accepted as collateral is reduced due to its projected intrinsic value fluctuations. The CCP collects margins as collateral in order to cover part of the losses in the case of a client's default, an insurance against the credit risk it assumes. The client's variation margin payments adjust the margin account of a client and are directly passed on to the respective client of the other end of the trade and must therefore be paid in cash. The client's initial margin payment is the stock of the client's margin account, which is kept with the CCP and may therefore be settled with any security, which is accepted by the CCP. A list of securities which are accepted as collateral payments is provided by the CCP and typically public information. Securities are subject to changes in valuation or acceptance when used to cover potential losses and carry therefore a risk themselves. In order to account for that valuation risk the securities accepted as collateral will be offset at a discount. Similar to the collateral reflecting the risk associated with the trade initially perceived by the CCP, the haircut reflects the valuation risk associated with that collateral as perceived by the CCP.

The CCP decides on the haircut prior to offering novation of derivative contracts and respective margin setting and publishes the discounts together with the securities accepted as collateral as public information. Haircuts apply to the collateral pledged as initial margin at the time of novation of a derivative trade and are not adjusted throughout the duration of that contract. The same haircuts apply to every client of that CCP, so there is no discretion among clients and risks associated with a client are not taken into account in the haircuts applied to their collateral. Risks associated with the member are part of the margin setting itself (Capponi and Cheng, 2018). The haircut applied to a security is a function of the de-valuation or liquidity risk of the security pledged as collateral and therefore only reflects the quality of that security.

Newly implemented legal requirements of collateral in derivative transactions increase the demand for securities which may be pledged as collateral (Duffie et al., 2015). Levels and Capel, 2012 find that high quality collateral is expensive, of limited availability and likely to become even more scarce. Accepting low quality collateral may provide a way for CCPs to alleviate the pressure on clients to provide collateral for trades subject to novation. CCPs may increase the volume of novated contracts by broadening the range in quality of accepted securities as this may help the participants to provide the collateral needed to hand the trade over to the CCP. Lowering the minimum required quality of assets to be accepted as collateral may however decrease overall quality of the stock of initial margin, which serves as the first resource to be drawn from in case of a default. For the case of bank lending Gorton and Ordoñez (2014) show that lending on low quality collateral decreases financial stability and may result in a crisis triggered by collateral devaluation.

CCPs may help in decreasing the collateral demand in two ways. First, the collateral requirements on a single trade for centrally cleared derivative contracts are lower as compared to bilateral contracts (BCBS, 2015). Second, the netting applied at the aggregate level of derivative contracts on the client level allows to decrease the marginal collateral demand for an additional derivative contract novated by the same CCP (D'Errico and Roukny, 2017).

CCPs decide whether an asset or asset class is eligible as collateral and what haircut it applies to the accepted assets. The risk that is associated with an asset eligible as collateral that needs to be covered by the haircut is judged by the CCP alone. The haircut may reflect the intrinsic valuation risk of an asset as well as any error made when estimating this risk. A low haircut may therefore speak in favor of high quality assets in the margin accounts of a CCP or an underestimation of the asset valuation risk by the CCP. The aggregate haircut applied to collateral assets additionally depends on the member structure providing the assets. The aggregate haircut is an indicator for the average quality of the stock of collateral in the margin account as perceived by the CCP.

In order to assess the collateral quality at the CCP level, I calculate the average haircut applied to the aggregate initial margin pledged by the clients with the CCP. The average haircut applied to assets accepted as collateral is 3.7 percent (Table 3.4), whereas central bank owned CCPs applied on average 1.9 percent haircut on the collected initial margin, exchange owned CCPs on average applied 4 percent and hybrid owned CCPs applied 3.96 percent (Table 3.15 Panel A). This pattern is confirmed by the group specific densities of the applied haircuts, which are depicted in Figure 3.21 showing relatively similar distributions for privately owned CCPs and a distribution which is shifted to the left for the central bank owned CCPs. The difference in applied haircuts between the ownership types is also statistically significant with a difference of 2 percentage points between central bank owned CCPs and others (Table 3.16 Column (2)). The time series group specific means are depicted in Figure 3.22 and show that non central bank owned CCPs consistently apply higher haircuts to the collateral accepted as initial margin as compared to their privately owned counterparts.

The same pattern applies, when looking at the haircut applied to the assets held with the default fund. Figure 3.23 plots the evolution of the haircut applied on average to the assets held as part of the default fund. While central bank owned CCPs apply the lowest haircut on average, exchange owned CCPs apply the highest haircut on assets held as default fund. Except for a large spike in the second and third quarter mid 2016 for the CCPs operated under a hybrid ownership, these figures remain largely stable, giving rise to a persistent pattern over time. The groups specific density of the haircut applied to default fund depicted in Figure 3.24 reveals a distribution for the hybrid owned CCPs which is shifted to the right compared to the central bank owned CCPs' distribution with a higher variance and an increased kurtosis for the exchanged owned CCPs. The average haircut applied to default fund assets is two percent (Table 3.4), whereas central bank owned CCPs only apply a haircut of 0.66 percent on average as compared to 1.65 and 2.19 percent for hybrid and exchange owned CCPs, respectively. The difference is also statistically significant with central bank owned CCPs applying 1.44 percent less haircut on default fund assets as compared to other ownership types (Table 3.16 Column (4)).

When considering the behavior of central bank owned CCPs in terms of margins setting and capital provision, it seems likely that central bank owned CCPs act more prudently compared to their for-profit counterparts. A low average haircut applied to margin and default fund collateral may unlikely be the result of underestimating the asset valuation risk, instead of the preferred acceptance of high quality assets. The observation remains that the asset quality as measured by the applied haircut and therefore as perceived by the CCP is structurally different between central bank owned and non-central bank owned CCPs.

3.7 Conclusion

Central clearing of standardized derivative contracts through CCPs in the European Union became mandatory in 2016 as a result of their contagious property in the unfold of the financial crisis beginning 2007. This regulatory effort was set in place to increase market transparency and decrease distributed risk of transferring distress between financial institutions. The outcome of this regulation is a network of a small number of clearing houses concentrating derivative exposure, with the strong incentive to increase market share, possibly jeopardizing the soundness of the European financial system. Further, the ownership structure of CCPs might influence their risk taking behavior (BIS, 2010). This paper takes this concern into account and analyzes differences in the composition of default resources of European central clearing counterparties with respect to collateral, capital and default fund buffers across ownership types. To this end, I collect individually reported regulatory data and compile a new panel data set.

This paper shows that the composition of default loss absorbing resources of CCPs differs significantly and persistently across ownership models. Central bank owned CCPs have a larger share of the novated trades' notional amount covered by initial margin and own pre-funded capital, which results in lower share of potential losses caused by a defaulting member that need to be covered by the surviving members and decreases the possibility of a CCP's default. CCPs owned by an exchange or in part by its members call for higher variation margin relative to initial margin and subsequent layers of the default waterfall. This results in a higher burden on the members' liquidity and increases the probability that subsequent layers of the default waterfall need to be mobilized if a member defaults as a result of the inability to comply with a margin call. I further find that central bank owned CCPs show an increased emphasis on loss mutualization, with larger mutual default funds relative to the initial margin required from clearing members. I finally show that CCPs owned by exchanges or in part by their clearing members apply higher haircuts on the assets accepted as initial margin and default fund contributions, which is an indicator for lower asset quality of default resources.

These findings give rise to the interpretation that the composition of default resources might be subject to misaligned incentives in the provision of clearing services between the regulatory and individual for-profit perspective. Central banks operating a CCP incorporate the policy objective of financial stability of the central clearing reform, while exchanges and members might be guided by the incentive to maximize the monetary benefits from clearing, that is in potential conflict. The main policy implication which may be drawn from the results is that the ownership of central clearing entities could be regulated to incorporate the incentives to be aligned with the goals of the clearing reform. A mandatory ownership in part by members, a central bank or similar regulatory agency might do the concentration of risk more justice. The provision of the public good of financial stability by for profit clearing entities may need to be reconsidered by policy makers.

A possible explanation as for why the default resource composition differs systematically across the ownership types might be the differences in the incentives to alter the default resource structure when faced with market competition. The competitive environment in the central clearing market may amplify the risk taking incentives shaped by the ownership structure. With an increased likelihood of the members to chose another CCP over margin setting, the more a CCP is forced to drive down margins in order to maintain its market share. This increases the uncovered share of the derivative trades and thereby the likelihood of the CCP to bear losses with the subsequent parts of the waterfall or even to default on the losses. In similar analyses of governance and competition, Broecker (1990) finds decreasing lending standards with increasing interbank competition and Santos and Scheinkman (2001) set up a model of exchange competition and find a suboptimal margin requirement in a competitive equilibrium.

The question whether these findings are the result of the incentives created by the competitive environment working through the ownership structure of CCPs is subject to further research. The entry of foreign CCPs authorized by ESMA (2018c) may serve as an exogenous shock to be studied in a Difference-in-Difference setting, with the ownership groups selecting the CCPs into treatment and control group in order to test for the causal effect of competition on the composition of loss absorbing resources. A differential effect of competition depending on the ownership type of CCPs would further point into the direction of misaligned incentives in the implementation of the European central clearing reform. A competition induced race to the bottom of collateral requirement and quality in central clearing in conjunction with the pivotal importance of CCPs counteracts the policy goals of the central clearing reform in the European Union.

Tables and Figures

CCP	Country	National Competent Authority	Date of Initial Authorization
CCP Austria Abwicklungsstelle für Börsengeschäfte GmbH (CCP.A)	Austria	Austrian Financial Market Authority (FMA)	August 14, 2014
Athens Exchange Clearing House (Athex Clear)	Greece	Hellenic Capital Market Commission	January 22, 2015
European Central Counterparty N.V.	Netherlands	De Nederlandsche Bank (DNB)	April 1, 2014
LCH SA	France	Autorité de Contrôle Prudentiel et de Résolution (ACPR)	May 22, 2014
Eurex Clearing AG	Germany	Bundesanstalt für Finanzdienstleistungs aufsicht (Bafin)	April 10, 2014
European Commodity Clearing	Germany	Bundesanstalt für Finanzdienstleistungs aufsicht (Bafin)	June 11, 2014
Keler CCP	Hungary	Central Bank of Hungary (MNB)	July 4, 2014
Cassa di Compensazione e Garanzia S.p.A. (CCG)	Italy	Banca d'Italia	May 20, 2014
ICE Clear Netherlands B.V.1	Netherlands	De Nederlandsche Bank (DNB)	December 12, 2014
KDPW CCP	Poland	Komisja Nadzoru Finansowego (KNF)	April 8, 2014
OMIClear - C.C., S.A.	Portugal	Comissão do Mercado de Valores Mobiliários (CMVM)	October 31, 2014
BME Clearing	Spain	Comisión Nacional del Mercado de Valores (CNMV)	September 16, 2014
Nasdaq OMX Clearing AB	Sweden	Finansinspektionen	March 18, 2014
LCH Ltd	United Kingdom	Bank of England	June 12, 2014
CME Clearing Europe Ltd	United Kingdom	Bank of England	August 4, 2014
LME Clear Ltd	United Kingdom	Bank of England	September 3, 2014
ICE Clear Europe Limited (ICE Clear Europe)	United Kingdom	Bank of England	September 19, 2016

TABLE 3.1: **Countries and Competent Authorities of European CCPs:** This table lists the 17 European CCPs authorized under EMIR, the respective countries of the CCP's headquarters, the national competent authorities in charge of the CCPs oversight as well as the date of initial authorization to operate as a CCP under EMIR. Source: ESMA (2018b).

Name	2015q2	2015q3	2015q4	2016q1	2016q2	2016q3	2016q4	2017q1	2017q2	2017q3	2017q4	2018q1
CCP Austria	n/a	n/a	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
BME Clearing S.A.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
CC&G	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
CME Clearing Europe Ltd	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	ceased	ceased	ceased	ceased
Eurex Clearing AG	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
European Central Counterparty N.V.	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
ICE Clear Europe	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
ICE Clear Netherlands B.V.	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
KDPW CCP	n/a	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
Keler CCP	n/a	n/a	n/a	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
LCH.Clearnet Ltd	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
LCH.Clearnet S.A.	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
LME Clear Ltd	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
Nasdaq OMX Clearing AB	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
OMIClear - C.C., S.A.	n/a	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.	avail.
Athex Clear	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	avail.
European Commodity Clearing	n/a	n/a	n/a	n/a	n/a	avail.	avail.	avail.	avail.	avail.	pdf	pdf

TABLE 3.2: **Availability of CPMI-IOSCO Quantitative Disclosures by CCP**: This table lists the available CPMI-IOSCO quantitative disclosure data for each CCP by quarter. Data availability is indicated by the green marked *avail.*, red marked *n/a* quarters are not available and yellow market *ceased* fields mark quarters in which the respective CCP reported no clearing activity.

Name	**Link to Public Quantative Disclosure**
CCP Austria	https://www.ccpa.at/en/cpmi-iosco/
BME Clearing S.A.	http://www.bmeclearing.es/ing/Resources/CPMI-IOSCO.aspx
CC&G (Cassa di Compensazione e Garanzia S.p.A.)	http://www.lseg.com/markets-products-and-services/post-trade-services/ccp-services/ccg/statistics/iosco-quantitative-disclosure
CME Clearing Europe	http://www.cmegroup.com/europe/clearing/cpmi-iosco-reporting.html
Eurex Clearing	http://www.eurexclearing.com/clearing-en/about-us/regulatory-standards
EuroCCP	https://euroccp.com/download/other
ICE Clear Europe	https://www.theice.com/clear-europe/regulation#quantitative-disclosures
ICEClearNetherlands	https://www.theice.com/clear-netherlands/regulation#quantitative-disclosures
KDPW_CCP	http://www.kdpwccp.pl/en/Members/Transparency/Pages/Terms_of_Use.aspx
Keler CCP	https://english.kelerkszf.hu/Key%20documents/CPMI%20IOSCO%20Disclosures/
LCH.Clearnet Ltd	http://www.lch.com/rules-regulations/cpmi-iosco
LCH.Clearnet S.A.	http://www.lch.com/rules-regulations/cpmi-iosco
LCH.Clearnet LLC	http://www.lch.com/rules-regulations/cpmi-iosco
LME Clear	https://www.lme.com/LME-Clear/Technology/Reports/CPMI-IOSCO-Disclosure
Nasdaq Clearing	http://www.nasdaqomx.com/transactions/posttrade/clearing/europeanclearing
OMIClear	http://www.omiclear.pt/Downloads/tabid/170/language/en-GB/Default.aspx
Six x-clear	http://www.six-securities-services.com/en/home/regulatory-affairs/regulatory-publications/consultation-responses.html
Takasbank	http://www.takasbank.com.tr/en/Pages/MKT.aspx
AthexClear	http://www.helex.gr/web/guest/regulated-publication
ECC	https://www.ecc.de/ecc-en/about-ecc/company/reports

TABLE 3.3: **Data Sources**: This table lists the sources from which the CPMI-IOSCO quantitative disclosures have been available.

Variable	**N**	**Mean**	**SD**	**Med.**	**Min.**	**Max.**
Avg. VM/IM	135	2.005	1.918	1.310	0.000	10.804
Notional covered by IM	101	0.498	0.608	0.191	0.000	3.058
Max. VM/IM	135	7.263	6.906	5.036	0.001	55.129
Max. VM/capital	140	38.316	50.073	17.598	0.001	311.757
Max. VM/default fund	129	0.837	1.083	0.402	0.000	7.147
Notional covered by capital	116	0.015	0.053	0.001	0.000	0.509
Capital/IM	150	0.537	0.540	0.285	0.044	2.759
EAD covered by Capital	99	8.617	15.347	1.990	0.059	81.764
Mutualization	149	23.216	40.962	13.289	2.855	361.969
Haircut on margin	132	3.737	1.957	3.604	0.237	9.811
Haircut on default fund	96	1.973	1.606	1.507	0.141	6.814

TABLE 3.4: **Summary Statistics:** This table lists the summary statistics of the variables used to compare the default resources composition between ownership types of CCPs. VM stands for variation margin, IM for initial margin and EAD is the exposure amount at default (expected loss given default). The relative size of maximum variation margin in terms of capital (Max. VM/capital) buffer and default fund size (Max. VM/default fund) are given as ratios, while all other measures are listed in percentage terms. All measures are given in post haircut terms when applicable. Mutualization is the amount of the initial margin held in relation to the size of the deafult fund. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018.

CCP	Ownership Model	Share in CCP	Owner of CCP	Ownership of CCP's Owner
CCP Austria	Exchange- and bank-owned	50%	Oesterreichische Kontrollbank AG	privately held (by commercial banks)
		50%	Wiener Börse AG	CEESEG AG
BME Clearing S.A.	Under the same ownership as an exchange	100%	Bolsas y Mercados Espanoles (BME) Group	publicly listed
CC&G (Cassa di Compensazione e Garanzia S.p.A.)	Under the same ownership as an exchange	100%	Borsa Italiana S.p.A.	London Stock Exchange Group
CME Clearing Europe Ltd	Under the same ownership as an exchange	100%	CME Group	publicly listed
Eurex Clearing AG	Under the same ownership as an exchange	100%	Eurex Frankfurt AG	Deutsche Börse Group
European Central Counterparty N.V.	User- and exchange-owned	25%	ABN AMRO Clearing Investments B.V.	ABN AMRO Clearing Bank N.V
		25%	Bats Trading Limited	Bats Trading, Inc.
		25%	DTCC Global Holdings B.V.	
		25%	Nasdaq Nordic Ltd.	Nasdaq, Inc.
ICE Clear Europe	Under the same ownership as an exchange	100%	Intercontinental Exchange, Inc.	publicly listed
ICE Clear Netherlands B.V.	Under the same ownership as an exchange	75%	Intercontinental Exchange, Inc.	publicly listed
		25%	ABN AMRO Clearing Bank N.V.	ABN AMRO Group N.V.
KDPW_CCP	Exchange- and central bank-owned	100%	KDPW S.A. (the CSD of Poland)	State Treasury Warsaw Stock Exchange National Bank of Poland
Keler CCP	Exchange- and central bank-owned	99,72%	KELER Ltd	National Bank of Hungary Budapest Stock Exchange Ltd
		0,15%	National Bank of Hungary	
		0,13%	Budapest Stock Exchange Ltd	National Bank of Hungary
LCH.Clearnet Ltd	User- and exchange-owned	100%	LCH.Clearnet Group Limited	London Stock Exchange Group Clearing Members
LCH.Clearnet S.A.	User- and exchange-owned	100%	LCH.Clearnet Group Limited	London Stock Exchange Group Clearing Members
LME Clear Ltd	Under the same ownership as an exchange	100%	HKEX Investment (UK) Limited	Hong Kong Exchanges and Clearing Limited (HKEX)
Nasdaq OMX Clearing AB	Under the same ownership as an exchange	100%	Nasdaq Nordic Ltd.	Nasdaq, Inc.
OMIClear - C.C., S.A.	Exchange-owned	50%	OMIP (Polo Portugues) S.G.M.R., S.A.	OMEL (Operador del mercado Iberico de Energia) Polo Espanol, S.A. OMIP (Operador do mercado Iberico (Portugal)) SGPS, S.A.
		50%	OMI (Polo Espanol), S.A.	OMEL (Operador del mercado Iberico de Energia) Polo Espanol, S.A. OMIP (Operador do mercado Iberico (Portugal)) SGPS, S.A.
Athex Clear	Exchange-owned	100%	Hellenic Exchanges-Athens Stock Exchange S.A.	publicly listed
European Commodity Clearing	Exchange-owned	100%	European Energy Exchange AG	Deutsche Börse Group

TABLE 3.5: **Ownership Structure of European Central Clearing Counterparties**: This table lists the owners of European CCPs as of 2017. Most CCPs are privately held by their linked exchanges and banks.

Ownership Model	CCP	Ownership Details
Centralbank owned	KDPW CCP	Exchange- and central bank-owned
	Keler CCP	Exchange- and central bank-owned
Exchange owned	BME Clearing S.A.	Under the same ownership as an exchange
	CC&G	Under the same ownership as an exchange
	CME Clearing Europe	Under the same ownership as an exchange
	Eurex Clearing	Under the same ownership as an exchange
	ICE Clear Europe	Under the same ownership as an exchange
	ICE Clear Europe F&O	Under the same ownership as an exchange
	ICE Clear Netherlands	Under the same ownership as an exchange
	LME Clear	Under the same ownership as an exchange
	Nasdaq Clearing	Under the same ownership as an exchange
	OMI Clear	Exchange-owned
Hybrid	CCP Austria	Exchange- and bank-owned
	Euro CCP	User- and exchange-owned
	LCH Clearnet Ltd.	User- and exchange-owned
	LCH Clearnet S.A.	User- and exchange-owned

TABLE 3.6: **Groups of CCPs by Ownership Model:** This table lists the CCPs classified by the ownership models for the analysis. Central bank owned CCPs are classified as such because the exchange holding shares in the CCP is also held by the central bank and therefore the CCP is ultimately owned by the respective central bank.

	A: Avg. VM/IM							
Ownership model	**N**	**Min.**	**Q$_{.25}$**	**Mean**	**Med.**	**Q$_{.75}$**	**Max.**	**SD**
hybrid	22	0.79	0.98	1.83	1.63	2.58	3.58	0.93
exchange owned	95	0.00	1.08	2.22	1.36	2.43	10.80	2.20
centralbank owned	18	0.52	0.91	1.09	1.09	1.33	1.68	0.29
	B: Max. VM/IM							
Ownership model	**N**	**Min.**	**Q$_{.25}$**	**Mean**	**Med.**	**Q$_{.75}$**	**Max.**	**SD**
hybrid	22	2.68	3.80	6.02	5.18	7.33	12.91	2.98
exchange owned	95	0.00	3.93	8.15	5.48	9.34	55.13	7.92
centralbank owned	18	2.65	3.12	4.10	3.99	4.49	6.39	1.17
	C: Notional covered by IM							
Ownership model	**N**	**Min.**	**Q$_{.25}$**	**Mean**	**Med.**	**Q$_{.75}$**	**Max.**	**SD**
hybrid	29	0.06	0.08	0.13	0.12	0.15	0.30	0.06
exchange owned	56	0.00	0.16	0.46	0.20	0.70	1.94	0.47
centralbank owned	16	0.43	0.63	1.30	1.12	1.72	3.06	0.82

TABLE 3.7: **Relative Size of Initial Margin by Ownership Model:** This table lists the average variation margin (panel A) and maximum variation margin (panel B) demanded by the CCP in each quarter as share of the total initial margin held after applying the respective haircut (post haircut) in percent on average for each ownership model group over the whole sample period 2015q2 up until 2018q1.

	(1)	(2)	(3)	(4)	(5)	(6)
D_{exchange}	1.169***		3.675***		−0.828***	
	(0.002)		(0.000)		(0.000)	
D_{hybrid}	0.754***		1.488***		−1.147***	
	(0.004)		(0.000)		(0.000)	
$D_{\text{central bank}}$		−1.089**		−3.256**		0.937**
		(0.023)		(0.037)		(0.019)
Constant	0.084	1.253***	1.225***	4.899***	1.200***	0.282*
	(0.254)	(0.000)	(0.001)	(0.000)	(0.001)	(0.087)
Adjusted R^2	0.060	0.053	0.103	0.090	0.410	0.357
Observations	135	135	135	135	101	101
δ_t	yes	yes	yes	yes	yes	yes
μ_y	2.005	2.005	7.263	7.263	0.498	0.498
σ_y	1.918	1.918	6.906	6.906	0.608	0.608
$\hat{y}^{\min}$	0.084	0.164	1.225	1.643	0.026	0.227
$\hat{y}^{\max}$	2.886	2.803	12.127	11.692	1.459	1.461

p-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3.8: **Mean Difference Tests for the Relative Size of Initial Margin:** This table reports the pooled cross-section estimation results from the regression defined in Equation 3.1 for the columns (1), (3) and (5), as well as in Equation 3.2 for the columns (2), (4) and (6). The dependent variable $y_{i,t}$ in the first two columns is the average variation margin call relative to total initial margin held in post haircut terms. Column (3) and (4) present the mean difference for the maximum variation margin relative to initial margin, columns (5) and (6) list the results for the notional amount covered by initial margin. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018. The explanatory variables D_{exchange}, D_{hybrid} and $D_{\text{central bank}}$ are a binary variables, which take the value of one for CCPs owned by an exchange or in part by users or by a central bank, respectively and zero otherwise. The model additionally includes quarterly time dummies represented as δ_t in Equations 3.1 and 3.2. Standard errors are clustered within the ownership groups.

	A: Max. VM/capital							
Ownership model	**N**	**Min.**	**Q$_{.25}$**	**Mean**	**Med.**	**Q$_{.75}$**	**Max.**	**SD**
hybrid	22	15.42	19.39	74.58	73.69	111.29	206.92	57.60
exchange owned	100	0.00	7.43	36.58	18.12	45.67	311.76	47.98
centralbank owned	18	1.61	2.30	3.64	3.83	4.66	6.48	1.37
	B: Max. VM/default fund							
Ownership model	**N**	**Min.**	**Q$_{.25}$**	**Mean**	**Med.**	**Q$_{.75}$**	**Max.**	**SD**
hybrid	22	0.15	0.29	0.83	0.77	1.17	2.64	0.68
exchange owned	89	0.00	0.23	0.99	0.48	1.40	7.15	1.21
centralbank owned	18	0.03	0.08	0.11	0.10	0.12	0.22	0.04

TABLE 3.9: **Maximum Variation Margin Size in Relation to Subsequent Default Resources:** This table lists the summary statistics of the maximum variation margin calls in relation to subsequent default resources by ownership model.

	(1)	(2)	(3)	(4)
D_{exchange}	0.794***		29.686***	
	(0.000)		(0.000)	
D_{hybrid}	0.661***		68.470***	
	(0.000)		(0.000)	
$D_{\text{central bank}}$		−0.767***		−36.919*
		(0.003)		(0.077)
Constant	0.922***	1.716***	22.674***	52.360***
	(0.000)	(0.000)	(0.000)	(0.000)
Adjusted R^2	0.156	0.154	0.185	0.107
Observations	129	129	140	140
δ_t	yes	yes	yes	yes
μ_y	0.837	0.837	38.316	38.316
σ_y	1.083	1.083	50.073	50.073
$\hat{y}^{\min}$	0.197	0.196	−4.717	−5.377
$\hat{y}^{\max}$	1.716	1.716	93.063	60.802

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3.10: **Mean Difference Tests for the Relative Size of Variation Margin Calls:** This table reports the pooled cross-section estimation results from the regression defined in Equation 3.1 for column (1) and (3) and in Equation 3.2 for column (2) and (4). The dependent variable $y_{i,t}$ in the first two columns is the maximum variation margin call relative to total default fund size in post haircut terms. The latter two columns list the result for the mean difference test of the maximum variation margin call relative to the CCP's own pre-funded capital. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018. The explanatory variables D_{exchange}, D_{hybrid} and $D_{\text{central bank}}$ are a binary variables, which take the value of one for CCPs owned by an exchange or in part by users or by a central bank, respectively and zero otherwise. The model additionally includes quarterly time dummies represented as δ_t in Equations 3.1 and 3.2. Standard errors are clustered within the ownership groups.

	A: Notional covered by capital							
Ownership model	**N**	**Min.**	$\mathbf{Q}_{.25}$	**Mean**	**Med.**	$\mathbf{Q}_{.75}$	**Max.**	**SD**
hybrid	30	0.00	0.00	0.00	0.00	0.01	0.01	0.01
exchange owned	70	0.00	0.00	0.01	0.00	0.00	0.51	0.06
centralbank owned	16	0.01	0.01	0.04	0.01	0.08	0.11	0.04
	B: Capital/IM							
Ownership model	**N**	**Min.**	$\mathbf{Q}_{.25}$	**Mean**	**Med.**	$\mathbf{Q}_{.75}$	**Max.**	**SD**
hybrid	41	0.05	0.08	0.39	0.21	0.49	1.22	0.39
exchange owned	91	0.04	0.23	0.48	0.26	0.46	2.76	0.55
centralbank owned	18	0.86	0.99	1.19	1.19	1.28	1.64	0.23
	C: EAD covered by Capital							
Ownership model	**N**	**Min.**	$\mathbf{Q}_{.25}$	**Mean**	**Med.**	$\mathbf{Q}_{.75}$	**Max.**	**SD**
hybrid	22	0.06	0.09	1.14	0.47	2.26	3.34	1.25
exchange owned	77	0.29	1.39	10.75	2.31	14.64	81.76	16.81

TABLE 3.11: **Relative Amount of Pre-funded Capital by Ownership Model:** This table lists the average variation margin (panel A) and maximum variation margin (panel B) demanded by the CCP in each quarter as share of the total initial margin held after applying the respective haircut (post haircut) in percent on average for each ownership model group over the whole sample period 2015q2 up until 2018q1.

	(1)	(2)	(3)	(4)	(5)
$D_{exchange}$	-0.025^{***}		-0.710^{***}		9.555^{***}
	(0.004)		(0.000)		(0.001)
D_{hybrid}	-0.035^{***}		-0.802^{***}		
	(0.002)		(0.000)		
$D_{central\ bank}$		0.028^{***}		0.740^{***}	
		(0.009)		(0.001)	
Constant	0.028^{***}	0.001^{**}	0.804^{***}	0.094^{***}	-1.355
	(0.001)	(0.038)	(0.000)	(0.000)	(0.496)
Adjusted R^2	0.100	0.094	0.210	0.204	0.107
Observations	116	116	150	150	99
δ_t	yes	yes	yes	yes	yes
μ_y	0.015	0.015	0.537	0.537	8.617
σ_y	0.053	0.053	0.540	0.540	15.347
$\hat{y}^{min}$	0.007	0.001	0.094	0.094	-4.86
$\hat{y}^{max}$	0.076	0.076	1.229	1.233	15.34

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3.12: **Mean Difference Tests for the Relative Size of the Capital Buffer:** This table reports the pooled cross-section estimation results from the regression defined in Equation 3.1 for the columns (1), (3) and (5), as well as in Equation 3.2 for the columns (2), (4) and (6). The dependent variable $y_{i,t}$ in the first two columns is the notional amount covered by the CCP's own pre-funded capital. Column (3) and (4) present the mean difference for the relative size of the capital buffer in terms of the total initial margin held in post haircut terms, columns (5) and (6) list the results for the expected loss given default (total replacement costs) that covered by the CCP's own pre-funded capital. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018. The explanatory variables $D_{exchange}$, D_{hybrid} and $D_{central\ bank}$ are a binary variables, which take the value of one for CCPs owned by an exchange or in part by users or by a central bank, respectively and zero otherwise. The model additionally includes quarterly time dummies represented as δ_t in Equations 3.1 and 3.2. Standard errors are clustered within the ownership groups.

Ownership model	**N**	**Min.**	$\mathbf{Q_{.25}}$	**Mean**	**Med.**	$\mathbf{Q_{.75}}$	**Max.**	**SD**
hybrid	41	4.90	6.90	14.34	13.59	19.07	28.18	6.81
exchange owned	90	2.85	6.17	23.55	8.03	17.43	361.97	51.30
centralbank owned	18	25.89	31.64	41.75	39.99	46.86	80.16	12.97

TABLE 3.13: **Mutualization by Ownership Model:** This table lists the summary statistics of the relative sizes of the members' actual default fund contributions and the initial margin pledged with the CCP, both in post haircut terms.

	(1)	(2)
D_{exchange}	-21.710^{***}	
	(0.007)	
D_{hybrid}	-29.674^{***}	
	(0.001)	
$D_{\text{central bank}}$		24.354^{***}
		(0.004)
Constant	24.565^{***}	2.855^{***}
	(0.005)	(0.000)
Adjusted R^2	0.095	0.087
Observations	149	149
δ_t	yes	yes
μ_y	23.216	23.216
σ_y	40.962	40.962
$\hat{y}^{\min}$	2.855	2.855
$\hat{y}^{\max}$	65.957	67.153

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3.14: **Mean Difference Tests for the Mutualization:** This table reports the pooled cross-section estimation results from the regression defined in Equation 3.1 in column (1), as well as in Equation 3.2 for column (2). The dependent variable $y_{i,t}$ is the size of the mutual default fund relative to the initial margin held, both in post haircut terms. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018. The explanatory variables D_{exchange}, D_{hybrid} and $D_{\text{central bank}}$ are a binary variables, which take the value of one for CCPs owned by an exchange or in part by users or by a central bank, respectively and zero otherwise. The model additionally includes quarterly time dummies represented as δ_t in Equations 3.1 and 3.2. Standard errors are clustered within the ownership groups.

	A: Haircut on margin							
Ownership model	**N**	**Min.**	**$Q_{.25}$**	**Mean**	**Med.**	**$Q_{.75}$**	**Max.**	**SD**
hybrid	41	1.38	2.27	3.96	3.47	5.59	7.23	1.80
exchange owned	73	0.24	2.74	4.06	3.88	5.27	9.81	1.90
centralbank owned	18	0.32	0.77	1.90	0.92	3.69	4.60	1.53
	B: Haircut on default fund							
Ownership model	**N**	**Min.**	**$Q_{.25}$**	**Mean**	**Med.**	**$Q_{.75}$**	**Max.**	**SD**
hybrid	11	0.72	1.18	1.65	1.31	1.53	3.73	0.93
exchange owned	75	0.14	1.03	2.19	1.59	3.39	6.81	1.70
centralbank owned	10	0.39	0.49	0.66	0.75	0.78	0.95	0.20

TABLE 3.15: **Haircut by Ownership Model:** This table lists the summary statistics of the applied haircut by ownership model.

	(1)	(2)	(3)	(4)
D_{exchange}	2.107***		1.514***	
	(0.000)		(0.000)	
D_{hybrid}	2.030***		0.977***	
	(0.000)		(0.001)	
$D_{\text{central bank}}$		−2.078***		−1.444***
		(0.000)		(0.004)
Constant	3.383***	5.490***	1.136***	2.650***
	(0.000)	(0.000)	(0.000)	(0.000)
Adjusted R^2	0.161	0.161	0.101	0.090
Observations	132	132	96	96
δ_t	yes	yes	yes	yes
μ_y	3.737	3.737	1.973	1.973
σ_y	1.957	1.957	1.606	1.606
$\hat{y}^{\min}$	1.676	1.677	0.535	0.529
$\hat{y}^{\max}$	5.49	5.49	2.65	2.65

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3.16: **Mean Difference Tests for the Average Haircut Applied to Margin and Default Fund Assets:** This table reports the pooled cross-section estimation results from the regression defined in Equation 3.1 for column (1) and (3) and in Equation 3.2 for column (2) and (4). The dependent variable $y_{i,t}$ in the first two columns is the haircut applied to assets accepted as initial margin. The latter two columns list the result for the mean difference test of the haircut applied to assets accepted as default fund contributions. The sample is quarterly data on the CCP level for the time period beginning in the second quarter 2015 until the fourth quarter of 2018. The explanatory variables D_{exchange}, D_{hybrid} and $D_{\text{central bank}}$ are a binary variables, which take the value of one for CCPs owned by an exchange or in part by users or by a central bank, respectively and zero otherwise. The model additionally includes quarterly time dummies represented as δ_t in Equations 3.1 and 3.2. Standard errors are clustered within the ownership groups.

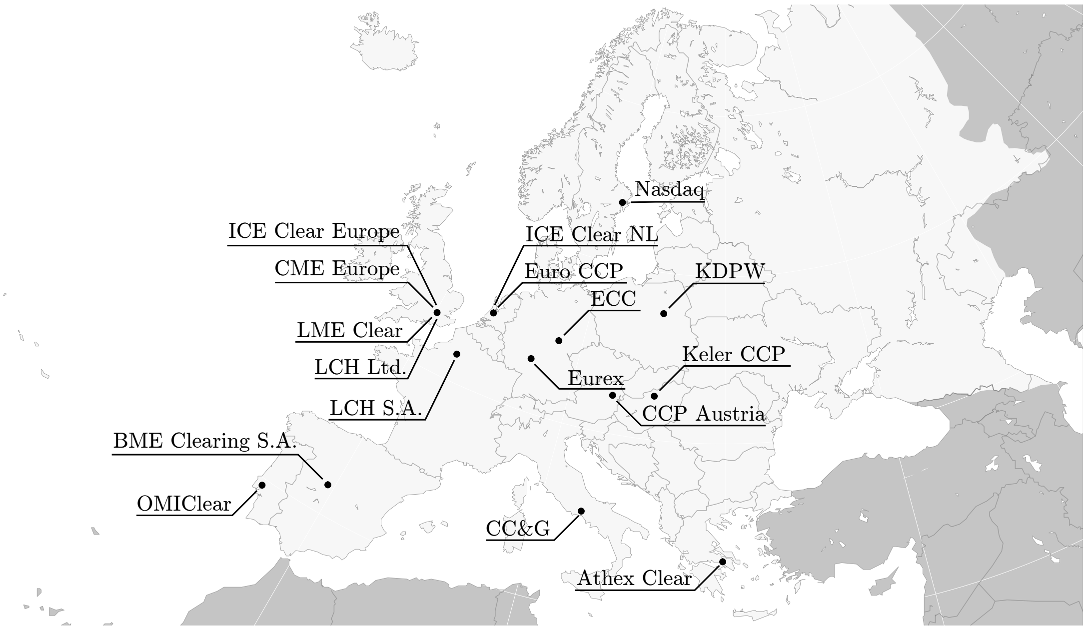

FIGURE 3.1: **Map of Authorized CCPs under EMIR:** This figure shows the location of headquarters of the 17 European CCPs authorized under EMIR. The underlying map of Europe is provided by `http://naturalearthdata.com/` as public domain. Positioning and labeling of the headquarters according to the hand collected data is my work.

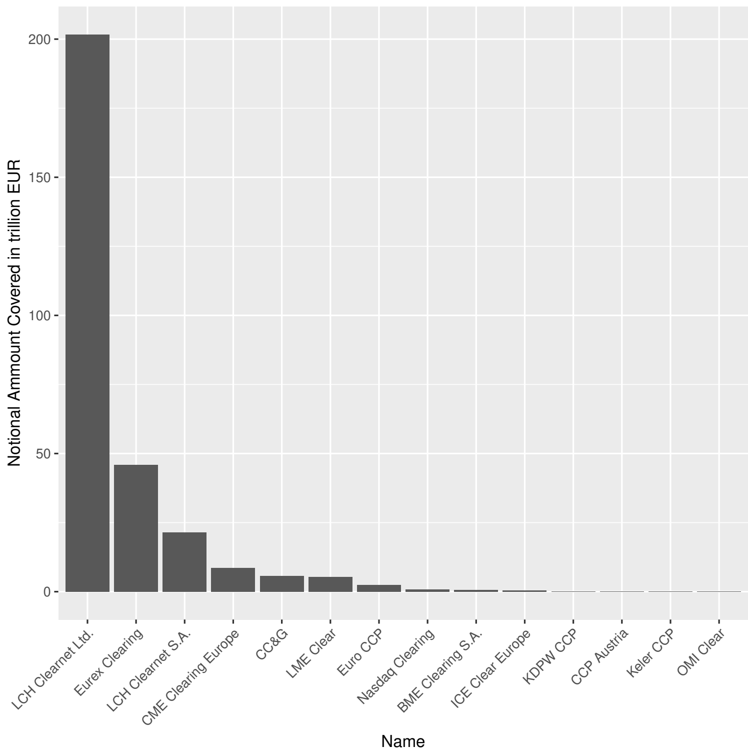

FIGURE 3.2: **Notional Amount Covered by CCPs:** This figure shows the notional amount covered of each European CCP as of Q3 2017.

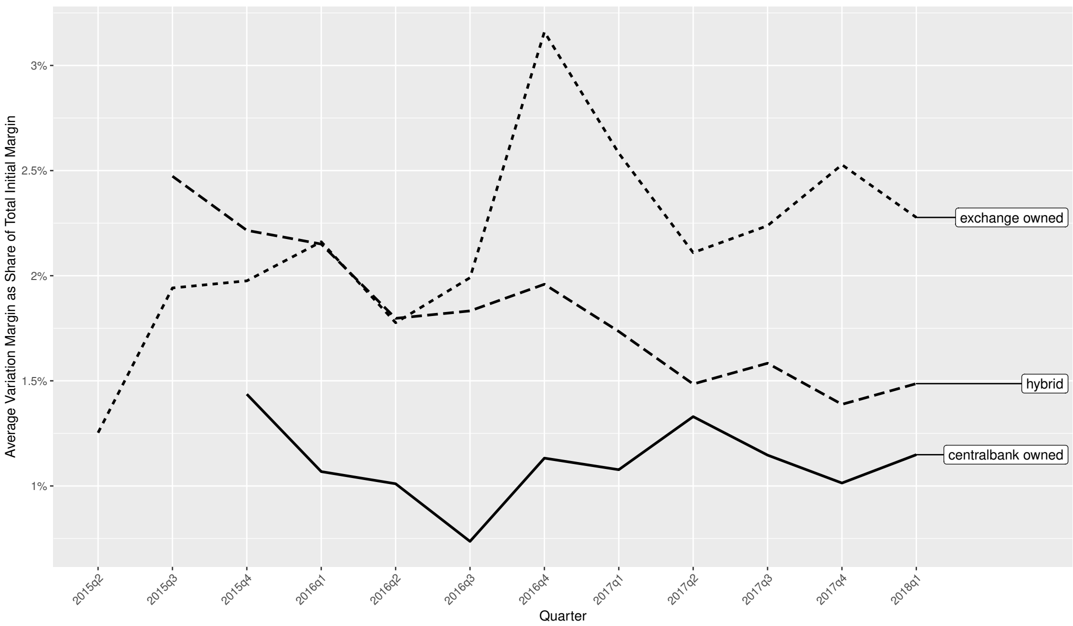

FIGURE 3.3: **Average Variation Margin as Share of Total Initial Margin Held by Ownership Type:** This figure depicts the evolution of the cross-sectional ownership group specific averages of the variation margin that is called for by the CCP vis-à-vis its clearing members in order to adjust the margin accounts of the parties associated with the trades affected by the re-evaluation. The variation margin is scaled by the total initial margin held at the end of each quarter after applying the respective haircut to the collateral (post haircut). The cross sectional distribution is depicted in Figure 3.4.

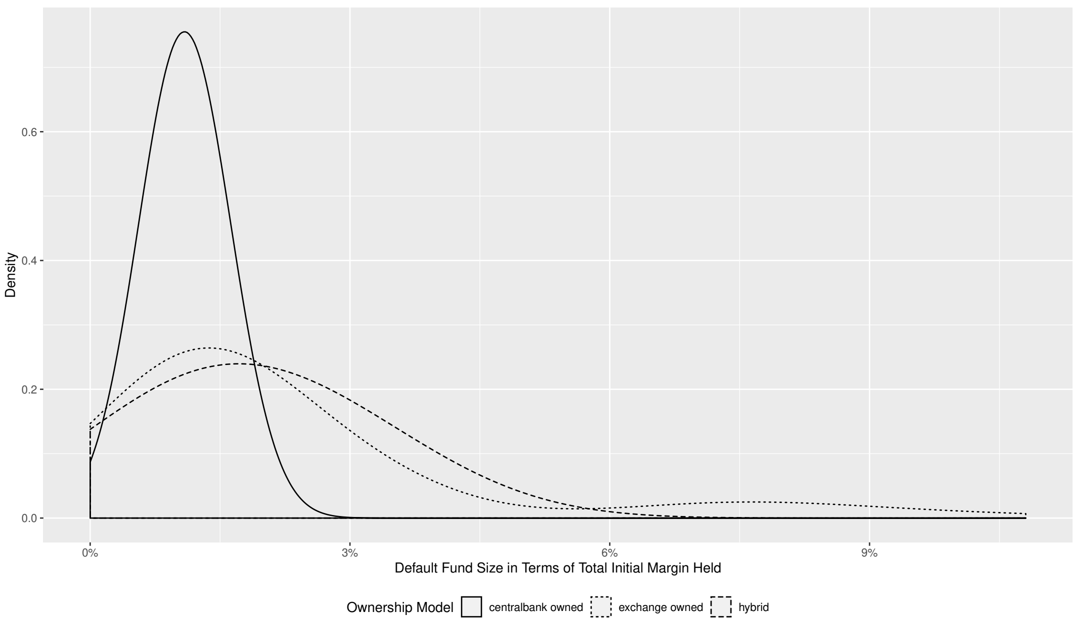

FIGURE 3.4: **Distribution of Average Variation Margin as Share of Total Initial Margin Held by Ownership Type:** This figure shows the distribution density of the average variation margin as share of total initial margin held by the CCPs in the respective ownership models.

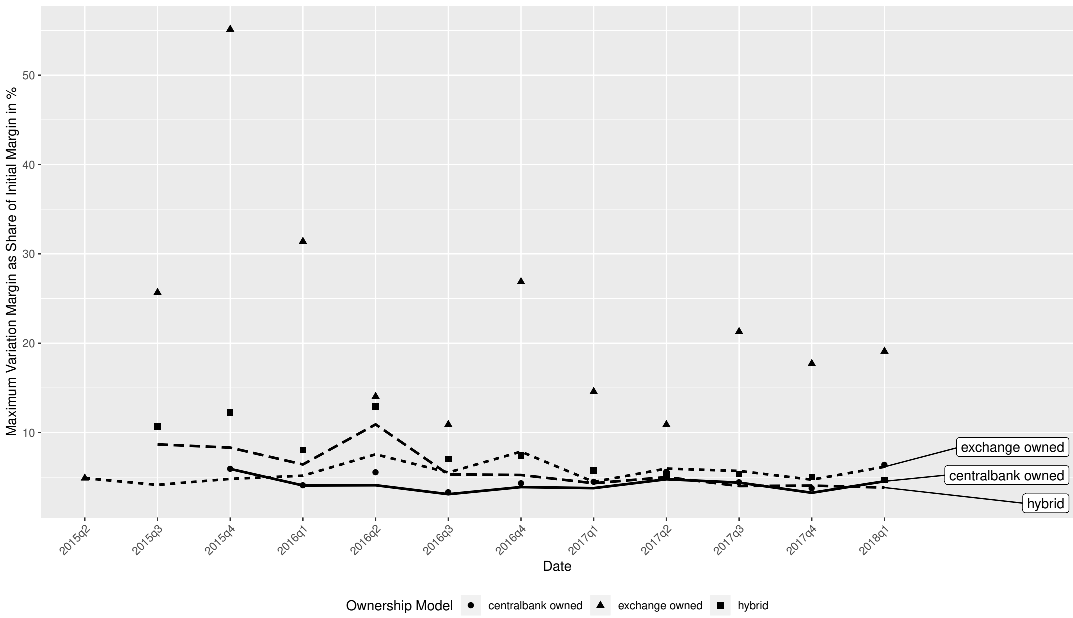

FIGURE 3.5: **Maximum Variation Margin as Share of Total Initial Margin Held by Ownership Type:** This figure depicts the evolution of the cross-sectional ownership group specific median of the quarterly maximum variation margin that is called for by the CCP vis-à-vis its clearing members in order to adjust the margin accounts of the parties associated with the trades affected by the re-evaluation. The variation margin is scaled by the total initial margin held at the end of each quarter after applying the respective haircut to the collateral (post haircut). The solid line represents the group specific median and the symbols mark the group specific maximum. The cross sectional distribution is depicted in Figure 3.6.

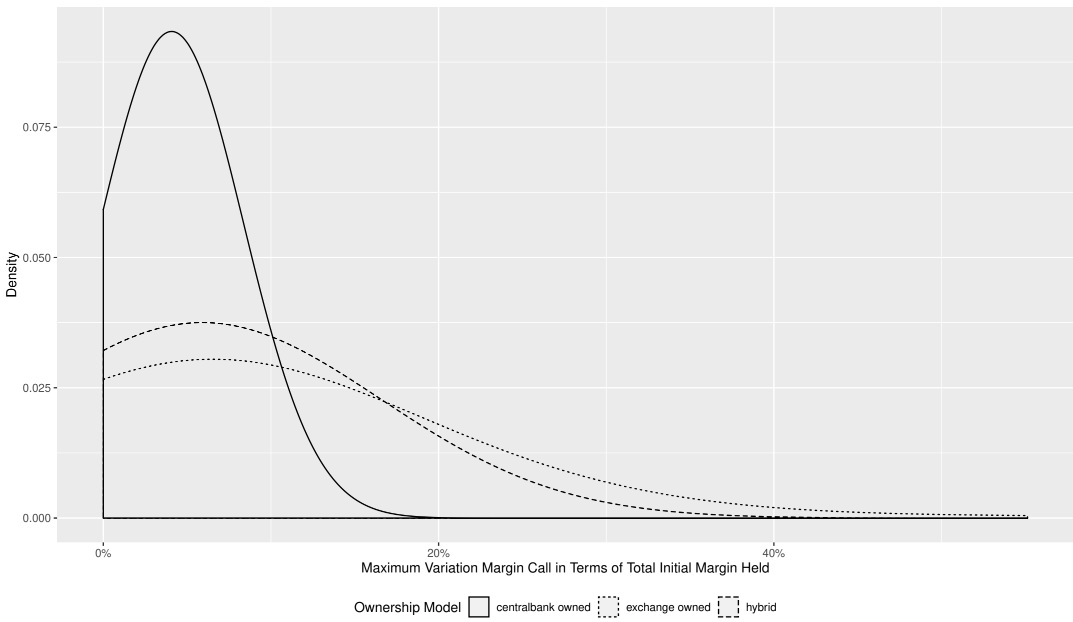

FIGURE 3.6: **Distribution of the Maximum Variation Margin as Share of Total Initial Margin Held by Ownership Type:** This figure shows the distribution density of the average maximum variation margin as share of total initial margin held by the CCPs in the respective ownership models.

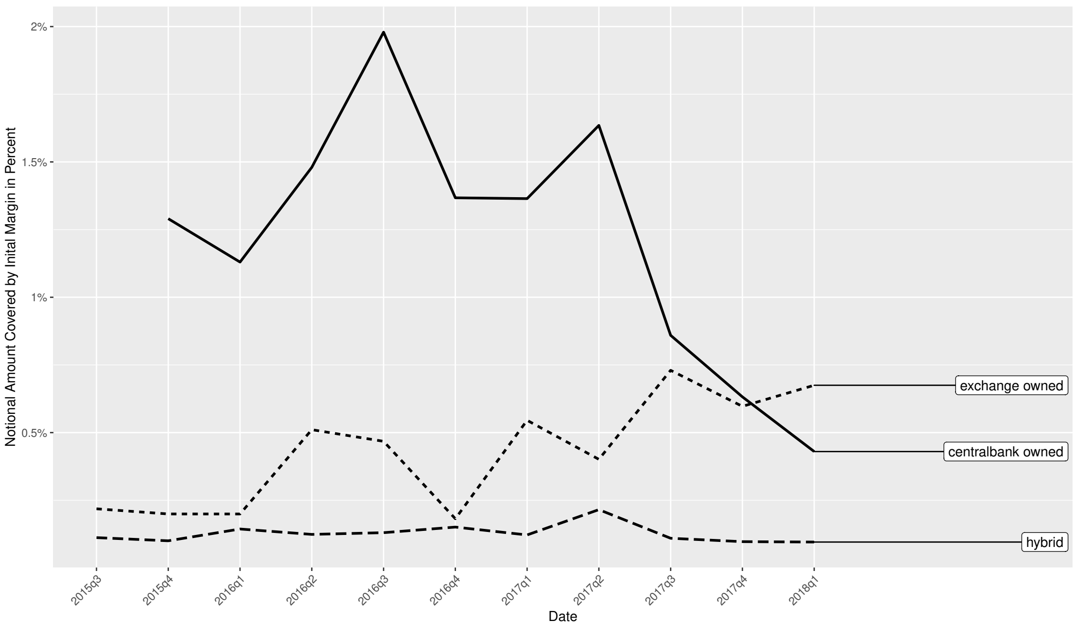

FIGURE 3.7: **Share of Notional Amount Covered by Initial Margin:** This figure depicts the evolution of the median share of novated trade volume that is covered by the total initial margin held at the CCP in post haircut terms for the respective ownership models. The cross sectional distribution is depicted in Figure 3.8.

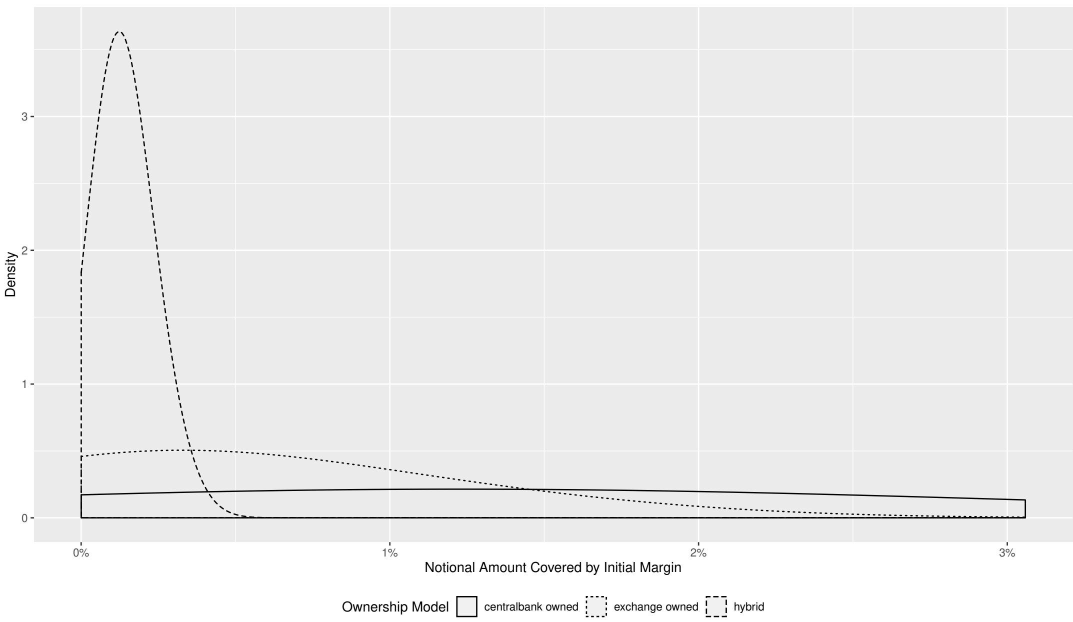

FIGURE 3.8: **Distribution of the Notional Amount that is Covered by Initial Margin:** This figure shows the distribution density of the share of novated trade volume that is covered by the total initial margin held at the CCP in post haircut terms for the respective ownership models.

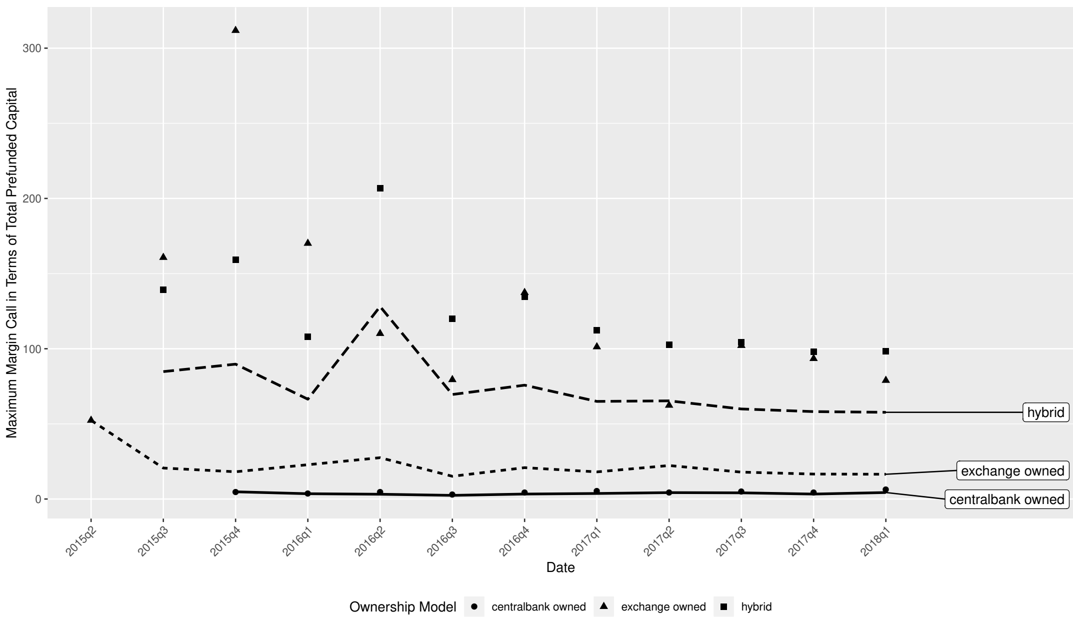

FIGURE 3.9: **Maximum Variation Margin Calls as Share of CCP's Own Capital by Ownership Type:** This figure depicts the evolution of the maximum variation margin calls in Terms of the CCP's own capital. The solid line represents the group specific median and the symbols mark the group specific maximum. The cross sectional distribution is depicted in Figure 3.12.

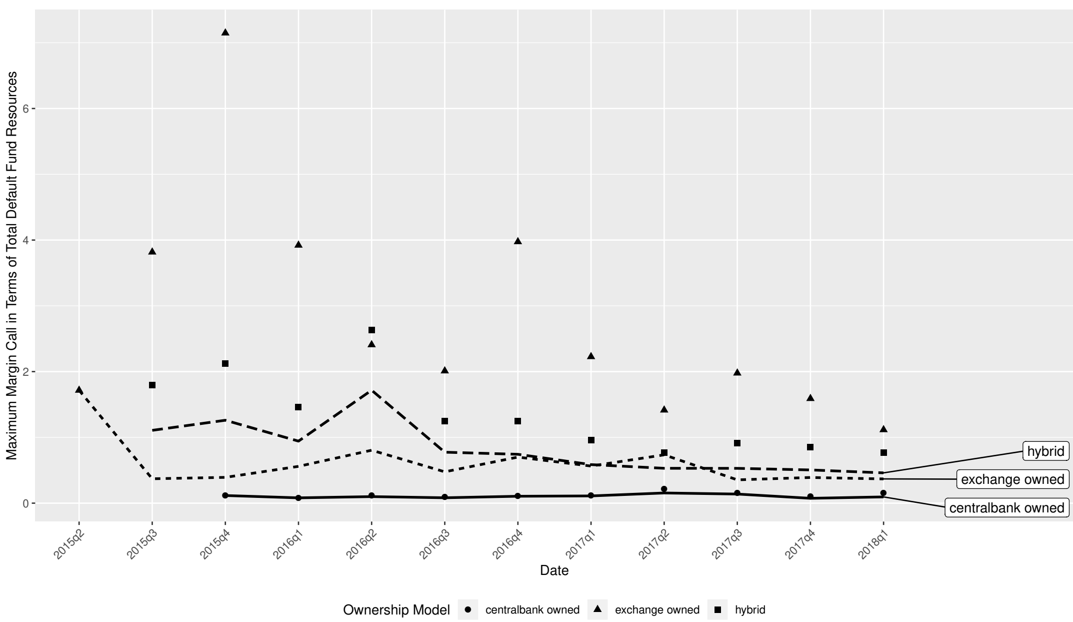

FIGURE 3.10: **Maximum Variation Margin Calls as Share of Total Default Fund Resources by Ownership Type:** This figure depicts the evolution of the maximum variation margin calls in Terms of the total default fund resources. The solid line represents the group specific median and the symbols mark the group specific maximum. The cross sectional distribution is depicted in Figure 3.11.

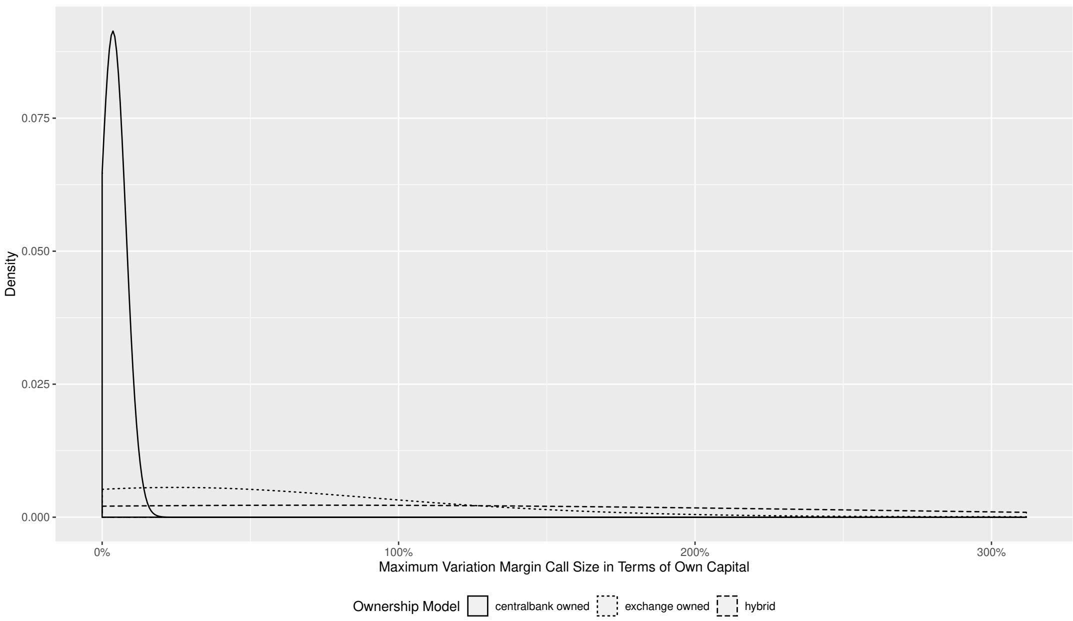

FIGURE 3.11: **Distribution of the Maximum Variation Margin Calls as Share of Total Default Fund Resources by Ownership Type:** This figure shows the distribution density of the maximum variation margin calls in Terms of the total default fund resources across the respective ownership models.

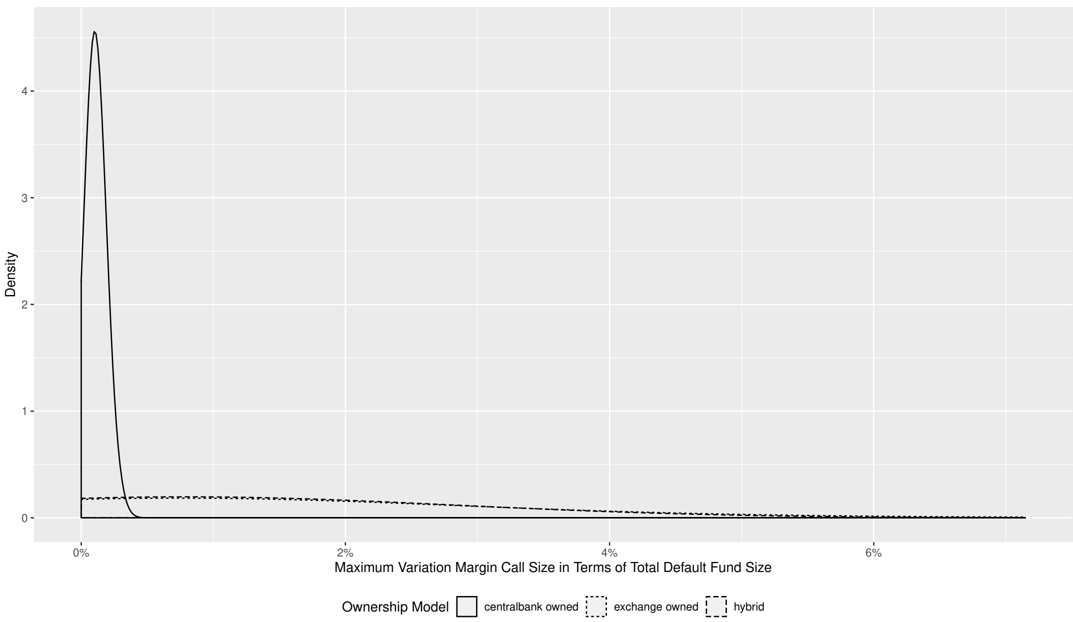

FIGURE 3.12: **Distribution of Maximum Variation Margin Calls as Share of CCP's Own Capital by Ownership Type:** This figure shows the distribution density of the maximum variation margin calls in Terms of the CCP's own capital across the respective ownership models.

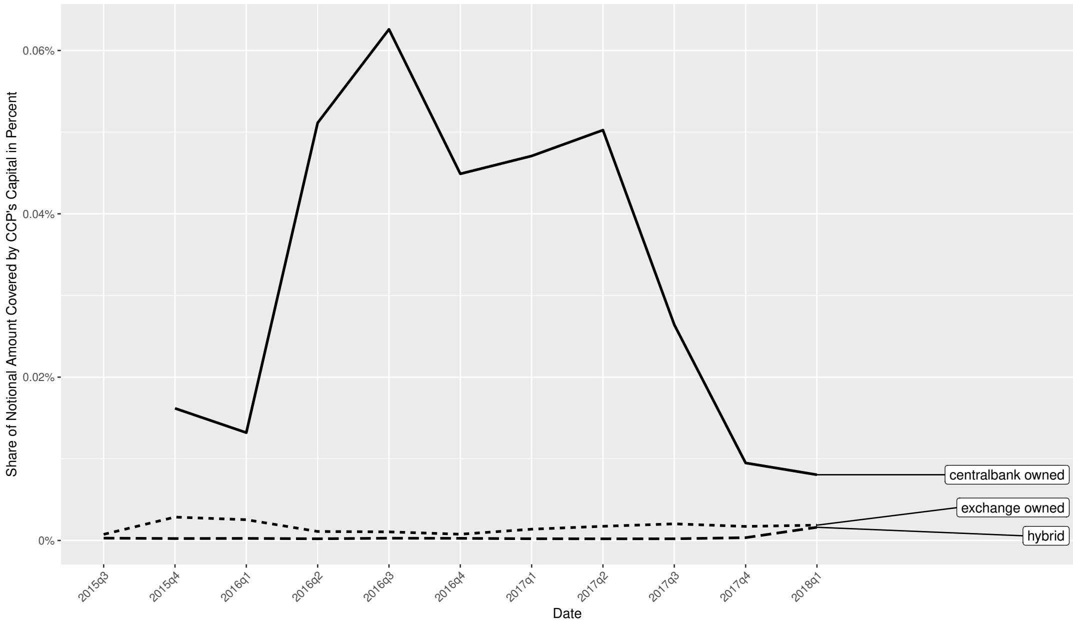

FIGURE 3.13: **Share of Notional Amount Covered by CCP's Capital:** This figure shows the median share of the notional amount novated by the CCP that is covered by the CCP's capital provided to the default fund waterfall in percent within the respective ownership groups. The cross sectional distribution is depicted in Figure 3.14.

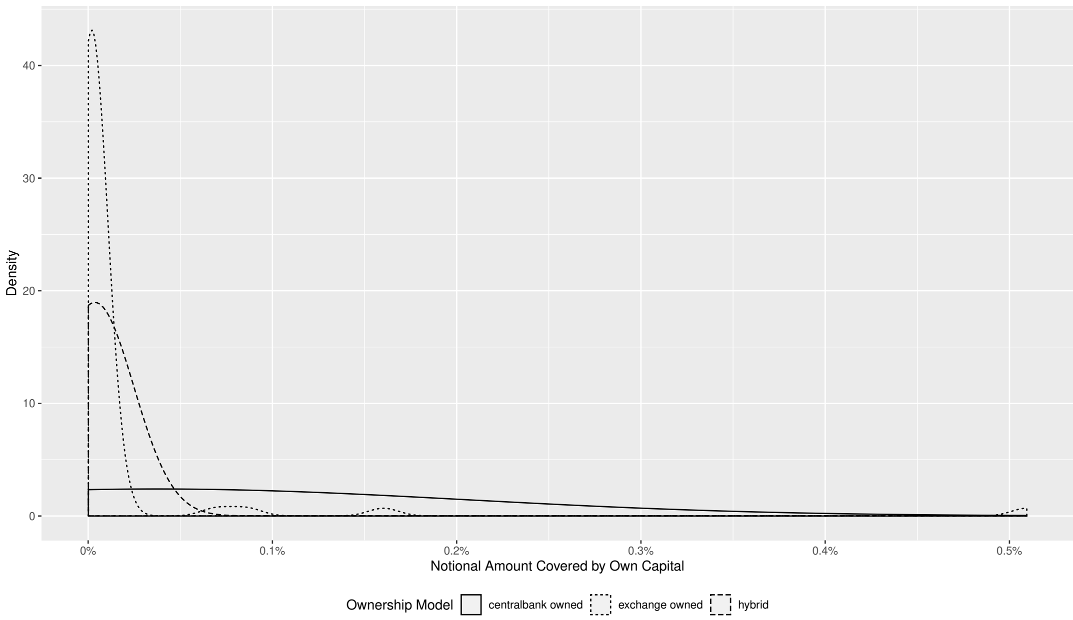

FIGURE 3.14: **Distribution of Notional Amount Covered by CCP's Capital by Ownership Type:** This figure shows the distribution density of the share of the notional amount novated by the CCP that is covered by the CCP's own pre-funded capital across the respective ownership models.

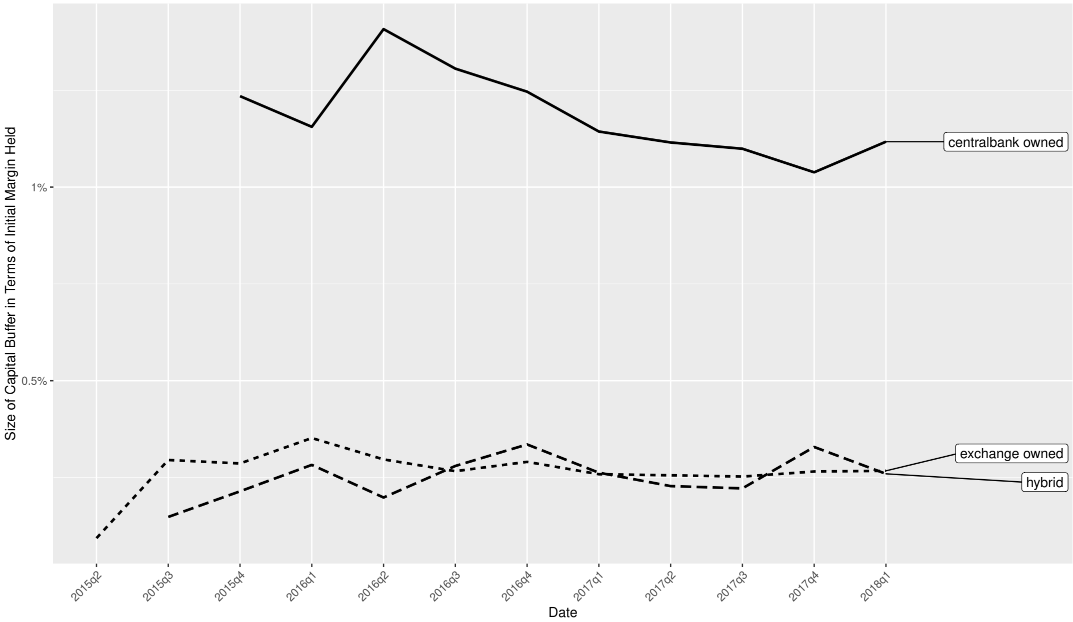

FIGURE 3.15: **Size of Capital Buffer in Terms of Initial Margin Held:** This figure shows the median size of the CCP's capital buffer relative to the initial margin held at the CCP in post haircut terms in percent within the respective ownership groups. The cross sectional distribution is depicted in Figure 3.16.

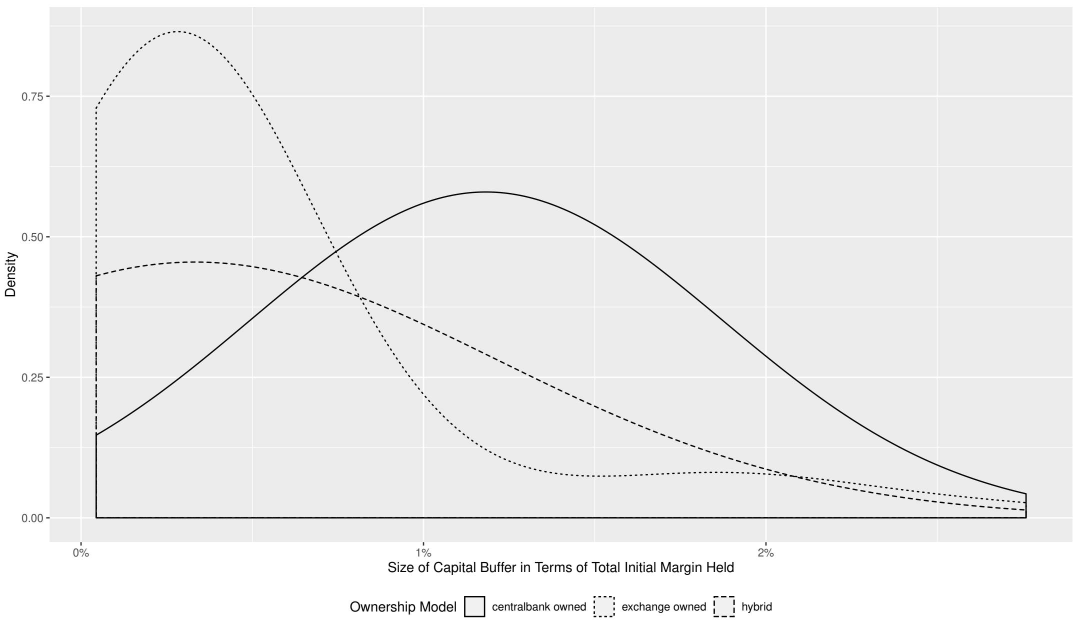

FIGURE 3.16: **Distribution of Capital Buffer Size in Terms of Initial Margin Held:** This figure shows the distribution density size of the CCP's capital buffer relative to the initial margin held at the CCP in post haircut terms across the respective ownership models.

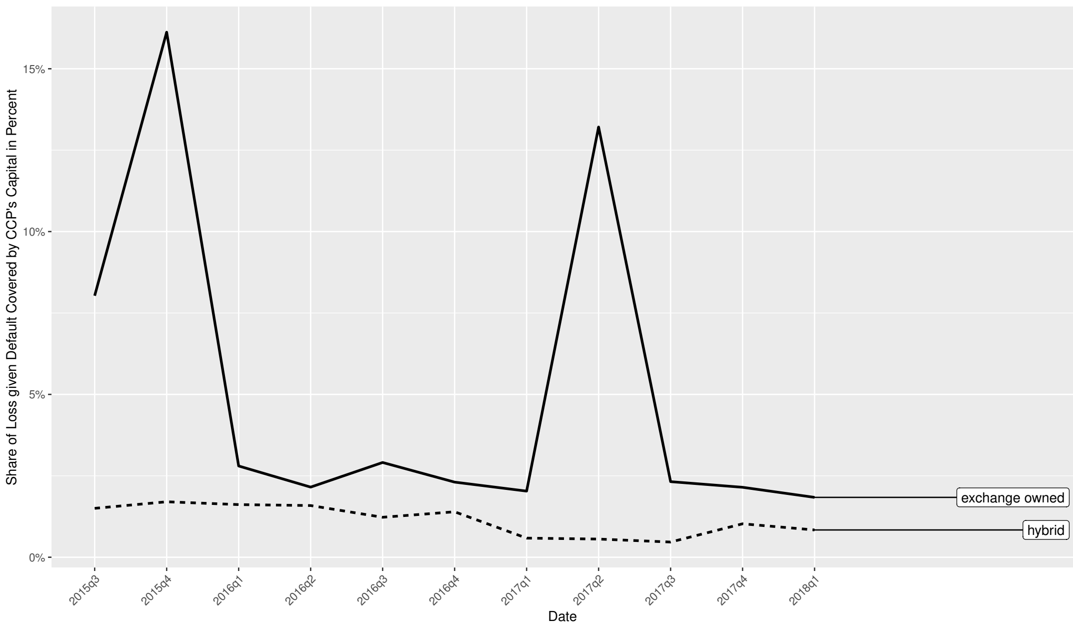

FIGURE 3.17: **Share of Loss Given Default that is Covered by CCP's own Pre-funded Capital:** This figure shows the median share of the loss given default that is covered by the CCP's own capital provided to the default fund waterfall in percent within the respective ownership groups. The cross sectional distribution is depicted in Figure 3.18.

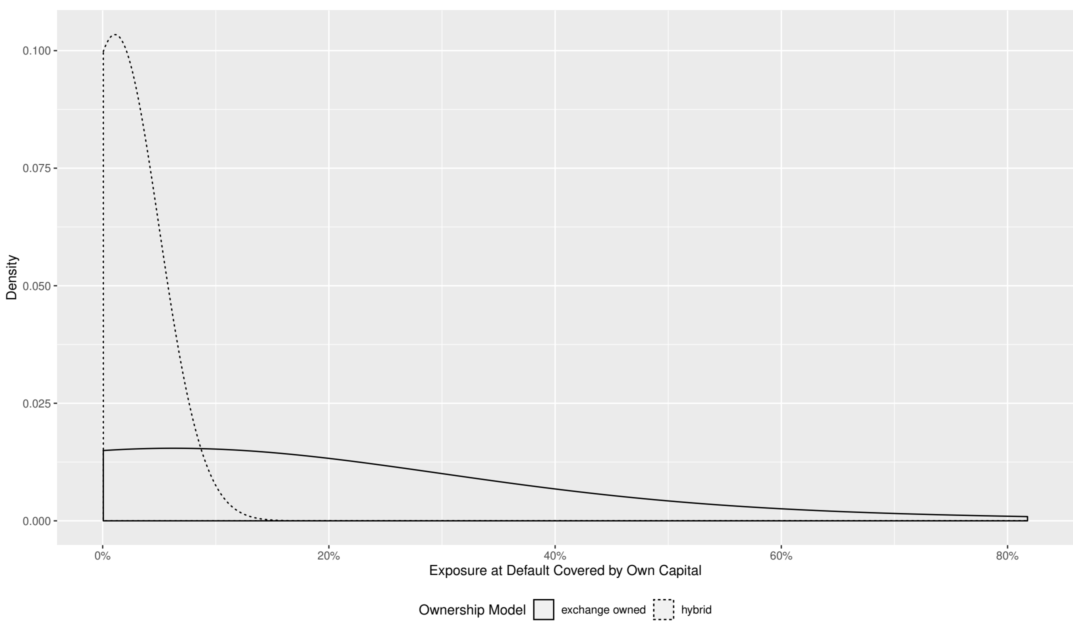

FIGURE 3.18: **Distribution of Loss Given Default that is Covered by CCP's own Pre-funded Capital:** This figure shows the distribution density of the share of the loss given default that is covered by the CCP's own capital across the CCPs in the respective ownership models.

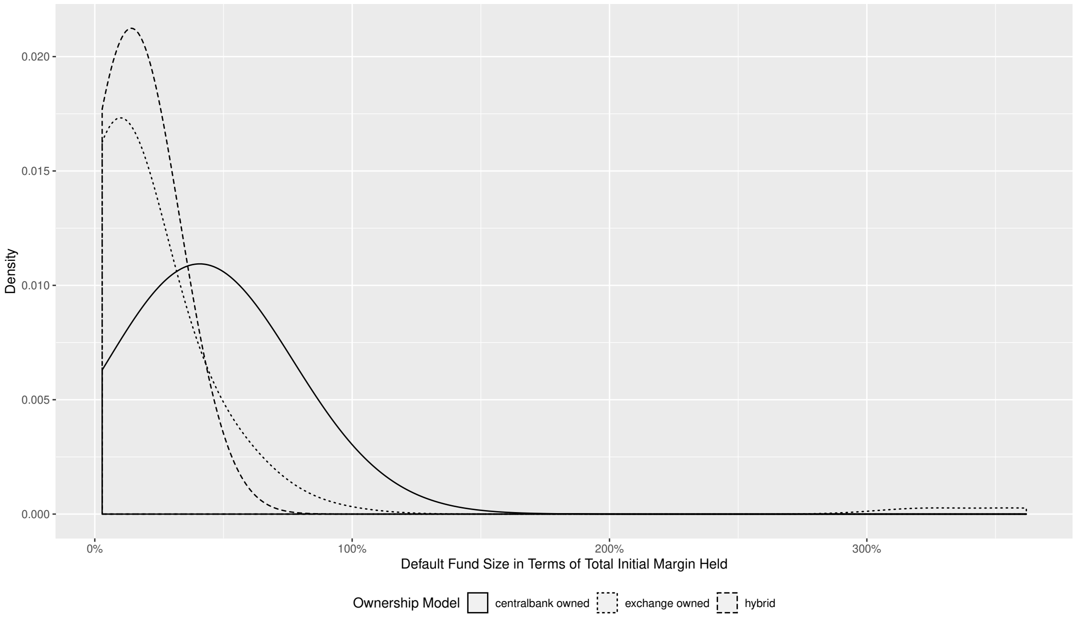

FIGURE 3.19: **Default Fund Size in Terms of Initial Margin Held:** This figure shows the density of the total default fund post haircut relative to the initial margin held by the CCPs in the respective ownership models.

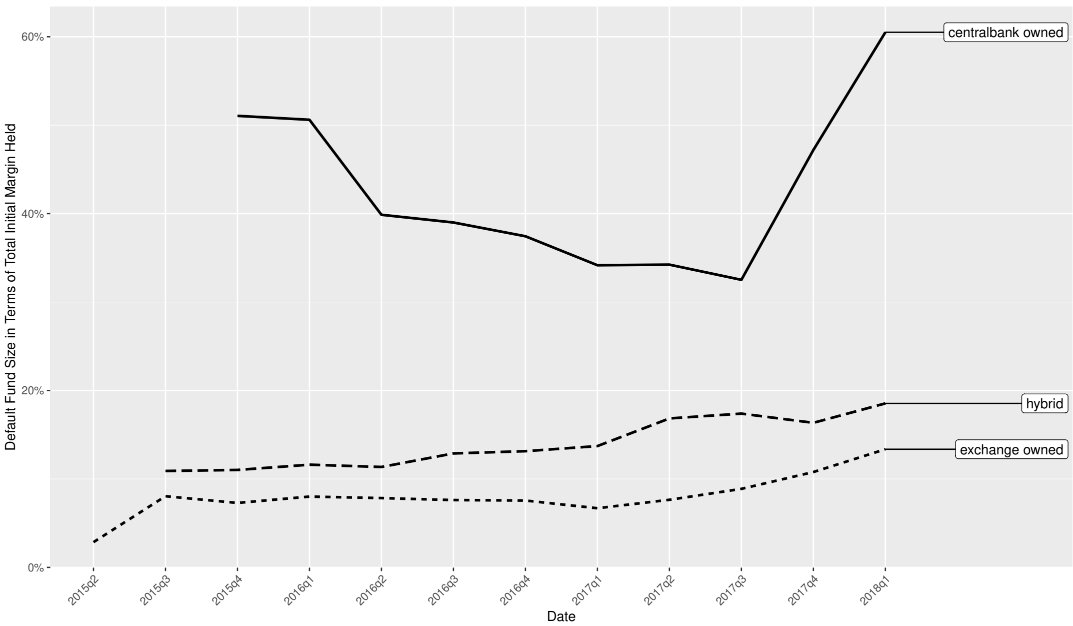

FIGURE 3.20: **Default Fund Size in Terms of Initial Margin Held:** This figure shows the evolution of the total default fund post haircut relative to the initial margin held by the CCP. The line defines the group median of the respective ownership models. The cross sectional distribution is depicted in Figure 3.19.

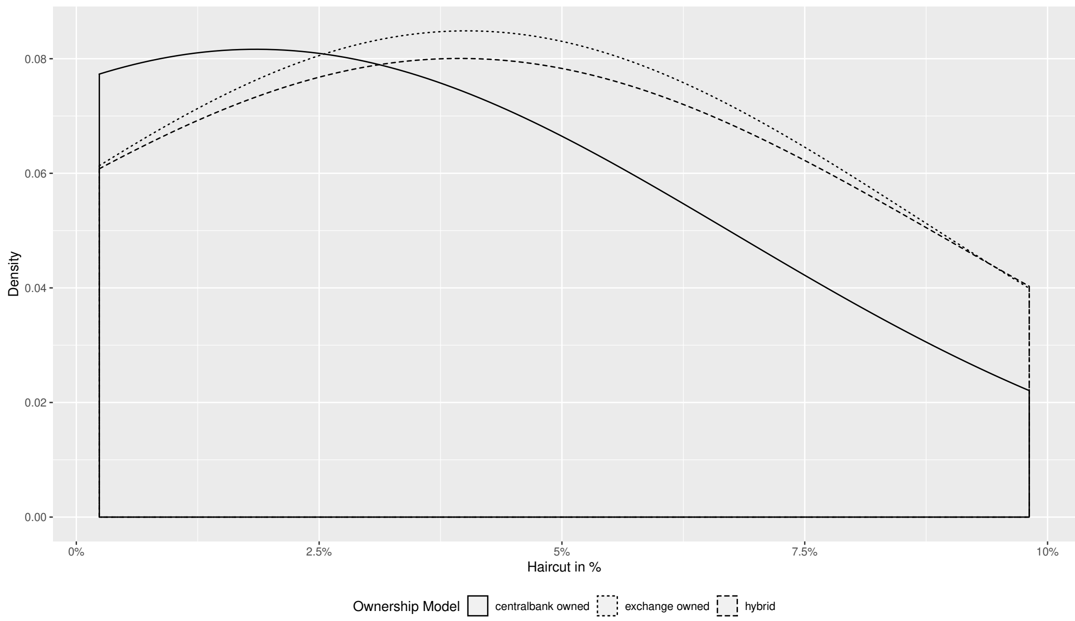

FIGURE 3.21: **Density of the Haircut Applied to Initial Margin by Ownership Type:** This figure depicts the density of the haircut applied to the pledged collateral on average by each CCP grouped into the three models of ownership.

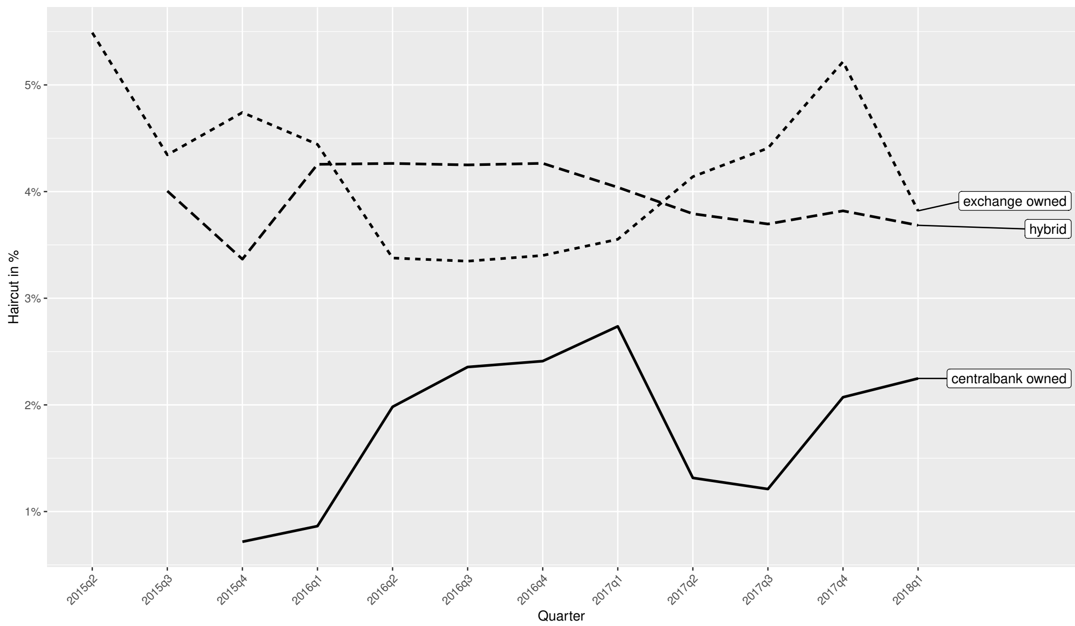

FIGURE 3.22: **Average Haircut Applied to Initial Margin by Ownership Type:** This figure depicts the evolution of the cross-sectional ownership group specific averages of the haircut the CCPs apply to collateral pledged as initial margin. The average haircut is the absolute difference between pre and post haircut initial margin held relative to the collateral held before the haircut is applied. The cross sectional distribution is depicted in Figure 3.21.

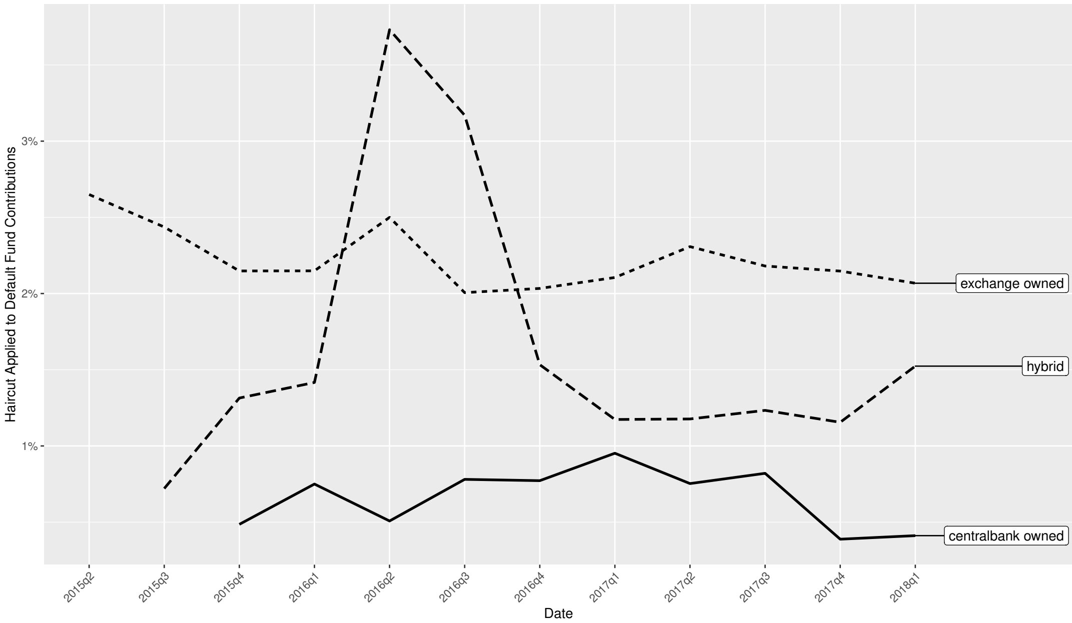

FIGURE 3.23: **Average Haircut Applied to the Default Fund Contributions by Ownership Type:** This figure depicts the evolution of the cross-sectional ownership group specific averages of the haircut the CCPs apply to collateral pledged as default fund contributions. The average haircut is the absolute difference between pre and post haircut default fund contributions relative to the value of the default fund before the haircut is applied. The cross sectional distribution is depicted in Figure 3.24.

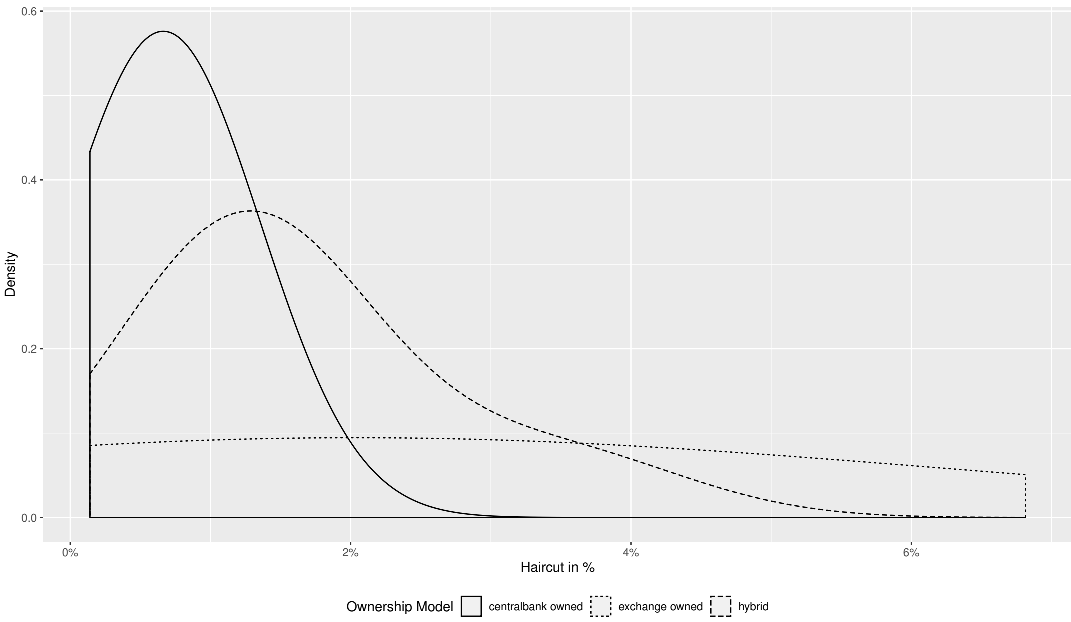

FIGURE 3.24: **Distribution of Average Haircut Applied to the Default Fund Contributions by Ownership Type:** This figure shows the distribution density of the average Haircut Applied to the Default Fund Contributions by the CCPs of the respective ownership models.

Chapter 4

Bank Risk and Central Clearing Networks in Europe

Abstract: *European regulatory efforts to disentangle the opaque and complex liability structures of bilateral over-the-counter derivative trading led to the increased importance of central clearing counterparties (CCPs) now posing systemic nodes in the financial markets network. In this paper I analyze the network structure of the European central clearing market. I find that the European clearing sector is highly interconnected, that banks with more clearing memberships are less risky, and that the correlation between the risk of a bank and that of its peers has declined significantly since the introduction of central clearing. These findings speak in favor of the shock absorbing capability of central clearing counterparties in relatively stable times.*

4.1 Introduction

> *"When everything else is stripped away, the most pressing issue is the management of risk. The focus of this is exchanges and, increasingly, the central clearing houses - indeed the prudent operation of central clearing houses is perhaps the single most important objective for the market authorities and regulators."*
>
> – SFC (1988, par.3.21, p.31)

The European Market Infrastructure Regulation (EMIR), which came into force in mid-2016, requires financial firms operating in Europe to clear all standardized derivatives with central clearing counterparties (CCPs) that must be authorized by the European Securities and Markets Authority (ESMA). EMIR is the European implementation of the joint efforts agreed by the G20 in Pittsburgh in 2009 in response to the previous financial crisis as part of its global efforts to limit the counterparty risk in derivatives trading G20, 2009, par.13. Bilaterally traded OTCs created opaque and complex network structures that contributed to underestimating contagion effects of the failure of an individual counterparty or contraction shock on the market (Wiggins and Metrick, 2014; Wiggins and Metrick, 2015). The G20 have defined the reform to create transparency through reporting obligations and to manage complexity through mandatory central clearing.

The clearing network hosts the counterparties that originate and trade derivative products, typically financial firms, and clearing houses, which may act as intermediaries. The introduction of central clearing in Europe and increasing incentives to settle standardized contracts via CCPs have led to the transformation of a bilateral derivatives network of counterparties into a network with several central hubs intermediating between them. The regulatory focus on derivatives clearing is thus determined by concentrating counterparty risk management on a small number of specially regulated entities. This has led to a market structure in which few companies offer a service that must be used by all European regulated financial firms. Central clearing shows characteristics of a natural monopoly, which may result in a highly competitive environment among the few players (Krahnen and Pelizzon, 2016). CCPs have been appreciated to be systemically important[1] (Wendt, 2015; Umar Faruqui and Takàts, 2018), while at the same time Pirrong (2011) finds that CCPs are prone to high risk taking due to competition.

Few service providers and the incentives to take on high risks led to a high concentration of risk in the financial system (Menkveld, 2017). Now, in turn, clearing members must be protected from the risk of a failing central clearing counterparty and the potential contagion of distress through these central agencies in the financial network. Hence it is so important to look at these central nodes within the financial network and the implications of the network structure on the soundness of the financial system. Established parts of the financial network have been researched for a long time and are better understood. Despite the potentially immense impact of central clearing on the stability of the European financial network, little is known about the

[1] "Since EMIR was first adopted in 2012, CCPs have become a systemically-important part of the financial sector and their importance is growing." (European Commission - Press release IP/19/1657, 13 March 2019). ESMA considers the systemically importance of CCPs since the amendments made in EMIR 2.2 as of May 2019.

market and its structure.

In order to be able to clear a trade with a CCP, the counterparties have to become members at that CCP. In this paper I describe the subset of CCPs and their members of the European clearing network using hand collected data for the year 2017. It is worth noting that the data represents the novated part of the derivative network, that is non-standard contracts remain to be traded bilaterally.[2] In contrast to the bilateral over-the-counter derivative network linking individual counterparties, the central clearing network only observes the links between clearing houses and their members.

In this paper, I analyze the network structure of the central clearing and implications for bank risk. I ask three research questions. First, how does the European central clearing network look like and what is its degree of interconnectedness? A network is formed in order to be able to clear derivative through central clearing counterparties, which is reserved do members of CCPs. Members include banks, insurers, central banks, funds, asset management and commodity trading firms. Second, does bank risk increase with the number of clearing connections? Banks have revealed to play an important role in the transmission of distress within the financial network (Allen and Gale, 2000) as well as the transmission of financial stress to the real economy (Chodorow-Reich, 2013), which is why it is important to look at the link between CCPs as systemically important institutions and banks. Third, did the introduction of central clearing in Europe increase the correlation of bank risk across the members of the same CCP? For the subset of banks, I analyze the relationship between bank risk and the number of clearing links maintained. Finally, I estimate peer effects in the clearing network as to measure the correlation of bank risk within the group of clearing members of the same CCP. To this end, I combine network data of members with yearly balance sheet information of bank members for the years 2014 to 2017.

My analysis shows that the European clearing network is highly interconnected. All European CCPs are connected to each other through multiple large clearing members. In order to analyze the relationship of bank risk and interconnectedness, I model

[2]The incentives created by the central clearing reform and the willingness of financial entities to adopt are discussed by Bellia et al. (2018).

bank risk measured by the Zscore as a function of the number of maintained clearing links and find that multiple clearing links in the network are not associated with higher bank risk. On the contrary, I find that more clearing memberships are associated with a healthier state of the bank clearing member. Further, I compare the correlation of banks' Zscore within the group of clearing members clearing at the same CCP before and after the implementation of mandatory central clearing. I find that correlation of bank health as measured by the Zscore is positive and significant prior to the implementation and declined significantly in the period afterwards. The setup so far, does not allow to control for confounding factors such as significant changes in the bilateral trading patterns or changes in the interbank market happening at the same time.

Despite frequently voiced concerns about risk concentration and additional channels of contagion of distress between nodes in the financial network, the results point to a diversification or selection effect in central clearing. This means that banks appear to spread counterparty risk across several clearing houses, and or clearing houses may select healthy banks to give them access to their clearing services. Furthermore, the results speak in favor of the ability of CCPs to act as buffers between the clearing members containing the transmission of distress. CCPs do not seem to have introduced group correlation among clearing members of the same CCP, at least in relatively tranquil times. On the contrary, previous default correlations are alleviated. From the CCP's point of view this means that counterparty default risk of clearing members seems not to be correlated, which is good news as the default fund of CCPs appears to be equipped to withstand the default of only one or two clearing members.

I add to the literature on bank risk and central clearing in two important aspects. The first concerns the relationship of clearing links and bank risk. A theoretical model with distinctive segments of derivative classes developed by Duffie and Zhu (2011) shows that an additional central clearing link adds to counterparty default risk exposure for some classes, whereas clearing multiple classes of derivatives with the same CCP reduces counterparty risk as compared the case where classes are cleared separately. The increase in counterparty risk in the model stems from the reduction in netting efficiency and the increase in demand for collateral. In this analysis I test whether additional clearing memberships contribute to bank risk. To this end I follow DeYoung and Torna (2013) who estimate the effect of non-traditional banking activities on bank failures during the financial crisis. They show that banks with an increasing share of non-interest-income become more risky in all activities, which increases overall bank risk as measured by the Zscore. I apply the analysis strategy of DeYoung and Torna (2013) to the hypothesis of Duffie and Zhu (2011) in order to test if additional clearing links of a bank are related to bank risk as reflected in the Zscore. The analysis only considers the risk part of the bank's risk-return-nexus as this is the main objective criterion that is targeted by the policy reform. How the clearing reform is affecting the bank's individual incentives to clear for reasons of profitability is discussed by Bellia et al. (2018) and D'Errico and Roukny (2017).

The second contribution concerns the relationship of network structures and the propagation of risk within the network. Acemoglu et al. (2015) describe a nonlinear relationship between interconnectedness and stability in financial networks, where increasing density of a network fortifies resilience through absorption until the too integrated networks destabilize the system due to an increase in risk correlation. The importance of network structure in relation to node characteristics for the amplification of shocks within financial networks is also pronounced by Glasserman and Young (2015). In a model calibrated with OTC data Heath et al. (2016) predict that the risk concentration following the clearing reform might introduce instability in the network, but the reduction of interconnectedness may decrease the contagion risk of distress.

In a related study analyzing the contagion of risk in European interbank networks Covi et al. (2019) also employ network properties and financial firm characteristics and find strong within group shock propagation effects. Although their analysis includes interbank derivative exposure, it lacks the effect of central clearing on network stability. By developing a multi-layer network indicator of system risk, Poledna et al. (2015) however show that the absence of important layers leads to the underestimation of risk propagation in the network. Kubitza et al. (2018) warn of the introduction of peer correlation into the system due to a potential increase in the price co-movement of underlying assets. On the contrary, CCPs may act as a buffer between their clearing members. Loon and Zhong (2014) analyze voluntary central clearing of CDS in the US and find a decreasing correlation of CDS pricing and the dealer's default risk, which speaks in favor of the ability of CCP's shielding members from the adverse effects of other member's default.

In order to test the change in bank risk correlation due the introduction of central clearing I build on Bramoullé et al. (2009) to estimate peer effects as Zscore correlations in the clearing network. In this analysis I confirm the prediction of Heath et al. (2016) and show that bank risk correlation decreases substantially between clearing members of the same CCP after the implementation of mandatory central clearing. The analysis however abstracts from the impact of node characteristics on the propagation of risk, whose importance is underlined by Covi et al. (2019). Another important aspect is that the underlying data only cover a relatively stable period and may not be representative of the context of unfavorable market conditions.

The analysis of member risk in clearing networks is becoming particularly important as CCPs are known to be correlated in their risk profile due to an overlap in the member base. Estimating a CCP's risk as measured by the weighted SRISK of their members, Berner et al. (2019) find that risk is highly correlated among CCPs. In addition, there is consensus about the serious adverse consequences of the default of a CCP for the financial market (Gibson et al., 2013; Duffie, 2014). For the time being, the orderly resolution of CCPs, which might shield the clearing members from bearing the substantial losses, remains an unresolved problem (Singh and Turing, 2018).

The remainder of the paper is structured as follows. Section 4.2 presents the data, the European Central Counterparty landscape and the regulation involved in clearing, Section 4.3 describes the clearing member network and its interconnectedness, Section 4.4 addresses the correlation of bank risk and the number of clearing connections, Section 4.5 shows that the correlation of bank risk between members that clear with the same CCP decreased with the implementation of central clearing and Section 4.6 concludes.

4.2 Data

The data comprises all European CCPs authorized under EMIR according to ESMA (2018b) and is not limited to institutions required to report CPMI-IOSCO[3] disclosure

[3]The Committee on Payments and Market Infrastructures (CPMI), formerly the Committee on Payment and Settlement Systems (CPSS), is a monitoring and standard proposing committee hosted at the Bank for International Settlements (BIS) and member of the G20's Financial Stability Board

information. A list of CCPs can be found in Table 3.1 of Chapter 3, together with the operating country, national competent authority in charge of supervision as well as the date of initial authorization. A map in Figure 3.1 of Chapter 3 depicts the location of the authorized CCPs across Europe.

The network is created from hand collected data from the CCPs' clearing member disclosures taken from the individual CCPs' websites as of 2017. The network data consists of links between 1,208 members and is used to describe the network structure in the first research question. To this data I merge yearly balance sheet information of bank members for the years 2014 to 2017 that is taken from the proprietary BankFocus data set provided by Moody's Bureau van Dijk. The record link consists of 405 exact and 180 hand corrected fuzzy matches, which is a total of 585 banks out of 1,208 unique members in the member data. The matched financial data includes banks located in 48 countries in all regions of the world. The remaining unmatched members include insurance companies, asset management firms, commodity trading institutions and central banks. In order to address the correlation of bank risk and clearing connections in the second research question, I require the availability of information on the variables to calculate the Zscore, equity ratio and three periods of return on average assets, and controls, such as total assets, share of non-performing loans and liquid assets, and accounting for measurement errors and outliers, which reduces the sample to 148 banks. In order to estimate the change of bank risk correlation at the time of the central clearing reform in the form of panel regression, the sample increases as I restrict my sample on the availability of the same variables as before, but I do not require information on trading income and cumulated off balance sheet items. But, as I further require observations to be available before and after the implementation of the clearing reform in 2016, which reduces the number of observations to 239 per year. When analyzing the exclusive non-overlapping subnetworks in which members form only one connections, the sample is reduced to 201 observations per year.

The network is undirected[4] and consists of vertices of the two classes "member" and

(FSB). The international Organization of Securities Commissions (IOSCO) is an association of securities regulating agencies based in Madrid.

[4]In an undirected network, claims between nodes go in both directions. In this case, for example, changes in margin coverage due to a margin call are collected by the CCP from the losing members and paid to the winning members. The direction of these payments may change with each call. In a directed network, however, the claims follow a one-way directed flow.

"CCP", called nodes, connected by links, called the edges. The network data structure is a three dimensional array of member and CCP connections with information on both classes of nodes varying over time. Each member in the record is listed at any time as often as it has memberships with a CCP. Models accounting for individual unobserved heterogeneity rely on fixed effects in panel regressions. In order to apply the panel regression models in Section 4.5 I convert the network data to panel data by collapsing on the member level for each point in time. In this way, only one entry per member remains at any one time. The links formed by the nodes are fixed as the information on CCP memberships is only available for 2017 resulting in a time in-variant network, which does not allow for an analysis of network formation as commonly done in the network analysis literature.

For the regressions involving the Zscore[5] in sections 4.4 and 4.5 I winsorize the data prior to the Zscore calculation at the one percent level and drop observations with negative equity ratio and Zscores four standard deviations above the mean. The summary statistics of the panel regression sample are listed in Table 4.1.[6] The sample comprises 239 banks, of which 71 are listed, which is about 30 percent. The log Zscore is on average 3.79 ranging from 0.11 to 5.71. Size as measured in log total assets is on average 16.64, ranging form 2.43 to 22.33. Cost-to-income ratio is on average 70.71 percent and 6.95 percent of gross loans are non performing loans. Figure 4.1 depicts the number of clearing connection in the network and describes a highly skewed distribution. The distribution of clearing links for the cross-section subset of bank is depicted in Figure 4.2, which is still skewed but more equally distributed as compared to the full network sample.

4.3 Clearing Member Network

In order to analyze the network structure resulting from the central clearing reform, I plot the CCPs' direct member connections in Figure 4.3. The network graph reveals a dense, but decentralized network. Multiple central hubs are formed by the central counterparties, as they are the nodes with the most links in the network. The network

[5]The calculation of the Zscore is described in Equations 4.1 and 4.2 in Section 4.4.

[6]Summary statistics for the cross-section of 2017 and the panel regression sample of single-connection subnetwork are listed in Table 4.2 and 4.3, respectively.

data is simplified prior to the analysis by removing multiple edges linking the same vertices and dropping loop edges. The simplified network contains 1,208 unique clearing members and 16 European CCPs forming 1,874 clearing connections. Although the network is of incomplete nature, every European CCP is connected to at least one other European CCP via at least one member.

The European clearing network is characterized by a number of central hubs formed by clearing members orbiting their directly linked CCP. The graph in Figure 4.3 depicts the clearing network employing of the Davidson-Harel layout algorithm.[7] Figure 4.1 plots the distribution of clearing links of each clearing member in the member network. Most of the clearing members, 76 percent, maintain only one clearing connection to a single CCP. Only 18 clearing members clear with eight or more CCPs.

The clearing members with a high number of clearing counterparties form an indirect connection between CCPs, and could be identified as a potential source of simultaneous distress to multiple CCPs or a channel of contagion passing the distress of one CCP to another. Members clearing with five or more CCPs are listed in Table 4.4, also showing the number of clearing connections. Figure 4.4 depicts the subgraphs of the clearing network in Figure 4.3 extracting only the direct clearing connections of the six most connected clearing members listed in Table 4.4. A ranking of CCPs by number of clearing members in the network is listed in Table 4.5. Summary statistics for the number of clearing memberships per CCP over time are listed in Table 4.6 and show only very limited variation over time, speaking in favor of a relatively fixed network.

Members do not only clear through that CCP but also provide a variety of services to them. In the process of novation, CCPs rely on the infrastructure of service providers that provide liquidity, credit, asset safe keeping, settlement and collateral investment. The complex structure of the service provider network of 26 CCPs worldwide and their 307 service providers has been analyzed by the Study Group on Central

[7]The Davidson-Harel layout algorithm developed by Davidson and Harel (1996) solves undirected networks with an energy function, which describes the residual energy that is inherent to all edge connected vertices and repels the objects from another. Minimizing the function determines the object's position within the graph and results in the graphic representation of the network. The algorithm used to visualize the data essentially determines how the network will be perceived and is not an objective procedure. See Noack (2003) for the comparison of energy based network algorithms. Furthermore, I would like to thank Katya Ognyanova for providing an excellent online repository on network visualization (Ognyanova, 2018).

Clearing Interdependencies[8] (SGCCI, 2018). The study reveals that some connected financial institutions provide a multitude of services to one or more CCPs, who clear through that CCP as a clearing member at the same time. The provision of services is concentrated on a set of few well interconnected financial institutions, resulting in a large exposure to these links, where the impact of a possible disruption to that link depends on the provided services. Large clearing members of a CCP provide at least three different services. Ten service providers in the network supply all financial services related to the clearing process of their connected CCPs. The concurrence of the interconnectedness of service providers, the resulting feedback loops and service clustering complicates drawing conclusion about the impact of a possible distress to one or more links in the network.

A further complication stems from the fact that not only the distribution of services in the network matters, but also the depth of the links providing those services. Droll et al. (2016) analyze the sub-custodian structure of financial institutions and find that a longer cascade of central securities depositories (CSDs) who provide asset safe keeping for financial institutions, which is a standard service to CCPs, is typically associated with weaker financial health. As the data at hand only allows for the inspection of the first layer of service provision, the implications of the depth structure is subject to further research. The following analysis of bank risk and central clearing links is based on banks only, and hence excludes all other non-bank CCP members. Figure 4.5 shows the bank member network, which is a subset of the previously shown CCP member network.

4.4 Clearing Connections and Bank Risk

The regulatory effort to centrally clear derivatives via CCPs increased the concentration of risks arising from derivatives within financial network (Umar Faruqui and Takàts, 2018). Financial firms that are obliged to clear their derivative trades through

[8]The SGCCI is a joint effort of Banque de France, Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin - Germany), Securities and Futures Commission (Hong Kong), Financial Services Agency (Japan), Monetary Authority of Singapore, Riksbank (Sweden), Financial Market Supervisory Authority (FINMA - Switzerland), Bank of England, Federal Reserve Bank of New York (United States), Commodity Futures Trading Commission (United States), Bank for International Settlements, European Central Bank, European Single Resolution Board, International Monetary Fund, BCBS, CPMI, IOSCO and FSB, which is chaired by the Federal Reserve Board (United States), see SGCCI (2018, p. 23).

CCPs choose the number of clearing memberships they want to maintain. Banks that offer trading services to clients that want to clear with members connected to other CCPs may then be exposed to the counterparty risk of multiple CCPs, but gain the ability to diversify their clearing activity across multiple clearing houses. From the point of view of regulators it is important to spot potential instabilities arising in financial networks if bank risk is correlated with clearing interconnectedness.

In this section I analyze the relationship of the number of central clearing connections of a single bank and its riskiness. Is the exposure of a bank to multiple CCPs associated with higher bank risk? Do risky banks choose to clear with more CCPs, or does the diversification of the derivative clearing across multiple counterparties reduce bank risk? In order to analyze the relationship between bank health and its interconnectedness, I model bank's health as measured by the Zscore as a function of the number of clearing connections.

The degree of interconnectedness may affect bank risk in both directions. On the one hand, the number of CCP links might go along with lower bank risk. The increase in clearing links diversifies the trading activity across multiple risk models run by the CCPs, sudden CCP specific margin calls may only affect part of the trades. Shocks from other members at the same CCP only affect part of the clearing network the member is connected to. Clearing the multiple CCPs allows the members to diversify their trades over multiple CCPs, so only a part of the trades may become worthless in the case of a CCPs default, limiting the exposure to a single CCP's default risk.

On the other hand, an increasing number of CCP links might be associated with higher bank risk. The exposure of banks to the risk of a failing CCP, which would be equitable to the simultaneous loss of all claims arising from trades cleared through this CCP, might affect the riskiness of the bank itself. Clearing with multiple CCPs might set incentive to increase the derivative trading volume in order to make up for the high fixed costs of a clearing membership. This might alter the income composition in favor of trading income, which tends to be more volatile and therefore increases bank risk as measured by the Zscore. Clearing with multiple CCPs decreases netting efficiencies, which increases the collateral demand, binding assets which need to be pledged initially and increases the demand for cash that is needed to settle the variation margin calls. The affiliation with multiple CCPs increases the risk of being affected by a failure of at least one CCP in the network, which renders all trades novated by the failing CCP worthless. Furthermore, from my model I cannot distinguish if bank risk decreases when the bank diversifies counterparty risk across multiple CCPs, or if it is the CCP which chooses the more healthier banks as members.

In order to evaluate bank's riskiness I calculate the Zscore, as a measure of the distance to default. Higher values indicate lower bank risk. The Zscore measures the amount of cumulative standard deviations of negative returns a firm's equity is capable to absorb. The main advantage of the Zscore compared to market based risk measures is the ability to evaluate listed and non-listed banks at the same time without the need to rely on regulatory data. For the analysis I use the measures developed by Roy (1952) to create cross sectional and time varying Zscore values.

Following Boyd and Graham (1986) I calculate the Zscore as the ratio of the sum of return on assets and the equity ratio over the standard deviation of returns:

$$\widehat{\mathrm{Zscore}_{it}} = \frac{\mathrm{RoaA}_{it} + \mathrm{equ}_{it}}{\sigma_{\mathrm{RoaA},it}}, \tag{4.1}$$

whereas RoaA_{it} is the annual return on average total assets, equ_{it} is the share of common equity over total assets and $\sigma_{\mathrm{RoaA},it}$ is the three period rolling window standard deviation[9] of the return on average assets of bank i at time t. The Zscore specification combining the three year rolling window period of the standard deviation of return on average assets with the contemporaneous values of asset return and equity ratio for annual data is chosen according to Delis et al. (2012) and Berger et al. (2014).

To ensure linearity and meet the OLS distribution assumptions, I follow Laeven and Levine (2009) and Lepetit and Strobel (2013) and log transform the Zscore with an added constant resulting in positive normally distributed values for the dependent variable in the following models:

$$\mathrm{Zscore}_{it} = log\left(1 + \widehat{\mathrm{Zscore}_{it}}\right). \tag{4.2}$$

In order to measure the relationship between bank health and the number of clearing links in the network, I estimate the following cross section OLS model for the

[9]The calculation is based on the contemporaneous value and two lags.

year 2017:

$$\text{Zscore}_{i,2017} = \alpha + \beta\, \text{CCPs}_{i,2017} + \gamma\, \mathbf{X}_{i,2016} + \varepsilon_{i,2017}, \tag{4.3}$$

where $\text{Zscore}_{i,2017}$ denotes the log Zscore of bank i in 2017, $\text{CCPs}_{i,2017}$ is the number of clearing links of bank i in 2017 and $\mathbf{X}_{i,2016}$ contains the controls variables taken from the CAMEL[10] approach to explain bank risk and include the ratio of non-performing loans to total gross loans, cost-to-income ratio, liquid assets as share of total assets and bank size measured as log of total assets, all lagged by one period. I follow Chiaramonte et al. (2015) and combine the Zscore measure and the CAMEL variables, leaving out the ones which are already included in the composition of the Zscore. The residual is captured by ε_i and standard errors are estimated with the Huber-White method. Since the variables in $\mathbf{X}_{i,2016}$ explaining the Zscore with the CAMEL approach could be endogenous to bank risk, I also estimate alternative specifications by excluding these controls or including controls for 2017, neither of which alters the results.

The control variables account for the confounding factors that interfere with the number of clearing links and financial health. The amount of cleared positions, for example, affects the liquidity of the balance sheet as assets need to be held as collateral. Large single members might become to risky for a single CCPs and have to diversify across multiple CCPs. To dispel further concerns of confounding effects, through which additional clearing links may affect bank risk, I additionally control for the share of trading income in gross income and the ratio of aggregated off balance sheet items to total assets by including both as interaction terms:

$$\begin{aligned} \text{Zscore}_{i,2017} = \alpha + \beta\, \text{CCPs}_{i,2017} + \gamma\, \mathbf{X}_{i,206} + \delta\, C_{i,2016} \\ + \eta\, (\text{CCPs}_{i,2017} \times C_{i,2017}) + \varepsilon_{i,2017}, \end{aligned} \tag{4.4}$$

whereas C_{it} contains the trading income or off balance sheet controls in the respective specification. An increase in clearing links for example might incentivize the member

[10] **C**apital adequacy, **A**ssets quality, **M**anagement capability, **E**arnings, and **L**iquidity.

to increase the volume of cleared derivative positions due to the high fixed costs of clearing memberships. A higher clearing volume in turn might increase trading income, which is more volatile as compared to interest income. This might then drive the standard derivation of return, which is included in the Zscore. The decrease in Zscore with an additional membership might then be confounded with a change in bank risk due to an increase in counterparty risk exposure, while actually the increase in derivative trading might be the driving force.

Results of the regressions are listed in Table 4.7. The uni-variate regression results listed in column 1 only including the number of CCP links (CCPs) without controlling for the CAMEL variables suggests that a higher number with CCP links is associated with a higher Zscore, indicating stronger bank health. An increase in one additional link is associated with a 6.7 percent higher Zscore of that clearing member. Controlling for the CAMEL variables increases the effect's magnitude to 8 percent and its statistical significance. Additionally controlling for the share of trading income to total gross income in column 3 as defined in Equation 4.4 renders the effect insignificant, but does not reverse the effect's direction. Controlling for the ratio of off-balance-sheet items of total assets, the effect increases to 13.6 percent and is statistically significant at the 5 percent level. Both, trading income and off balance sheet items do not fundamentally alter the marginal relationship between bank health and the number of clearing links.

As a robustness check, I additionally make use of the year 2018, and collapse year 2017 and 2018 after the implementation of the central clearing reform and run the same regression as defined in Equation 4.3. The results are listed in Table 4.8 which show the same effect. The model variations are arranged in the same way as compared to the regression including only the last period, excluding controls in column 1, including controls in column 2 and additionally controlling for trading income and off balance sheet items in column 3 and 4, respectively. The coefficient for $\text{CCPs}_{i,2017}$ previously rendered insignificant when controlling for trading income is now statistically significant.

The choice in the number of central clearing memberships is a trade-off. The main benefit of central clearing from the member's perspective is the ability to net open positions and significantly decrease the collateral that is needed to be pledged with the counterparty. Increasing the number of clearing links distributes the member's clearing activity across multiple CCPs and reduces the ability to net its derivative positions. Besides,clearing memberships are costly and potentially dangerous, members need to contribute to the CCP's default fund and are obliged to post additional funds if the default resources are wiped out by another member's default. On the other hand, increasing the number of clearing links enables the bank to offer clearing to customers only willing to clear with specific CCPs. This increases the number of possible trades and generates fee income for the bank offering that service.

Clearing with central counterparties requires a club membership with the CCP. CCPs screen their members and may deny risky banks entry to their club. As CCP membership is public information, CCPs may restrict risky banks from clearing with multiple CCPs in order to contain possible contagion of distress.

Riskier banks may want to decrease the number of clearing links as they might have a higher incentive to reduce the required collateral through netting. The balance sheet's asset side becomes less liquid when assets are used as collateral, therefore funding needs to become more stable, which is more costly for risky banks. But still, it is unclear whether this is due to diversification of the bank, or due to a selection mechanism of the CCP. In any case, the positive association seem to outweigh the possible negative correlation as described before.

Banks do not only connect to CCPs but also to the member network of that CCP, clearing with multiple CCPs therefore increases the exposure to other bank's failures and banks that were previously not a clearing counterparty are now part of the network and add to the exposure to bank's default. But as CCPs may act as a buffer between counterparties, central clearing could in general decreases the exposure to previously bilaterally linked trading counterparties. In order to access the ability of CCPs to absorb these shocks from other member I analyze the correlation of bank risk in the next section.

4.5 Peer Effects in Central Clearing

One possible adverse effect the regulation might have brought about is the increase in the sensitivity of the member's bank health with regard to the CCP's other members, which I call peers in the following. Therefore CCPs may provide an important transmission channel for the contagion of financial distress within the banking sector (Umar Faruqui and Takàts, 2018). I showed in Section 4.4 that increased interconnectedness in the clearing network is not associated with higher bank risk. But still, if the risk of peers is strongly correlated the problem of risk may arise in the time dimension. An increase in interconnectedness may enable the network to absorb shocks. But an increase in underlying asset prices co-movement for example might introduce peer correlation into the system. If the network becomes too dense, the correlation of risk may destabilize the financial system.

Two main sources for default risk correlation arise from central clearing. First, the shock that stems from the CCP's actions spreads simultaneously to all its members. This scenario would come into play if the CCP adjusts its risk model, changes collateral requirements or executes rule based periodic margin calls simultaneously to its members. Such shocks arise from the center of the clearing subnetworks and propagate to all directly connected nodes at the same time and thus increase the correlation of the subnetwork node's health. The most profound shock of this sort would be a CCP's default.

Second, a member's derivative positions may affect the price and liquidity of assets held and used as collateral by multiple members. The most severe shock is the inability of a member to cover its variation margin requirements and a resulting default. The most prominent case is the default of Einar Aas on September 11, 2018, member at Nasdaq Clearing at that time. The losses from the remaining open trades went through the margin accounts, the CCP's own capital and two-thirds of the mutual default fund.[11]

The risk of moral hazard that member increase risk as an effect of the central clearing reform is a main concern of its critics (Mayordomo and Posch, 2016). CCPs, on the other hand, have been designed to withstand such shocks and shield members from adverse correlation in the clearing process. They act as risk managers by securing the margin requirement coverage at a preset frequency and buffer against the effects of another member's default. But, as I show in Chapter 3 of this thesis, the default waterfall seems to be equipped to withstand fluctuations during tranquil times. It

[11] See `https://www.nytimes.com/2019/05/03/business/central-counterparties-financial-meltdown.html`, Retrieved 18 May 2019.

is not clear whether CCPs can withstand crisis periods. The shock absorption may work only up to a certain size of the shock and result in a false sense of security. A scenario adverse enough would trigger a tail risk to an institution that is commonly appreciated as too big to fail.

Centrally clearing of derivatives requires handing over the transaction to a central counterparty via novation. This may only be done by counterparties who both have a member account with the CCP. As a result CCPs are placing themselves as central nodes in subsets of the clearing network. In this section I analyze the relationship of central clearing networks and the correlation of clearing members' health. I ask wether the introduction of CCPs rendered systematic risk correlated enough to become systemic.

Again this analysis only applies the bank subset of the clearing network described in Section 4.3. A graphical representation of the network is plotted in Figure 4.5, which reveals that there is no disconnected entity or group within the network and every CCP is again connected to another CCP via at least one bank clearing member.[12] In this setting, I contrast the peer correlation of in the Zscore in the pre-regulation bilateral clearing network structure with the peer correlation in the centralized subnetworks arising with the regulation in the post period from 2016 onward. I estimate the following equation:

$$\text{Zscore}_{it} = \alpha_i + \alpha_t + \beta\, \overline{\text{Zscore}}_{g_{-i}t} + \gamma \left(\text{post} \times \overline{\text{Zscore}}_{g_{-i}t}\right) + \delta\, \mathbf{X}_{i,t-1} + \varepsilon_{it}, \quad (4.5)$$

whereas Zscore_{it} denotes the log Zscore of bank i at time t as described in Equations 4.1 and 4.2, $\overline{\text{Zscore}}_{g_{-i}t}$ is the equally weighted average Zscore of the group g leaving out member i, post is a binary variable taking the value of one in 2017 and zero in 2015. $\mathbf{X}_{i,t-1}$ contains the following control variables: ratio of non-performing loans to total gross loans, cost-to-income ratio, liquid assets as share of total assets and bank size measured as log of total assets, all lagged by one period, α_i and α_t capture the individual and time fixed effects, respectively. ε_{it} is the idiosyncratic time variant

[12] The network graph employs the force-directed algorithm developed by Fruchterman and Reingold (1991), which emphasizes the strong connections of the CCPs through their members by placing them closely together towards the center of the network.

error term, and standard errors are estimated with the Huber-White method. The coefficients of interest β and γ may only be interpreted as correlation coefficients conditional on the control variables. Again, including contemporaneous controls or excluding them completely does not alter the results, which supports the requirement for exogenous controls.

The fixed effects model for estimating peer effects is specified according to Bramoullé et al. (2009), whereas the use of group fixed effects is not applicable as the specification described in Equation 4.5 allows for nodes to form connections to multiple CCPs creating overlapping groups. In a alternative specification nodes only form connections with one CCP, which is estimating Equation 4.5 for the subset of single-connected nodes forming exclusive groups, where the group fixed effect is captured by the individual fixed effects, as there is no time variation in the formation of the network.

The control variables are taken from the CAMEL approach and account for the confounding effects of bank characteristics on the sensitivity of the individual Zscore to the group Zscore. The summary statistics are listed in Table 4.1, size and group mean Zscore are in log terms, the ratios of non performing loans to total gross loans, costs to gross income, and liquid to total assets are in percentage terms. The network data describes clearing groups with a mean size of 42.3 members and median size of 20.5. The bank subnetwork in the regression sample has a mean group size of 14 members per CCP. The evolution of the unweighted group mean Zscore of all clearing members within that group over time is depicted in Figure 4.6.

The results of the peer effects regression described in Equation 4.5 are listed in Table 4.9 without controlling for $\mathbf{X_{it}}$ in column 1 and with controls in column 2. The results of the two estimates are very similar revealing a strong and statistically significant correlation of the individual and group Zscore prior to the introduction of mandatory clearing and a significantly decreased correlation afterwards. That is β is positive and statistically significant , γ is negative and statistically significant, meaning that in the pre period when post equals 0, there is a strong positive correlation. γ shows the difference between the pre and post period, meaning that the correlation is statistically significantly lower in the post compared to the pre period. Whether the correlation of individual and group Zscore is still significant in the post period, will be shown by the marginal effects of the group Zscore conditional on the post period. The marginal effects reported in Table 4.10 reveal the pre and post period correlation coefficients by combining the coefficients of the interaction terms in Equation 4.5 for the estimation including the control variables. The pre-period group correlation is 0.89 and significantly different from zero with a p-value of 0.025. In the post period the correlation coefficient is decreased to 0.358 and not statistically different from zero. The network transformation of the central clearing reform may have resulted in a less integrated network in the sense of Acemoglu et al. (2015) and the shock absorption of a less dense network reduces risk correlation, which may help to contain systemic risk.

As a robustness check, I re-estimate the regression as in Equation 4.9 with the subset of banks that clear via one CCP only. In this sample the groups do not overlap and form a set of disconnected closed neighborhoods as presented in Figure 4.7.[13] The regression results are listed in Table 4.11 and are again presented excluding control variables in column 1 and including controls in column 2. The coefficients are of similar nature compared to the effects in Table 4.9 only increased in magnitude and significance. Which is not surprising given that the groups include banks that form only a bond with each other. To a certain extend, there might be a mechanical increase in the effect as the selection into clearing groups is not random. The summary statistics of this sample are listed in Table 4.3 and are not structurally different from the characteristics of the sample which in underlying the main regression. The structural difference of this model compared to the previous one is that the group fixed effect is now captured by the individual fixed effect and time invariant unobserved characteristics of the clearing subnetworks are now controlled for.

4.6 Conclusion

The central clearing reform implemented in Europe in 2016 mandatorily requires European firms to clear standardized derivatives via an authorized central clearing counterparty. This resulted in a transformation of the clearing landscape from a dense bilateral interconnection into a network of cental hubs. With this transformation

[13]The graph also employs the force-directed algorithm developed by Fruchterman and Reingold (1991), which in this case creates separate spheres for each group.

came possible adverse consequences such as risk concentration and an increase in risk correlation within the group members at CCPs, which is feared to increase systemic risk.

In this paper, I describe the central clearing network in Europe using hand collected membership data for the 16 European based CCPs authorized under EMIR. The network may be characterized as closely connected and highly interwoven with every CCP being connected to another CCP through at least one member. The findings imply that special supervisory attention should be paid to the banks now operating in clearing clusters and systemically important CCPs are interconnected through their members.

I further analyze the relationship between clearing links in the network and the financial members' health as indicated by the Zscore. I find that a higher number of clearing connections is associated with statistically significantly lower bank risk, measured with an increase in the Zscore by about 6.7 to 13.6 percent per additional link. This might speak in favor of diversification of the derivative activity across multiple clearing houses or a selection mechanism by the CCPs to accept only healthy applicants as members who already clear elsewhere in order to prevent contagion of potential distress.

Further, I analyze the change in correlation of bank health within groups of banks clearing at the same CCP in order to extract potential peer effects of distress before and after the implementation of the central clearing reform. I assume that banks clearing at the same CCP had some bilateral derivative exposure prior to the reform and do not randomly assign into groups in order to gain from the ability to net positions with established trading partners when clearing their trades. I find that the within group correlation of bank health as indicated by the Zscore significantly decreased after the implementation of mandatory central clearing. It seems that CCPs act as buffers to absorb shocks and successfully shield their members from contagion. This finding speaks in favor of the ability of CCPs to decrease risk exposure in derivative networks to some degree. The main policy implication which may be drawn from the results is that the channel of risk contagion in the clearing network may have shifted away from directly linked peers and may now be concentrated in the center of clearing clusters at the CCPs, whose default absorbing resources may not be equipped well enough to absorb larger shocks to the system,[14] potentially spreading financial distress to their clearing members.

The results may be interpreted with caution as this analysis only examines the network between CCPs and their members during tranquil times. The panel estimations do not account for confounding factors, such as significant changes in the bilateral trading patterns or changes in the interbank market happening at the same time. The analysis of bank risk relies on a few observations in a short time frame and consider one indicator of bank risk only. I do not include relevant non-bank members, outlying cases or examine potential tail risks. CCPs need to be build to withstand extreme adverse shocks. Due to their size and risk concentration, CCPs are considered to be too big to fail systemically important financial hubs. The decreased correlation of risk between bank clearing members in quiet times should not result in a false sense of security.

Possible extensions for the analysis of the effect of central clearing on banking network health and shock propagation include the construction of clearing clusters based on characteristics not directly related to derivatives such as interbank connections and using the central clearing reform as a exogenous shock to measure the causal effect of central clearing on the correlation of bank risk in the network. Additionally one could examine the moderating effects of node characteristics and the specific change in network characteristics, such as centrality and the within or between cluster connection ratio, that is provided by the clearing link in order to assess effectiveness of the central clearing reform.

[14]See Chapter 3 for a discussion of CCPs' loss absorbing resources.

Tables and Figures

Variable	N	Mean	SD	Med.	Min.	Max.
Dependent variable						
Zscore	478	3.792	1.132	3.927	0.112	5.707
Independent variables						
$\overline{\text{Zscore}}_{g-i}$	478	3.677	0.304	3.733	2.462	4.969
NPL	478	6.951	9.278	3.220	0.000	53.290
Cost-to-income	478	70.712	31.574	66.350	14.650	297.170
Liquid assets	478	22.521	18.586	17.210	0.260	97.310
Log assets	478	16.635	2.427	16.679	9.088	22.329

TABLE 4.1: **Summary Statistics of the Panel Regression Sample:** This table shows summary statistics for the dependent variables and bank-level control variables used as input for the panel regressions presented in Table 4.9 as defined in Equation 4.5. The sample consists of 478 observations from 239 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the log of the Zscore as defined in Equations 4.1 and 4.2. $\overline{\text{Zscore}}_{g-i}$ is the average Zscore of the peers that are clearing with the same CCP excluding the bank itself. NPL denotes the fraction of impaired loans relative to total gross loans (in percent) and is used as a measure of asset quality. Cost-to-income is the ratio of total expenses to gross income (in percent) and is an indicator of management quality. Liquid assets is a measure of liquidity, calculated as the share of liquid assets in total assets (in percent). Log assets is the log of total assets and measures bank size. The dependent variable is calculated for the years 2015 and 2017. Only banks for which data is available in both years are included in the sample. Size, liquidity, asset and management quality measures are calculated with a one year lag, in 2014 and 2016, respectively, in order to alleviate possible endogeneity concerns regarding the control variables. All data is winsorized at the one percent level prior to the calculations. Observations with negative equity ratio or a Zscore four times its standard deviations above the mean are dropped.

Variable	N	Mean	SD	Med.	Min.	Max.
Dependent variables						
Zscore_{2017}	148	3.761	0.780	3.879	1.805	5.013
$\text{Zscore}_{\overline{2016/17}}$	148	3.670	0.750	3.755	1.615	4.901
Independent variables						
CCPs	148	1.966	1.688	1.000	1.000	8.000
NPL	148	6.814	8.463	3.255	0.060	31.240
Cost-to-income	148	67.295	19.574	67.060	31.410	128.340
Liquid assets	148	21.991	18.381	16.705	2.410	86.490
Log assets	148	16.835	2.369	16.868	11.086	20.333
Trading income	148	6.286	13.311	2.275	−8.340	81.260
Off-balance-sheet	148	0.197	0.387	0.096	0.001	3.766

TABLE 4.2: **Summary Statistics of the Cross-section Regression Sample:** This table shows summary statistics for the dependent variables and bank-level control variables used as input for the cross-section regressions presented in Tables 4.7 and 4.8 as defined in Equations 4.3 and 4.4. The sample consists of 148 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variables are the log of the Zscore as defined in Equations 4.1 and 4.2 for the year 2017 (Zscore_{2017}) and as the average of 2016 and 2017 ($\text{Zscore}_{\overline{2016/17}}$). CCPs is the number of clearing links maintained by the bank, ranging from one to eight with an average of two. NPL denotes the fraction of impaired loans relative to total gross loans (in percent) and is used as a measure of asset quality. Cost-to-income is the ratio of total expenses to gross income (in percent) and is an indicator of management quality. Liquid assets is a measure of liquidity, calculated as the share of liquid assets in total assets (in percent). Log assets is the log of total assets and measures bank size. Size, liquidity, asset and management quality measures are calculated for the year 2016 in order to alleviate possible endogeneity concerns regarding the control variables. Additional controls include Trading income, which measures the share of trading income in total gross income (in percent) and Off-balance-sheet, which is the ratio of aggregated balance sheet items relative to total assets on balance sheet (in percent). Both variables are used in the interaction terms as defined in Equation 4.4 and are calculated for the year 2017. All data is winsorized at the one percent level prior to the calculations. Observations with negative equity ratio or a Zscore four times its standard deviations above the mean are dropped.

Variable	N	Mean	SD	Med.	Min.	Max.
Dependent variable						
Zscore	402	3.756	1.150	3.898	0.112	5.707
Independent variables						
$\overline{\text{Zscore}}_{g-i}$	402	3.651	0.316	3.644	2.462	4.969
NPL	402	7.260	9.542	3.260	0.000	53.290
Cost-to-income	402	70.936	32.207	66.520	14.650	297.170
Liquid assets	402	22.796	19.275	17.190	0.260	97.310
Log assets	402	16.466	2.423	16.546	10.624	22.182

TABLE 4.3: **Summary Statistics for the Panel Regression of the Single-connection Subnetwork:** This table shows summary statistics for the dependent variables and bank-level control variables used as input for the panel regressions presented in Table 4.11 as defined in Equation 4.5 for the subset of the network of European central clearing counterparties including members with a single clearing connection only. The sample consists of 402 observations from 201 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the log of the Zscore as defined in Equations 4.1 and 4.2. $\overline{\text{Zscore}}_{g-i}$ is the average Zscore of the peers that are clearing with the same CCP excluding the bank itself. NPL denotes the fraction of impaired loans relative to total gross loans (in percent) and is used as a measure of asset quality. Cost-to-income is the ratio of total expenses to gross income (in percent) and is an indicator of management quality. Liquid assets is a measure of liquidity, calculated as the share of liquid assets in total assets (in percent). Log assets is the log of total assets and measure bank size. The dependent variable is calculated for the years 2015 and 2017. Only banks for which data is available in both years are included in the sample. Size, liquidity, asset and management quality measures are calculated with a one year lag, in 2014 and 2016, respectively, in order to alleviate possible endogeneity concerns regarding the control variables. All data is winsorized at the one percent level prior to the calculations. Observations with negative equity ratio or a Zscore four times its standard deviations above the mean are dropped.

Name	Connections
Goldman Sachs International	13
Abn Amro Clearing Bank N.V.	12
J.P. Morgan Securities PLC	11
Merrill Lynch International	10
Morgan Stanley & Co International PLC	9
Banco Santander S.A.	8
Rbc Europe Limited	7
Citibank Europe PLC	7
Deutsche Bank AG	7
Credit Suisse International	7
Credit Suisse Securities (Europe) Limited	7
Hsbc Bank PLC	7
Intl Fcstone Ltd	7
Nomura International PLC	7
Marex Financial Limited	7
Ubs Limited	7
Unicredit Bank AG	7
Bnp Paribas Securities Services	6
Citigroup Global Markets Ltd	6
Barclays Bank PLC	6
Commerzbank AG	6
Natixis	6
Societe Generale	6
E D & F Man Capital Markets Limited	5
Banca Imi S.P.A	5
Flow Traders B.V.	5
Societe Generale International Limited	5
The Royal Bank Of Scotland PLC	5

TABLE 4.4: **List of Clearing Members with the most Connections:** This table lists the clearing members with the most CCP connections in the data.

CCP Name	**Clearing Members in Network**
Eurex Clearing	629
CC&G	162
LCH Clearnet Ltd.	156
BME Clearing S.A.	140
Keler CCP	131
LCH Clearnet S.A.	102
CCP Austria	70
Euro CCP	44
LME Clear	44
KDPW CCP	34
CME Clearing Europe	22
OMI Clear	13
Nasdaq Clearing	9
ICE Clear Netherlands	4
Total	1560

TABLE 4.5: **List of Clearing Members in Network by CCP:** This table lists the number of clearing members of each CCP in the data as of 2017.

Date	**N**	**Min.**	**$Q_{.25}$**	**Mean**	**Med.**	**$Q_{.75}$**	**Max.**	**SD**
2015q3	11	1	11.0000	57.0909	46.0000	68.0000	183	57.6827
2015q4	13	1	17.0000	54.0769	51.0000	62.0000	186	51.8097
2016q1	14	1	9.5000	52.6429	48.5000	61.7500	193	52.4765
2016q2	15	1	12.5000	59.3333	51.0000	67.5000	195	61.2124
2016q3	15	1	13.0000	60.0667	51.0000	68.0000	196	59.7763
2016q4	14	1	11.2500	62.5714	31.0000	70.0000	255	77.4405
2017q1	15	1	18.0000	67.6000	56.0000	72.0000	240	70.2229
2017q2	14	1	15.2500	65.2857	40.5000	70.0000	240	73.0968
2017q3	14	1	16.5000	65.2857	40.5000	70.0000	241	72.7846
Total	126	1	10.5000	60.5238	48.0000	70.7500	255	62.7526

TABLE 4.6: **Direct clearing memebers of CCPs by quarter:** This table lists the number of direct clearing members of European CCPs in each quarter.

	(1)	(2)	(3)	(4)
CCPs	0.067*	0.080**	0.078	0.136**
	(0.077)	(0.038)	(0.144)	(0.018)
NPL		−0.029***	−0.030***	−0.029***
		(0.000)	(0.000)	(0.000)
Cost-to-income		−0.009***	−0.008**	−0.009***
		(0.007)	(0.015)	(0.006)
Liquid assets		−0.002	−0.001	−0.003
		(0.586)	(0.864)	(0.340)
Log assets		−0.051*	−0.048	−0.050*
		(0.081)	(0.104)	(0.083)
Trading income			−0.009	
			(0.255)	
CCPs × Trading income			0.001	
			(0.817)	
Off-balance-sheet				0.655*
				(0.059)
CCPs × Off-balance-sheet				−0.303
				(0.188)
Constant	3.629***	5.301***	5.240***	5.209***
	(0.000)	(0.000)	(0.000)	(0.000)
Adjusted R^2	0.015	0.159	0.162	0.172
Observations	148	148	148	148
μ_y	3.761	3.761	3.761	3.761
σ_y	0.780	0.780	0.780	0.780

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 4.7: **Cross-section Regression Results for 2017:** This table reports the cross-section estimation results from the regression defined in Equation 4.3. The sample consists of 148 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the log of the Zscore as defined in Equations 4.1 and 4.2 for the year 2017. CCPs is the number of clearing links maintained by the bank, ranging from one to eight with an average of two. Bank-level controls include NPL, the fraction of impaired loans relative to total gross loans (in percent), Cost-to-income, the ratio of total expenses to gross income (in percent), Liquid assets, the share of liquid assets in total assets (in percent) and Log assets, the log of total assets. Size, liquidity, asset and management quality measures are calculated for the year 2016 in order to alleviate possible endogeneity concerns regarding the control variables. Additional controls include Trading income, the share of trading income in total gross income (in percent) and Off-balance-sheet, the ratio of aggregated balance sheet items relative to total assets on balance sheet (in percent). Both latter variables are used in the interaction terms in columns three and four respectively as defined in Equation 4.4 and are calculated for the year 2017. Summary statistics are reported in Table 4.2. Standard errors are estimated with the Huber-White method.

	(1)	(2)	(3)	(4)
CCPs	0.069*	0.084**	0.092*	0.130**
	(0.060)	(0.023)	(0.074)	(0.020)
NPL		−0.026***	−0.027***	−0.026***
		(0.000)	(0.000)	(0.000)
Cost-to-income		−0.008**	−0.008**	−0.008**
		(0.012)	(0.023)	(0.012)
Liquid assets		−0.000	0.002	−0.001
		(0.982)	(0.656)	(0.669)
Log assets		−0.055*	−0.054*	−0.054*
		(0.052)	(0.061)	(0.055)
Trading income			−0.009	
			(0.250)	
CCPs × Trading income			0.000	
			(0.997)	
Off-balance-sheet				0.577*
				(0.087)
CCPs × Off-balance-sheet				−0.245
				(0.272)
Constant	3.535***	5.152***	5.102***	5.059***
	(0.000)	(0.000)	(0.000)	(0.000)
Adjusted R^2	0.017	0.147	0.157	0.159
Observations	148	148	148	148
μ_y	3.670	3.670	3.670	3.670
σ_y	0.750	0.750	0.750	0.750

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 4.8: **Cross-section Regression Results for the Collapsed Period of 2016 and 2017:** This table reports the cross-section estimation results from the regression defined in Equation 4.3. The sample consists of 148 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the average of the log Zscore as defined in Equations 4.1 and 4.2 for the years 2016 and 2017. CCPs is the number of clearing links maintained by the bank, ranging from one to eight with an average of two. Bank-level controls include NPL, the fraction of impaired loans relative to total gross loans (in percent), Cost-to-income, the ratio of total expenses to gross income (in percent), Liquid assets, the share of liquid assets in total assets (in percent) and Log assets, the log of total assets. Size, liquidity, asset and management quality measures are calculated for the year 2016 in order to alleviate possible endogeneity concerns regarding the control variables. Additional controls include Trading income, the share of trading income in total gross income (in percent) and Off-balance-sheet, the ratio of aggregated balance sheet items relative to total assets on balance sheet (in percent). Both latter variables are used in the interaction terms in columns three and four respectively as defined in Equation 4.4 and are calculated for the year 2017. Summary statistics are reported in Table 4.2. Standard errors are estimated with the Huber-White method.

	(1)	(2)
$\overline{\text{Zscore}}_{g-i}$	0.788^{*}	0.892^{**}
	(0.053)	(0.026)
post × $\overline{\text{Zscore}}_{g-i}$	-0.524^{*}	-0.533^{*}
	(0.092)	(0.077)
NPL		0.009
		(0.687)
Cost-to-income		-0.005^{**}
		(0.037)
Liquid assets		−0.018
		(0.137)
Log assets		−0.288
		(0.421)
Adjusted R^2	0.067	0.104
Observations	478	478
μ_y	3.792	3.792
σ_y	1.132	1.132
Controls	no	yes
TimeFE	yes	yes
MemberFE	yes	yes

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 4.9: **Peer Effects Regression Results:** This table reports the estimation results from the panel regression defined in Equation 4.5. The sample consists of 478 observations from 239 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the log of the time variant Zscore as defined in Equations 4.1 and 4.2. $\overline{\text{Zscore}}_{g-i}$ is the average Zscore of the peers that are clearing with the same CCP excluding the bank itself. Bank-level controls include NPL, the fraction of impaired loans relative to total gross loans (in percent), Cost-to-income, the ratio of total expenses to gross income (in percent), Liquid assets, the share of liquid assets in total assets (in percent) and Log assets, the log of total assets. The dependent variable is calculated for the years 2015 and 2017. Only banks for which data is available in both years are included in the sample. Size, liquidity, asset and management quality measures are calculated with a one year lag, in 2014 and 2016, respectively, in order to alleviate possible endogeneity concerns regarding the control variables. Summary statistics are reported in Table 4.1. Standard errors are clustered at the bank-level.

Period	**Correlation coefficient**		**95% conf. interval**	
pre	0.892	(0.025)	0.111	1.672
post	0.358	(0.309)	−0.332	1.049

p-values in parentheses

TABLE 4.10: **Marginal Peer Effect:** This table reports the marginal peer effects calculated from the regression results reported in Table 4.9 column two as defined in Equation 4.5. The rows contrast the correlation coefficient obtained from the interaction term in Equation 4.5 for the pre and post period by employing the delta method, together with the respective 95 percent confidence intervals.

	(1)	(2)
$\overline{\text{Zscore}}_{g-i}$	1.021**	1.014**
	(0.031)	(0.026)
post × $\overline{\text{Zscore}}_{g-i}$	−0.675**	−0.651**
	(0.048)	(0.046)
NPL		−0.006
		(0.852)
Cost-to-income		−0.004*
		(0.061)
Liquid assets		−0.019
		(0.227)
Log assets		−0.398
		(0.387)
Adjusted R^2	0.072	0.107
Observations	402	402
μ_y	3.756	3.756
σ_y	1.150	1.150
Controls	no	yes
TimeFE	yes	yes
MemberFE	yes	yes

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 4.11: **Peer Effects Regression Results for the Single-connection Subnetwork:** This table reports the estimation results from the panel regression defined in Equation 4.5 for the subset of the network of European central clearing counterparties including members with a single clearing connection only. The sample consists of 402 observations from 201 banks that are clearing members of the 16 European based central clearing counterparties (CCP) authorized according to ESMA (2018b). The dependent variable is the log of the time variant Zscore as defined in Equations 4.1 and 4.2. $\overline{\text{Zscore}}_{g-i}$ is the average Zscore of the peers that are clearing with the same CCP excluding the bank itself. Bank-level controls include NPL, the fraction of impaired loans relative to total gross loans (in percent), Cost-to-income, the ratio of total expenses to gross income (in percent), Liquid assets, the share of liquid assets in total assets (in percent) and Log assets, the log of total assets. The dependent variable is calculated for the years 2015 and 2017. Only banks for which data is available in both years are included in the sample. Size, liquidity, asset and management quality measures are calculated with a one year lag, in 2014 and 2016, respectively, in order to alleviate possible endogeneity concerns regarding the control variables. Summary statistics are reported in Table 4.3. Standard errors are clustered at the CCP-level.

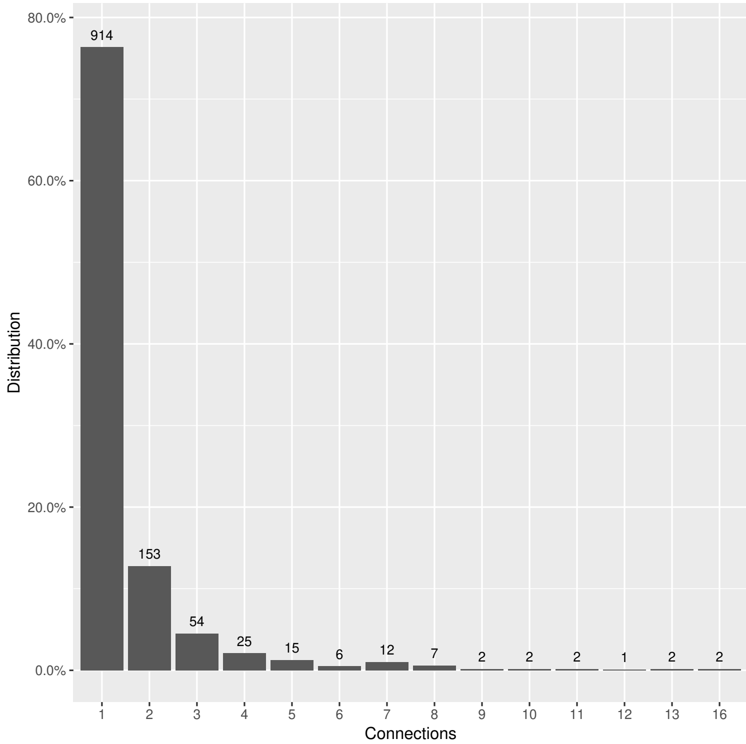

FIGURE 4.1: **Distribution of Members' Clearing Connections in Network:** This figure shows the distribution of linked CCPs per clearing member.

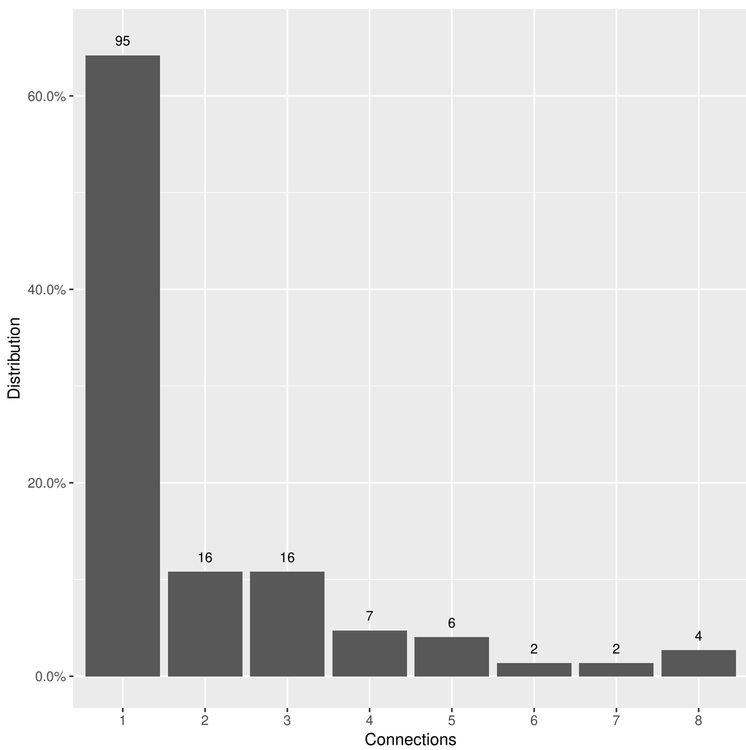

FIGURE 4.2: **Distribution of Members' Clearing Connections in Sample:** This figure shows the distribution of linked CCPs per clearing member in the cross-section sample.

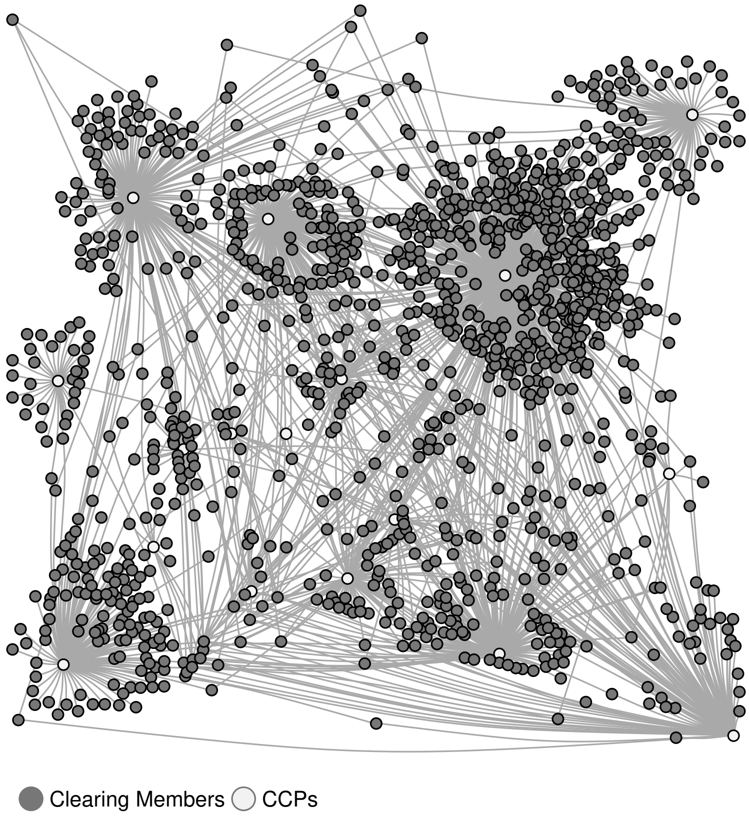

FIGURE 4.3: **Clearing Member and Counterparty Network:** This figure shows the member network of European central clearing counterparties as of 2017. As a positioning mechanism I applied the Davidson-Harel simulated annealing layout algorithm developed by Davidson and Harel, 1996. The algorithm encloses the members (periphery), which belong to a CCP (centers) and thus emphasizes the multiple central hub characteristic of the clearing network structure.

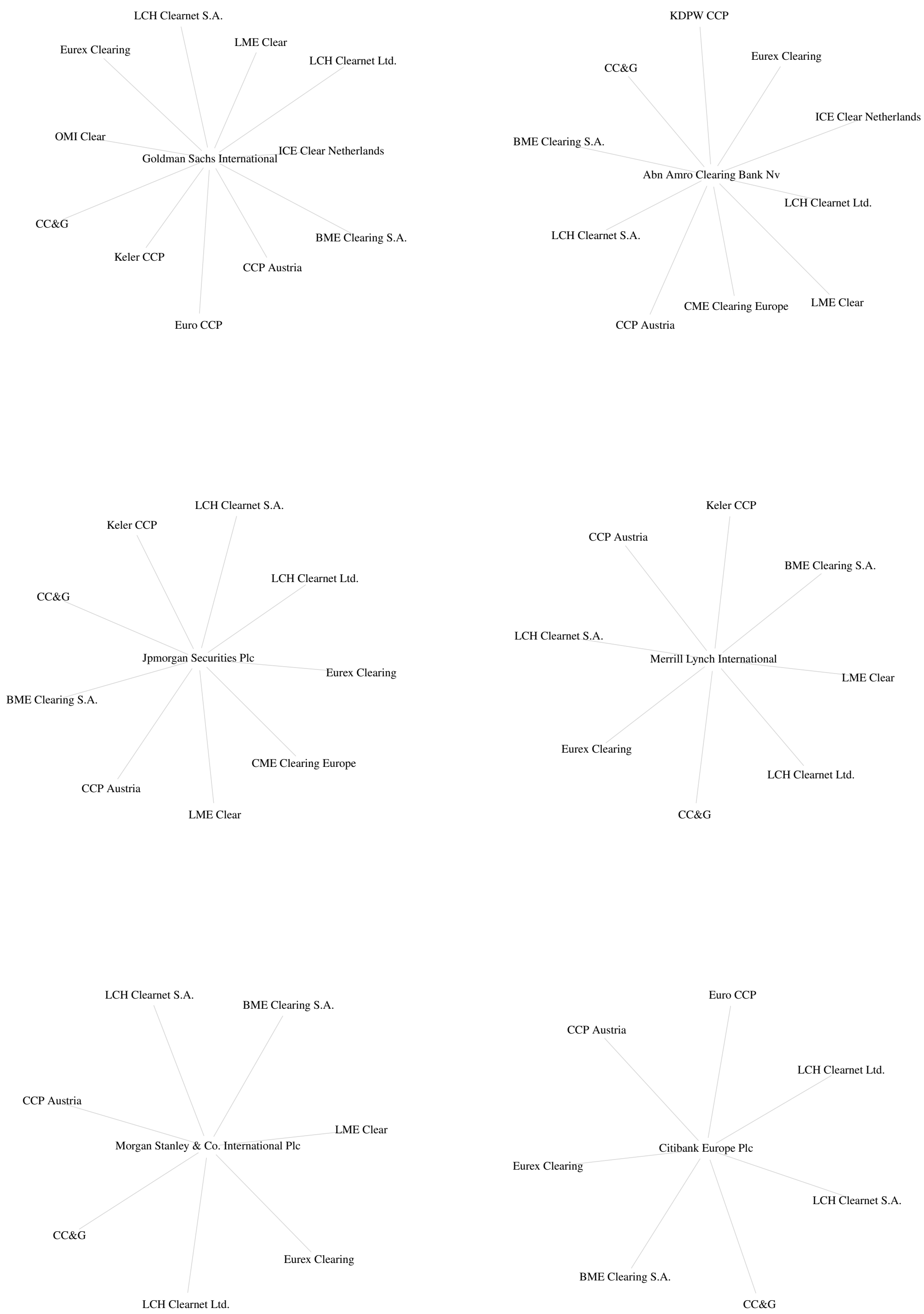

FIGURE 4.4: **Subgraphs of Clearing Network:** This figure shows the subgraphs of Figure 4.3 including the six largest clearing member nodes in terms of CCP connections.

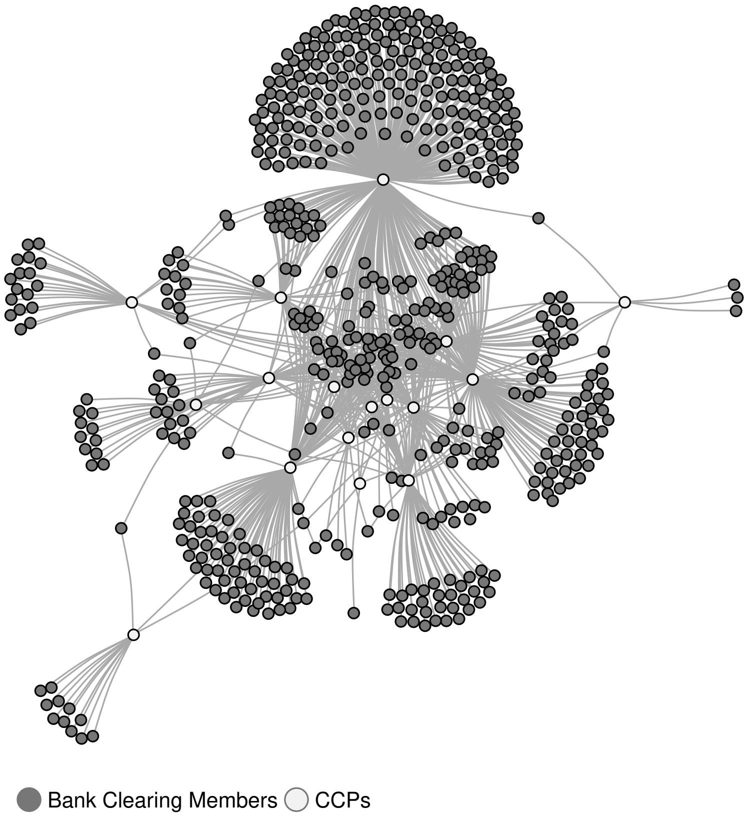

FIGURE 4.5: **Bank subset of the Clearing Network:** This figure shows the bank member network of European central clearing counterparties as of 2017. As a positioning mechanism I applied the Fruchterman-Reingold force-directed layout algorithm.

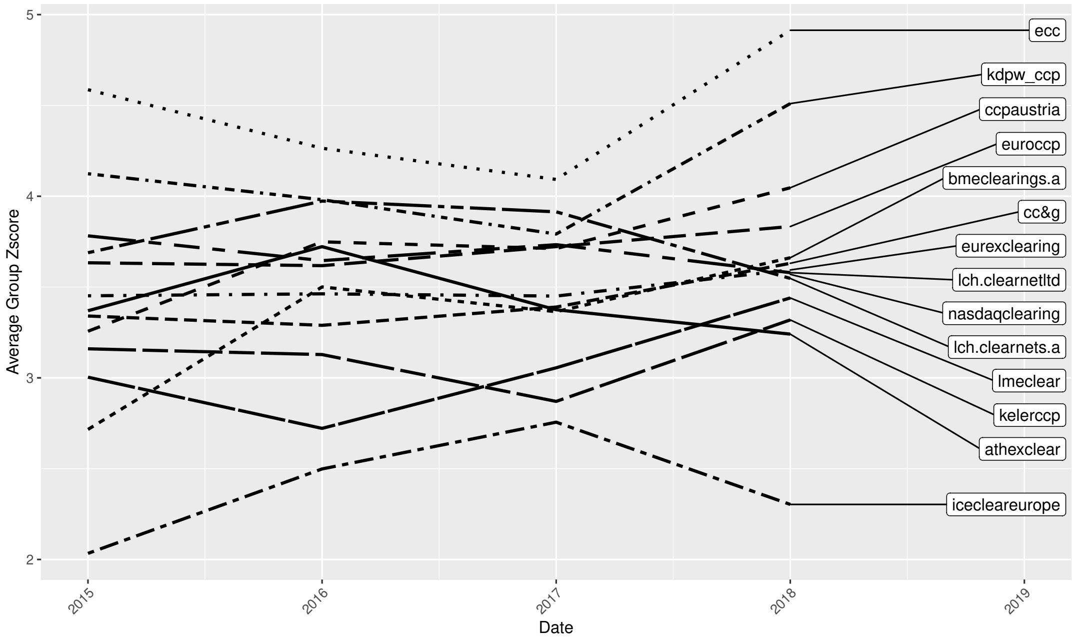

FIGURE 4.6: **Mean of Members' Zscore by CCP:** This figure shows evolution of the unweighted mean of members' log Zscore by CCP.

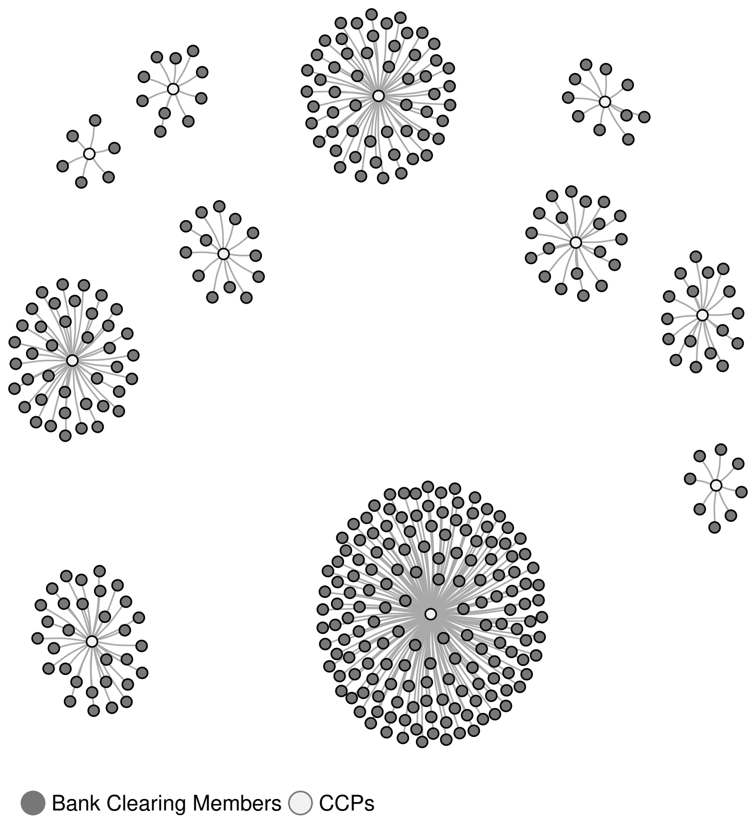

FIGURE 4.7: **Closed Neighborhood subset of the Clearing Network:** This figure shows the subset of the network of European central clearing counterparties including members with a single clearing connection only. As a positioning mechanism I applied the Fruchterman-Reingold force-directed layout algorithm.

Chapter 5

Conclusion

> *"There is a theory which states that if ever anyone discovers exactly what the Universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable. There is another theory which states that this has already happened."*
>
> – Douglas Adams
>
> The Hitchhiker's Guide to the Galaxy

The analysis of differential effects of financial market interventions constitutes a crucial part in the evaluation of their effectiveness to provide a framework which allows for the operation of a stable financial system. It is therefore increasingly important to understand how financial reforms and policy tools affect the concerned financial entities depending on their individual characteristics and interconnectedness. The aim of this thesis is to contribute to this understanding by analyzing the application of macroprudential policies and the implementation of the central clearing reform, as two applications of financial market interventions aiming at contributing to a more resilient financial system. Thereby, it can shed light on how parent bank funding affects the response of the lending behavior of their branches to changes in reserve requirements (Chapter 2), how the ownership type of central clearing counterparties correlates with the structure of their loss absorbing capacities (Chapter 3), and finally how the interconnectedness of derivative clearing banks is associated with their own risk and the correlation of risk with their counterparties (Chapter 4).

To this extent Chapter 2 reveals that the parent banks' funding structure affect the transmission of macroprudential policies to credit supply of their branches. The analysis documents that the aggregate outcome of reserve requirements is driven by the heterogeneity of banks' responses to macroprudential policies and dynamics within a banking group. In addition, the analysis shows that macroprudential regulation can be an effective tool for emerging economies to mitigate the negative effects of exogenously driven periods of capital outflows on credit growth. Alleviating reserve requirements can help to maintain credit supply by weaker branches of parent banks during crisis periods. The outcome of changes in macroprudential policies therefore depends on the characteristics of the regulated parent banks and the network maintained within the banking group.

Chapter 3 shows that the composition of default loss absorbing resources of central clearing counterparties (CCPs) differs significantly and persistently across ownership types. CCPs operated by a central bank observe a higher share of notional amount covered by margin and capital, resulting in a lower share of remaining losses to be covered by the clearing members and a reduction in the possibility of a CCP's default. CCPs operated by an exchange or in part by its members observe higher variation margin calls relative to other forms of default absorbing resources, resulting in a higher burden on the members' liquidity and an increase in the probability that subsequent layers of the default waterfall need to be mobilized if a member defaults due to the inability to meet a margin call. In addition, I show that CCPs owned by exchanges or in part by their clearing members apply higher haircuts to the assets accepted as initial margin and default fund contributions, which is an indicator for lower asset quality of default resources. The main policy implication is that the composition of default resources might be subject to misaligned incentives in the provision of clearing services, between the regulatory and individual for-profit perspective, as the central banks incorporate the policy objective of financial stability of the central clearing reform, while exchanges and members might not necessarily do so.

Chapter 4 describes the central clearing network in Europe which may be characterized as closely connected and highly interwoven with every CCP being connected to another CCP through at least one member. The analysis shows that banks now operate in clearing clusters and systemically important CCPs are interconnected through their members, which may require additional attention by policy makers. Analyzing the relationship between clearing links in the network and bank health, I find that a higher number of clearing connections is associated with lower bank risk. This may be seen as a positive effect of diversification or the result of a selection mechanism by the CCPs aiming to prevent contagion of distress between clusters. Finally, I find that the correlation of bank risk within clearing clusters decreases significantly after the implementation of mandatory central clearing reform. This may speak in favor of CCPs acting as buffers to absorb shocks and shielding their members from contagion of financial distress.

In summary, the thesis discusses crucial aspects of the differential effects of financial market interventions. It demonstrates the significance of individual characteristics and the interconnectedness of regulated financial entities for the outcome of financial regulation. It thus highlights the importance of taking these factors into account when implementing and evaluating financial market interventions. This insight is of non-negligible significance given the importance of a well functioning and resilient financial system for a prosperous real economy and thus for a life in prosperity for the many.

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