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Contents

List of Tables

List of Figures

To the stability of the European Union.

Chapter 1

Preface and outline of the thesis

"*The regulation proposed by the Basel Committee on Banking Supervision should not be assessed in isolation [...] The changes in the financial system caused by the regulation will have to be factored in also by the policy authorities. For central banks, the changes may be far-reaching, ranging from the transmission mechanism of monetary policy to interactions with several aspects of the operational frameworks.*"

Smaghi, 2010

The global financial crisis in 2007-2009 exposed the absence of adequate regulation within the banking sector which had built up an excessive amount of on- and off-balance sheet leverage and had neglected basic principles of liquidity risk management (Acharya and Richardson, 2009, Adrian and Shin, 2010, Goodhart, 2008). As a response, the Basel Committee on Banking Supervision presented a revised and augmented regulatory framework. Since the financial crisis had demonstrated that microprudential regulation is not sufficient in safeguarding financial stability, the regulators put an emphasizes on macroprudential policies to improve the resilience of the financial sector. Key reforms in this respect are the tightening of capital requirements and the introduction of uniform liquidity requirements (BCBS, 2010).

Regarding the evaluation of this new regulatory framework, Lorenzo Bini Smaghi, Member of the Executive Board of the European Central Bank, emphasized in a speech at an international banking conference, that the new regulatory framework has to be evaluated in the context of other measures. He also stressed the need to include the new regulatory parameters into the considerations for other policies, especially monetary policy. How closely financial stability and monetary policy are interconnected with each other had already become apparent during the crisis period.

In the course of the financial crisis, in Europe prolonged by the European debt crisis, central bankers had to act on financial stability concerns to ensure the transmission mechanism of monetary policy. Prominent examples of these interventions are the regime shift of the open market operations of the European Central Bank (ECB) in 2008 and its Securities Markets Programme during the height of the European debt crisis. Both measures were taken because financial markets were no longer functioning. By providing additional liquidity to the market, ECB directly contributed to the easing of the respective situation, supporting financial stability (Garcia-de-Andoain et al., 2016; Krishnamurthy et al., 2017). These measures are covered by the umbrella term unconventional monetary policy, which also includes measures taken after central banks' policy rates hit the zero lower bound.

The new regulatory framework only contributes to financial stability if it is successful in improving the resilience of the financial sector. Also monetary policy is only successful if it can effectively target its overarching goal price stability. Therefore, the fundamental changes of these closely connected areas created a large demand for evaluation. While previous to the financial crisis, the empirical evidence for the interaction of macroeconomic policies and financial stability was rather scarce (De Graeve et al., 2008), the literature on the matter has rapidly expanded since then (e.g. Acharya et al., 2019; Adrian and Shin, 2008; Borio and Zhu, 2012; Drechsler et al., 2016; Koetter, 2019; Tonzer, 2015). However, given the extent and the complexity of the changes, many questions remain.

This thesis contributes to the discussion on monetary policy and banking regulation, especially in the context of other macroeconomic policies. Chapter 2 evaluates the effectiveness of conventional monetary policy in the post-crisis environment which is heavily influenced by the measures taken in regard to financial stability, and other unconventional monetary policy instruments. Chapter 3 and 4 review banking regulation in form of a liquidity requirement and bank levies in the context of macroeconomic policies. The results highlight how regulation can be counteracted by other policy frameworks, contributing to the evaluation of the requirements. Chapter 5 further contributes to the discussion on the interdependencies of banking regulation and monetary policy, highlighting that security valuation and capital regulation reduce the recapitalization effect of unconventional monetary policy.

In Chapter 2, we investigate whether a reduction in ECB's deposit facility rate has successfully prevented banks from storing liquidity as reserves at the central bank. The post-crisis period is especially interesting for the effectiveness of this policy rate because it is the interest rate banks earn on their excess reserve holdings with the central bank. Excess reserves are a consequence of ECB's unconventional policy since 2008 and therefore a recent phenomenon.

The uniform policy rates across Euro area countries can have different effects across banks, leading to heterogeneous and unforeseen responses. Thus, we consider the effectiveness of the deposit facility rate across banks' business models and use the bank-level net interest margin to proxy for a bank's interest sensitivity in terms of its business model. In a competitive environment with decreasing interest rates especially interest income reliant banks should be concerned with the central bank's interest rate policy.

Using an interaction model, we find that banks adjust their reserve holdings in a direct response to changes in the deposit facility rate and depending on the interest rate sensitivity of their business model. Banks with higher net interest margins reduce reserve holdings by more if the deposit facility rate is reduced, following the rational that a high net interest margin can be associated with a high exposure to a potential decrease of the very same. We find evidence that the freed up liquidity benefits the loan supply, supporting monetary policy transmission. These findings remain robust when accounting for simultaneous adjustments of balance sheet positions and an array of other tests.

In sum, the results provide important evidence that conventional monetary policy can work during unconventional times. However, there are limitations to the effectiveness of the conventional monetary policy instrument. We show that banks' incentives to reallocate the portfolio are stronger for banks in non-GIIPS countries. This limited effectiveness of a conventional monetary policy instrument can be one reason why the ECB has chosen to extend unconventional monetary policy.

In Chapter 3, we review the interaction effect of bank levies and corporate income taxes (CIT) on bank leverage. Bank levies, which are bank taxes typically based on non-deposit liabilities, provide incentive to reduce leverage. Corporate income taxation makes debt financing more attractive because interest on debt is tax-deductible in most countries but return on equity is not. Moreover, we study how the design of bank levies affects their impact upon leverage. The assessment of such regulatory reforms is relevant given that also on the European level bank levies are applied for example to finance the Single Resolution Fund. A better understanding of the impact of bank levies on banks' capital structure depending on corporate taxation is also relevant from a financial stability perspective given the crucial role of bank leverage in the global financial crisis (De Mooij et al., 2013).

For a sample of EU countries for the period 2006-2014, we investigate how bank leverage is affected by the introduction of regulatory levies depending on CIT rates. Our estimation yields three key results. First, we confirm Célérier et al. (2018)'s and Devereux et al. (2015)'s results that the direct effect of bank levies on bank leverage is negative and statistically significant, indicating that the incentive of debt funding is reduced. Second, higher CIT rates mitigate the leverage-reducing effect of bank levies. In countries with higher CIT rates, the introduction of a bank levy reduces bank leverage less than in countries with lower CIT rates. Third, for the most elevated CIT rates, the positive incentive for capitalization is fully counteracted by the debt bias of taxation. Statistically, this means that the marginal effect for high CIT countries turns insignificant.

In Chapter 4, I assess whether Euro area banks have adjusted their collateral pledging behavior with the ECB in response to the introduction of the liquidity coverage ratio (LCR). The LCR is the first liquidity requirement implemented on EU-level following Basel III. An altered pledging behavior indicates that banks have exploited an arbitrage opportunity via the central bank's refinancing operations to improve their LCR value. This would have direct implications for the risk mitigating effect of the regulation and therefore is of high importance for policy makers.

The arbitrage possibility via the collateral pledged with ECB's refinancing operations is present because ECB's collateral framework includes more, less liquid assets than the LCR framework. Banks, which can use assets only for one of the two purposes, can pledge assets which are not LCR eligible, but ECB eligible as collateral with the central bank and correspondingly withhold the most liquid assets to be counted into the LCR. Doing so, the bank can improve its LCR value without altering its liquidity risk profile simply by adjusting its pledging behavior with the central bank.

Using a proprietary dataset with bank-level information on central bank collateral, I consider the biggest Euro area banks participating in the Eurosystem's refinancing operations before and after the LCR introduction. I use the existence of national liquidity requirements to proxy for banks' incentives to exploit the differential treatment of central bank eligible assets. The conjecture is that in the presence of a preceding national liquidity regulation, the need to alter the pledging behavior in response to the LCR introduction is expected to be less pronounced because those banks already made adjustments to comply with their national liquidity regulation.

Empirically, I find that banks without a national liquidity requirement decrease the average liquidity profile for marketable collateral by over 30% in comparison to banks with a preceding national liquidity regulation. This result supports the hypothesis that banks exploit the arbitrage opportunity via the central bank's refinancing operations to improve their LCR value. Further results regarding non-marketable collateral and the collateral value do not contradict this finding.

In Chapter 5, I highlight that security valuation and country-level capital regulation reduce the recapitalization effect of unconventional monetary policy. Unconventional monetary policy measures like asset purchase programms aim to reduce the yield of certain securities (Cycon and Koetter, 2015; Krishnamurthy et al., 2017). This also increases the market value of securities already held by financial institutions and adds to their capitalization (Acharya et al., 2019; Rodnyansky and Darmouni, 2017). I contribute to this literature by highlighting two aspects so far not considered in context with the recapitalization effect.

First, the recapitalization effect depends on the applied valuation method of the security. Banks use two different valuation methods for the securities on their balance sheet. From these two methods only securities measured at fair value can mirror an increase in the market price, while securities valued at amortized cost are not affected by it.

The second aspect not yet considered by the recapitalization literature are prudential filters. Prudential filters remove unrealized gains and losses of a certain group of fair valued securities from banks' regulatory capital to reduce its volatility. Thereby, they limit the transmission of the unrealized price increases to regulatory capital to a subset of fair valued securities.

Considering Acharya et al. (2019)'s work on the Outright Monetary Transactions announcement, I emphasize the effects of security valuation and prudential filters on the recapitalization gain. I find that the recapitalization effect is reduced on average by 20 to 98% compared to the previously estimated gain. Therefore, I stress that the highlighted aspects have to be considered to avoid a systematic overestimation of the potential recapitalization gain and to estimate potential effects of it to the real economy.

The dissertation is structured as follows. Chapter 2 to 5 represent the four research papers that conform the main part of the dissertation. Complementing the general contribution of the dissertation outlined in this introduction, each chapter carefully addresses its individual contribution to the literature. Chapter 6 concludes.

Chapter 2

Do conventional monetary policy instruments matter in unconventional times?*

Abstract: *This paper investigates how declines in the deposit facility rate set by the ECB affect euro area banks' incentives to hold reserves at the central bank. We find that, in the face of lower deposit rates, banks with a more interest-sensitive business model are more likely to reduce reserve holdings and allocate freed-up liquidity to loans. The result is driven by banks in the non-GIIPS countries of the euro area. This reveals that conventional monetary policy instruments have limited effects in restoring monetary policy transmission during times of crisis.*

2.1 Introduction

Since the recent financial and sovereign debt crisis, the euro area has faced continued distress in financial markets and the hampered transmission of monetary policy. To counter these developments, the European Central Bank (ECB) has implemented conventional and unconventional policy measures.[1] These measures include, among others, low interest rates, longer-term refinancing operations, and the implementation of asset purchase programs. Some of these measures such as the Securities Markets Programme (SMP) aim primarily to maintain the functioning of monetary policy transmission. Banks have a pivotal role in the transmission mechanism, and they react

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[1] More specifically, monetary policy in the euro area is implemented by the Eurosystem. The Eurosystem comprises the European Central Bank (ECB) and the national central banks (NCBs) of those countries that have adopted the euro. For the sake of brevity, we use the acronym ECB henceforth.

to improved credit conditions and other incentives to increase loan supply. In this regard, whether the ECB succeeds in maintaining the functioning of monetary policy transmission not least depends on how banks respond to these measures.

In this paper, we test the effectiveness of conventional monetary policy during the recent distress period. While an expanding strand of literature has considered the effects of unconventional monetary policy on bank behavior, our paper is among the first to assess conventional policy tools across euro area countries. We focus on the effect of the deposit facility rate on bank reserves and ask whether the reduction in the policy rate has successfully prevented banks from storing liquidity as reserves at the ECB. A change in the deposit facility rate alters returns on a bank's assets, in particular reserves, which might in turn induce the bank to reallocate its assets. If in line with the ECB's policy, the bank would turn away from holding reserves to loan granting. Importantly, we test the effectiveness across banks' business models and different countries for the period 2009-2014 using the identification strategy applied by Cornett et al. (2011).

Recent developments suggest that there is good reason to assess the effects of conventional monetary policy. The decline in the deposit facility rate has been accompanied by a steady increase in banks' reserve holdings. Our study shows that, for banks with a more interest-sensitive business model, declines in the deposit facility rate can succeed in shifting central bank reserves into loans. However, there are limitations to this conventional policy instrument because the results mainly apply to banks that are located in the non-GIIPS[2] countries. Thus, our findings contribute to the policy debate on the effectiveness of conventional versus unconventional monetary policy across euro area countries.

The reserve management of euro area banks has been a particularly interesting topic in recent years. Before the financial crisis, bank reserves were almost entirely attributable to mandatory reserves. These are determined by multiplying the reserve ratio by the reserve base. The reserve ratio is

[2]Euro area countries excluding Greece, Ireland, Italy, Portugal and Spain.

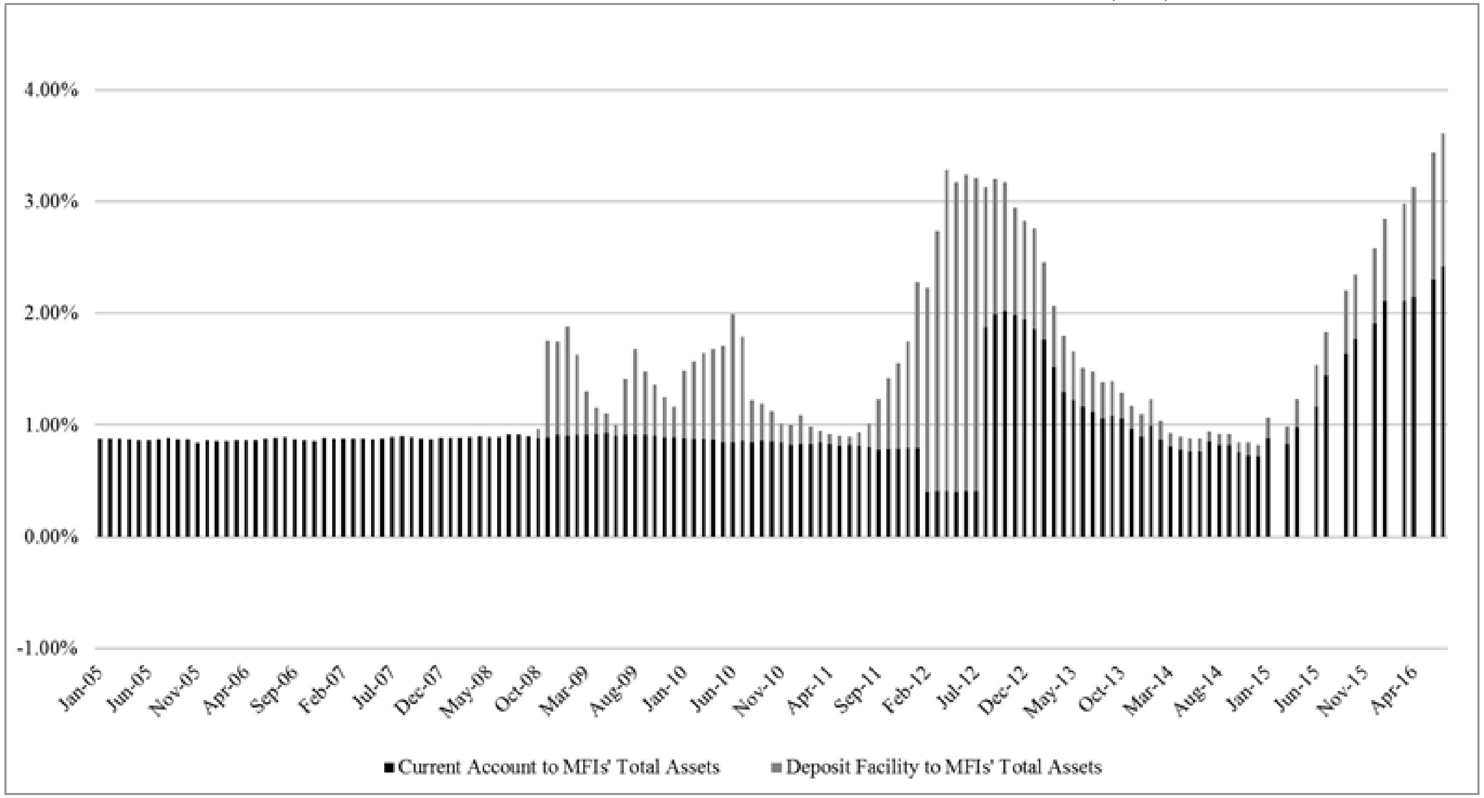
set by the ECB, which also defines the balance sheet items included in the reserve base. Hence, prior to 2008, the main determinant of reserves was – conditionally on the reserve base defined by the respective liabilities of banks – the ECB's policy regarding reserve requirements. By contrast, Figure 2.1 shows that since 2008, bank reserves have increased above mandatory requirements and become considerably more volatile. A similar increase in aggregate excess reserves has been documented for the U.S. banking system (Kandrac and Schlusche, 2017; Keister and McAndrews, 2009; Martin et al., 2013). Although the amount of aggregate reserves in the system is outside of control of the individual bank, the appearance of excess reserves raises the question of whether a bank engages in an active (excess) reserve management.

Lowering the deposit facility rate should reduce banks' incentives to hold liquidity at the central bank (Arseneau, 2017; Lee, 2016). Large volumes of excess reserves indicate that banks are withholding or even hoarding liquidity at the central bank. For the individual bank, these funds might alternatively be channeled into the real sector and consequently foster economic activity. Therefore, the ECB has lowered the deposit facility rate repeatedly since the start of the financial crisis to alter the stance of monetary policy and restore the monetary transmission mechanism, e.g., through encouraging loan supply. A decrease in the deposit facility rate can induce cost pressure for the individual bank and create a "hot potato effect" for liquidity, as reserves are liquidity holdings that earn very low or negative interest rates (Keister et al., 2008). Therefore, banks have an incentive to shift liquidity into more profitable assets – that do not move one-to-one with the deposit facility rate – rather than to hold reserves. If the deposit facility rate is effective at altering banks' incentives to hold reserves, it can be a useful and transparent tool for reallocating liquidity and fostering monetary policy transmission.[3]

[3]While depressed margins resulting from reduced interest rates might increase banks' risk taking, also known as the risk taking channel of monetary policy, this is outside the scope of our analysis (see e.g. Buch et al., 2014; Dell'Ariccia et al., 2017; Heider et al., 2019; Ioannidou et al., 2014; Jiménez et al., 2014; Lambert and Ueda, 2014; Lamers et al., 2019; Maddaloni and Peydró, 2011)

FIGURE 2.1: Bank reserve holdings in the euro area

This graph shows the evolution of bank reserves of monetary financial institutions (MFIs) in the euro area over the period from January 2005 to April 2016. Bank reserves can be decomposed into the current account holdings (depicted in black) and the deposit facility holdings (depicted in gray). The former are located at the national central banks while the latter are administered by the ECB. The graph shows the holdings of the accounts scaled by total assets (in %) of MFIs in the euro area. *Source*: Datastream



However, uniform policy rates across euro area countries can have different effects across banks, leading to heterogeneous and unforeseen responses.[4] In particular, banks with a strong focus on interest-sensitive activities due to a more traditional business model should be particularly concerned with the ECB's interest rate policy. Hence, banks that are more reliant on net interest income – for instance, due to a higher share of loans and deposits – should be more sensitive to interest rate changes. The reason is that these banks are more involved in interest-bearing activities, more dependent on the related income sources, and should therefore be more affected by changes in interest rates. Also, in a low interest rate environment and in the presence of competitive pressure, banks have to reduce loan rates but cannot reduce deposit rates to the same extent (Claessens et al., 2016; Claessens et al., 2018). The latter point gains in importance in the presence of the zero lower bound, because negative interest rates cannot be passed through one-to-one to depositors. Banks with an interest-sensitive business model are thus likely to be more sensitive to declines in the deposit facility rate.

For identification purposes, we specify an interaction model exploiting the fact that banks' responses to policy rates should depend on the interest sensitivity of the business model. Given that individual banks are unlikely to influence the ECB's policy decisions, concerns of reverse causality are reduced.[5] Another potential source of endogeneity is that banks might simply increase loans (and reduce reserves) as they respond to higher demand for loans following a decline in interest rates. However, in our specification, such a demand-side effect is ruled out as long as bank-specific demand for loans does not vary systematically with the net interest margin of banks.[6] Therefore, our results show that banks adjust their reserve holdings in direct response to changes in the deposit facility rate and depending on the interest

[4]As shown by Garcia-de-Andoain et al. (2016), this argument of uneven effects across euro area countries also applies to central bank liquidity provision during recent years.

[5]Furthermore, we show that there are parallel trends across bank and country groups in the evolution of the interest sensitivity of banks' business model, which reduces concerns that our results might be driven by systematic differences across banks or countries.

[6]To further rule out that demand-side effects drive our result regarding the shift from reserves to loans, we include several variables to extract effects stemming from the demand side in a robustness exercise in Section 2.4.5.

sensitivity of their business model. Importantly, the effect is heterogeneous across banks: banks with high net interest margins reduce reserve holdings by more if the deposit facility rate is reduced. This is in line with the rational that a high net interest margin can be associated with a high exposure to a potential decrease of the very same. It is also consistent with recent discussions about the sustainability of interest-sensitive business models in a low interest rate environment.

As concerns portfolio reallocations, we find that this liquidity freed up due to declining reserves benefits the loan supply, thus supporting the functioning of monetary policy. These results remain robust when accounting for simultaneous adjustments of balance sheet positions and an array of other tests. In sum, the results provide important evidence that conventional monetary policy can work during unconventional times. However, there are limitations to the effectiveness of the conventional monetary policy instrument: We show that banks' incentives to reallocate the portfolio are stronger for banks in non-GIIPS countries. The fact that effectiveness of the policy instrument is more pronounced for only banks in some countries can be one reason why the ECB has chosen to extend unconventional monetary policy beyond 2014.

While our paper looks at the effects of conventional monetary policy during times of crisis, there is a growing body of literature focusing on unconventional monetary policy and its effects on bank behavior (e.g. Acharya et al., 2019; Chodorow-Reich, 2014; Lambert and Ueda, 2014; Koijen et al., 2019; Mamatzakis and Bermpei, 2016). Acharya et al. (2019) find a recapitalizing effect for banks through the announcement of the Outright Monetary Transactions (OMT) program. This effect is particularly strong for banks from GIIPS countries, which have benefited from declines in the sovereign yields of these countries. In response, banks with a larger exposure to sovereign bond holdings – and thus a relatively larger recapitalization effect – extended their loan supply. This reaction was particularly pronounced for poorly capitalized banks and low-quality borrowers. Kandrac and Schlusche (2017) assess the relationship between unconventional monetary policy in the

U.S. and banks' reserve holdings as well as loan and risk-taking behavior. We complement their work by studying the role of the deposit facility rate for banks' reserve holdings, and thereby the effectiveness of a policy instrument in the hand of central banks, and portfolio reallocation.[7]

Furthermore, our paper contributes to the literature on the (heterogeneous) transmission of unconventional monetary policy (Cycon and Koetter, 2015; Hristov et al., 2014).[8] Acharya et al. (2017) provide evidence of an impaired transmission of monetary policy conditional on banks' riskiness. The effect of negative interest rates in the euro area on banks' risk-taking behavior was recently analyzed by Heider et al. (2019). These authors find that banks with a higher deposit share are more inclined to provide loans to riskier borrowers after the introduction of negative deposit policy rates. One reason behind this finding may be that banks are reluctant to shift negative deposit rates onto their depositors. This is in line with the reasoning put forward by Arseneau (2017), who shows for the U.S. that banks expect a decline in profits in a low interest rate environment. We contribute to this literature by focusing on the effectiveness of the deposit facility rate regarding banks' balance sheet management and depending on bank heterogeneities.

Also, our paper contributes to the literature on banks' liquidity management. Given liquidity strains in the interbank market, mainly due to a lack of counterparties considered as solvent, banks might park liquidity as reserves at the central bank (Heider et al., 2015). For example, Nyborg and Östberg (2014) draw a connection between the interbank market situation and the volume of liquid stocks. They show that tighter conditions in interbank markets lead banks to "pull back" liquidity by selling (less liquid) financial assets, thus increasing the volume of (highly) liquid assets. For the German banking system, Podlich et al. (2017) find that following the Lehman

[7] Price or yield induced portfolio rebalancing in the context of liquidity are considered by Albertazzi et al. (2018), Paludkiewicz (2018), Rodnyansky and Darmouni (2017), Tischer (2018).

[8] Key studies on the transmission of monetary policy via the bank lending/credit channel in normal times include, amongst others, Bernanke and Gertler (1995) and Kashyap and Stein (2000).

collapse, banks shifted to highly liquid assets, which can be readily converted into central bank liquidity. Thus, reserve holdings at the central bank can be part of banks' liquidity management during times of crisis. Cornett et al. (2011) analyze U.S. banks' liquidity management during the recent financial crisis. They find that banks with more illiquid asset portfolios increased their liquid assets while they decreased their lending. By linking liquidity management back to monetary policy, we draw on this literature and take into account that the effectiveness of monetary policy is likely to depend on how heterogeneous banks manage their (overall) liquidity.

The paper proceeds as follows. Section 2.2 describes institutional details and the development of banks' holdings of central bank reserves. In Section 2.3, we present the regression framework and provide an overview of our sample and data. Section 2.4 discusses the findings and their implications, and we conduct robustness tests. The final section concludes.

2.2 Central bank reserves

In this section, we describe the regulatory setting and changes in monetary policy that drive the evolution of bank reserves. Bank reserves are assets held by banks at the central bank. In the pre-crisis period, aggregated bank reserve holdings within the euro area remained stable by below 1% of the total assets of monetary financial institutions (MFIs). They roughly matched the mandatory reserves.[9] This has changed since the start of the financial crisis. As shown by Figure 2.1, bank reserves have increased above mandatory requirements and become considerably more volatile. These excess reserves are the bank reserves we are interested in.

The underlying reasons for the increase in bank reserves and the evolution of excess reserves are fundamental changes in the liquidity-providing factors of the euro area in combination with pronounced distress in interbank markets (see e.g. Abbassi et al., 2014, Acharya and Merrouche, 2012, Afonso et al., 2011, Ashcraft et al., 2011, Nyborg and Östberg, 2014). Specifically,

[9] Also, for the U.S., Kroeger et al. (2018) find evidence of a "reserve-scarcity regime" before the crisis.

the switch to the full allotment mechanism for the main refinancing operations, the introduction of longer-term refinancing operations, as well as the asset purchase programs and the easing of collateral requirements have led to a massive supply of liquidity by the central bank.

The emergence of excess reserves also becomes visible when considering the accounts bank reserves are held at. Bank reserves can be placed in the current account and the deposit facility at the national central bank. The current account covers mandatory reserves but can also hold voluntary (excess) reserves.[10] The deposit facility covers only voluntary reserves. Figure 2.1 shows the aggregated holdings of euro area banks in the current account and the deposit facility relative to the total assets of the MFIs of the euro area.

For the time period before 2012, we can reasonably assume that excess reserves were held (preferably) in the deposit facility because its yield, the deposit facility rate, was higher than the yield on excess reserves in the current account, which does not bear any interest. Therefore, we can differentiate approximately between mandatory and excess reserves: mandatory reserves should equal current account holdings, whereas excess reserves should be reflected by deposit facility holdings. Thus, from Figure 2.1, we can infer that the current account holdings, which have been rather constant – as depicted by the black part of the bars – reflect the mandatory reserves to be held under the constant reserve requirements ratio of two percent. In contrast, reserve holdings in the deposit facility, as depicted by the gray part of the bars, represent the bulk of excess reserves and fluctuate considerably over time.

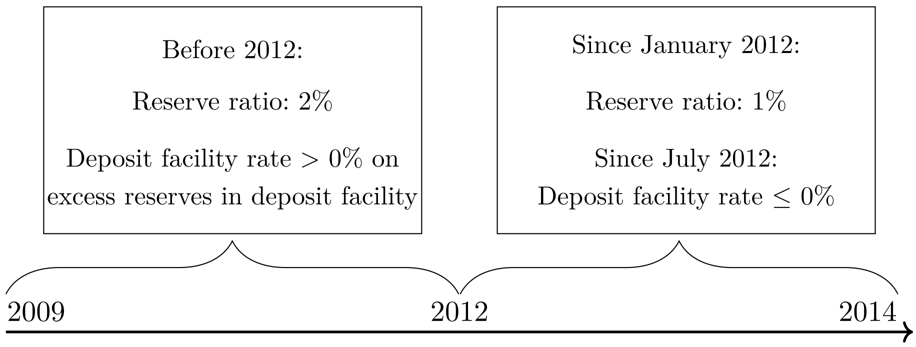
In 2012, two events changed the set-up. First, the reserve ratio was halved from two percent to one percent in January 2012. This becomes visible in the drop in reserves held in the current account, as depicted by the black bars in Figure 2.1. Second, the deposit facility rate was reduced to zero percent in

[10] Mandatory reserves apply to the following items: overnight deposits, deposits with agreed maturity up to 2 years, deposits redeemable at notice up to 2 years, debt securities issued with agreed maturity up to 2 years, and money market paper; see: `https://www.ecb.europa.eu/press/pr/date/1998/html/pr981013_3.en.html`

July 2012. Due to this second event, it is no longer possible to differentiate easily between mandatory and excess reserves by simply considering the two accounts. The reason is that the deposit facility lost its favorable yield over the current account.[11] Nevertheless, this is no longer crucial for our research because we know for sure that regardless of the account in which banks place their voluntary reserves, they earn the same rate of interest, the deposit facility rate. Before the ECB reduced the deposit facility rate even further in 2014, the equal yield of the two accounts became contractual.[12] Figure 2.2 provides a timeline that marks key changes in these policy instruments.

FIGURE 2.2: Timeline of the ECB's reserve policy

This graph shows key events regarding changes in the deposit facility rate and reserve requirements set by the ECB during our sample period from 2009 to 2014. *Source*: Own illustration.



The economic significance of reserves becomes clear when one considers the costs that reserves created in recent years for the euro area banking system. Since 2013, banks have not earned any additional interest on their excess reserves. Since 2014, reserves within the euro area have created interest expenses, which amounted to approximately 68 million euro in 2014, 784 million euro in 2015, and 2.68 billion euro in 2016.[13] While these numbers might be small relative to the size of the overall banking system, it is reasonable for each individual bank to want to minimize its share of these costs. The opportunity cost or "hot potato effect" of holding reserves is also addressed by Keister et al. (2008), as well as Lee (2016).

[11] This also explains the sharp increase in excess reserves in the current account as shown in the supplementary material (Figure A.9).

[12] `https://www.ecb.europa.eu/ecb/legal/pdf/oj_jol_2014_168_r_0015_en_txt.pdf`; Decision of the European Central Bank of 5 June 2014 on the remuneration of deposits, balances and holdings of excess reserves (ECB/2014/23) (2014/337/EU).

[13] Calculations are based on period averages of daily positions.

Garcia-de-Andoain et al. (2016) show that central bank liquidity has replaced the demand for liquidity in the interbank market, whose dysfunctionality is visible in the development of the Euro Overnight Index Average (Eonia). Figure 2.3 shows the evolution of the ECB's policy rates since 2005. In addition to the deposit facility rate, the lending facility rate (which is the lending counterpart of the deposit facility rate) and the main refinancing rate are shown. The figure also shows the Eonia rate, which is the average rate at which banks can borrow money overnight in the interbank market. Prior to the financial crisis, the Eonia rate fluctuated around the main refinancing rate and thereby symbolized the transmission of (conventional) monetary policy via the interbank market. However, for the past eight years, it has moved closer to the deposit facility rate. Hence, Figure 2.3 shows that the ECB has implicitly switched from a standard "interest rate corridor system" to a "floor operating system".[14] This development does not necessarily mean that banks are now able to obtain refinancing at a much lower rate in interbank markets. Rather, it is the result of a structural change in the allocation of liquidity within the euro area.

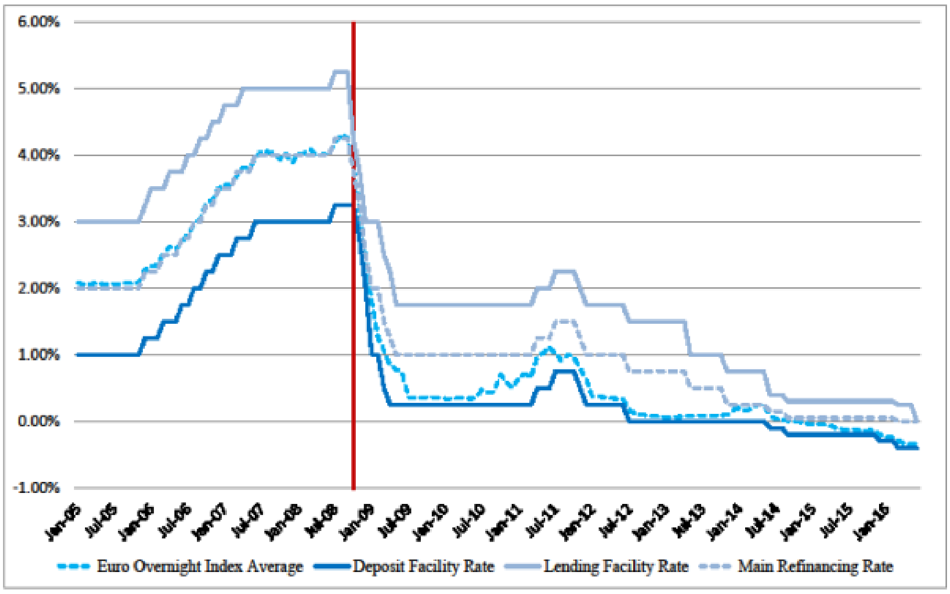
Prior to the financial crisis, system-wide liquidity was reallocated via the interbank market, with the ECB injecting only limited amounts of liquidity. Interbank lending rates varied within the interest rate corridor of the deposit facility rate and the lending facility rate. Since the introduction of the full allotment policy in October 2008, banks have been able to receive liquidity directly from the ECB's open market operations at the main refinancing rate. Banks with sufficient central bank collateral, therefore, have no incentive to pay interest rates higher than the main refinancing rate, which exerts downward pressure on interbank rates and limits the demand for central bank money among banks (Garcia-de-Andoain et al., 2016). Banks with insufficient central bank collateral are unlikely to receive liquidity via the interbank markets.[15] The proximity of Eonia and the deposit facility rate

[14] The partial breakdown of interbank markets is also reflected by a decline in the Eonia volume, as shown in the supplementary material (Figure A.10).

[15] Given the broad collateral framework of the ECB, scarcity of central bank collateral is an indicator for solvency problems.

Figure 2.3: Key interest rates in the euro area

This graph shows the evolution of ECB policy rates (in %) over the period from January 2005 to January 2016. The three policy rates include the deposit facility rate (deep blue, solid line), the lending facility rate (light blue, solid line), and the main refinancing rate (light blue, dashed line). The fourth rate displayed in the graph is the Euro Overnight Index Average (Eonia) (turquoise, dashed line). Eonia is a reference rate for uncollateralized overnight interbank lending. The vertical line marks October 2008, the month when the ECB introduced its fixed rate, full allotment policy. It also highlights the beginning of a period of continuously decreasing policy rates, which was only temporarily interrupted in 2011. *Source*: ECB.



shows that the interbank market is frequented only by very few, highly secure banks – while many other banks that are not considered as secure counterparts any more have lost access to funding through the interbank market.

From a macroeconomic perspective, the amount of liquidity within the euro area is mostly determined by the monetary policy operations of the ECB.[16] Despite our interest in microeconomic developments, there is also macroeconomic evidence that liquidity is reallocated among euro area countries and therefore also among banks. The Bruegel database of Eurosystem lending operations developed by Pisani-Ferry and Wolff (2012) provides evidence that, in some countries, the demand for liquidity provided by the ECB via its main and longer-term refinancing operations changed considerably over time (Figure A.11). Banks in countries such as Germany and Luxembourg, where banks find it easier to attract liquidity through

[16]Keister and McAndrews (2009) give a very good explanation on this for the U.S.

the interbank market, have reduced their demand for central bank liquidity, while banks in the GIIPS[17] countries have increased their demand considerably.

In sum, three main observations can be made. First, bank (excess) reserves have increased significantly in recent years, due to fundamental changes in monetary policy and malfunctioning interbank markets. Second, the deposit facility rate can be considered the yield paid on excess reserves and therefore constitutes the main instrument by which the ECB can affect the excess reserve holdings of the individual bank.[18] Third, the liquidity needs of banks prevail in peripheral euro area countries, as reflected by the divergent use of central bank liquidity. In combination with the malfunctioning of the interbank market, this implies that the increase in bank reserves stems mainly from banks in liquidity-rich countries. This might have implications for the effectiveness of monetary policy transmission in peripheral versus core euro area countries.

2.3 Estimation framework

To test our research question, we need data on banks' reserve holdings and the deposit facility rate over a reasonably long time period for a cross-section of countries. We thus make use of bank-level data from Bankscope for 17 euro area countries, having the advantage that distorting effects resulting from different central bank policies are eliminated.[19] The sample period spans 2009-2014 because a fundamental change in the set-up of the main refinancing operations occurred in 2008, when the ECB switched to the fixed-rate, full allotment policy. More details on the regression model and the data are provided in the following.

[17]Greece, Ireland, Italy, Portugal and Spain

[18]In the aggregate, the deposit facility rate can affect bank reserves only indirectly via the demand of liquidity.

[19]Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain. Latvia and Lithuania are excluded because they joined the euro area only recently.

2.3.1 Regression model

To analyze the differential effect of the deposit facility rate on banks' balance sheet decisions depending on banks' net interest margins, we use a panel regression model, which is similar in technical terms to Cornett et al. (2011):

$$\begin{aligned}\frac{\Delta\text{Balance Sheet Postiion}_{ijt}}{\text{Total Assets}_{ijt-1}} &= v_i + v_{jt} + \alpha_1 \Delta\text{DFR}_t \times \text{NIM}_{ijt-1} \\ &+ \alpha_2 \text{Bank Controls}_{ijt-1} + \epsilon_{ijt}\end{aligned} \tag{2.1}$$

The empirical model measures the change in the balance sheet position (ΔBalance Sheet Postiion$_{ijt}$) of bank i in country j from period t-1 to period t relative to the overall size of the balance sheet in period t-1 (Total Assets$_{ijt-1}$). The way in which the dependent variable is constructed proxies how the respective position on banks' balance sheets changes relative to the overall size of the balance sheet (see also, Schandlbauer, 2017).[20] A change in the deposit facility rate alters returns on a bank's assets, in particular reserves, which might in turn induce the bank to reallocate its assets. If in line with the ECB's policy, the bank would turn away from holding reserves to loan granting. Consequently, once we find that banks adapt their reserve holdings, we analyze whether and to what extent they rebalance their portfolios towards alternative balance sheet positions, such as liquid assets or loans.[21]

To identify the influence of the ECB's deposit facility rate, we exploit the fact that the effect of the deposit facility rate should be heterogeneous across banks. In particular, banks' responsiveness to changes in interest rates should depend on the interest sensitivity of the business model, which we proxy by the net interest margin and explain in greater detail in Section 2.3.2. Therefore, the empirical model includes an interaction term of the change in the deposit facility rate (ΔDFR$_t$) with the bank-specific net interest margin (NIM$_{ijt-1}$). The main coefficient of interest, α_1, reflects banks' sensitivity

[20] Regardless of the choice of the balance sheet position used as the dependent variable, we base all regressions on the sample of banks for which we have data on bank reserves.

[21] To account for simultaneity among balance sheet positions, we check the robustness of our results by estimating 3SLS regressions in Section 2.4.4

to changes in the deposit facility rate depending on the net interest margin. Hence, similar to Cornett et al. (2011), we are interested in the responsiveness across banks rather than the aggregate effect of changes in the policy rate.

The ECB's policy is assumed to be exogenous from the perspective of the individual bank, that is, the probability that the reserve holdings of a single bank drive the ECB interest rate policy should be negligible. By adding fixed effects (v_i and v_{jt}), we extract any confounding factors embedded in time-invariant bank characteristics, stemming from common macroeconomic shocks and time trends in the euro area, or relating to macroeconomic environment at the country level. To control for other determinants of banks' balance sheet decisions, we control for key bank-specific features, Bank Controls$_{ijt-1}$, by including the deposits to asset ratio, the size of assets (in logs), the equity to assets ratio, as well as the return on assets ratio and the net interest margin. The net interest margin and all other bank-specific controls are lagged by one period to reduce simultaneity concerns. Standard errors are clustered at the bank level.

The time span analyzed is characterized by further changes in (un)conventional monetary policy tools such as the main refinancing rate or longer-term refinancing operations (LTROs). While simultaneous changes affecting banks in all countries alike are absorbed by time fixed effects, we extend our model to capture the ECB's unconventional monetary policy as explained in Section 2.3.3. In robustness tests, we add further variables to control for demand-side effects in credit markets.

2.3.2 Bank-level data

The yearly bank-level data for 17 euro area countries over the period 2009-2014 are taken from Bankscope. Using Bankscope data allows studying balance sheet reallocation across European countries while due to the annual frequency of the data our analysis provides insights about longer-term adjustments rather than short-term movements in balance sheet items. Our baseline sample is determined by the banks in the euro area for which we obtain information on central bank reserves.[22] This produces a sample of larger banks that have, on average, lower net interest margins.[23] Regarding our research question, this should work against us in the empirical analysis. The reason is that larger banks have, on average, a less interest-sensitive business model because they are less reliant on interest-bearing activities (Demirgüç-Kunt and Huizinga, 2010; Kasman et al., 2010). As a consequence, these banks should be affected by the ECB's interest rate setting and respond to the proposed mechanism to a minor extent.

We control for outliers by adjusting the sample along the following dimensions. We only retain banks whose specialization type is indicated as bank holding company, commercial bank, cooperative bank or savings bank. We drop bank observations with missing assets, zero assets or zero equity as well as implausible values for key ratios, for example, if the loan to asset ratio is larger than one. Finally, all bank-level variables are winsorized at the one percent level. A detailed description of the data sources is provided in the appendix, and summary statistics can be found in Table 2.1.[24]

We use three different balance sheet positions as the dependent variable in equation (2.1): (i) bank reserves, (ii) liquid assets, and (iii) total loans.

(i) ***Bank reserves***: Bank reserves are a position on the asset side of the balance sheet. They can be subdivided into mandatory and excess reserves, which are held either in the ECB's deposit facility or in the current account of the national central banks. From Bankscope, we obtain the composite position. Given that mandatory reserves are determined by regulation, banks can only actively manage excess reserves if we assume that the funding side is relatively stable over time. Hence, excess reserves are the main component to be affected by the deposit facility rate.

[22]The sample stops in 2014 due to the discontinuation of our main data source (Bankscope).

[23]In total, the banks in our sample cover 42% of all monetary financial institutions' assets in the euro area. Data on euro area MFI's total assets have been taken from the ECB.

[24]Summary statistics for the subsample of banks with a net interest margin above or below the sample average can be found in the supplementary material (Table A.11).

Table 2.1: Summary statistics

This table shows summary statistics of the bank- and country-level variables used in our analysis. The sample period spans 2009-2014. *Source*: see data appendix (Section A.1).

Variable	No. of obs.	Mean	Std. dev.	Min	Max
Bank-specific variables					
Δ Reserves_t to Total Assets_{t-1} (in %)	1978	-0.01	2.82	-18.42	17.96
Δ Liquid Assets_t (excl. Reserves) to Total Assets_{t-1} (in %)	1978	-0.59	6.79	-26.68	29.24
Δ Loans_t to Total Assets_{t-1} (in %)	1976	-0.38	7.04	-25.19	33.49
Δ Total Assets_t to Total Assets_{t-1}(in %)	1978	-1.54	13.42	-56.71	36.75
Net Interest Margin (in %)	1978	1.99	1.41	0.09	16.35
Deposits to Total Assets (in %)	1977	54.16	23.14	0.49	94.61
ln Assets	1978	15.91	1.74	9.61	19.69
Equity to Total Assets (in %)	1978	9.02	6.81	1.48	68.81
Return on Assets (in %)	1978	0.58	1.17	-4.60	8.40
Loans to Total Assets (in %)	1976	57.67	20.56	2.06	92.40
Net Interest Income to Total Assets (in %)	1978	1.85	1.20	0.08	12.58
Net Fees and Commissions to Total Assets (in %)	1975	0.84	0.92	-0.36	9.2
Total Regulatory Capital Ratio (in %)	1355	16.59	7.99	6.78	62.81
Liquid Assets to Total Assets (in %)	1978	18.95	18.02	0.96	84.16
Gov. Debt Holdings to Total Assets (in %)	1562	7.91	8.88	0.00	45.25
Δ (Agg. Loans_t - Own Loans_t)/ (Agg. Assets_{t-1} - Own Assets_{t-1}) (in %)	1975	-0.39	4.41	-19.24	17.49
HighCapitalGroup (0/1)	1453	0.31	0.46	0.00	1.00
HighNIMbanks (0/1)	1978	0.36	0.48	0.00	1.00
Country-specific variables					
Δ 10-Year Government Bond Yield (in pp)	1945	-0.41	0.73	-2.04	2.35
Δ Share of ECB-Funded Bank Liabilities (in pp)	1959	0.01	1.67	-2.38	5.20
MRO & LTRO to MFI's Total Assets (in %)	1746	0.0026	0.0027	0.0003	0.0094
Δ Firms' Credit Demand (Index)	1921	2.39	15.60	-31.25	30.00
Δ Overall Credit Standards (Index)	1532	-4.85	13.48	-40	27.08
Δ MFIs' Cost of Borrowing for Non-Financial Corporations (in pp)	1978	-0.42	0.80	-2.59	1.00
GIIPS (0/1)	1978	0.24	0.43	0.00	1.00
Euro area					
Δ Deposit Facility Rate (in pp)	1978	-0.43	0.83	-2.53	0.25
Δ Main Refinancing Rate (in pp)	1978	-0.55	0.82	-2.62	0.25

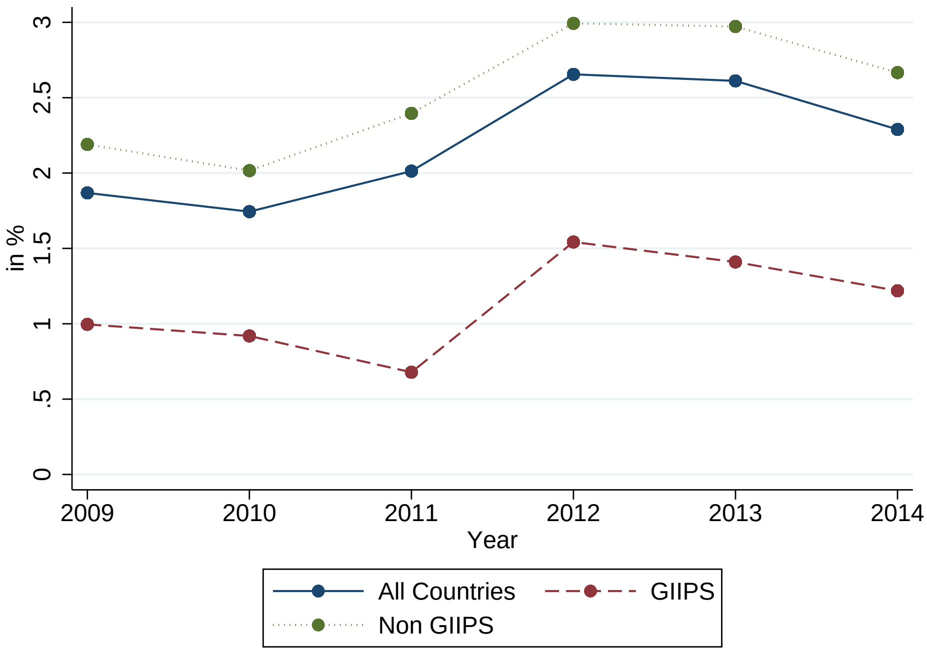
This assumption is supported by the aggregate data of the ECB, which indicate that mandatory reserves do not fluctuate much over time. Rather, they are determined by the regulatory reserve ratio, which defines how many reserves banks have to hold (Figure 2.1). Knowing that mandatory reserves equal the reserve ratio times banks' deposits, we implicitly control for the level of mandatory reserves by including banks' deposits to assets ratio as explanatory variable in the empirical analysis.

A further advantage is that the regulatory reserve ratio remains constant over a long period of time. One exception is the reduction in the reserve ratio in January 2012 from two to one percent. We control for this change in the following regression analysis. Figure 2.4 shows that despite this decline in the reserve ratio, the average share of reserves for the banks in our sample has remained rather stable, which also holds across subgroups.

FIGURE 2.4: Evolution of the average reserve ratio

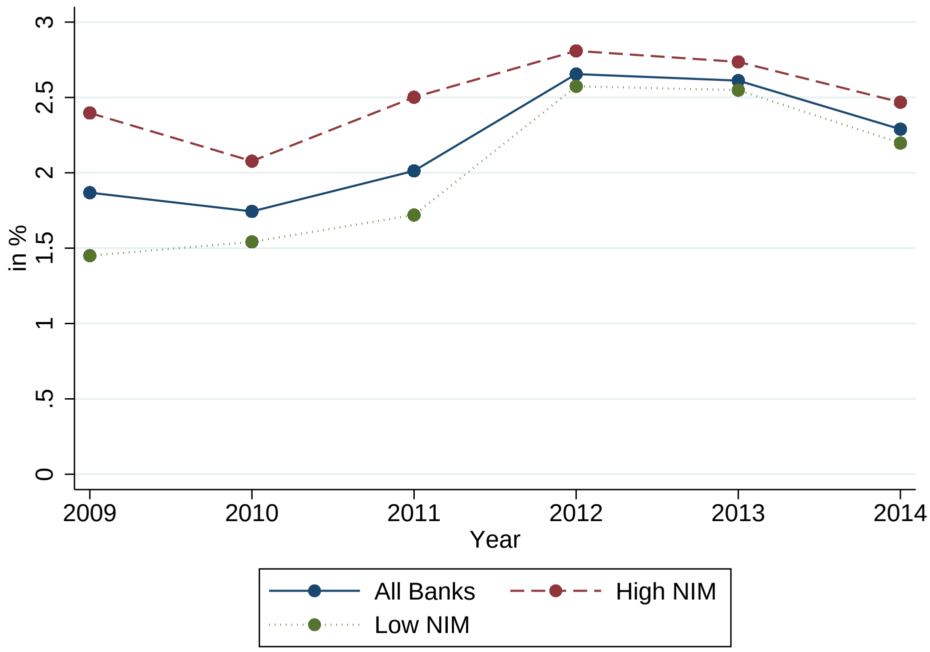
This graph shows the average share of reserves to total assets (in %) of our sample of banks for the period from 2009 to 2014. In panel a), we show the average pattern across all sample countries (blue, solid line), GIIPS countries (red, dashed line), and non-GIIPS countries (green, dotted line). In panel b), we show the average pattern across all banks (blue, solid line), banks with an average net interest margin (NIM) below (green, dotted line), or equal to/above (red, dashed line) the sample mean of the net interest margin. *Source*: Bankscope.

a) Average reserve ratio: GIIPS vs. non-GIIPS banks



If banks respond to the ECB's policy rate and change their reserve holdings, the immediate question is this: to which other asset position is this freed-up liquidity allocated? Hence, we consider portfolio positions that are crucial for the transmission of monetary policy, including liquid assets (excluding reserves) and total loans.

b) Average reserve ratio: high NIM vs. low NIM banks



(ii) ***Liquid assets***: Bank reserves are a subcomponent of the position "liquid assets" and can even be considered the most liquid assets a bank can hold. Therefore, a natural response to lowering yields on reserves might be to switch to other liquid asset positions. Hence, we analyze the effect of the ECB's policy on liquid assets, excluding reserves, to test whether banks switch from reserves to other liquid assets. This would impede the transmission of the ECB's monetary policy because banks would not reallocate the liquidity from reserves to loans.

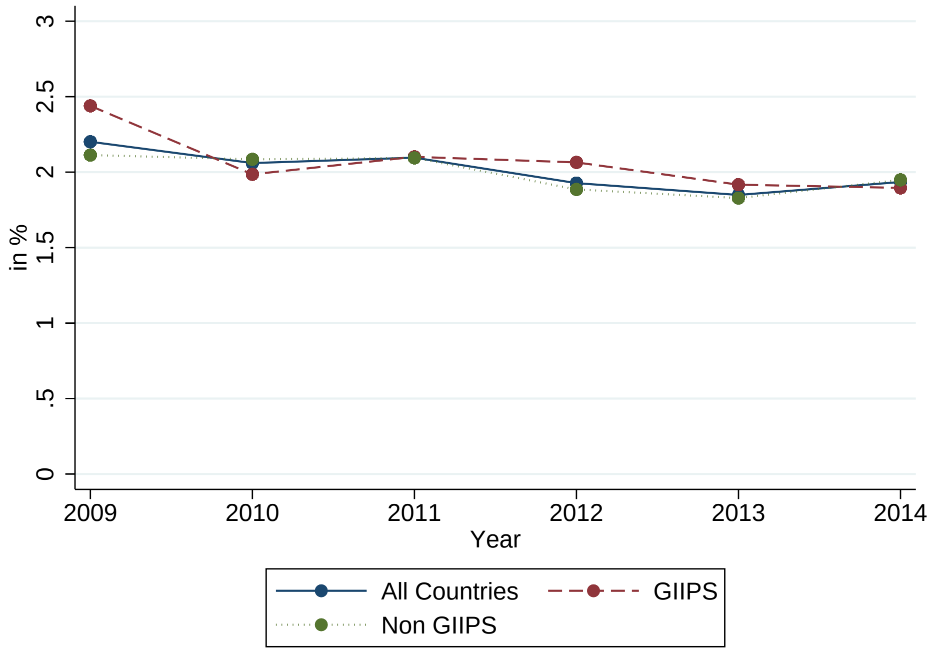
(iii) ***Total loans***: Finally, we consider the portfolio position the ECB wants to indirectly affect with its policy interventions, that is, bank loans. By considering the indirect effect of the deposit facility rate on the change in loans relative to the balance sheet total of the preceding period, we test whether the traditional lending channel of monetary policy works. description

The interest sensitivity of banks' business models is approximated by the net interest margin, defined as net interest income relative to average earning assets (in percent). From Figure 2.5, it can be observed that the average net interest margin has been relatively constant over the sample period, with some evidence of a downward trend. There seems to be no systematic difference between banks in GIIPS and non-GIIPS countries.

FIGURE 2.5: Net interest margin over time

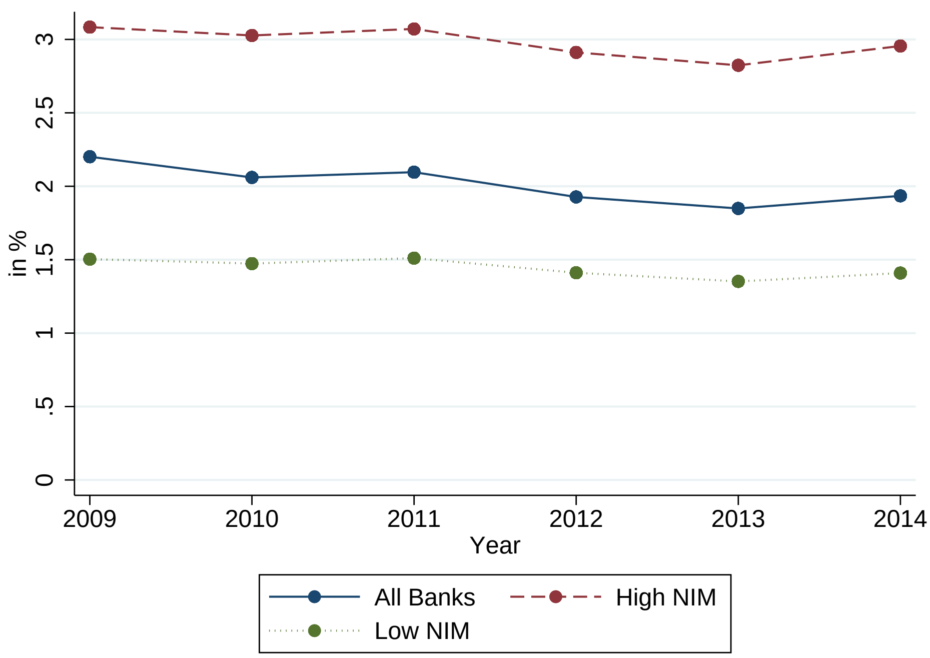
This graph shows the average net interest margin (NIM, in %) of our sample of banks for the period from 2009 to 2014. In panel a), we show the average pattern across all sample countries (blue, solid line), GIIPS countries (red, dashed line), and non-GIIPS countries (green, dotted line). In panel b), we show the average pattern across all banks (blue, solid line), banks with an average net interest margin (NIM) below (green, dotted line), or equal to/above (red, dashed line) the sample mean of the net interest margin. Source: Bankscope.

a) Net interest margin: GIIPS vs. non-GIIPS banks



We expect banks to be affected differentially by changes in the deposit facility rate depending on their reliance on interest-bearing activities like traditional lending and deposit-taking and the relevance of the income accrued therefrom (Arseneau, 2017; Borio et al., 2017; Busch and Memmel, 2017; Claessens et al., 2016; Gambacorta and Marques-Ibanez, 2011; Genay, 2014; Nucera et al., 2017). If banks have a more traditional business model and thus rely more on net income from interest-bearing activities, they should be more concerned with changes in the underlying policy rates. Obviously, the net interest margin as a proxy for the interest sensitivity of the business model is not free of critique, and in Section 2.4.3, we conduct

b) Net interest margin: high NIM vs. low NIM banks



robustness tests with alternative proxies. Nevertheless, its usage is supported by the following considerations.

First, the hypothesis that banks with a more traditional and thus interest-sensitive business model are more concerned about the low interest rate policy can be traced back to Samuelson (1945), who argues that bank performance is affected by declining interest rates because lending rates are more elastic than deposit rates. This is even more true if banks are faced with interest rates at the zero lower bound or even extending into negative territory. As such, Dombret et al. (2019) emphasize that low policy rates can place substantial pressure on German banks due to their focus on interest income. Thus, the net interest margin should not only proxy the extent to which banks generate profits from average earning assets; it should also cause differential responses to the ECB's interest rate policy.

Second, the interpretation of the net interest margin as a proxy for the interest sensitivity of banks' business models is supported by Lepetit et al. (2008), who find that banks with a higher income share in commissions and fees have smaller net interest rate margins. Nguyen (2012) accounts for potential endogeneity between non-interest income and the net interest margin, and also finds a significant negative relationship between both variables. In addition, central banks, regulators, and academics have recently emphasized the role of the net interest margin in the context of the current low interest rate policy (Ampudia, Heuvel, et al., 2019; Claessens et al., 2016).[25] Hence, the higher the level of the net interest margin, the higher the exposure to a potential decrease of the very same and thus the need to defend the margin level through a more sensitive reaction to changes in policy rates.

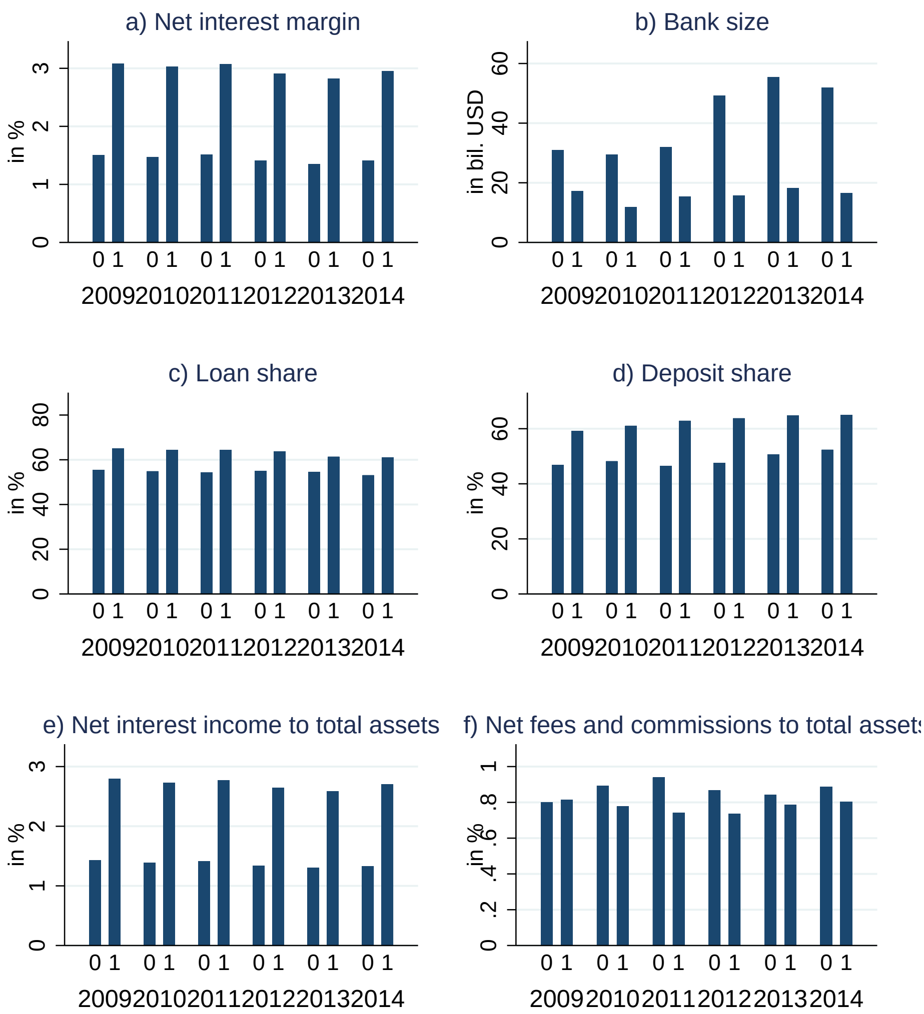
Finally, compared to "simple" balance sheet based measures, the net interest margin has the advantage that it not only captures whether banks have a more traditional business model (and hence a higher interest sensitivity) but also the exposure to interest rates on the asset and liability site is jointly as well as the maturity structure of assets and liabilities is implicitly accounted for. Still we can show that the net interest margin relates well to other proxies capturing banks' reliance on interest-sensitive business activities. To compare the net interest margin to alternative measures of banks' reliance on interest-dependent activities, we define two groups of banks: we take the sample average of the net interest margin and define a dummy variable that takes a value of one for banks with a net interest margin higher than the sample average, and zero otherwise. This dummy variable thus differentiates between banks with and without a strong reliance on an interest-sensitive business model. Figure 2.6 depicts the average of the a) net interest margin, b) bank size, c) loan share, d) deposit share, e) net interest income share, and f) net fees and commissions, differentiating between banks with an, on average, high net interest margin (dummy variable equals one) and banks for which the dummy variable equals zero.

The rather stable pattern of the net interest margin from Figure 2.5 can also be observed within the two groups of banks with on average higher or lower net interest margins (Panel b). Similar to Figure 2.5 focusing on

[25] https://www.federalreserve.gov/econresdata/notes/ifdp-notes/2016/low-for-long-interest-rates-and-net-interest-margins-of-banks-in-advanced-foreign-economies-20160411.html, http://www.faz.net/aktuell/finanzen/meine-finanzen/sparen-und-geld-anlegen/abhaengigkeit-von-zinserstraegen-aufseher-erhoehen-den-druck-auf-die-banken-14291634.html

FIGURE 2.6: Heterogeneity of banks by net interest margin

This graph shows the average amount of a) the net interest margin, b) bank size (total assets in billion USD), c) the loan share, d) the deposit share, e) the net interest income share, and f) the net fees and commissions share of our sample of banks and the period from 2009 to 2014. The sample is decomposed into banks with an average net interest margin (NIM) below (0) or equal to/above (1) the sample mean of the net interest margin. *Source*: Bankscope.

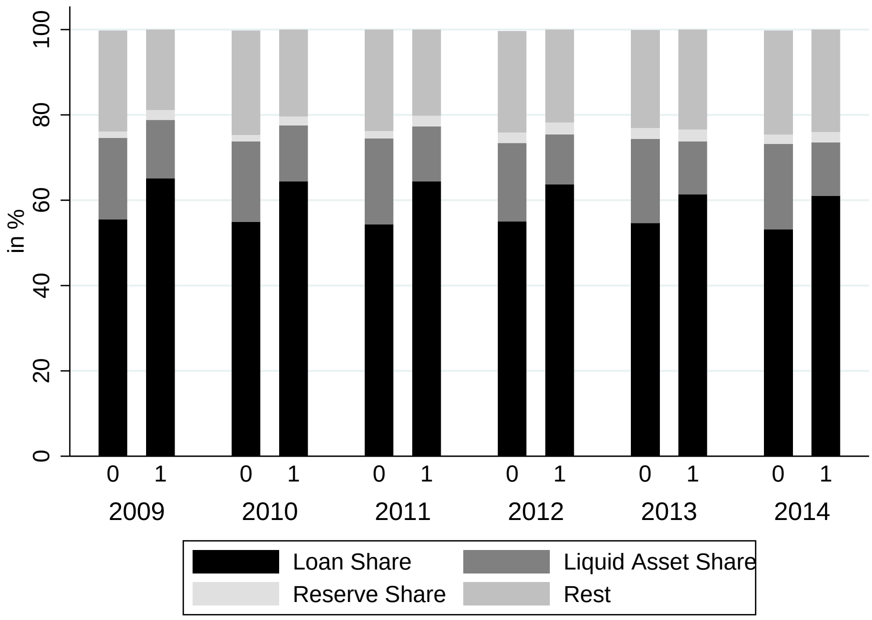


the evolution of the net interest margin across different bank groups and despite the difference in levels, there seems to be a parallel trend in the averaged series. This reduces concerns that systematic differences over time between more and less affected banks drive our results. Banks that are, on average, more dependent on interest-generating activities captured by a higher net interest margin are, on average and as commonly observed, smaller regarding balance sheet size, more involved in the traditional lending and deposit taking business, have a higher share of net interest income to total assets, and a smaller share of net fees and commissions (despite that this variable tends to be very volatile).

In line with these observations, banks with a more interest-sensitive business model differ regarding the composition of their portfolios, as seen in Figure 2.7. These banks show a larger share of loans to total assets reflecting a more traditional business model. In contrast, banks with lower net interest margins have a higher share of liquid assets on their balance sheets.

FIGURE 2.7: Bank portfolio composition by net interest margin

This graph shows the average composition of the balance sheet (in %) of our sample of banks for the period from 2009 to 2014. The sample is decomposed into banks with an average net interest margin (NIM) below (0) or equal to/above (1) the sample mean of the net interest margin. *Source*: Bankscope.



We add further explanatory variables that control for banks' reliance on deposit funding, calculated as the deposits to total assets ratio, and for banks' size, measured as the log of total assets. Additionally, we control for bank capitalization by including the equity to assets ratio, and we control for profitability captured by the return on assets. The correlations in Table 2.2 show that larger banks seem to have a lower net interest margin (Demirgüç-Kunt and Huizinga, 2010; Kasman et al., 2010). Furthermore, changes in one of the subcomponents of banks' portfolios correlate positively with changes in the total balance sheet scaled by total assets in the previous period.

Table 2.2: Correlation matrix: bank-level variables

This table shows the correlation matrix for the bank-level variables used in our analysis. The sample period spans 2009-2014. *Source*: Bankscope.

	Δ Reserves$_t$ to Total Assets$_{t-1}$ (in %)	Δ Liquid Assets$_t$ to Total Assets$_{t-1}$ (in %)	Δ Loans$_t$ to Total Assets$_{t-1}$ (in %)	Δ Total Assets$_t$ to Total Assets$_{t-1}$ (in %)	Net Interest Margin (in %)	Deposits to Total Assets (in %)	ln Assets	Equity to Total Assets (in %)	Return on Assets (in %)	Loans to Total Assets (in %)	Net Interest Income to Total Assets (in %)	Net Fees and Commissions to Total Assets (in %)	Total Regulatory Capital Ratio (in %)	Liquid Assets to Total Assets (in %)	Gov. Debt Holdings to Total Assets (in %)	Δ (Agg. Loans$_t$-Own Loans$_t$)/(Agg. Assets$_{t-1}$-Own Assets$_{t-1}$) (in %)	HighCapitalGroup (0/1)	HighNIMbanks (0/1)
Δ Reserves$_t$ to Total Assets$_{t-1}$ (in %)	1																	
Δ Liquid Assets$_t$ to Total Assets$_{t-1}$ (in %)	-0.12	1																
Δ Loans$_t$ to Total Assets$_{t-1}$ (in %)	0.09	0.03	1															
Δ Total Assets$_t$ to Total Assets$_{t-1}$ (in %)	0.19	0.53	0.65	1														
Net Interest Margin (in %)	0.01	0.05	0.12	0.13	1													
Deposits to Total Assets (in %)	-0.01	0.07	0.12	0.13	0.14	1												
ln Assets	-0.01	0.02	-0.07	-0.02	-0.29	-0.20	1											
Equity to Total Assets (in %)	0.00	-0.08	0.04	-0.06	0.28	-0.24	-0.41	1										
Return on Assets (in %)	0.04	0.09	0.31	0.28	0.28	0.05	-0.02	0.19	1									
Loans to Total Assets (in %)	0.01	0.04	0.02	0.08	0.26	-0.07	0.08	-0.02	0.01	1								
Net Interest Income to Total Assets (in %)	0.00	0.01	0.07	0.07	0.97	0.13	-0.30	0.28	0.24	0.30	1							
Net Fees and Commissions to Total Assets (in %)	0.00	-0.02	-0.01	-0.04	-0.02	0.02	-0.19	0.19	0.14	-0.21	-0.05	1						
Total Regulatory Capital Ratio (in %)	-0.03	-0.09	-0.01	-0.16	0.10	-0.15	-0.30	0.66	0.13	-0.31	0.13	0.12	1					
Liquid Assets to Total Assets (in %)	0.03	0.02	0.01	-0.09	-0.21	0.02	-0.18	0.07	0.00	-0.74	-0.24	0.26	0.32	1				
Gov. Debt Holdings to Total Assets (in %)	-0.04	0.01	-0.05	0.07	0.00	0.01	-0.20	-0.01	-0.05	-0.27	-0.02	0.07	0.16	-0.12	1			
Δ (Agg. Loans$_t$ - Own Loans$_t$)/ (Agg. Assets$_{t-1}$ - Own Assets$_{t-1}$) (in %)	0.06	0.09	0.52	0.42	0.04	0.00	0.02	0.00	0.16	0.06	0.04	0.02	0.02	-0.02	-0.14	1		
HighCapitalGroup (0/1)	-0.01	0.03	0.09	0.11	0.52	0.29	-0.33	0.12	0.10	0.20	0.54	-0.05	0.00	-0.18	0.08	0.04	1	
HighNIMbanks (0/1)	-0.01	-0.07	0.08	-0.04	0.07	-0.01	-0.27	0.39	0.13	-0.26	0.06	0.10	0.60	0.23	0.06	0.09	0.03	1

2.3.3 Country-level data

To evaluate the effects of the ECB's conventional monetary policy, we collect data on key policy rates as provided by the ECB.[26] Our main variable of interest is the deposit facility rate. The pattern of the deposit facility rate becomes visible in Figure 2.3, and it can be observed that the policy rate is actively managed by the ECB. The deposit facility rate has also got public attention more recently. For instance, the Financial Times (2016) stated that "The deposit rate charged on bank reserves parked in the coffers of the ECB has, along with quantitative easing, become one of the most important pillars of Eurozone monetary policy."[27]

We complement the data set by adding the main refinancing rate because it might also affect banks' balance sheet decisions. The inclusion of the main refinancing rate helps monitor the effects of changes in lending rates and control for potential effects of changes in the spread between the borrowing and the lending rate. The main refinancing rate is preferred over the lending "counterpart" of the deposit facility (the marginal lending facility) because the main refinancing operations are the most frequent (conventional) source of liquidity provision in the euro area. It is important to note that the main refinancing rate has an indirect effect on banks' reserve holdings due to its effect on the aggregated supply of reserves within the system. However, the weekly accessible and (nearly) unlimited liquidity supply by the ECB via its open market operations makes it unlikely that the same banks that constantly hold excess reserves request additional funding via the main refinancing rate at the same time.

[26]The policy rates are included in the regression analysis as first difference. To aggregate policy rates to the yearly frequency, we calculate weighted averages, where the weights are based on the fraction of days for which a rate has been set. The reasoning is that the annual change in banks' balance sheet position should be the outcome of how long a rate has prevailed.

[27]Lowering the deposit facility rate closely follows the policy applied by the Danish central bank, with the important difference that the ECB offers fewer possibilities to evade the negative deposit facility rate when holding reserves. For example, the Danish central bank did not exert penalty rates on the current account. See e.g. `http://bruegel.org/2014/06/negative-deposit-rates-the-danish-experience/`

Controls for unconventional monetary policy include the share of ECB-funded bank liabilities to total liabilities[28] , the 10-year government bond yield, and the reliance on ECB refinancing operations. By including the share of ECB-funded bank liabilities capturing the aggregate usage of ECB liquidity across all monetary financial institutions in a country, we control for country-specific effects of unconventional monetary policy measures of the ECB, such as the switch to the fixed-rate, full allotment policy or changes in collateral requirements. Both measures led to an increase in liquidity access for euro area banks and, therefore, might have had an influence on how banks allocate their funds.[29]

The change in the government bond yield controls for the effects of the extensive securities markets programs or public sector purchase programs of the ECB. When the ECB buys extensive amounts of government bonds – also through the national central banks in the euro area – banks are affected in two ways. First, the value of the government bonds increases because there is additional demand. This drives up the price of government bonds already held by banks. Acharya et al. (2019) describe this development observed after the announcement of the OMT program as "backdoor recapitalization". The second way in which the public sector purchase programs affect banks is by depressing the yield of government bonds. This makes them less attractive for future investment and might induce banks to reallocate their portfolios. We furthermore control for these channels in the regressions by adding the share of government debt holdings at the bank level.[30]

Finally, we use information provided by Pisani-Ferry and Wolff (2012) to construct a more explicit measure at the country level capturing the exposure to both LTROs and main refinancing operations (MROs). Similarly

[28]The share of ECB-funded bank liabilities captures all loans granted by the European System of Central Banks (ESCB) relative to the total liabilities of a country's monetary financial institutions (MFIs). The total liabilities do not cover capital, reserves or remaining liabilities, and the MFIs do not include the ESCB itself or money market funds. Source: `http://sdw.ecb.europa.eu/reports.do?node=1000003383`

[29]By controlling for effects of unconventional monetary policy, we also check for supply effects in line with the theory of Cukierman (2016) concerning the source of bank reserves.

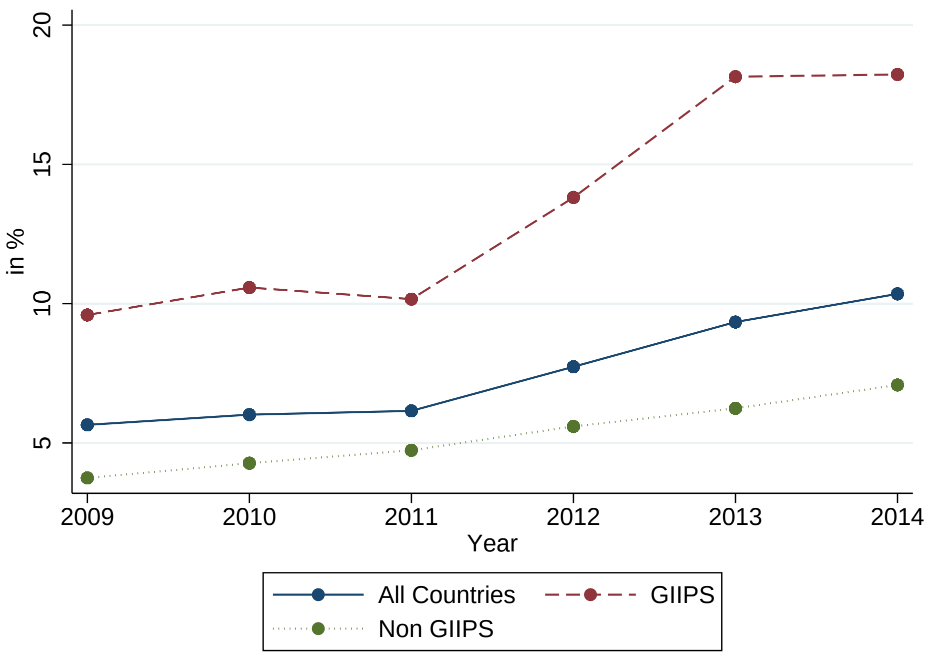
[30]This variable is only available for a subset of banks such that it is not included in the baseline model.

to the data used in Daetz et al. (2018), this dataset is based on hand-collected information on country's uptake of LTROs and MROs derived from national central bank websites. Figure 2.8 shows that these proxy variables for unconventional monetary policy not only vary substantially over time but also do so across country groups when comparing the average pattern of GIIPS countries to the other countries in the sample. Summary statistics are provided in Table 2.1. A correlation table of the country-level variables can be found in Table 2.3.

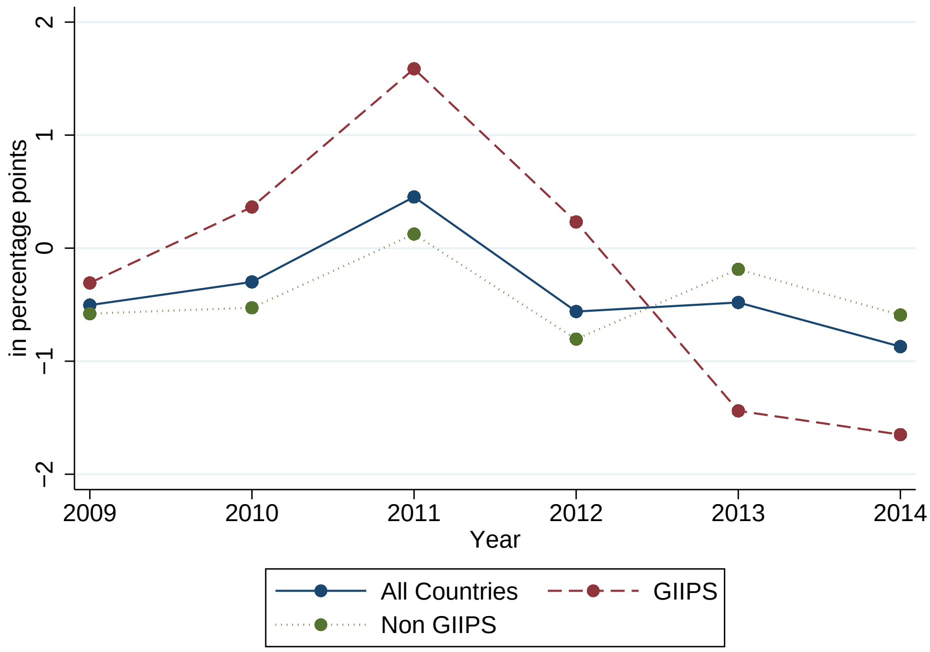
FIGURE 2.8: Controls for unconventional monetary policy

This graph shows in panel a) the average change in the ECB-funded share of monetary financial institutions' liabilities (in percentage points) of our sample of countries for the period from 2009 to 2014. Panel b) shows the average change in government bond yields (in percentage points). Panel c) shows banks' share of government bonds in total assets (in percent). Panel d) shows the average ECB's refinancing operations to monetary financial institutions' assets (in percent). We show the average pattern across all sample countries (blue, solid line), GIIPS countries (red, dashed line), and non-GIIPS countries (green, dotted line). *Source*: Bankscope, ECB, Main Economic Indicators, OECD, Pisani-Ferry and Wolff (2012).

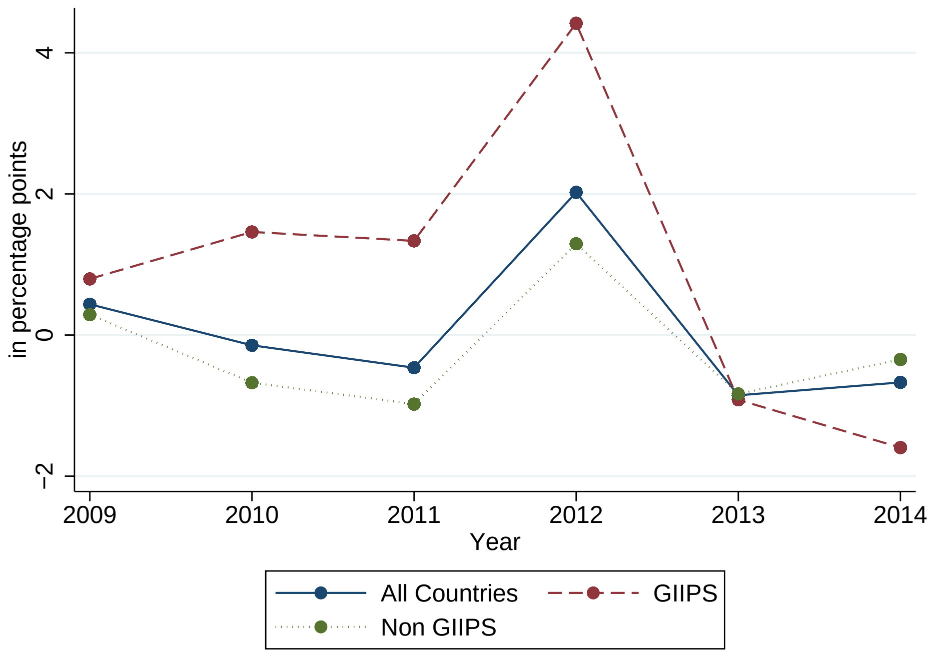
a) Change in the ECB-funded share of monetary financial institutions' liabilities



b) Change in government bond yields



c) Government debt holdings to total assets



2.4 Empirical analysis

In this section, we first show that changing the deposit facility rate results in portfolio reallocations depending on the interest sensitivity of banks' business models. We then investigate which banks in which countries drive our results

d) ECB refinancing operations to monetary financial institutions' total assets

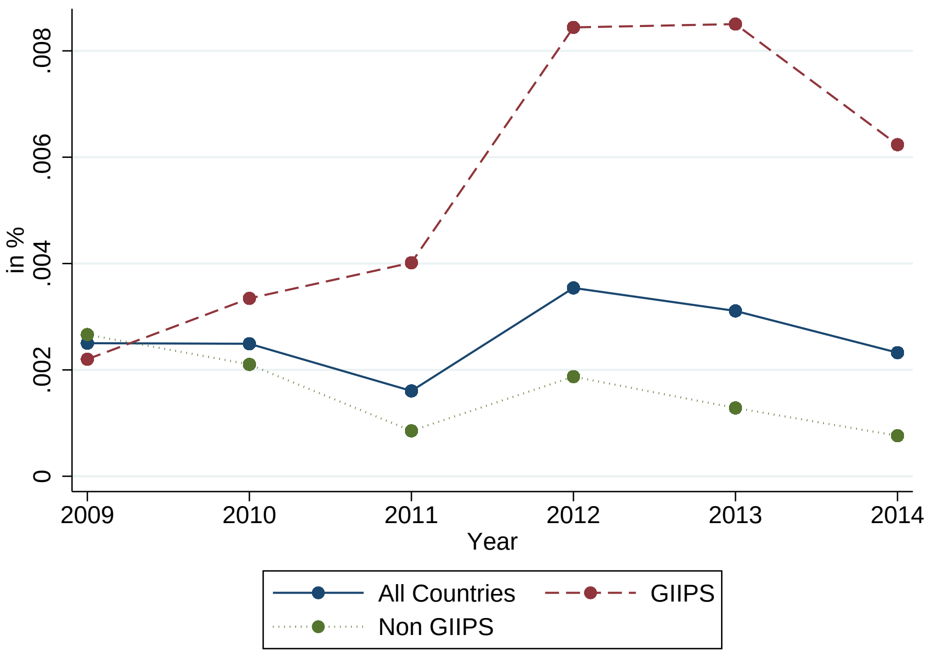


TABLE 2.3: Correlation matrix: country-level variables

This table shows the correlation matrix for country-level variables used in our analysis. The sample period spans 2009-2014. *Source*: see data appendix (Section A.1).

	Δ 10-Year Government Bond Yield (in pp)	Δ Share of ECB-Funded Bank Liabilities (in pp)	MRO & LTRO to MFI's Total Assets (in %)	Δ Firms' Credit Demand (Index)	Δ Overall Credit Standards (Index)	Δ MFIs' Cost of Borrowing for Non-Financial Corporations (in pp)	GIIPS (0/1)
Δ 10-Year Government Bond Yield (in pp)	1						
Δ Share of ECB-Funded Bank Liabilities (in pp)	0.40	1					
MRO & LTRO to MFI's Total Assets (in %)	-0.08	0.38	1				
Δ Firms' Credit Demand (Index)	-0.19	-0.36	0.04	1			
Δ Overall Credit Standards (Index)	0.13	0.07	-0.04	-0.30	1		
Δ MFIs' Cost of Borrowing for Non-Financial Corporations (in pp)	0.33	-0.02	0.04	-0.13	0.58	1	
GIIPS (0/1)	0.04	0.25	0.70	0.04	-0.10	0.03	1

and conduct further robustness tests to account for alternative business model measures, simultaneity of balance sheet positions, and potentially confounding factors.

2.4.1 Baseline results

The results in Table 2.4 show that, in the face of a lower deposit rate, banks with a more interest-sensitive business model, as reflected by a higher net interest margin, reduce reserves by more than banks with a lower net interest margin. Thus, banks with a higher net interest margin are more sensitive to changes in the deposit facility rate, that is, banks' liquidity holdings in the form of reserves at the central bank increase less (more) in response to negative (positive) changes in the deposit facility rate. This is in line with the hypothesis that banks with an interest-sensitive business model are hit more severely by – and are thus more responsive to – the low interest rate policy of the ECB. Consequently, this result complements existing literature on unconventional monetary policy showing that effects are heterogeneous depending on banks' liquidity and balance sheet management (e.g. Acharya et al., 2019).[31]

A noteworthy feature is that the heterogeneous effect seems unsurprising in the context of unconventional monetary policies, as those policies can be differentially applied across banks. By contrast, monetary policy rates, such as the deposit facility rate, apply uniformly to all banks, and our result shows that this policy instrument effectively targets some banks more than others. This is in line with the study by Heider et al. (2019), who focus on the introduction of negative deposit rates and find that effects are heterogeneous along the distribution of banks' deposit ratio. We investigate this point in more detail below.

Based on the size of the coefficient in Column (1), we can assess the economic significance of the effect. For a bank with a one-standard-deviation-higher net interest margin (1.4), the effect of the change in the deposit facility rate on the dependent variable is higher by approximately 2.3 percentage

[31]To evaluate whether the effect of a change in the deposit facility rate goes in a reasonable direction, we rerun the regression model excluding time fixed effects but including the deposit facility rate as such. Figure A.12 in the supplementary material depicts the marginal effect of a change in the deposit facility rate on reserves conditional on banks' net interest margin. An increase in the deposit facility rate has a positive effect on banks' reserve holdings; this effect increases and turns statistically significant for banks with a relatively high net interest margin. However, given that no time fixed effects are included, this estimation has to be taken with caution.

TABLE 2.4: Baseline model

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta \text{Assets}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	1.603***	2.123	-3.255***	2.987
	(0.546)	(1.932)	(0.871)	(2.519)
Net Interest Margin$_{t-1}$	0.050	1.060**	-0.201	1.288
	(0.090)	(0.417)	(0.350)	(0.953)
Deposits to Assets$_{t-1}$	-0.021	0.139***	0.094**	0.441***
	(0.022)	(0.051)	(0.044)	(0.092)
ln Assets$_{t-1}$	-2.770**	-13.513***	-2.834	-22.832***
	(1.275)	(2.947)	(1.932)	(4.723)
Equity to Assets$_{t-1}$	-0.043	-0.263**	0.204	0.009
	(0.042)	(0.129)	(0.142)	(0.270)
Return on Assets$_{t-1}$	-0.211*	0.487**	0.331	0.842*
	(0.118)	(0.241)	(0.251)	(0.494)
Δ Main Refinancing Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	-1.461***	-2.308	3.572***	-2.690
	(0.532)	(1.938)	(0.837)	(2.523)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Observations	1978	1978	1976	1978
R-squared	0.18	0.24	0.48	0.48
Number of Banks	516	516	515	516

points. This differential effect can be considered economically meaningful, as it amounts to approximately 80% of the standard deviation of the dependent variable (2.8).[32]

It is important to note that banks' sensitivity to the deposit facility rate depending on the net interest margin is almost negligible in economic terms if the change in the deposit facility and the main refinancing rate coincide. The reason is the similar size of the coefficients of the interaction terms. If the rate changes would coincide throughout, we would expect to find no effect as the cost-revenue trade-off and resulting balance sheet reallocation decisions should not be affected. However, this is not the case throughout the period and we find effects. This goes back to the fact that the annualized changes of the two rates can differ, which reduces multicollinearity issues.

[32]The result is also economically significant bearing in mind that reserve holdings were almost constant before the crisis.

Considering the time period on which our analysis is based, rates have been changed 13 times and four times, i.e., in 30% of the cases, these changes did not coincide.[33] From a statistical point of view, the coefficients estimates are identified based on the dissimilar variation in the two rates. From a policy perspective, this implies the important result that only dissimilar changes in the borrowing and the lending rate, leading to an increase or decrease in the interest rate corridor, have economically significant effects.

Given that banks change their reserve holdings as a response to changes in the deposit facility rate and conditional on their business model, we are interested to know which asset positions the liquidity is reallocated into. In line with this consideration, Christensen and Krogstrup (2018) discuss the evidence of a "reserve-induced portfolio balance channel". Therefore, we repeat the calculations in Columns (2)-(4) wherein the dependent variable now represents other balance sheet positions such as liquid assets, loans, and total assets.

Opposite to reserves, we find that changes in the deposit facility rate do not significantly influence banks' sensitivity regarding their decisions to hold liquid assets (Table 2.4, Column 2). This implies that banks with a more interest-sensitive business model do not significantly reallocate more liquidity to liquid assets in response to a change in the deposit facility rate. Hence, we do not find significant evidence that monetary policy transmission is impeded. Also, the result does not yield any evidence for the hypothesis that banks, which cannot pass on declines in interest margins to customers due to competitive pressure, invest in more profitable and liquid assets other than loans, thereby generating risks in the financial system, for example, by fueling asset price bubbles.

By contrast, banks with a more interest-sensitive business model tend to increase (decrease) their loans by more given a decrease (increase) in the

[33] In our sample period, deposit facility rate (DFR) and main refinancing rate (MRR) were changed differently on 21 January 2009, 13 May 2009, 8 May 2013, and 13 Nov 2013. Given that we calculate weighted averages for the DFR and the MRR, where the weights are based on the fraction of days for which a rate has been set, the changes in both rates entering the regression differ four times (2009 and 2013 because DFR and MRR were changed differently and 2010 and 2014 because we use the weighted average annual rate).

deposit facility rate, as reflected by the negative and significant coefficient of the interaction term (Table 2.4, Column 3).[34] This finding implies that a reduction in the deposit facility rate can eventually translate into changes in the loan supply by banks. The results are in line with the finding of a "reserve-induced portfolio balance channel" by Kandrac and Schlusche (2017), who show for the U.S. that loan growth has been higher in regions with higher reserve holdings. Furthermore, it supports the notion that, in principle, a conventional instrument such as the deposit facility rate can effectively foster monetary policy transmission – even during times when unconventional measures are used.

However, our results show that the effect is heterogeneous across banks. The manner in which a reduction in the deposit facility rate translates into a higher loan supply in the aggregate therefore critically depends on the structure of the banking system and, in particular, on the extent to which banks rely on an interest-sensitive business model. To obtain a complete picture, we also examine the growth of banks' total assets (Column 4). In doing so, we want to check whether changes in the different portfolio positions are due to portfolio rebalancing or due to a change in total assets, whereas the insignificant coefficient of the interaction term is in favor of the former.

Obviously, there are other changes in monetary policy during the considered time period, which might confound our results. Thus, we extend the baseline estimation in two dimensions:[35]

As concerns the first extension, we run additional tests controlling for key changes in monetary policy by dependent variable (Table 2.5 a)-c)). The baseline model is presented in Column (1), in Column (2), we exclude the year 2009 from the estimations. The reason is that in this year the

[34]For a bank with a one-standard-deviation-higher net interest margin (1.4), the effect of the change in the deposit facility rate on the dependent variable is stronger by approximately 4.6 percentage points, which amounts to approximately 65% of the standard deviation of the dependent variable (7.0).

[35]The results of the following robustness tests for total assets can be found in the supplementary material (Tables A.12 & A.13). As a further robustness test, we controlled for differences in growth rates of banks by including the lagged growth rate of assets, results are available upon request.

deposit facility rate showed the largest drop and we want to rule out that our results are simply driven by that, whereas our coefficient of interest remains significant.[36] In Column (3), we control for the change in the reserve ratio in 2012 by including an interaction between the deposit ratio and a dummy variable that takes a value of one for the period 2012-2014 and zero otherwise.

TABLE 2.5: Alternative channels of monetary policy

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Column (1) shows the baseline model. Column (2) excludes the year 2009. Column (3) controls for the change in the reserve ratio in 2012. Column (4) controls for the deposit facility reaching the zero lower bound and turning negative. Column (5) conducts a horse race with the deposit share as a relevant channel of the deposit facility rate. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

a) Reserves

	(1)	(2)	(3)	(4)	(5)
Explan. Var. Dep. Var.	Δ Bank Reserves$_t$ /Assets$_{t-1}$				
Δ Deposit Facility Rate$_t$ × Net Interest Margin$_{t-1}$	1.603***	1.354*	1.577***	1.563***	1.610***
	(0.546)	(0.796)	(0.536)	(0.539)	(0.546)
Deposits to Assets$_{t-1}$ × Dummy 2012			-0.004		
			(0.010)		
Deposits to Assets$_{t-1}$ × Dummy 2014				0.014	
				(0.010)	
Δ Deposit Facility Rate$_t$ × Deposits to Assets$_{t-1}$					0.002
					(0.003)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1978	1722	1978	1978	1978
R-squared	0.18	0.17	0.18	0.18	0.18
Number of Banks	516	497	516	516	516

In Column (4), we account for the fact that from 2014 on interest rates entered negative territory and interact the deposit ratio and a dummy variable that takes a value of one for the year 2014 and zero otherwise.

[36]In Table A.15, we refine this test by sequentially narrowing down the sample period. While the coefficient is of similar magnitude across samples, it slightly loses significance over time, which makes sense as otherwise there would have been no need for the central bank to adopt other measures. Still, the coefficient of the interaction term of the deposit facility rate and the net interest margin in Column (4) of Table A.15 has a p-value of 0.180.

b) Liquid assets (excl. reserves)

Explan. Var. Dep. Var.	(1)	(2)	(3) Δ Liquid Assets$_t$ /Assets$_{t-1}$	(4)	(5)
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	2.123	0.488	1.990	2.003	2.187
	(1.932)	(1.672)	(1.946)	(1.931)	(1.922)
Deposits to Assets$_{t-1}$ $\times$ Dummy 2012			-0.020		
			(0.022)		
Deposits to Assets$_{t-1}$ $\times$ Dummy 2014				0.042	
				(0.032)	
Δ Deposit Facility Rate$_t$ $\times$ Deposits to Assets$_{t-1}$					0.017
					(0.011)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,722	1,978	1,978	1,978
R-squared	0.24	0.22	0.24	0.24	0.24
Number of Banks	516	497	516	516	516

c) Loans

Explan. Var. Dep. Var.	(1)	(2)	(3) Δ Loans$_t$ /Assets$_{t-1}$	(4)	(5)
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	-3.255***	-3.375***	-3.240***	-3.266***	-3.270***
	(0.871)	(0.934)	(0.894)	(0.878)	(0.875)
Deposits to Assets$_{t-1}$ $\times$ Dummy 2012			0.002		
			(0.014)		
Deposits to Assets$_{t-1}$ $\times$ Dummy 2014				0.004	
				(0.018)	
Δ Deposit Facility Rate$_t$ $\times$ Deposits to Assets$_{t-1}$					-0.004
					(0.010)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,976	1,720	1,976	1,976	1,976
R-squared	0.48	0.47	0.49	0.49	0.49
Number of Banks	515	496	515	515	515

While this approach follows the idea by Heider et al. (2019), it is limited due to the fact that our sample period stops in 2014 such that longer-run balance sheet effects are less likely to occur in our setting. Column (4) reveals that results are robust to this alternative channel. This seems plausible due to the before mentioned circumstance that the deposit facility rate only turned negative in 2014.

Finally, we conduct a horse race with the "deposit channel" by adding to the baseline model an interaction between the deposit ratio and the deposit facility rate (Column 5). If it would be the deposit share that is the key channel that transmits changes in the deposit facility rate to banks' balance sheet positions, then this term should become significant while the interaction with the net interest margin should lose significance. Results reveal that this is not the case providing evidence that the net interest margin has explanatory power.

As concerns the second extension, we control more specifically for unconventional monetary policy related to refinancing operations and asset purchase programs and possible channels through which it might affect banks' portfolio decisions (Tables 2.6 a) - c)). To do so, we add alternative measures for or channels of unconventional monetary policy such as government bond yields (Column 2) or the share of ECB-funded liabilities (Column 3).

Also, banks' government debt holdings play an important role when it comes to unconventional monetary policy (Carpinelli and Crosignani, 2017). For example, Crosignani et al. (2019) show that demand for sovereign debt increased due to its role as collateral in the context of the ECB's LTROs. However, even without adjusting sovereign debt in the balance sheet, the literature has shown that banks with higher exposures benefited from the OMT program due to capital gains (Acharya et al., 2019; Acharya et al., 2018; Krishnamurthy et al., 2017). Thus, we collect banks' government debt holdings as provided by Bankscope to test whether our results remain robust when controlling for this potential confounding channel of unconventional monetary policy (Column 4).[37]

Finally, Column (5) shows results when controlling for a country's uptake of LTROs and MROs. It can be seen that our main result remains robust

[37]We have also included a triple interaction between our interaction term of interest and banks' government debt holdings and find that the change in the deposit facility rate is channeled via the net interest margin while this effect does not differ between banks with a lower and banks with a higher exposure to sovereigns (Table A.16). Also controlling for business cycle dynamics by adding interactions of the net interest margin with indicators for the recent development of the business cycle (GDP growth and inflation) left our main result intact (results available upon request).

Table 2.6: Unconventional monetary policy

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Column (1) shows the baseline model. Columns (2)-(5) include controls for the ECB's unconventional monetary policy, which are interacted with the net interest margin. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

a) Reserves

	(1)	(2)	(3)	(4)	(5)
Explan. Var. Dep. Var.			Δ Bank Reserves$_t$ /Assets$_{t-1}$		
Δ Deposit Facility Rate$_t$					
$\times$ Net Interest Margin$_{t-1}$	1.603***	1.775***	1.532***	1.705**	1.691**
	(0.546)	(0.648)	(0.557)	(0.665)	(0.734)
Δ 10-Year Government Bond Yield$_t$					
$\times$ Net Interest Margin$_{t-1}$		-0.001			
		(0.106)			
Δ Share of ECB-Funded Bank Liabilities$_t$					
$\times$ Net Interest Margin$_{t-1}$			-0.032		
			(0.055)		
Gov. Debt Holdings to Total Assets$_{t-1}$					
$\times$ Net Interest Margin$_{t-1}$				0.010	
				(0.031)	
Gov. Debt Holdings to Total Assets$_{t-1}$				0.051	
				(0.075)	
MRO & LTRO to MFI's Total Assets$_t$					
$\times$ Net Interest Margin$_{t-1}$					-9.285
					(43.721)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1978	1,945	1,959	1,514	1,746
R-squared	0.18	0.18	0.18	0.24	0.14
Number of Banks	516	511	515	428	465

while, given a higher usage of these programs, banks with a more traditional business model as proxied by the net interest margin are more sensitive regarding their loan supply.[38]

2.4.2 Heterogeneities

Market fragmentation in the euro area that is mirrored, for example, by diverging risk premia across countries, has been a key concern for policymakers since the start of the sovereign debt crisis. This might result

[38] As a final check of potential confounding effects of unconventional monetary policy, we exploit that confounding effects are of higher importance in countries with more excessive exposure to unconventional monetary policy measures. In Table A.17, we thus use the controls for unconventional monetary policy and exclude countries from the analysis that lie in the 75th percentile of the distribution.

b) Liquid assets (excl. reserves)

Explan. Var. Dep. Var.	(1)	(2)	(3)	(4)	(5)
	Δ Liquid Assets_t /Assets_{t-1}				
Δ Deposit Facility Rate_t $\times$ Net Interest Margin_{t-1}	2.123	1.116	2.814	3.878**	2.709
	(1.932)	(2.322)	(2.016)	(1.853)	(3.574)
Δ 10-Year Government Bond Yield_t $\times$ Net Interest Margin_{t-1}		-0.453*			
		(0.263)			
Δ Share of ECB-Funded Bank Liabilities_t $\times$ Net Interest Margin_{t-1}			0.254*		
			(0.130)		
Gov. Debt Holdings to Total Assets_{t-1} $\times$ Net Interest Margin_{t-1}				-0.108**	
				(0.047)	
Gov. Debt Holdings to Total Assets_{t-1}				0.293**	
				(0.120)	
MRO & LTRO to MFI's Total Assets_t $\times$ Net Interest Margin_{t-1}					115.806
					(151.938)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,945	1,959	1,514	1,746
R-squared	0.24	0.23	0.23	0.28	0.25
Number of Banks	516	511	515	428	465

c) Loans

Explan. Var. Dep. Var.	(1)	(2)	(3)	(4)	(5)
	Δ Loans_t /Assets_{t-1}				
Δ Deposit Facility Rate_t $\times$ Net Interest Margin_{t-1}	-3.255***	-2.443**	-3.567***	-2.971***	-3.746***
	(0.871)	(1.200)	(0.864)	(1.107)	(1.201)
Δ 10-Year Government Bond Yield_t $\times$ Net Interest Margin_{t-1}		0.290**			
		(0.147)			
Δ Share of ECB-Funded Bank Liabilities_t $\times$ Net Interest Margin_{t-1}			-0.132*		
			(0.070)		
Gov. Debt Holdings to Total Assets_{t-1} $\times$ Net Interest Margin_{t-1}				-0.032	
				(0.041)	
Gov. Debt Holdings to Total Assets_{t-1}				0.288***	
				(0.091)	
MRO & LTRO to MFI's Total Assets_t $\times$ Net Interest Margin_{t-1}					171.293*
					(95.993)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,976	1,943	1,957	1,514	1,744
R-squared	0.48	0.48	0.49	0.55	0.49
Number of Banks	515	510	514	428	464

in differential access to liquidity. For example, Abbassi et al. (2014) find that the sovereign debt crisis made it more difficult for banks located in peripheral countries to access liquidity in interbank markets. To test for heterogeneities across euro area countries, Table 2.7 shows the results for the baseline model estimated with a triple interaction to test whether banks in GIIPS countries react differently. It can be seen that the effect of the interaction term ($\Delta \text{DFR}_t \times \text{NIM}_{t-1}$) differs significantly between GIIPS and non-GIIPs banks. In non-GIIPS countries, banks with a higher net interest margin are more sensitive to a decline in the deposit facility rate and respond by lowering reserves (Column 1) and increasing loans (Column 4). This reallocative effect is reduced in GIIPS countries.

Various reasons may be driving this result. From an economic viewpoint, market fragmentation, in particular the divergence of borrowing costs across countries and differences in liquidity needs, might explain the higher sensitivity for the sample of non-GIIPS countries.

Banks in GIIPS countries might suffer from weak fundamentals that reduce the extent to which they can access interbank markets and crimp their flexibility to adjust to the ECB's monetary policy. Thus, banks in non-GIIPS countries will behave differently than those in GIIPS countries with regard to their liquidity demand and reserve holdings. While the former deposit excess reserves at the central bank, the latter fulfill their liquidity needs by borrowing from the central bank. The central bank is preferred over the interbank market because funding is provided at lower costs than in the interbank market, which discriminates across countries and demands a risk premium. Hence, it is not surprising that the economic effect on reserves is stronger for non-GIIPS countries, given that banks in those countries are much more likely to hold reserves, and are thus affected by the interest paid on this asset position.[39]

Additionally, the significant result for the change in loans scaled by total

[39]Figure A.13 shows different uses of central bank liquidity across euro area countries. Figure A.15 in the supplementary material provides some additional evidence of these differences by showing reserve holdings/borrowing of domestic MFIs at/from the national central bank for Germany and Spain (see also Vari, 2019).

Table 2.7: Country heterogeneity

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. A triple interaction term between the deposit facility rate, the net interest margin and a dummy variable (GIIPS) being one for a GIIPS country and zero otherwise is included. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta \text{Assets}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	1.694***	2.214	-3.462***	2.832
	(0.548)	(1.913)	(0.828)	(2.392)
Δ Deposit Facility Rate$_t$				
$\times$ GIIPS	-0.466	2.251	-1.634	3.829
	(0.476)	(2.519)	(1.804)	(4.017)
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$				
$\times$ GIIPS	-0.452**	-0.535	0.785*	0.130
	(0.198)	(0.351)	(0.439)	(0.784)
Net Interest Margin$_{t-1}$				
$\times$ GIIPS	-0.135	0.673	2.718*	6.763**
	(0.586)	(1.559)	(1.630)	(3.351)
Net Interest Margin$_{t-1}$	0.037	0.979***	-0.375	0.762
	(0.089)	(0.371)	(0.265)	(0.622)
Deposits to Assets$_{t-1}$	-0.025	0.134***	0.104**	0.448***
	(0.022)	(0.051)	(0.044)	(0.090)
ln Assets$_{t-1}$	-2.824**	-13.568***	-2.712	-22.744***
	(1.271)	(2.954)	(1.929)	(4.735)
Equity to Assets$_{t-1}$	-0.048	-0.269**	0.208	0.005
	(0.041)	(0.129)	(0.142)	(0.267)
Return on Assets$_{t-1}$	-0.223*	0.448*	0.285	0.657
	(0.120)	(0.240)	(0.257)	(0.489)
Δ Main Refinancing Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	-1.482***	-2.304	3.700***	-2.444
	(0.535)	(1.925)	(0.809)	(2.387)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Observations	1978	1978	1976	1978
R-squared	0.18	0.24	0.49	0.48
Number of Banks	516	516	515	516

assets of the previous period is retained and larger (in absolute terms) for the non-GIIPS sample. This suggests that the effects are mainly driven by banks in countries that have only been affected by the recent financial and sovereign debt crisis to a minor extent, and it adds another dimension of heterogeneity with respect to the transmission channel of monetary policy. Similar results are found by Al-Eyd and Berkmen (2013), showing that monetary policy transmission is hampered in stressed countries of the euro area.

Hence, the deposit facility rate seems to be more effective in non-GIIPS countries. One obvious reason, as discussed above, is that banks in those countries have a higher share of reserves and are thus more affected by declines in the respective yield. Another reason may be that banks are less capital-constrained in those countries, with the result that they are able to transform reserves into loans with the objective of earning higher interest but without fearing that they may become constrained by regulatory capital requirements. Along these lines, we test whether our results depend on banks' regulatory capital by adding a triple interaction including the change in the deposit rate, the net interest margin and a dummy variable taking a value of one if a bank has, on average, a regulatory capital ratio larger than the sample mean and zero otherwise. Table A.18 reveals that capitalization plays a minor role and does not result into differentially significant effects. We do not find that banks with a high capital ratio show a different sensitivity than banks with a low capital ratio.

2.4.3 Alternative proxies for interest sensitivity of banks' business model

In this section, we test whether the results depend on the choice of the net interest margin as a proxy for the interest sensitivity of banks' business model. We replace the net interest margin with four alternative measures. First, the loan share is a direct measure to capture reliance on traditional lending business, and indirectly interest income. Second, the net interest income share in total assets reflects the importance of net interest income relative to banks' balance sheet size. Third, we use the ratio of net fees and commissions to total assets, whereas banks with higher values might find it easier to recur to alternative sources of income excluding net interest income and would thus be less sensitive to interest rate changes. Fourth, the deposit share captures reliance on retail funding.

The results in Table 2.8 reveal that despite changing the proxy for the interest sensitivity of banks' business model, our main conclusions remain valid. Following a decrease in the deposit facility rate, banks with a higher loan share, and respectively, a higher net interest income share, decrease reserve holdings and increase lending. We find opposite effects when interacting the deposit facility rate with banks' net fees and commissions ratio. This corroborates the previous results because the variable is defined such that higher values would indicate a less interest-sensitive business model.

The only exception is the deposit share as following an increase (decrease) in the deposit facility rate, banks' with a higher deposit share expand (reduce) their balance sheet, which affects all balance sheet items. These results follow in a broader sense the argumentation by Heider et al. (2019) namely that lowering deposit rates affects lending heterogeneously depending on banks' deposit share. For their setting, which is in various dimensions different to ours, the authors find that especially during a period of negative deposit rates, banks' with a higher share of deposits face relatively higher funding costs with negative implications for net worth. They show that "high-deposit banks" are more likely to reduce lending (and to take on more risks). Hence, via the "deposit channel", we find a shrinkage of the balance sheet but not portfolio rebalancing from reserves into other assets.[40]

To verify whether the "deposit channel" interacts with our results, we include a triple interaction with the deposit share (Table A.19). We see that the coefficient of the triple interaction term is very small such that the share of deposits is of minor importance for the transmission of the deposit facility rate to banks' portfolio reallocation channeled via the net interest margin (see also Section 2.4.1 for further tests on the "deposit channel").

2.4.4 Simultaneous equations

To account for the simultaneity between the individual balance sheet positions, we repeat the previous calculation by running 3SLS estimations.[41] This estimation strategy controls for the endogeneity of balance sheet positions

[40] Drechsler et al. (2017) study the link between monetary policy and households' deposit holdings at banks.

[41] This estimation method has been applied by, e.g., Elyasiani and Zhang (2015), Horvath (2013), and Shim (2013). An IV approach has also been chosen by Kandrac and Schlusche (2017) for a related question based on U.S. data.

Table 2.8: Alternative proxies for interest sensitivity of business model

This table shows regression results obtained from estimating a modified equation (2.1) for a sample of euro area banks. The estimation period is 2009-2014. The dependent variable is given in the column header. The policy rates are interacted with a) net interest margin, b) loan share, c) net interest income share, d) net fees and commissions share, and e) deposit share. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta \text{Assets}_t}{\text{Assets}_{t-1}}$
a) *Net Interest Margin*				
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	1.603***	2.123	-3.255***	2.987
	(0.546)	(1.932)	(0.871)	(2.519)
Observations	1,978	1,978	1,976	1,978
R-squared	0.18	0.24	0.48	0.48
Number of Banks	516	516	515	516
b) *Loans to Total Assets*				
Δ Deposit Facility Rate$_t$				
$\times$ Loans to Total Assets$_{t-1}$	0.114***	0.292***	-0.504***	-0.056
	(0.041)	(0.111)	(0.062)	(0.164)
Observations	1,977	1,977	1,976	1,977
R-squared	0.18	0.26	0.56	0.48
Number of Banks	515	515	515	515
c) *Net Interest Income to Total Assets*				
Δ Deposit Facility Rate$_t$ $\times$ Net				
Interest Income to Total Assets$_{t-1}$	1.758***	1.480	-4.493***	1.167
	(0.647)	(2.287)	(0.920)	(3.034)
Observations	1,978	1,978	1,976	1,978
R-squared	0.18	0.24	0.49	0.48
Number of Banks	516	516	515	516
d) *Net Fees and Commissions to Total Assets*				
Δ Deposit Facility Rate$_t$ $\times$ Net Fees				
and Commissions to Total Assets$_{t-1}$	-1.824*	-1.190	3.263**	4.436
	(0.942)	(1.846)	(1.290)	(3.505)
Observations	1,974	1,974	1,972	1,974
R-squared	0.18	0.23	0.49	0.48
Number of Banks	515	515	514	515
e) *Deposits to Total Assets*				
Δ Deposit Facility Rate$_t$				
$\times$Deposits to Total Assets$_{t-1}$	0.061*	0.221**	0.137*	0.661***
	(0.034)	(0.105)	(0.071)	(0.151)
Observations	1,978	1,978	1,976	1,978
R-squared	0.17	0.24	0.48	0.49
Number of Banks	516	516	515	516
Controls	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes

and the simultaneous correlations of error terms across equations. Given that correlations across equations are taken into account, this approach yields more efficient estimates than a 2SLS approach. From an economic point of view, we can account for the fact that changes in the deposit facility rate should have a direct effect on banks' reserve holdings, particularly for banks with a more interest-sensitive business model. Indirect effects emerge as soon as banks reallocate reserves into other asset-side positions. This is mirrored in the set-up of the system of equations:

The first stage regression is equal to equation (2.1) with reserves as the dependent variable, which is instrumented with the interaction term between the change in the deposit facility rate and the net interest margin. In the second stage, the dependent variable is either liquid assets or loans. In contrast to the baseline model, the interaction term of the deposit facility rate and the net interest margin is no longer included. Instead, the second stage regression controls for the effect of changes in banks' reserve holdings relative to total assets by including the predicted value of reserves that has been obtained by the first stage regression.

The results of these estimations can be found in Table 2.9. Column (1) shows the first stage regression with reserves as the dependent variable for the full sample. As is to be expected, for the first stage regression, the results of the 3SLS estimation are close to the previous results obtained by OLS estimations (Table 2.4, Column 1). The interaction term of the change in the deposit facility rate and the net interest margin remains positive and significant.[42] In the second stage estimation, we obtain a negative and highly significant coefficient of the predicted value of reserves on loans (Column 3). Hence, in line with our baseline results, banks' lending decisions are negatively affected by an increasing share of reserve holdings on banks' balance sheets. Vice versa, this provides evidence for a reallocation of freed-up reserves into loans and supports our results obtained from OLS estimations.

The simultaneous estimations allow obtaining a more nuanced view on the economic magnitude of portfolio reallocations. From Column (1) of Table 2.9, we obtain that following a typical decline in the deposit facility rate by 25 basis points, a bank with an average net interest margin reduces reserves

[42]We cannot apply overidentification tests to evaluate the validity of the instrument because we have only one instrument for the endogenous variable.

TABLE 2.9: Simultaneous equations (3SLS)

This table shows regression results obtained from estimating the baseline specification in a set-up of simultaneous equations. The estimation sample covers euro area banks and the period 2009-2014. In Column (1), the estimates of the first stage regression with reserves as the dependent variable are shown. Columns (2) and (3) show the estimates of the second stage estimations with liquid assets (excl. reserves) and loans as dependent variables. Here, the predicted value for reserves as derived from the first stage regression is included. The estimates for liquid assets and loans are obtained by running two separate 3SLS estimations. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$			
$\times$ Net Interest Margin$_{t-1}$	1.641***		
	(0.411)		
Net Interest Margin$_{t-1}$	-0.010	0.864**	-0.216
	(0.142)	(0.380)	(0.364)
Deposits to Assets$_{t-1}$	-0.026**	0.154***	0.052
	(0.013)	(0.039)	(0.037)
ln Assets$_{t-1}$	-2.703***	-10.010***	-7.611***
	(0.578)	(2.078)	(1.988)
Equity to Assets$_{t-1}$	-0.006	-0.191	0.203*
	(0.044)	(0.119)	(0.114)
Return on Assets$_{t-1}$	-0.236***	0.699**	-0.067
	(0.085)	(0.277)	(0.265)
Δ Main Refinancing Rate$_t$			
$\times$ Net Interest Margin$_{t-1}$	-1.628***	-0.519**	0.220
	(0.405)	(0.246)	(0.236)
Estimate(Δ Bank			
Reserves$_t$ /Assets$_{t-1}$)		1.254*	-1.782***
		(0.672)	(0.643)
Country-Time Fixed Effects	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Observations	1976	1976	1976
P-value of chi^2-test	0.0000	0.0000	0.0000
Number of Banks	515	515	515

by 0.82 percentage points. In turn, Column (3) reveals that a decline in estimated reserve holdings by one percentage point leads to an increase in loans by 1.8 percentage points. This result implies that a reduction in the deposit facility rate results in an over proportional increase in loans compared to the decline in reserves. The reason can be seen from Column (2): when accounting for simultaneity, banks also shrink down their liquid asset position following reduced incentives to hold reserves due to a lower interest rate. This is confirmed in unreported regressions when exchanging the dependent variable in Column (1) by adding reserves and liquid assets

together. Explaining loan supply by the then estimated change in the combined liquid asset position, it turns out that following a decline in the deposit facility rate, there is a positive effect on loans that is, however, smaller than unity.

Estimating a simultaneous equation model helps taking into account simultaneous adjustment of balance sheet items. Still a potential concern can arise because the net interest margin might be correlated with lending. However, we do not look at the net interest margin as such but interact it with the change in the deposit facility rate. Assuming that the deposit facility rate is exogenous from the perspective of the individual bank, recent literature argues that the interaction term including one exogenous and one endogenous variable delivers consistent results (Bun and Harrison, 2019; Dreher et al., 2015; Nizalova and Murtazashvili, 2016; Nunn and Qian, 2014; Nunn and Qian, 2012). We have to assume in such a case that the net interest margin is the main channel through which the deposit facility rate affects portfolio rebalancing decisions and we test for the relevance of other channels of monetary policy (Table A.14). It is also to note that the net interest margin is relatively stable over time (Figure 2.5) while the deposit facility rate is significantly lowered such that a significant coefficient should be driven by the change in the deposit facility rate and its effect on loan supply.[43]

To check the validity of the instrument, in Table A.20, we test whether our instrument is useful by drawing on the exclusion restriction (Angrist et al., 2010). We start by testing our 3SLS model for a subset of countries, for which the instrument can be plausibly assumed to not work. We assume that in countries with low reserves, the proposed channel should be irrelevant and thus the instrument weak. This should apply to the GIIPS countries (see Figure 2.4). Column (1) shows results when reserves is the dependent variable, which is explained by the interaction term ($\Delta \mathrm{DFR}_t \times \mathrm{NIM}_{t-1}$), whereas the coefficient of this term should not be significant. Also the

[43]To reduce simultaneity concerns, we conducted further tests interacting the deposit facility rate with banks' average net interest margin over the sample period, which did not affect the robustness of our results. As market power might drive the relation between loan supply and net interest margins, we have excluded banks with an asset share in the 75th percentile of the distribution and results remain robust (available upon request).

estimated change in reserves as obtained from Column (1) should not show a significant coefficient for loans as dependent variable (Column 2). Finally, in the reduced form and for loans as dependent variable, the coefficient of the interaction term should not be significant (Column 3), which is indeed the case.

2.4.5 Loan demand

Finally, we address concerns of demand-side effects for loans. Assuming that banks are not identical in their net interest margins, the set-up of our regression model separates demand from supply-side effects by making use of heterogeneous responses by banks to changes in the deposit facility rate along the distribution of the net interest margin. The inclusion of country-time fixed effects extracts demand side effects at the country level that affect all banks alike.[44] To further rule out that demand-side effects drive our result in the loan regression, in Table 2.10, we include several variables to extract effects stemming from the demand side.

These variables include firms' credit demand (Column 2) and overall credit standards (Column 3) from the bank lending survey of the ECB. In Column (4), we control for the borrowing costs of non-financial corporations, assuming that higher borrowing costs relate to declines in demand for credit. In Column (5), we draw on related literature and calculate a demand control by taking the growth rate of loans relative to total assets by all banks in country j excluding bank i. This approach is similar to Aiyar (2012) whereas due to limitations of Bankscope we cannot calculate this loan growth rate based on the exposure of a bank to specific credit segments in a country. Nevertheless, it might be a more specific demand control than country-time fixed effects as it is calculated from bank-level loan data. When including this demand control, the coefficient of interest loses most in magnitude (in absolute terms) compared to previous tests, but across all specifications, it remains significant.

[44]Results remain robust when inserting bank specialization-time fixed effects into the model, which should trace out time-varying demand side effects common to a banking group (available upon request).

TABLE 2.10: Loan demand

This table shows robustness tests for the baseline specification (Column 1). The estimation sample covers euro area banks and the period 2009-2014. The dependent variable is the change in loans to assets in the preceding period. In Column (2), firms' credit demand (backward looking) from the ECB Bank Lending Survey is controlled for. In Column (3), overall credit standards (backward looking) from the BLS are controlled for. Column (4) includes the change in MFIs' cost of borrowing for non-financial corporations. In Column (5), a demand control following Aiyar (2012) is included. It is defined as Δ (Agg. Loans_t - Own Loans_t)/(Agg. Assets_{t-1} - Own Assets_{t-1}), whereas aggregate loans are defined at the country level and own loans refers to loans of bank i in that country at time t. The variables at the bank level are included with a lag. Bank and country-time fixed effects, respectively bank and time fixed effects, are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Explan. Var. Dep. Var.	Δ Loans_t /Assets_{t-1}				
Δ Deposit Facility Rate_t					
× Net Interest Margin_{t-1}	-3.255***	-3.205**	-3.632***	-3.150***	-3.013***
	(0.871)	(1.540)	(1.262)	(0.884)	(0.758)
Net Interest Margin_{t-1}	-0.201	-0.235	0.906	-0.197	-0.003
	(0.350)	(0.364)	(0.893)	(0.338)	(0.422)
Deposits to Assets_{t-1}	0.094**	0.054	0.060	0.094**	0.080*
	(0.044)	(0.047)	(0.049)	(0.044)	(0.042)
ln Assets_{t-1}	-2.834	-2.849	-2.227	-2.767	-2.791
	(1.932)	(2.035)	(2.077)	(1.930)	(1.731)
Equity to Assets_{t-1}	0.204	0.218	0.185	0.202	0.169
	(0.142)	(0.149)	(0.164)	(0.142)	(0.143)
Return on Assets_{t-1}	0.331	0.238	0.225	0.313	0.353
	(0.251)	(0.257)	(0.277)	(0.250)	(0.261)
Δ Main Refinancing Rate_t					
× Net Interest Margin_{t-1}	3.572***	3.383**	3.943***	3.584***	3.380***
	(0.837)	(1.440)	(1.196)	(0.830)	(0.763)
Δ Firms' Credit Demand_t					
× Net Interest Margin_{t-1}		-0.001			
		(0.012)			
Δ Overall Credit Standards_t					
× Net Interest Margin_{t-1}			-0.002		
			(0.017)		
Δ MFIs' Cost of Borrowing					
for Non-Financial_t					
× Net Interest Margin_{t-1}				-0.194	
				(0.242)	
Δ (Agg. Loans_t - Own Loans_t)/					
(Agg. Assets_{t-1} - Own Assets_{t-1})					0.382***
					(0.081)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,976	1,976	1,530	1,976	1,976
R-squared	0.48	0.48	0.45	0.48	0.41
Number of Banks	515	496	402	515	515

2.5 Concluding remarks

This paper studies the effects of a conventional monetary policy instrument, the deposit facility rate, on euro area banks' portfolio management over the period 2009-2014, while taking into account the interest sensitivity of banks' business model. Lowering the deposit facility rate should reduce banks' incentives to hold reserves at the central bank due to lower interest earnings and can thus induce portfolio reallocation.

Our results show that, first, the higher the interest sensitivity of banks' business model, captured by the net interest margin, the more banks reduce reserve holdings when facing a decline in the deposit facility rate. This shows that a common monetary policy can result in different outcomes across banks and thereby across countries depending on the characteristics of the banking sector.

Second, in the presence of excess reserves, we find evidence that the deposit facility rate has reallocation effects that can play an important role for the transmission of monetary policy: banks with a more interest-sensitive business model show a positive sensitivity to decreasing policy rates regarding changes in the loan position.

Third, effects are most pronounced for banks in non-GIIPS countries of the euro area. This reveals that conventional monetary policy instruments have limited effects in restoring monetary policy transmission during times of crisis.

Appendix A

A.1 Data appendix

Variable	Description	Data Source
Bank-specific variables		
Δ Reserves to Total Assets of t-1 (in %)	Change in a bank's reserve holdings between period t and t-1 relative to total assets of period t-1	Bankscope
Δ Liquid Assets (excl. Reserves) to Total Assets of t-1 (in %)	Change in a bank's liquid assets (excl. bank reserves) between period t and t-1 relative to total assets of period t-1	Bankscope
Δ Loans to Total Assets of t-1 (in %)	Change in a bank's loans between period t and t-1 relative to total assets of period t-1	Bankscope
Δ Assets to Total Assets of t-1 (in %)	Annual growth of total bank assets	Bankscope
Net Interest Margin (in %)	(Interest income–interest expense)/ average earning assets	Bankscope
ln Assets	Log of total assets (in US$ million)	Bankscope
Deposits to Total Assets (in %)	Bank's total deposits relative to total assets	Bankscope
Equity to Total Assets (in %)	Bank's total equity relative to total assets	Bankscope
Return on Assets (in %)	Operating profit relative to average assets	Bankscope
Net Fees and Commissions to Total Assets (in %)	Net fees and commissions relative to total assets	Bankscope
Net Interest Income to Total Assets (in %)	Net interest income relative to total assets	Bankscope
Total Regulatory Capital (in %)	Total regulatory capital relative to total assets	Bankscope
Loans to Total Assets (in %)	Loans relative to total assets	Bankscope
Gov. Debt Holdings to Total Assetst (in %)	Government debt holdings relative to total assets	Bankscope
Liquid Assets to Total Assets (in %)	Liquid assets relative to total assets	Bankscope
Δ (Agg. Loans$_t$ - Own Loans$_t$)/ (Agg. Assets$_{t-1}$ - Own Assets$_{t-1}$) (in %)	Change in agg. net loans excl. own loans in t relative to agg. total assets excl. own total assets of period t-1	Bankscope
HighCapitalGroup (0/1)	Dummy variable being one for banks with an average capital ratio higher than or equal to the sample average (16.21 %)	Bankscope
High Net Interest Margin (0/1)	Dummy variable being one for banks with an average net interest margin higher than or equal to the sample average (2.06%)	Bankscope
Country-specific variables		
Δ 10 Year Government Bond Yield (in percentage points)	First difference of the yield for 10-year government bonds	Main Economic Indicator, OECD

Data appendix (continued)

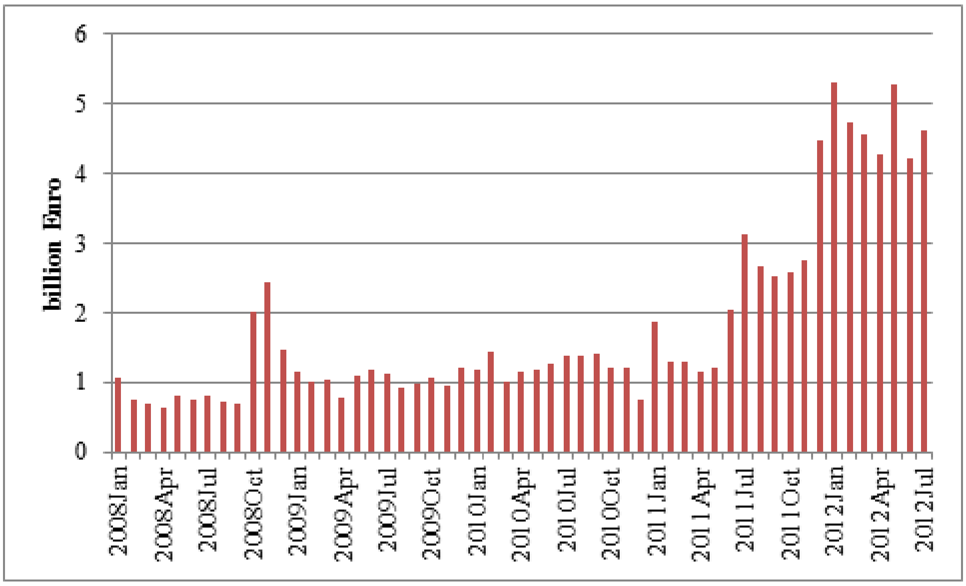
Variable	Description	Data Source
Country-specific variables (continued)		
Δ Share of ECB-Funded Bank Liabilities (in percentage points)	First difference of the ECB-funded share of monetary financial institutions' liabilities (excluding reserves, capital and remaining liabilities)	ECB
Δ Firms' Credit Demand (diffusion index)	First difference of firms overall credit demand for past quarter, annual average, diffusion index where positive values correspond to increase in demand	Bank Lending Survey, ECB
Δ Overall Credit Standards (diffusion index)	First difference of overall credit standards for firms for past quarter, annual average, diffusion index where positive values correspond to tightening of standards	Bank Lending Survey, ECB
MRO & LTRO to MFI's Total Assetst (in %)	Average main and longer-term refinancing operations divided by assets of monetary financial institutions	Pisani-Ferry and Wolff (2012); Eurostat
Δ MFI's Cost of Borrowing for Non-Financial Corporations (in percentage points)	First difference of cost of borrowing of new business for non-financial corporations	ECB
GIIPS (0/1)	Dummy variable being one for banks in Greece, Italy, Ireland, Portugal, and Spain	
Euro area rates		
Δ Deposit Facility Rate (in percentage points)	First difference of the deposit facility rate, a policy rate of the ECB	ECB
Δ Main Refinancing Rate (in percentage points)	First difference of the main refinancing rate, a policy rate of the ECB	ECB

A.2 Figures

FIGURE A.9: Excess reserve holdings in the euro area

This figure shows monthly values of "total excess reserves of credit institutions subject to minimum reserve requirements in the euro area" (in billion Euro) hold in the current account for the period January 2008-July 2012 and August 2012-December 2014. Excess reserves increase in January 2012 due to a decline in the reserve ratio from 2% to 1%. In July 2012, the deposit facility rate was set to zero such that the deposit facility lost the favorable yield over the current account explaining the increase in excess reserves in the current account (whereas previously excess reserves have mainly been stored in the deposit facility). *Source*: European Central Bank.

a) Jan 2008- Jul 2012



b) Aug 2012- Dec 2014

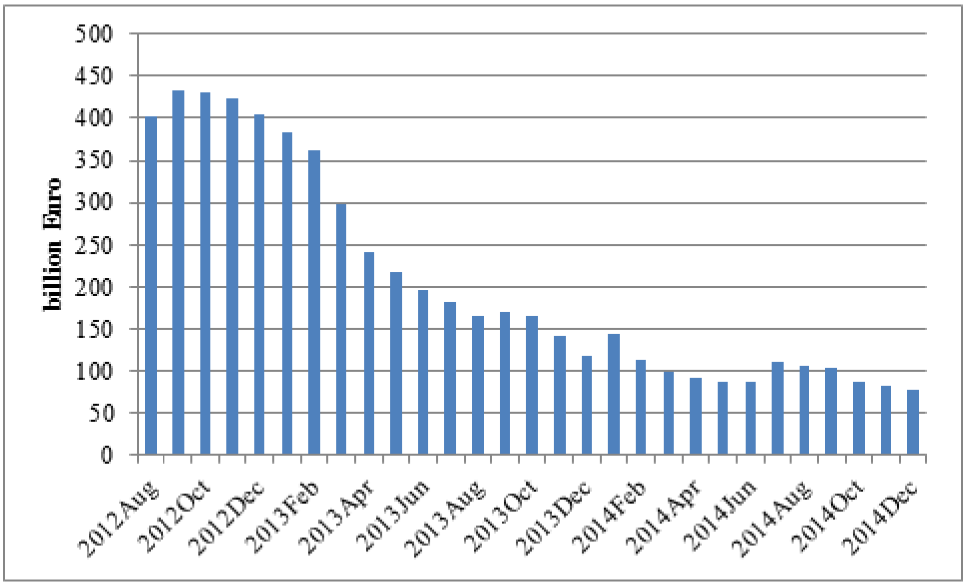


Figure A.10: Eonia volume

This figure shows the daily Eonia volume of overnight lending in billion Euro from 01.01.2008 to 31.12.2014. *Source*: European Central Bank.

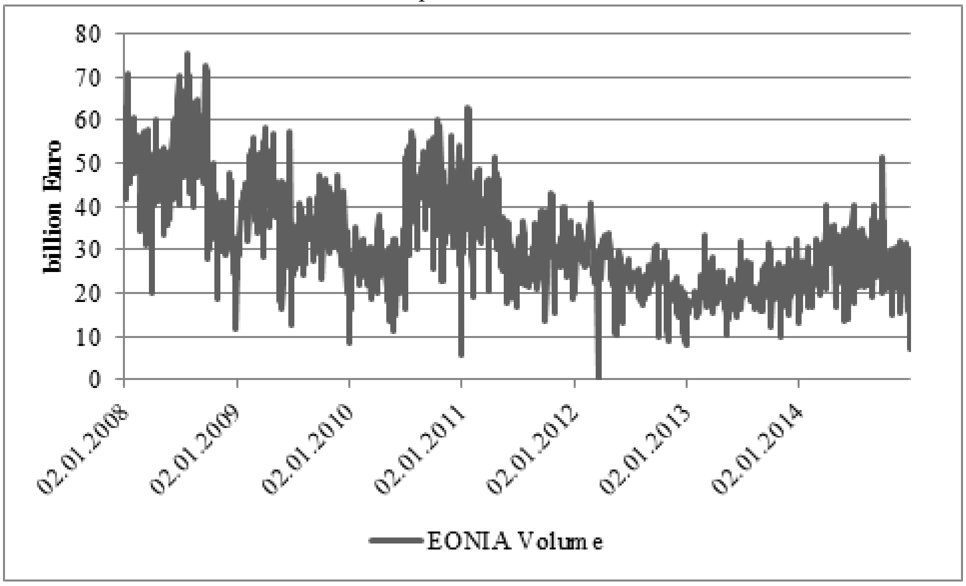


Figure A.11: Usage of euro system main and longer-term refinancing operations

This graph shows countries' usage of the main refinancing operations and the longer-term refinancing operations in billion Euro for the period from January 2003 to January 2016. Graph and data are taken from the Bruegel database of Eurosystem lending operations as developed in Pisani-Ferry and Wolff (2012).

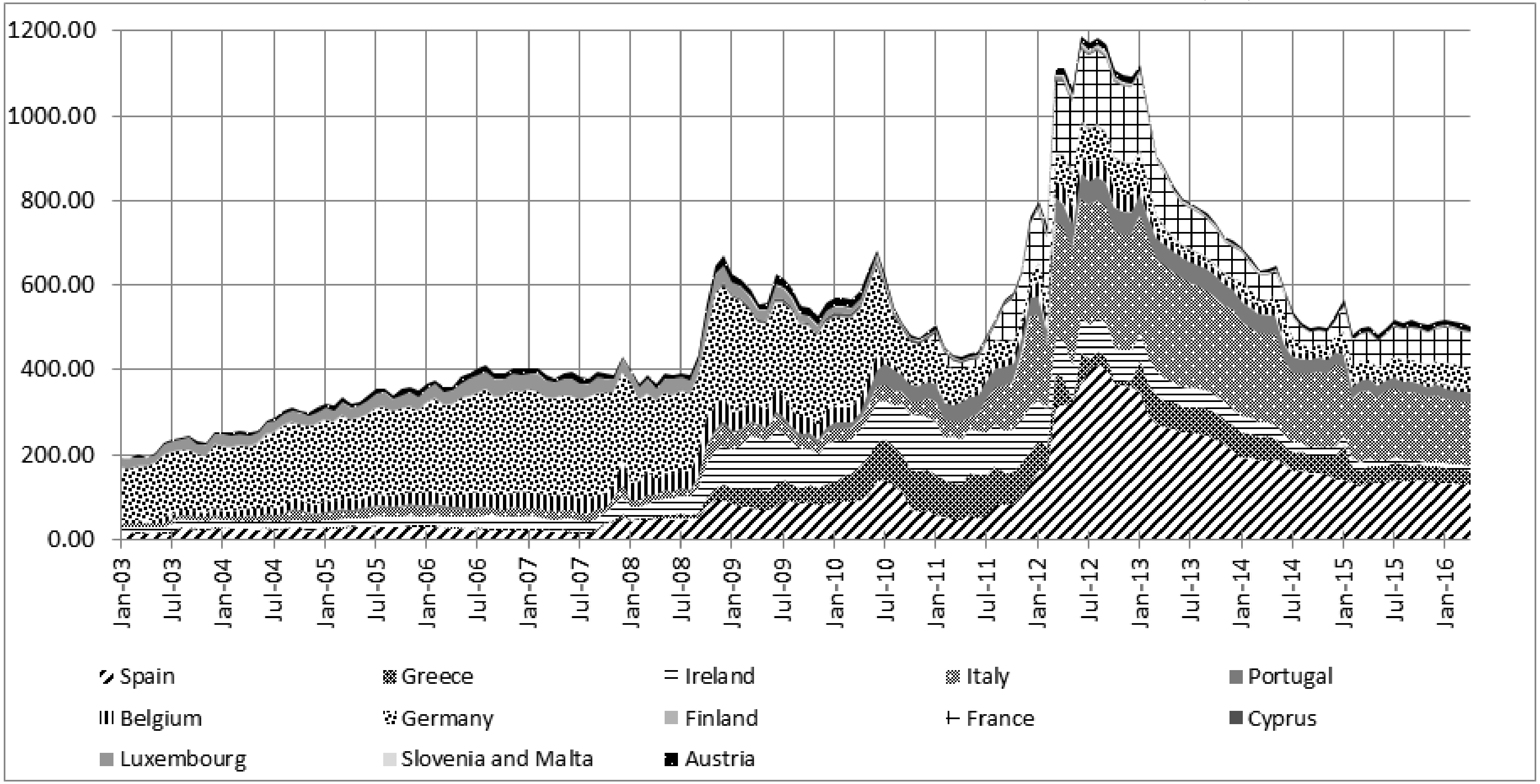


FIGURE A.12: Marginal effect of a change in the deposit facility rate

This graph shows the marginal effect on reserves holdings (in %) of the change in the deposit facility rate conditional on a bank's net interest margin (in %). The estimation is based on a sample of euro area banks and the period 2009-2014. The model is specified as in equation (2.1) with the exception that time fixed effects are excluded and the change in the deposit facility rate as such is included in the regressions. The marginal effect (solid line) is surrounded by 90% confidence bands (dotted lines). *Source*: own calculations.

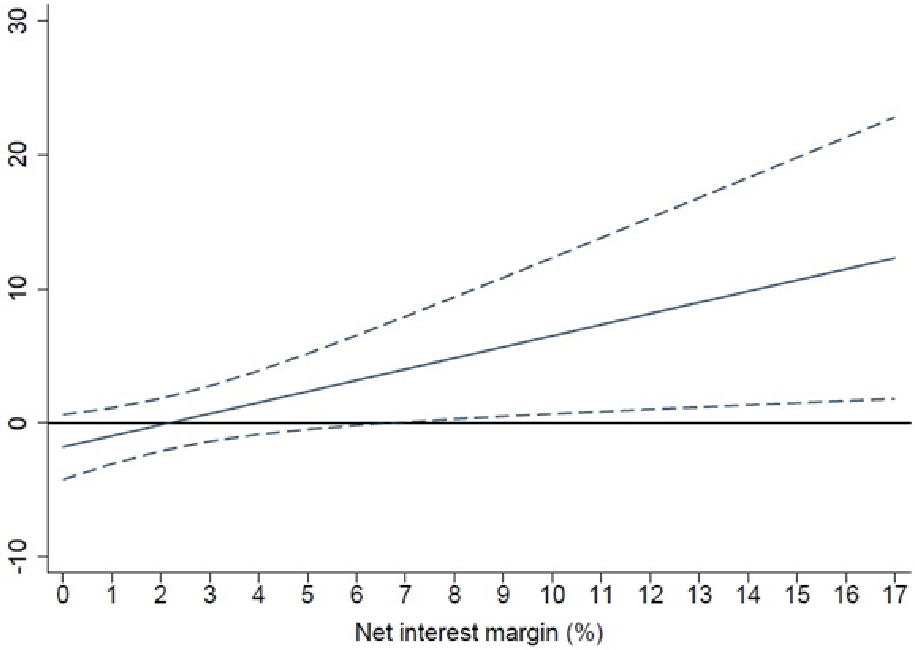
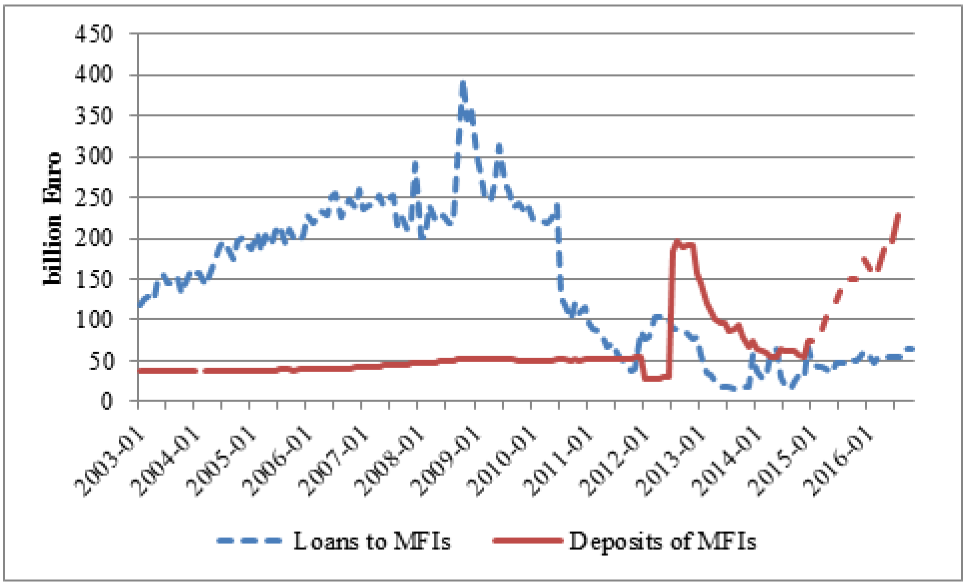


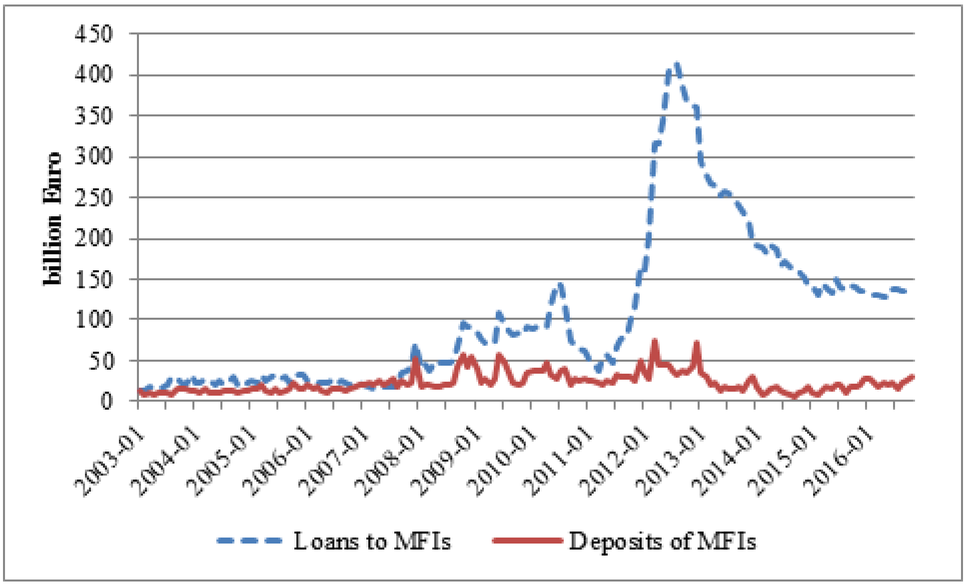
FIGURE A.13: Excess reserve holdings in the euro area

This figure shows the reserves hold by domestic monetary financial institutions (MFIs) at their national central bank (red, solid line) as well as the loans provided from the national central bank to the domestic MFIs (blue, dotted line) in billion Euro for the period from January 2003 to October 2016. Panel a) refers to the German banking system and data are obtained from the Deutsche Bundesbank. Panel b) refers to the Spanish banking system and data are obtained from the Banco de España.

a) Germany



b) Spain



A.3 Tables

Table A.11: Summary statistics of key variables by net interest margin

This table shows summary statistics of bank-level variables used in our analysis. The sample period spans 2009-2014. Statistics are shown for the full sample as well as for banks with an average net interest margin (NIM) below, or equal to/ above the sample mean of the net interest margin. For more information on the variables, see the data appendix in the paper. *Source*: see data appendix (Section A.1) appendix

	Full Sample			High NIM banks			Low NIM banks		
Variable	No. of obs.	Mean	Std. dev.	No. of obs.	Mean	Std. dev.	No. of obs.	Mean	Std. dev.
Bank-specific variables									
Δ Reservest to Total Assetst-1 (in %)	1978	-0.01	2.82	720	-0.05	2.98	1258	0.01	2.73
Δ Liquid Assetst (excl. Reserves) to Total Assetst-1 (in %)	1978	-0.59	6.79	720	-0.30	5.65	1258	-0.75	7.37
Δ Loanst to Total Assetst-1 (in %)	1976	-0.38	7.04	720	0.41	7.84	1256	-0.84	6.51
Δ Total Assetst to Total Assetst-1 (in %)	1978	-1.54	13.42	720	0.39	11.79	1258	-2.64	14.16
Net Interest Margin (in %)	1978	1.99	1.41	720	2.97	1.86	1258	1.43	0.55
Deposits to Total Assets (in %)	1977	54.16	23.14	720	62.98	19.05	1257	49.10	23.75
ln Assets	1978	15.91	1.74	720	15.14	1.65	1258	16.35	1.64
Equity to Total Assets (in %)	1978	9.02	6.81	720	10.12	6.91	1258	8.39	6.68
Return on Assets (in %)	1978	0.58	1.17	720	0.73	1.38	1258	0.49	1.02
Loans to Total Assets (in %)	1976	57.67	20.56	720	63.23	14.12	1256	54.48	22.88
Net Interest Income to Total Assets (in %)	1978	1.85	1.20	720	2.70	1.53	1258	1.36	0.52
Net Fees and Commissions to Total Assets (in %)	1975	0.84	0.92	717	0.78	0.55	1258	0.87	1.08
Total Regulatory Capital Ratio (in %)	1355	16.59	7.99	561	16.60	8.00	794	16.58	7.99
Liquid Assets to Total Assets (in %)	1978	18.95	18.02	720	14.71	11.59	1258	21.37	20.43
Gov. Debt Holdings to Total Assets (in %)	1562	7.91	8.88	583	8.88	9.14	979	7.33	8.67
Δ (Agg. Loanst - Own Loanst)/(Agg. Assetst-1 - Own Assetst-1) (in %)	1975	-0.39	4.41	719	-0.18	4.75	1256	-0.51	4.20
HighCapitalGroup (0/1)	1453	0.31	0.46	591	0.33	0.47	862	0.30	0.46
Country-specific variables									
Δ 10-Year Government Bond Yield (in pp)	1945	-0.41	0.73	707	-0.36	0.83	1238	-0.44	0.66
Δ Share of ECB-Funded Bank Liabilities (in pp)	1959	0.01	1.67	712	0.21	1.87	1247	-0.11	1.53
MRO & LTRO to MFI's Total Assetst (in %)	1746	0.0026	0.0027	623	0.003	0.0029	1123	0.0024	0.0026
Δ Firms' Credit Demand (Index)	1921	2.39	15.60	692	1.46	15.77	1229	2.91	15.49
Δ Overall Credit Standards (Index)	1532	-4.85	13.48	605	-4.82	14.43	927	-4.88	12.83
Δ MFIs' Cost of Borrowing for Non-Financial Corporations (in pp)	1978	-0.42	0.80	720	-0.45	0.83	1258	-0.40	0.77
GIIPS (0/1)	1978	0.24	0.43	720	0.29	0.46	1258	0.22	0.41
Euro area									
Δ Deposit Facility Rate (in pp)	1978	-0.43	0.83	720	-0.49	0.90	1258	-0.39	0.79
Δ Main Refinancing Rate (in pp)	1978	-0.55	0.82	720	-0.61	0.89	1258	-0.52	0.78

TABLE A.12: Alternative channels of monetary policy: total assets

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Column (1) shows the baseline model. Column (2) excludes the year 2009. Column (3) controls for the change in the reserve ratio in 2012. Column (4) controls for the deposit facility reaching the zero lower bound and turning negative. Column (5) conducts a horse race with the deposit share as a relevant channel of the deposit facility rate. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Explan. Var. Dep. Var.			Δ Assets$_t$ /Assets$_{t-1}$		
Δ Deposit Facility Rate$_t$					
$\times$ Net Interest Margin$_{t-1}$	2.987	0.090	2.978	2.652	3.023
	(2.519)	(2.651)	(2.549)	(2.503)	(2.515)
Deposits to Assets$_{t-1}$					
$\times$ Dummy 2012			-0.001		
			(0.035)		
Deposits to Assets$_{t-1}$					
$\times$ Dummy 2014				0.117***	
				(0.042)	
Δ Deposit Facility Rate$_t$					
$\times$ Deposits to Assets$_{t-1}$					0.009
					(0.016)
Controls	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,722	1,978	1,978	1,978
R-squared	0.48	0.47	0.48	0.49	0.48
Number of Banks	516	497	516	516	516

Table A.13: Unconventional monetary policy: total assets

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Column (1) shows the baseline model. Columns (2)-(5) include controls for the ECB's unconventional monetary policy, which are interacted with the net interest margin. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Explan. Var. Dep. Var.			Δ Assets$_t$ /Assets$_{t-1}$		
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	2.987	3.326	2.816	6.217**	5.261
	(2.519)	(3.096)	(2.489)	(2.508)	(4.704)
Δ 10-Year Government Bond Yield$_t$ $\times$ Net Interest Margin$_{t-1}$		-0.493			
		(0.539)			
Δ Share of ECB-Funded Bank Liabilities$_t$ $\times$ Net Interest Margin$_{t-1}$			-0.040		
			(0.188)		
Gov. Debt Holdings to Total Assets$_{t-1}$ $\times$ Net Interest Margin$_{t-1}$				-0.030	
				(0.069)	
Gov. Debt Holdings to Total Assets$_{t-1}$				0.317*	
				(0.191)	
MRO & LTRO to MFI's Total Assets$_t$ $\times$ Net Interest Margin$_{t-1}$					515.073**
					(240.432)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,945	1,959	1,514	1,746
R-squared	0.48	0.48	0.48	0.57	0.48
Number of Banks	516	511	515	428	465

Table A.14: Confounding channels of monetary policy

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Panel a) shows the results for reserves as the dependent variable, panel b) for liquid assets, panel c) for loans. Alternative channels of monetary policy based on banks' balance sheet data are added to the baseline model. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

a) Reserves

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Explan. Var. Dep. Var.				Δ Bank Reserves$_t$ /Assets$_{t-1}$			
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	1.603***	1.610***	1.629***	1.633***	1.625***	1.517**	1.351**
	(0.546)	(0.546)	(0.550)	(0.553)	(0.548)	(0.645)	(0.547)
Δ Deposit Facility Rate$_t$ $\times$ Deposits to Assets$_{t-1}$		0.002					
		(0.003)					
Δ Deposit Facility Rate$_t$ $\times$ ln Assets$_{t-1}$			0.095				
			(0.075)				
Δ Deposit Facility Rate$_t$ $\times$ Equity to Assets$_{t-1}$				-0.013			
				(0.010)			
Δ Deposit Facility Rate$_t$ $\times$ Return on Assets$_{t-1}$					-0.052		
					(0.081)		
Regulatory Capital Ratio$_{t-1}$						-0.075	
						(0.063)	
Δ Deposit Facility Rate$_t$ $\times$ Regulatory Capital Ratio$_{t-1}$						0.011	
						(0.025)	
Liquid Assets to Assets$_{t-1}$							-0.110***
							(0.030)
Δ Deposit Facility Rate$_t$ $\times$ Liquid Assets to Assets$_{t-1}$							-0.004
							(0.006)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,978	1,978	1,978	1,978	1,316	1,978
R-squared	0.18	0.18	0.18	0.18	0.18	0.27	0.2
Number of Banks	516	516	516	516	516	389	516

b) Liquid assets (excl. reserves)

Explan. Var. Dep. Var.	(1)	(2)	(3) Δ Liquid Assets$_t$ /Assets$_{t-1}$	(4)	(5)	(6)	(7)
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	2.123	2.187	2.067	2.225	1.993	1.220	0.935
	(1.932)	(1.922)	(1.934)	(1.932)	(1.925)	(2.208)	(1.916)
Δ Deposit Facility Rate$_t$ $\times$ Deposits to Assets$_{t-1}$		0.017					
		(0.011)					
Δ Deposit Facility Rate$_t$ $\times$ ln Assets$_{t-1}$			-0.205				
			(0.145)				
Δ Deposit Facility Rate$_t$ $\times$ Equity to Assets$_{t-1}$				-0.045			
				(0.035)			
Δ Deposit Facility Rate$_t$ $\times$ Return on Assets$_{t-1}$					0.320		
					(0.197)		
Regulatory Capital Ratio$_{t-1}$						-0.079	
						(0.169)	
Δ Deposit Facility Rate$_t$ $\times$ Regulatory Capital Ratio$_{t-1}$						0.034	
						(0.034)	
Liquid Assets to Assets$_{t-1}$							-0.523***
							(0.053)
Δ Deposit Facility Rate$_t$ $\times$ Liquid Assets to Assets$_{t-1}$							-0.016
							(0.020)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,978	1,978	1,978	1,978	1,978	1,316	1,978
R-squared	0.24	0.24	0.24	0.24	0.24	0.23	0.35
Number of Banks	516	516	516	516	516	389	516

c) Loans

Explan. Var. Dep. Var.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Δ Loans$_t$ /Assets$_{t-1}$						
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	-3.255***	-3.270***	-3.204***	-3.291***	-3.219***	-4.616***	-2.952***
	(0.871)	(0.875)	(0.878)	(0.871)	(0.883)	(0.740)	(0.883)
Δ Deposit Facility Rate$_t$ $\times$ Deposits to Assets$_{t-1}$		-0.004					
		(0.010)					
Δ Deposit Facility Rate$_t$ $\times$ ln Assets$_{t-1}$			0.204				
			(0.150)				
Δ Deposit Facility Rate$_t$ $\times$ Equity to Assets$_{t-1}$				0.017			
				(0.037)			
Δ Deposit Facility Rate$_t$ $\times$ Return on Assets$_{t-1}$					-0.094		
					(0.232)		
Regulatory Capital Ratio$_{t-1}$						0.094	
						(0.127)	
Δ Deposit Facility Rate$_t$ $\times$ Regulatory Capital Ratio$_{t-1}$						0.046*	
						(0.027)	
Liquid Assets to Assets$_{t-1}$							0.106**
							(0.048)
Δ Deposit Facility Rate$_t$ $\times$ Liquid Assets to Assets$_{t-1}$							0.031**
							(0.012)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,976	1,976	1,976	1,976	1,976	1,315	1,976
R-squared	0.48	0.48	0.49	0.48	0.48	0.54	0.49
Number of Banks	515	515	515	515	515	389	515

Table A.15: Sample period

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The baseline estimation period spans 2009-2014. The dependent variable is given in bold and by dependent variable we show results when narrowing down the sample period towards a period in which unconventional monetary policy was used more extensively as indicated in the column header. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1) 2009-2014	(2) 2010-2014	(3) 2011-2014	(4) 2012-2014
Explan. Var. Dep. Var.	**Δ Bank Reserves$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	1.603***	1.354*	1.578*	1.277
	(0.546)	(0.796)	(0.859)	(0.880)
Observations	1,978	1,722	1,436	1,140
R-squared	0.18	0.17	0.16	0.14
Number of Banks	516	497	478	456
Explan. Var. Dep. Var.	**Δ Liquid Assets$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	2.123	0.488	0.086	0.901
	(1.932)	(1.672)	(1.680)	(1.784)
Observations	1,978	1,722	1,436	1,140
R-squared	0.24	0.22	0.23	0.26
Number of Banks	516	497	478	456
Explan. Var. Dep. Var.	**Δ Loans$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	-3.255***	-3.375***	-4.122***	-3.243***
	(0.871)	(0.934)	(0.998)	(1.091)
Observations	1,976	1,720	1,434	1,138
R-squared	0.48	0.47	0.54	0.66
Number of Banks	515	496	477	455
Explan. Var. Dep. Var.	**Δ Assets$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	2.987	0.090	-0.457	2.180
	(2.519)	(2.651)	(2.629)	(2.844)
Observations	1,978	1,722	1,436	1,140
R-squared	0.48	0.47	0.53	0.64
Number of Banks	516	497	478	456
Controls	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes

Table A.16: Triple interaction with government debt holdings

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. A triple interaction term between the deposit facility rate, the net interest margin and a dummy variable (GIIPS) being one for a GIIPS country and zero otherwise is included. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta \text{Assets}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	1.893***	3.852**	-2.942**	6.316**
	(0.686)	(1.860)	(1.166)	(2.546)
Gov. Debt Holdings to Total Assets$_{t-1}$	0.075	0.292**	0.293***	0.330
	(0.081)	(0.127)	(0.100)	(0.204)
Δ Deposit Facility Rate$_t$ $\times$ Gov. Debt Holdings to Total Assets$_{t-1}$	0.070	0.021	0.033	0.037
	(0.071)	(0.058)	(0.055)	(0.105)
Net Interest Margin$_{t-1}$ $\times$ Gov. Debt Holdings to Total Assets$_{t-1}$	0.002	-0.098*	-0.026	-0.034
	(0.033)	(0.051)	(0.047)	(0.073)
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$ $\times$ Gov. Debt Holdings to Total Assets$_{t-1}$	-0.025	0.019	0.007	-0.013
	(0.024)	(0.024)	(0.034)	(0.054)
Net Interest Margin$_{t-1}$	-0.403	2.631**	1.001	3.160*
	(0.439)	(1.124)	(0.972)	(1.815)
Deposits to Assets$_{t-1}$	-0.009	0.013	0.035	0.261***
	(0.026)	(0.054)	(0.055)	(0.084)
ln Assets$_{t-1}$	-1.674	-17.130***	-6.108**	-31.563***
	(1.279)	(3.272)	(2.490)	(5.304)
Equity to Assets$_{t-1}$	0.039	-0.098	0.346**	0.342
	(0.062)	(0.103)	(0.153)	(0.291)
Return on Assets$_{t-1}$	-0.241	0.338	-0.021	0.094
	(0.164)	(0.218)	(0.271)	(0.407)
Δ Main Refinancing Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	-1.876***	-3.805**	3.467***	-5.755**
	(0.595)	(1.807)	(1.060)	(2.495)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Observations	1,514	1,514	1,514	1,514
R-squared	0.24	0.28	0.55	0.57
Number of Banks	428	428	428	428

TABLE A.17: Unconventional monetary policy and outliers

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in bold and by dependent variable we show results when excluding the top 25th percentile of banks (Column 2)/ countries (Columns 3 - 4) with respect to the measure for unconventional monetary policy as indicated in the column header. Control variables at the bank level are included in the estimation but not reported. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)
		Excluding top 25th percentile of		
	Baseline	Government bond holders	MRO users	ECB funded liabilities holder
Explan. Var. Dep. Var.	**Δ Bank Reserves$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	1.603***	1.548***	1.764***	1.738***
	(0.546)	(0.562)	(0.593)	(0.588)
Observations	1,978	1,588	1,549	1,532
R-squared	0.18	0.23	0.18	0.18
Number of Banks	516	436	433	411
Explan. Var. Dep. Var.	**Δ Liquid Assets$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	2.123	2.022	2.523	2.594
	(1.932)	(1.942)	(2.002)	(2.020)
Observations	1,978	1,588	1,549	1,532
R-squared	0.24	0.26	0.25	0.25
Number of Banks	516	436	433	411
Explan. Var. Dep. Var.	**Δ Loans$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	-3.255***	-3.298***	-3.271***	-3.141***
	(0.871)	(0.938)	(0.914)	(0.920)
Observations	1,976	1,586	1,547	1,530
R-squared	0.48	0.52	0.49	0.49
Number of Banks	515	435	432	410
Explan. Var. Dep. Var.	**Δ Assets$_t$ /Assets$_{t-1}$**			
Δ Deposit Facility Rate$_t$ $\times$ Net Interest Margin$_{t-1}$	2.987	1.560	2.172	2.447
	(2.519)	(2.214)	(2.229)	(2.270)
Observations	1,978	1,588	1,549	1,532
R-squared	0.48	0.53	0.50	0.50
Number of Banks	516	436	433	411
Controls	Yes	Yes	Yes	Yes
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes

TABLE A.18: The role of capitalization

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. A triple interaction term between the deposit facility rate, the net interest margin and a dummy variable (HighCapitalGroup) being one for banks with an average capital ratio larger than the sample mean and zero otherwise is included. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta\text{Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta\text{Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta\text{Assets}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate_t				
$\times$ Net Interest Margin_{t-1}	1.814***	2.074	-4.419***	1.453
	(0.685)	(2.310)	(0.863)	(2.857)
Δ Deposit Facility Rate_t				
$\times$ HighCapitalGroup	-0.146	1.321	1.152	1.580
	(0.315)	(0.995)	(1.071)	(1.521)
Δ Deposit Facility Rate_t				
$\times$ Net Interest Margin_{t-1}				
$\times$ HighCapitalGroup	0.013	-0.374	-0.194	-0.666
	(0.142)	(0.312)	(0.519)	(0.598)
Net Interest Margin_{t-1}				
$\times$ HighCapitalGroup	0.978	0.925	-1.144	-1.576
	(0.626)	(1.358)	(1.495)	(2.599)
Net Interest Margin_{t-1}	-0.598	2.304**	1.477	5.514***
	(0.392)	(0.916)	(0.960)	(1.821)
Deposits to Assets_{t-1}	-0.020	0.089*	0.106**	0.415***
	(0.025)	(0.050)	(0.046)	(0.088)
ln Assets_{t-1}	-2.837*	-12.718***	-0.560	-17.575***
	(1.618)	(3.683)	(2.058)	(5.342)
Equity to Assets_{t-1}	-0.009	-0.331**	0.321**	0.410
	(0.059)	(0.143)	(0.161)	(0.282)
Return on Assets_{t-1}	-0.266*	0.450*	0.382	0.934*
	(0.137)	(0.255)	(0.255)	(0.510)
Δ Main Refinancing Rate_t				
$\times$ Net Interest Margin_{t-1}	-1.676**	-1.869	4.804***	-0.572
	(0.666)	(2.244)	(0.765)	(2.704)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Observations	1,453	1,453	1,452	1,453
R-squared	0.23	0.23	0.53	0.50
Number of Banks	397	397	397	397

TABLE A.19: Triple interaction with deposit share

This table shows regression results obtained from estimating equation (2.1) for a sample of euro area banks. The estimation period spans 2009-2014. The dependent variable is given in the column header. Compared to the baseline results, a control for banks' deposits to total assets, which is also interacted with the net interest margin and the change in the deposit facility rate, is included. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{ Liquid Assets}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{ Loans}_t}{\text{Assets}_{t-1}}$	(4) $\frac{\Delta \text{ Assets}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	1.698***	2.264	-3.014***	4.223*
	(0.562)	(1.961)	(0.971)	(2.528)
Δ Deposit Facility Rate$_t$				
$\times$ Deposits to Assets$_{t-1}$	0.012*	0.025	0.025*	0.068**
	(0.007)	(0.020)	(0.014)	(0.029)
Net Interest Margin$_{t-1}$				
$\times$ Deposits to Assets$_{t-1}$	0.001	0.000	0.001	-0.035
	(0.004)	(0.016)	(0.010)	(0.022)
Δ Deposit Facility Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$				
$\times$ Deposits to Assets$_{t-1}$	-0.004	-0.004	-0.012***	-0.026***
	(0.003)	(0.006)	(0.004)	(0.009)
Net Interest Margin$_{t-1}$	-0.024	1.007	-0.344	2.960*
	(0.218)	(0.894)	(0.653)	(1.512)
Deposits to Assets$_{t-1}$	-0.022	0.150**	0.089*	0.527***
	(0.025)	(0.067)	(0.048)	(0.109)
ln Assets$_{t-1}$	-2.797**	-13.859***	-2.720	-22.592***
	(1.282)	(2.973)	(1.955)	(4.742)
Equity to Assets$_{t-1}$	-0.045	-0.255*	0.192	0.026
	(0.041)	(0.130)	(0.144)	(0.265)
Return on Assets$_{t-1}$	-0.223*	0.502**	0.280	0.663
	(0.124)	(0.249)	(0.256)	(0.489)
Δ Main Refinancing Rate$_t$				
$\times$ Net Interest Margin$_{t-1}$	-1.457***	-2.356	3.600***	-3.085
	(0.536)	(1.947)	(0.867)	(2.509)
Country-Time Fixed Effects	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Observations	1,978	1,978	1,976	1,978
R-squared	0.18	0.24	0.49	0.48
Number of Banks	516	516	515	516

TABLE A.20: Loans and net interest margin: exclusion restriction

This table shows regression results obtained from estimating the baseline specification in a set-up of simultaneous equations. The estimation sample covers euro area banks of GIIPS countries and the period 2009-2014. In Column (1), the estimates of the first stage regression with reserves as the dependent variable are shown. Column (2) shows the estimates of the second stage estimation with loans as dependent variable. Here, the predicted value for reserves as derived from the first stage regression is included. Column (3) shows the reduced form estimation. The variables at the bank level are included with a lag. Bank and country-time fixed effects are included. Standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Explan. Var. Dep. Var.	(1) $\frac{\Delta \text{ Bank Reserves}_t}{\text{Assets}_{t-1}}$	(2) $\frac{\Delta \text{Loans}_t}{\text{Assets}_{t-1}}$	(3) $\frac{\Delta \text{ Loans}_t}{\text{Assets}_{t-1}}$
Δ Deposit Facility Rate$_t$			
$\times$ Net Interest Margin$_{t-1}$	-0.184		-2.281
	(0.984)		(2.481)
Net Interest Margin$_{t-1}$	-0.243	4.787	0.061
	(0.383)	(17.944)	(0.056)
Deposits to Assets$_{t-1}$	0.035	-0.376	-3.918
	(0.022)	(2.475)	(2.743)
ln Assets$_{t-1}$	-0.788	5.863	0.299*
	(1.088)	(56.015)	(0.160)
Equity to Assets$_{t-1}$	0.021	0.033	0.408
	(0.063)	(1.510)	(0.272)
Return on Assets$_{t-1}$	0.021	0.149	1.772*
	(0.108)	(1.950)	(0.966)
Δ Main Refinancing Rate$_t$			
$\times$ Net Interest Margin$_{t-1}$	-0.081	4.203	3.203
	(0.983)	(17.815)	(2.478)
Estimate(Δ Bank			
Reserves$_t$ /Assets$_{t-1}$)		12.409	
		(67.607)	
Country-Time Fixed Effects	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Observations	1976	1976	1976
P-value of chi^2-test	0.0000	1.0000	0.0000
Number of Banks	163	163	163

Chapter 3

Interactions between bank levies and corporate taxes: How is bank leverage affected?*

Abstract: *Regulatory bank levies set incentives for banks to reduce leverage. At the same time, corporate income taxation makes funding through debt more attractive. In this paper, we explore how regulatory levies affect bank capital structure, depending on corporate income taxation. Based on bank balance sheet data from 2006 to 2014 for a panel of EU-banks, our analysis yields three main results: The introduction of bank levies leads to lower leverage as liabilities become more expensive. This effect is weaker the more elevated corporate income taxes are. In countries charging very high corporate income taxes, the incentives of bank levies to reduce leverage turn ineffective. Thus, bank levies can counteract the debt bias of taxation only partially.*

3.1 Introduction

Regulatory bank levies provide incentives for banks to reduce leverage, as they are typically designed as a tax on liabilities. At the same time, corporate income taxation makes funding through debt more attractive, because interest on debt is tax-deductible in most countries while return on equity is not. In this paper, we ask how effective regulatory bank levies are in reducing bank leverage, depending on the corporate income tax (CIT) rate. Moreover, we study how the design of bank levies affects their impact upon leverage. As the European Banking Union also uses bank levies to finance the Single Resolution Fund, evidence regarding the impact of bank levies on

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bank behavior conditional on the corporate tax environment contributes to the assessment of such regulatory reforms.

The literature shows that corporate income taxes affect bank capital structure (De Mooij and Keen, 2016) and that banks exposed to regulatory levies strengthen capitalization (Célérier et al., 2018; Devereux et al., 2015). However, empirical evidence on the interaction effects between regulatory and corporate taxes is so far missing. Against the background of the evaluation of changes in banking regulations and potential interactions between different policy interventions (FSB, 2017), this paper aims at filling this gap. Our goal is to investigate what role regulatory bank levies play in counteracting the debt bias of taxation. A better understanding of the impact of bank levies on bank capital structure, depending on corporate taxation, is crucial given that the debt bias of taxation is shown to not only increase leverage of both non-financial and financial firms, but also the probability of systemic banking crises (De Mooij et al., 2013).

In the aftermath of the global financial crisis, many European countries introduced regulatory levies, the goal being to internalize banks' contribution to systemic risk. On the one hand, bank levies are aimed at establishing funds to finance the restructuring and resolution of banks in distress. On the other hand, banks' funding composition should be influenced by taxing non-deposit liabilities of banks, thereby setting an incentive for lower leverage and funding risk. Given the opposite incentives for higher bank leverage that result from corporate taxation, the goal of this paper is to better understand the interaction effects between regulatory and corporate taxes, thus understanding the consequences for the effectiveness of bank levies as a tool to increase financial stability through a less risky bank capital structure.

Using bank-level balance sheet data for EU-countries over the 2006 – 2014 period, we investigate how bank leverage is affected by the introduction of regulatory levies, depending on CIT rates. The regression analysis yields three key insights. First, we confirm findings from previous literature (Célérier et al., 2018; Devereux et al., 2015) that the direct effect of bank levies on leverage is negative and statistically significant. Banks in countries where a levy is introduced, such that debt funding becomes more expensive, show lower leverage than banks that are not subject to a levy. Second, higher CIT rates mitigate the leverage-reducing effect of bank levies. In countries with higher CIT rates, an introduction of a bank levy reduces leverage less than in countries with lower tax rates. Third, and lastly, for the most elevated CIT rates, the positive incentives of bank levies on capitalization are not large enough to counteract the debt bias of taxation. Indeed, the effect of a bank levy turns statistically insignificant in high-corporate income tax countries, such that the goal of fostering financial stability through lower leverage cannot be fulfilled by the regulatory tax.

Our analysis bridges and, thus, contributes to two strands of the literature. A first set of related studies deals with the implications of the introduction of regulatory bank levies since the global financial crisis. Exploiting variation in bank levies in the European Union (EU) across countries, banks and time, Devereux et al. (2015) present empirical evidence that banks exposed to regulatory levies increase their equity ratio, thus reducing funding risk. At the same time, portfolio risk is shown to increase. Concentrating on different bank-level outcome variables, Buch et al. (2016) show that loan supply and deposit rates were, on average, not significantly affected by the introduction of the bank levy in Germany. However, the most affected banks reduced loan supply and deposit rates while raising lending rates. An increase in lending rates is also found after the introduction of the Hungarian levy by Capelle-Blancard and Havrylchyk (2017). For a sample of EU banks, Kogler (2018) finds that banks pass the levies through to customers via higher lending rates while keeping deposit rates constant. This effect is weaker for the well-capitalized banks that are less exposed to the levies.[1] Our analysis differs from these studies as we focus, besides the direct impact of levies on bank leverage, on the interactions between bank levies and the CIT.

[1] Kogler (2018) discusses theoretically the interaction effects between corporate taxation and levies for the pass-through of bank levies to customers in terms of lending rate increases. If the levy payment is not tax deductible, as in Germany or the UK, the pass-through is expected to be stronger than in countries where the levy payment can be deducted so that double taxation is prevented.

A second strand of literature investigates the relationship between corporate income taxation and leverage. As summarized in a meta-study by Feld et al. (2013), the design of the corporate tax system is an important determinant of non-financial firms' capital structure. Typically, tax systems incentivize leveraging since interest paid on debt is tax-deductible whereas the return on equity is not. To lower their tax burden, firms tilt their capital structure more toward debt than they would in the absence of this tax preference for debt. The positive effect of the CIT on leverage is well established in the literature.[2] Findings by Heider and Ljungqvist (2015) suggest asymmetric effects of tax rates on leverage: U.S. firms' leverage responds to tax increases, but not to tax cuts.

As banks face different funding decisions than non-financial firms and are subject to regulatory capital requirements, they were typically excluded from the analysis of capital structures pre-crisis. Yet, Gropp and Heider (2010) show that, as long as banks hold more capital than required by regulation, the drivers of capital structure are similar for financial and non-financial firms. Still, banks tend to be more leveraged than non-financial firms. Berg and Gider (2017) find that this difference is largely explained by lower asset side risk of banks due to diversification.

Regarding the role of CIT for bank capital structure, a small but growing literature concludes that the debt bias of taxation also affects financial firms. Comparing the tax sensitivity of banks' and non-banks' capital structure, Heckemeyer, Mooij, et al. (2017) find similar values for both groups of firms. However, the tax sensitivity differs across firm size and leverage. While larger and capital-tight banks react less to tax changes, the relationship between tax rates and the size of non-banks is found to be U-shaped. De Mooij and Keen (2016) argue that capital buffers that are typically above regulatory capital requirements leave scope for taxes to affect bank leverage. Based on bank balance sheet data for 82 countries, they confirm that banks' reaction

[2]For an overview, see Bremus and Huber (2016). Another but less related strand of literature analyzes whether and how much corporate income taxes are shifted to customers (see e.g. Banerji et al., 2018, Capelle-Blancard and Havrylchyk, 2014) and how securitization is affected by the CIT (Gong et al., 2015).

to taxation is, on average, similar to that of non-financial firms and that large banks are less tax-sensitive than small ones.[3] Related studies for the United States (Milonas, 2018; Schandlbauer, 2017) confirm a significant impact of tax changes on bank leverage, which differs across bank characteristics like capitalization and size. Using Italian data, Gambacorta et al. (2017) provide evidence that banks reduce leverage following tax reductions and that non-deposit liabilities decline more than deposits. Focusing on the capital structure of multinational banks, Gu et al. (2015) show that the debt bias of taxation also affects bank subsidiaries and that international tax differences lead to debt shifting to countries with high taxes.

Shifting the focus from CIT to the effects of bank levies and of "Allowances for Corporate Equity" (ACE), Célérier et al. (2018) find that tax reforms that make leverage more expensive increase bank capitalization, while simultaneously promoting lending. Regarding tax reforms, they exploit, on the one hand, that several countries have reduced the tax discrimination against equity by allowing for a deduction of a notional interest rate for equity through ACEs, while others have not. On the other hand, they also exploit the introduction of bank levies that increase the total cost of capital, since liabilities are taxed, thus becoming more expensive. In a similar vein, Schepens (2016) presents evidence that the capitalization of Belgian banks significantly increased after implementation of an ACE in 2006.

While the discussed studies analyze the effects of CIT and of regulatory taxes separately, we contribute to the literature by estimating the effects of introducing bank levies, depending on CIT rates. By examining the interaction effects between regulatory and corporate income taxes, we aim at gauging how far bank levies can counteract the debt bias of taxation. The remainder of the paper is structured as follows. In the following Section 3.2, we explain the theoretical link between bank leverage and taxes, both corporate income taxes and bank levies. Section 3.3 describes both the data used and its sources as well as our empirical model specification. We

[3]Hemmelgarn and Teichmann (2014) find smaller, but also statistically significant, effects of CIT-changes on bank leverage.

discuss the regression results and several robustness tests in Section 3.4, while Section 3.5 concludes and presents potential policy implications.

3.2 Bank leverage and taxes

Both corporate income taxes and bank levies are related to bank leverage. The expenses of bank levies that are designed as a tax on liabilities typically increase with the amount of wholesale funding and leverage:[4]

$$\begin{aligned} &\textit{Bank levy expenses} = \\ &\textit{Levy rate} * (\textit{Total liabilities} - \textit{Customer deposits} - \textit{Equity}) \end{aligned} \tag{3.1}$$

Consequently, the cost of debt (or: leverage) increases, making debt funding less attractive. Bank levies target exclusively the financial sector, especially credit institutions. In the aftermath of the global financial crisis, bank levies were introduced as an instrument to establish resolution funds to finance the resolution and restructuring of banks in distress (e.g. Cyprus, Germany, Latvia, and Sweden). In addition, countries opting for a bank levy that taxes wholesale funding aimed at reducing systemic risk by providing incentives for banks to shift from an over-reliance on short-term interbank financing to more stable funding sources such as customer deposits and equity capital (Kogler, 2018). Along these lines, Devereux et al. (2015) present a theoretical model of bank leverage, a tax on liabilities, and bank capital requirements where banks maximize the expected return to shareholders by choosing, among others, the optimal level of total debt (or leverage, as the amount of total assets is kept fixed for simplicity). In that framework, banks react to an increase in the tax on debt by reducing leverage. Similarly, in the model by Keen (2018), optimal leverage falls the higher the levy is, since the cost of leverage increases. These considerations lead to our first testable hypothesis:

Hypothesis 1: *A bank levy on debt incentivizes banks to reduce leverage.*

[4] See appendix B1 for a detailed overview on which countries use wholesale liabilities as a tax base for their bank levy and Section 3.3.2 for more information on the data.

In contrast to bank levies, corporate income taxes are a general instrument targeting the non-financial as well as the financial sector. The main objective is to generate revenues for the public sector. Given that interest payments on debt are tax deductible, expenses due to corporate income taxes amount to

$$\begin{aligned} CIT\ expenses = CIT\ rate * \\ (Net\ income\ before\ taxes\ \&\ interest - Interest\ payments\ on\ debt). \end{aligned} \tag{3.2}$$

There is no explicit aim to target the behavior of taxed entities as concerns their capital structure. Nevertheless the empirical and theoretical literature documents that higher CIT rates set incentives for both non-financial firms and banks to increase leverage in order to lower tax expenses (Feld et al., 2013; Gropp and Heider, 2010; De Mooij and Keen, 2016; Langedijk et al., 2015). This debt bias of taxation results from the fact that interest rate costs for external debt are generally tax deductible, and thereby reduce the taxable net income of a company, whereas interest on equity is not.

As shown in the model of corporate income taxes and bank leverage presented by De Mooij and Keen (2016), if banks optimally choose total debt in a world with capital requirements, they borrow up to the point where the expected costs of violating the capital requirement equals the tax advantage of debt. The model implies that higher tax rates result in banks increasing their optimal amount of debt. The marginal tax benefit of debt increases in the corporate income tax rate, thus increasing the optimal level of debt if tax rates rise. We can thus form the second hypothesis:

Hypothesis 2: *Bank leverage is higher the more elevated corporate income tax rates are.*

Due to opposing effects of corporate income tax rates and bank levies on leverage, the question arises of whether there is an interconnection between corporate income taxes, bank levies and bank leverage. If this is the case, it bears important policy implications. In particular, considering the case that the leverage-reducing effect of a bank levy taxing wholesale funding interacts reversely with the debt bias of taxation of the corporate income tax. In such a context, the effectiveness of the regulatory policy instrument cannot be guaranteed. Due to the hypothesized effects above, we suspect that the negative effect of bank levies on leverage can potentially be lowered conditional on the height of the corporate income tax:

Hypothesis 3: *The leverage-reducing effect of bank levies is counteracted by the size of the corporate income tax rate.*

In what follows, we empirically analyze the nexus between regulatory and corporate taxation and its effect on bank leverage.

3.3 Data and methodology

In order to shed light on the effect of bank levies on leverage, depending on the prevailing CIT, we construct a linked micro-macro dataset that connects bank balance sheet variables with country-level information on the introduction and design of bank levies, as well as CIT rates. The baseline sample covers 2,771 banks in 27 EU-countries over the 2006–2014 period, which yields 10,774 bank-year observations. The sample period ends in 2014 because, since 2015, banks in EU member states participating in the European Banking Union must make levy contributions to the Single Resolution Fund. We next describe our dataset and some key features of the variables of interest, before discussing our estimation and identification strategy.

3.3.1 Bank-level data

Annual balance sheet and income statements for banks in 27 EU member states were obtained from Bankscope by Bureau van Dijk for the 2006 – 2014 period.[5] In order to clean the data from misreporting and outliers, we apply several standard screens. We eliminate bank observations if negative values of equity, assets, and loans are reported or when the loans-to-assets

[5]We do not cover all 28 EU-countries as Croatian banks do not report all control variables included in the regression equation and, therefore, drop out of the sample.

or the equity-to-assets ratio exceeds one. Further, only banks with at least three observations across the sample period are kept. Following De Mooij and Keen (2016) and Kogler (2018), we consider unconsolidated accounts that end at national borders and to which national tax rates and in general also regulatory bank levies apply. That is, we include observations with Bankscope consolidation codes U1 (unconsolidated statement with no consolidated companion) and U2 (unconsolidated statement with a consolidated companion). In terms of bank business models, our baseline sample includes bank holdings and holding companies, commercial banks, cooperative banks, and savings banks. In order to prevent outliers from affecting our results, we winsorize all bank-level variables at the top and bottom 1%-percentile.

Following the banking literature, our dependent variable, leverage of bank i in year t, is defined as liabilities divided by total assets (Berg and Gider, 2017; Gropp and Heider, 2010; Gu et al., 2015). Figure 3.1 illustrates that at the sample median, leverage has followed a slight upward trend between 2007 and 2013, with the highly leveraged banks (75th percentile) showing a rather stable leverage ratio, while leverage trended upwards for lower-leverage banks (25th percentile). The standard bank-level control variables that gauge bank size, profitability, and risk are also sourced from Bankscope. Appendix B1 provides a detailed data description of all variables used in the regression analysis. Table 3.1 reports summary statistics for our baseline regression sample. The sample mean of bank leverage, as measured by total liabilities to total assets, is 90%, varying between 8.5 and 98%. Regarding the unconditional correlations between the bank-level variables included in the regression model below, Table 3.2 reveals that leverage is higher for larger banks and lower for more profitable and more risky banks in our sample.

3.3.2 Country-level data

Information on bank levies, like the year of the introduction and the tax base, is taken from Devereux et al. (2015) and double-checked with the ECB's Macroprudential Policies Evaluation Database by Budnik and Kleibl (2018). We also verify whether countries have implemented a bank levy in

FIGURE 3.1: Evolution of bank leverage

This figure illustrates the evolution of bank leverage as measured by total liabilities to total assets for the sample median as well as the 25th and 75th percentile.

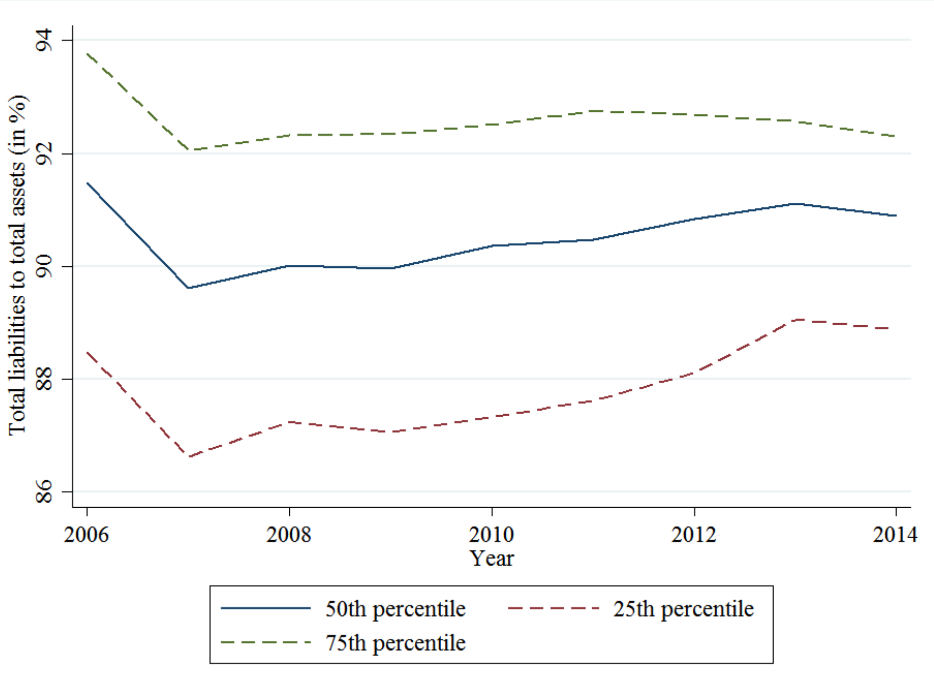


TABLE 3.1: Descriptive statistics

These descriptive statistics are based on the baseline regression sample (Table 3.4, Column 1). The sample period spans 2006-2014. Source: See data description in appendix B.1.

	Obs	Mean	SD	Median	Min	Max
Bank-level variables						
Total liabilities to total assets (in %)	10,774	89.56	5.98	90.69	8.46	98.01
Lag of ln(total assets)	10,774	6.96	1.81	6.70	3.27	12.35
Lag of return on assets (in %)	10,774	0.75	1.07	0.78	-4.55	6.00
Lag of impaired loans (in %)	10,774	6.82	6.45	4.95	0.09	39.04
Country-level variables						
Bank levy (0/1 dummy)	10,774	0.42	0.49	0.00	0.00	1.00
Corporate tax rate (in %)	10,774	30.17	5.11	30.94	10.00	40.36
GDP growth (in %)	10,774	0.11	2.44	0.59	-14.81	11.62
Inflation (in %)	10,774	1.78	1.27	1.60	-1.71	15.24
Supervisory forbearance discretion (0-4)	10,774	1.31	1.03	1.00	0.00	4.00
Factors mitigating moral hazard (0-4)	10,774	1.79	0.55	2.00	0.00	3.00

those years not covered by Devereux et al. (2015). Detailed information on the data source by country is provided in appendix B.2.

In our baseline regressions, we include 27 EU-countries and construct a dichotomous variable that equals one if a bank levy is in place in a given country and year, and zero otherwise. Appendix B.2 contains detailed information on the countries that implemented the levy, the implementation year, and the tax base. The majority of countries implemented a levy in

Table 3.2: Cross-correlations

This table shows correlation coefficients between the variables used in the regression models. The sample period spans 2006-2014. Source: See data description in appendix B.1.

	Total liabilities to total assets (in %)	Bank levy (0/1 dummy)	Corporate tax rate (in %)	GDP growth (in %)	Inflation (in %)	Lag of ln(total assets)	Lag of return on assets (in %)	Lag of impaired loans (in %)	Supervisory forbearance discretion (0-4)	Factors mitigating moral hazard (0-4)
Total liabilities to total assets (in %)	1									
Bank levy (0/1 dummy)	0.05	1								
Corporate tax rate (in %)	0.06	0.00	1							
GDP growth (in %)	0.01	0.25	-0.06	1						
Inflation (in %)	-0.02	-0.25	-0.14	0.07	1					
Lag of ln(total assets)	0.23	-0.05	-0.01	0.05	0.02	1				
Lag of return on assets (in %)	-0.13	0.12	0.11	0.10	0.05	-0.05	1			
Lag of impaired loans (in %)	-0.13	-0.21	-0.2	-0.09	-0.04	-0.12	-0.33	1		
Supervisory forbearance discretion (0-4)	-0.16	-0.33	0.06	-0.06	0.05	0.16	-0.01	0.02	1	
Factors mitigating moral hazard (0-4)	0.16	-0.09	0.44	-0.09	-0.04	-0.03	0.04	0.02	-0.25	1

2011, while others adopted it earlier or later. As shown in Table 3.3, prior to 2009, no banks included in our sample were subject to a levy, whereas in 2011, about one-third of the banks had to pay levies. The share of affected banks increased to 73% at the end of our sample period. The timing is in line with the start of policy discussion about the implementation of levies to finance restructuring funds and internalize banks' contribution to systemic risk after the financial crisis (IMF, 2010).

Table 3.3: Distribution of bank observations by years

This table presents the number and fraction of banks in the baseline sample that are subject to a levy and the ones that are not by sample year. Source: Own calculations.

	Number of bank observations			**Share of bank observations with levy**	
Year	without levy	with levy	total	by year	accumulated
2006	251	0	251	0%	0%
2007	754	0	754	0%	0%
2008	836	0	836	0%	0%
2009	894	59	953	6%	2%
2010	914	64	978	7%	3%
2011	674	353	1,027	34%	10%
2012	693	804	1,497	54%	20%
2013	667	1,546	2,213	70%	33%
2014	609	1,656	2,265	73%	42%
Total	6,292	4,482	10,774		

Among the 17 countries that have introduced a bank levy within our sample period, the majority implemented the levy design as suggested by the IMF (2010), namely as a tax on liabilities (i.e. total assets less equity) minus deposits. With this levy design, all non-deposit liabilities are taxed, thus making leverage more expensive. Appendix B.2 reveals that there are, however, seven European countries that chose different levy designs.[6] In Hungary and Slovenia, for example, the levy is paid on total assets, whereas in France the minimum equity requirement is used as the tax base. Given the heterogeneity of the design of levies and the resulting differences in incentives set for capital structure, we restrict the "treatment group" in further regression exercises to the countries that impose the standard "liabilities minus deposits (L – D)" design.[7]

Information on corporate income taxes is obtained from the Oxford Centre of Business Taxation.[8] The corporate income tax rate for country c in year t is computed as the sum of the federal tax rate and the local tax rate taking into account surcharge and deductibility of local taxes. As shown by the summary statistics in Table 3.1, while the average CIT in our sample is 30%, the range of tax rates varies quite substantially between 10% (Bulgaria, Cyprus) and 40% (Spain). This variation is useful in the following empirical analysis as it helps identify the differential effects of regulatory bank levies depending on the existing CIT. Correlation coefficients (Table 3.2) show weakly positive relationships between banks' liabilities to assets and both the bank levy dummy variable and the CIT rate.

Further country-level control variables, like GDP growth and inflation or regulatory variables, come from the International Financial Statistics and from Barth et al. (2013).

[6]Poland only implemented a levy in 2016.

[7]See Kogler (2018) for a description of different levy designs in Europe.

[8]`https://www.sbs.ox.ac.uk/faculty-research/tax/publications/data`; missing information for Latvia, Lithuania, Malta and Cyprus is added from Devereux et al. (2015) and KPMG (2014).

3.3.3 Regression model

In order to analyze how the introduction of bank levies affects bank capital structure, depending on the prevailing CIT, we estimate the following regression equation

$$\begin{aligned} LA_{ict} = {} & \alpha_i + \gamma_t + \beta_1 Levy_{ct} + \beta_2 CIT_{ct} + \beta_3 Levy_{ct} * CIT_{ct} \\ & + \beta_4 X_{ict-1} + \beta_5 Y_{ct} + \epsilon_{ict} \end{aligned} \tag{3.3}$$

using a panel fixed-effects estimator. The dependent variable, bank leverage of bank i in country c at time t, is defined as the ratio of liabilities (total assets minus equity) to total assets (LA_{ict}). The main explanatory variables of interest are $Levy_{ct}$, a dummy variable that equals one if a bank levy is in place in country c at time t, and CIT_{ct}, the corporate income tax rate in country c at time t. Capturing bank levies by a country-specific dummy variable is a very crude proxy and ignores that some countries implement different levy designs and exclude, for example, small banks from the levy. Thus, in Section 3.4.2, we assess in more detail the role of the levy design and, in further robustness tests, we restrict the sample to include only larger banks.

Based on theoretical considerations and empirical results from previous literature, we expect the direct effect of a bank levy on leverage, β_1, to be negative, whereas the direct effect of CIT, β_2, is supposed to be positive. The total effect of bank levies on leverage, depending on the CIT, is given by $\beta_1 + \beta_3 * CIT$. To investigate how effective bank levies are at counteracting the debt bias of taxation, our coefficient of interest is β_3, i.e. the interaction effect between the bank levy and the corporate income tax rate. Supposed that leverage is lower for banks that are affected by a levy relative to banks that are not ($\beta_1 < 0$), then the larger and positive β_3 is, the more the leverage-reducing effect from the levy is mitigated with higher CIT rates.

The vector X_{ict-1} contains bank characteristics, all lagged by one year to account for potential simultaneity concerns.[9] Following the literature, we include the log of total assets (in million USD) and the square of the log of total assets to control for bank size, the return on assets (in %) to measure profitability, and the ratio of non-performing loans to gross loans (in %) as a measure of bank risk. The term Y_{ct} summarizes annual GDP growth, inflation, and regulatory variables, that is, country-level controls. Common time trends in the data are accounted for by including yearly time dummies (γ_t). To control for unobserved time-invariant bank characteristics, all regression models include a set of bank fixed effects (α_i). Thereby, we can test whether banks subject to a levy changed their leverage compared to banks not affected by a levy with similar bank-level and country-level characteristics. Robust standard errors are clustered at the bank level.

For our identification of effects, we exploit variation in the introduction of bank levies across countries and time. Importantly, during our sample period, changes in bank capital regulation, like the stepwise implementation of Basel III that started in 2013, also affected the choice of bank capital structure. As we control for observed and unobserved bank and country characteristics, it is nevertheless reasonable to suppose that two otherwise similar banks – one located in an EU-country that introduced a levy and the other located in an EU country without levies – are affected similarly by regulatory and institutional changes at the EU-level.[10] Furthermore, as we outline below, most changes become only effective after 2014. To control for the fact that existing regulatory standards are enforced differently across EU-countries and that differences in the strength of moral hazards can impact leverage, we add two variables reflecting banking regulation in country c at time t, namely supervisory forbearance discretion and various factors mitigating moral hazard. Potential concerns about endogeneity are discussed in Section 3.4.3.

[9] Due to the fact that we lag the control variables by one period, our estimation covers the dependent variable for the years 2006-2014 and links it to bank-level control variables based on 2005-2013.

[10] In robustness tests, we exclude the years after 2012 that are most likely to be influenced by regulatory changes or the announcement thereof. In addition, we add bank group-and-time fixed effects to control for different exposure of banks to changes in regulation depending on their capital ratio.

3.4 Regression results

This section discusses estimation results for the baseline sample including bank observations from EU-countries, using banks from those countries that introduced a levy as the treatment group and the remaining banks as the control group. We then limit the sample to countries with a more homogenous levy design, before testing the robustness of our findings with respect to additional changes in the sample composition.

3.4.1 Determinants of bank leverage

Table 3.4 reports the regression results from estimating equation 3.3. Confirming previous findings from the literature, the results point to a negative effect of levies on bank leverage, while leverage is positively related to CIT rates. On the one hand, banks in countries that have introduced bank levies reduce leverage relative to other banks, given that most countries implement a levy scheme making debt funding more expensive. On the other hand, banks facing higher CIT rates have higher liabilities to assets ratios due to the debt bias of taxation. The estimated interaction effect between regulatory and corporate taxes, β_3, is positive: This finding suggests that if a country introduces a bank levy, higher CIT rates mitigate the leverage-reducing effect of the levy.

The estimated direct effect of the bank levy dummy in Column (4) implies that for banks in countries with a bank levy in place, the liabilities to assets ratio is 4.5 percentage points lower than for the other banks, on average, if $CIT = 0$. Given the sample mean of 89.5%, this corresponds to a reduction in leverage of 5% at the sample mean. Regarding the coefficient on CIT, we find that an increase in the CIT rate of one standard deviation (5.1 pp) translates into an increase in leverage of 0.5 percentage points if no levy is in place ($Levy = 0$). When it comes to the total marginal effect of bank levies, depending on the CIT, the estimated coefficients suggest that at the sample mean of the CIT (30.2%), the introduction of a bank levy reduces bank leverage by only 0.4 percentage points. Thus, the introduction of a bank

Table 3.4: Determinants of bank leverage

This table shows regression results based on the empirical specification of equation (3.3) for a sample of European banks. The estimation period covers 2006-2014. The dependent variable is total liabilities relative to total assets (in %). Bank levy is a country-level dummy variable that is one if a bank levy is in place and zero otherwise. Corporate tax rate is a continuous variable, also defined at the country level. All models include bank-level and country-level controls, as well as bank and time fixed effects. Bank-level controls are included with a lag and standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)
	Total liabilities to total assets$_t$			
Bank levy$_t$		-0.532	-0.750**	-4.520***
		(0.335)	(0.345)	(0.867)
Corporate tax rate$_t$			0.176***	0.097**
			(0.044)	(0.043)
Corporate tax rate$_t$ $*$ Bank levy$_t$				0.135***
				(0.027)
GDP growth$_t$	0.038	0.055	0.083**	0.102**
	(0.046)	(0.043)	(0.042)	(0.043)
Inflation$_t$	0.116	0.126*	0.117	0.047
	(0.075)	(0.076)	(0.077)	(0.074)
Ln total assets$_{t-1}$	6.940***	6.812***	7.239***	7.449***
	(1.886)	(1.854)	(1.878)	(1.885)
Ln total assets$^2_{t-1}$	-0.213**	-0.208**	-0.239**	-0.251**
	(0.107)	(0.105)	(0.106)	(0.107)
Return on assets$_{t-1}$	-0.290***	-0.285***	-0.283***	-0.290***
	(0.063)	(0.063)	(0.064)	(0.065)
Impaired loans$_{t-1}$	-0.011	-0.013	-0.011	-0.005
	(0.021)	(0.020)	(0.021)	(0.021)
Supervisory forbearance discretion$_t$	-0.387***	-0.286	-0.435**	-0.624***
	(0.145)	(0.191)	(0.185)	(0.194)
Factors mitigating moral hazard$_t$	0.461	0.399	0.384	0.372
	(0.375)	(0.355)	(0.359)	(0.344)
Time fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Number of observations	10,774	10,774	10,774	10,774
R-squared	0.068	0.069	0.073	0.079
Number of banks	2,771	2,771	2,771	2,771

levy only goes a small way in promoting a more stable bank capital structure in EU-countries with average CIT rates. For the countries with the lowest CIT rates in the sample (10%), the corresponding marginal effect amounts to -3.2 percentage points, whereas it is weakly positive for the maximum observed CIT rate (40.4%).

Figure 3.2 (a) shows the whole range of marginal effects of bank levies on leverage, depending on CIT rates based on Table 3.4, Column 4. It illustrates that the leverage-reducing effect of bank levies is most pronounced for banks in countries with low CIT rates. The higher the CIT rate, the smaller the favorable effect – from a regulatory perspective – of bank levies becomes. For the highest CIT rates in our sample, the sign of the effect changes. This positive but only weakly statistically significant marginal effect is mainly driven by the comparison of French and Spanish banks (subject to levies) with Italian banks (no levy). All three countries have high CIT rates and the positive effect of the levies is plausible, since the tax base in France and Spain is minimum equity requirements and deposits, respectively, rather than non-deposit liabilities. Thus, the baseline model points into an important direction for further analysis, namely that interaction effects between bank levies and CIT rates vary with the design of the bank levy.

The estimated coefficients on the control variables are in line with the related literature. Bank leverage increases with bank size, but this effect levels off and turns negative for the largest banks. Higher profitability allows banks to accumulate equity, such that leverage declines. Bank risk, as measured by the ratio of non-performing loans to gross loans, inflation, and institutions mitigating moral hazard, do not seem to systematically affect leverage, whereas leverage tends to be higher during booms but lower in countries where supervisors have less discretion if banks violate the laws (higher values of the variable "supervisory forbearance discretion").

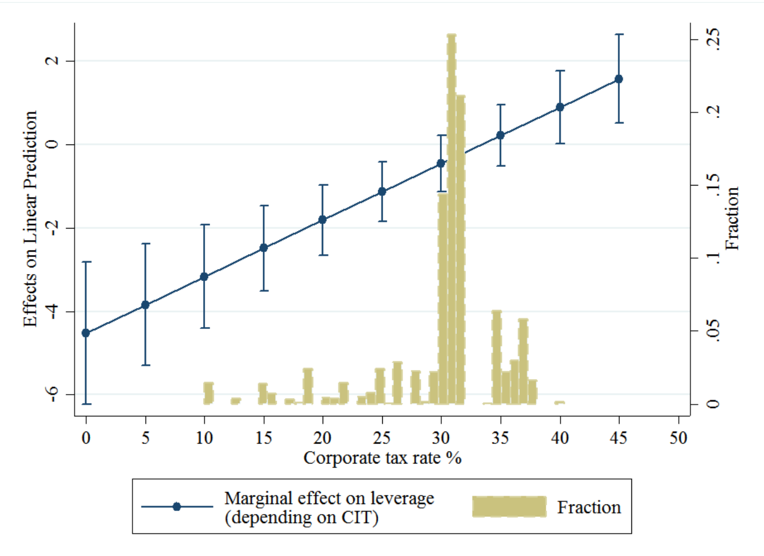
3.4.2 The importance of the levy design

Since the design of bank levies differs across countries, in a next step, we split the regression sample according to the tax base of the levy. For those banks subject to a levy designed as a liabilities tax (L-D), theory predicts a negative link with leverage as a liabilities tax makes debt financing more expensive (Devereux et al., 2015). However, for banks affected by levies with a different tax base, like risk-weighted or total assets (Finland, Hungary, Slovenia), deposits (Cyprus, Ireland, Spain), or minimum capital requirements (France), the impact on leverage is not clear. To account for different levy regimes, we exclude, for example, bank observations of those countries that implemented a levy but did not design it as a liabilities tax over the whole sample period (compare also appendix B.2).

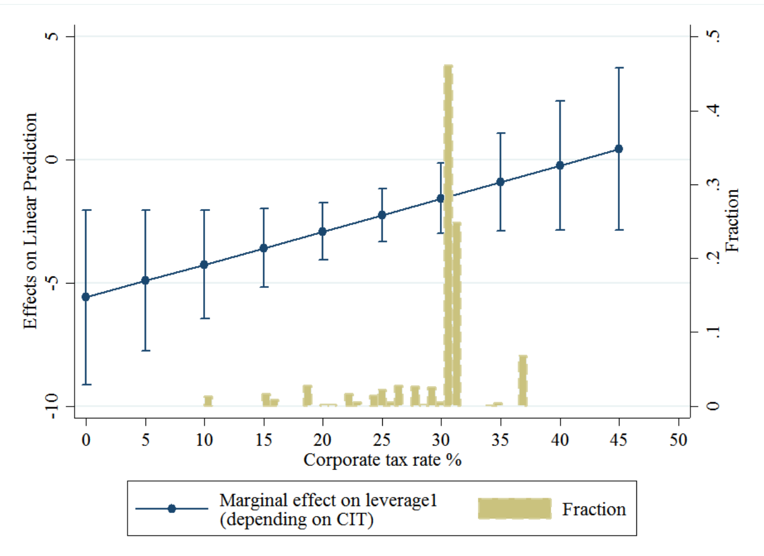
FIGURE 3.2: Marginal effects

This figure plots the marginal effects of levies (bank levy = 1 versus bank levy = 0) on bank leverage for the different observations of corporate income taxes (left hand side). On the right hand side, the fraction of observations for the histogram of corporate income taxes can be read. While subplot (a) shows the marginal effects for the entire country sample, subplot (b) summarizes the findings for the sample including countries where "liabilities minus deposits (L-D)" is the tax base of the levy. Source: Own calculations.

(a) Whole sample



(b) L-D sample



The estimation results in Table 3.5 reveal that our baseline results are driven by banks subject to a levy in the form of a liabilities tax. The leverage-reducing direct effect of the bank levy becomes stronger when excluding countries with different tax bases that provide mixed incentives for bank capital structure (Column 2). Further, the positive and significant effects of CIT and of the interaction term between the levy and CIT on leverage remain intact. In contrast, in countries where the levy design differs and is not focused on making debt funding more expensive, levies are ineffective at promoting a more stable bank capital structure, no matter how low or high the corporate tax rates are (Columns 3 – 5).

TABLE 3.5: Determinants of bank leverage, depending on levy design

This table shows regression results based on the empirical specification of equation (3.3). The estimation period covers 2006-2014. The dependent variable is total liabilities relative to total assets (in %). Bank levy is a country-level dummy variable that is one if a bank levy is in place and zero otherwise. Corporate tax rate is a continuous variable, also defined at the country level. Column (1) repeats the baseline results from Table 3.4, Column (4). Columns (2)-(5) show the estimates for subgroups with regard to the levy design. As indicated in the column header, the estimation sample covers countries with the respective levy tax base and countries that never implemented a levy. All models include bank-level and country-level controls, as well as bank and time fixed effects. Bank-level controls are included with a lag and standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
	Baseline	Tax base: L-D	Tax base: RWA or minimum equity requ.	Tax base: deposits	Tax base: total assets
Bank levy$_t$	-4.520***	-5.590***	-1.839	-1.293	3.356
	(0.867)	(1.807)	(4.261)	(1.297)	(6.93)
Corporate tax rate$_t$	0.097**	0.167***	-0.071	0.022	-0.174**
	(0.043)	(0.062)	(0.049)	(0.102)	(0.069)
Corporate tax rate$_t$ $*$ Bank levy$_t$	0.135***	0.134*	0.077	0.002	-0.169
	(0.027)	(0.074)	(0.125)	(0.04)	(0.35)
GDP growth$_t$	0.102**	0.122***	0.046	0.211**	0.056
	(0.043)	(0.045)	(0.035)	(0.088)	(0.039)
Inflation$_t$	0.047	0.075	0.197***	-0.332*	0.174**
	(0.074)	(0.067)	(0.075)	(0.193)	(0.074)
Ln total assets$_{t-1}$	7.449***	7.643***	6.484***	6.514***	6.462***
	(1.885)	(1.937)	(1.464)	(1.683)	(1.578)
Ln total assets$^2_{t-1}$	-0.251**	-0.233**	-0.221**	-0.198*	-0.196**
	(0.107)	(0.109)	(0.089)	(0.113)	(0.099)
Return on assets$_{t-1}$	-0.290***	-0.230***	-0.243***	-0.260***	-0.278***
	(0.065)	(0.066)	(0.07)	(0.078)	(0.076)
Impaired loans$_{t-1}$	-0.005	-0.011	0.028	0.015	0.014
	(0.021)	(0.022)	(0.022)	(0.024)	(0.022)
Supervisory forbearance discretion$_t$	-0.624***	-0.704***	-0.601***	-1.701***	-0.565***
	(0.194)	(0.181)	(0.19)	(0.481)	(0.184)
Factors mitigating moral hazard$_t$	0.372	0.623*	-0.008	-0.878	0.393
	(0.344)	(0.373)	(0.376)	(0.692)	(0.438)
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observations	10,774	9,180	6,228	5,456	5,213
R-squared	0.079	0.158	0.174	0.096	0.214
Number of banks	2,771	2,451	1,018	938	851

Figure 3.2 (b) illustrates the marginal effect of a levy on bank liabilities on leverage, depending on the corporate income tax rate. Compared to Figure 3.2 (a), the estimations exclude all countries implementing a levy with a tax

base other than liabilities minus deposits. It confirms the previous finding that bank levies reduce leverage more, the lower CIT rates are and, hence, the lower the debt bias of taxation is. However, in countries with high CIT rates, bank levies are an ineffective tool for positively influencing capitalization. Their marginal effect is statistically insignificant in these cases. Thus, the leverage-reducing effect of bank levies is more pronounced for the L-D design, i.e. for pure liabilities taxes.

In terms of economic significance, the estimated effects of the levy for the L-D-sample are – unsurprisingly – a bit larger compared to the effects for the full sample including all levy types: Table 3.5, Column (2) reveals that leverage is 5.6 percentage points lower in countries with a liabilities tax in place. For those countries with the lowest CIT rates in the sample (10%), a levy leads to a reduction in leverage of 4.3 percentage points, whereas under the highest CIT rates (37%), a tax on liabilities still somewhat mitigates leverage (-0.6 percentage points relative to banks not subject to a levy). Thus, when comparing the results from Tables 3.4 and 3.5, it appears that bank levies that are designed as a tax on liabilities are more efficient in incentivizing a more stable bank funding structure, even for higher CIT rates.

Overall, the estimation results point to a favorable effect of bank levies on capitalization and this is the more so, the smaller the debt bias of taxation. For very high CIT rates, the resulting incentives for debt financing exceed the incentives from the bank levy to reduce leverage, such that the overall effect of the levies turns insignificant in these countries. Not surprisingly, the strengths of the levy-effect and, hence, its effectiveness to foster financial stability through lower leverage depends on levy design.

3.4.3 Potential sources of endogeneity

Regarding potential endogeneity issues, one could be concerned about reverse causality, meaning that high bank leverage drives the introduction of bank levies. However, this would imply a positive link between leverage and the introduction of bank levies, whereas we find a negative relationship between the two variables. Thus, our estimates would be biased downwards, such that they reflect a conservative estimate of the effect of levies on leverage if we do not fully control for reverse causality. Additionally, many countries did not primarily aim at influencing bank capital structure with the introduction of bank levies, but rather at filling bank resolution and restructuring funds. Lastly, we consider leverage at the bank level but control for the introduction of the levy at the country level. This approach lowers concerns about reverse causality as individual banks might not drive the outcome of the regulatory process.

A further concern could be related to anticipation effects. For example, anticipating the introduction of bank levies, banks might, pre-introduction, lower leverage ratios in order to reduce regulatory costs. However, as bank levies were introduced quickly in most countries after first political discussion (see Section 3.3.2) and partially refer to balance sheets of years preceding the introduction (see e.g. Buch et al., 2016, Devereux et al., 2015), it is unlikely that banks already adjusted their capital structure before the introduction. Again, such anticipatory adjustments would rather bias our results downwards because we would underestimate the full decline in leverage.

Finally, with respect to confounding factors that influenced bank capital structure at the same time as levies, we control for a large set of potential candidates. Disruptions due to the financial crisis, the European sovereign debt crisis, and expansionary monetary policy affecting all banks alike are captured by time fixed effects. Country-level macroeconomic developments, which obviously differed across the sample countries, and differences in the stance of regulation in the banking sector are controlled for by including a corresponding set of variables and country-level regulatory controls as described above.

As a response to the financial crisis, the regulatory framework has been reformed substantially with potential effects on banks' capital structure. However, our sample ends in 2014, whereas regulatory changes with respect to capital and liquidity requirements under Basel III were subsequently phased-in. Also, as concerns the establishment of the European Banking

Union - one of the key regulatory changes in Europe after the financial and sovereign debt crisis - Koetter et al. (2019) show that many countries are delaying the implementation of the directives underlying the implementation of the European Banking Union into national law. Still, to control for shocks in the context of financial and regulatory reforms after the crisis that may affect specific bank groups differently, in robustness checks discussed in Section 3.4.4, we add interactions of bank group and year fixed effects, where banks are categorized according to their capital ratio (Devereux et al., 2015; Kogler, 2018).

3.4.4 Robustness tests

We run several robustness checks in order to test the sensitivity of our results with respect to levy design, bank group-specific shocks and sample composition. Table 3.6 summarizes the main findings.

We first assess whether changes in the levy rate as well as the timing of the introduction of the levy impacts on our findings. Table 3.6 reveals that our baseline results (Table 3.4, Column 4) are driven by banks in countries with an increasing levy rate over time (Column 2)[11] and by banks that were subject to bank levies early on (2012 or earlier) (Columns 2 and 6). When restricting the analysis to banks in countries that introduced the levy after 2011 or after 2012 only, the effects of the levy and of the CIT turn statistically insignificant (Columns 3 and 5). This result might reflect that levies have been most effective in countries implementing them relatively quickly after first political discussions such that banks could not adjust *ex ante.*

[11]Sweden increased its levy rate in 2011 from 0.018% of non-deposit liabilities to 0.036%. Austria, Cyprus, France, Hungary, Latvia, and the United Kingdom have also increased their levy rate since introducing it (Budnik and Kleibl, 2018).

Table 3.6: Robustness checks

This table shows regression results based on the empirical specification of equation (3.3). The estimation period covers 2006-2014 if not indicated otherwise. The dependent variable is total liabilities relative to total assets (in %). Bank levy is a country-level dummy variable that is one if a bank levy is in place and zero otherwise. Corporate tax rate is a continuous variable, also defined at the country level. For comparison, the baseline results from Table 3.4 are reported in Column (1). Column (2) restricts the sample to banks in countries increasing the levy rate over time, while Columns (3)-(6) present results for subsamples of countries that introduced levies relatively early or later. In Column (7), we add interactions of bank group and time fixed effects. Bank groups are based on the quartiles of bank equity ratios to the baseline model. All models include bank-level and country-level controls, as well as bank and time fixed effects. Bank-level controls are included with a lag and standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Baseline	Increasing levy rate	Levy introduced after 2011	Levy introduced 2011 or earlier	Levy introduced after 2012	Levy introduced 2012 or earlier	With bank group-time FE
Bank levy$_t$	-4.520***	-6.984***	-0.991	-4.455***	-0.485	-4.429***	-1.848***
	(0.867)	(1.385)	(2.537)	(0.902)	(4.463)	(0.858)	(0.614)
Corporate tax rate$_t$	0.097**	0.108**	0.015	0.086*	0.010	0.087**	0.134***
	(0.043)	(0.044)	(0.090)	(0.044)	(0.111)	(0.043)	(0.039)
Corporate tax rate$_t$ $*$ Bank levy$_t$	0.135***	0.204***	-0.002	0.121***	-0.017	0.121***	0.059***
	(0.027)	(0.039)	(0.075)	(0.027)	(0.126)	(0.026)	(0.019)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank group-time fixed effects	No	No	No	No	No	No	Yes
Number of observations	10,774	7,151	5,475	10,400	5,404	10,471	10,774
R-squared	0.068	0.157	0.093	0.127	0.093	0.126	0.238
Number of banks	2,771	1,196	940	2,660	925	2,675	2,771

Second, since adjustments in leverage due to changes in financial regulations or responses to the global financial crisis may have been heterogeneous across banks with different capitalization, we follow Devereux et al. (2015) and Kogler (2018) and account for bank group-specific time trends. For that goal, dummy variables are computed for each quartile of the equity ratio for the entire sample and are then interacted with year dummies. Adding these bank group-time fixed effects does not affect the sign or statistical significance of the baseline results, but reduces the size of the coefficient on the bank levy dummy as well as the coefficient on the interaction with the CIT rate (Column 7).

Appendix B.3 provides additional estimations to test the sensitivity of our results with respect to the included banks, countries, and time. The latter point is especially important considering that our sample includes a non-crisis period, the financial and sovereign debt crisis episode and a period characterized by the re-regulation of the European banking sector with potentially different underlying dynamics in the banking system. When splitting the sample into different time periods to rule out that unobserved common factors drive our result, it appears that the results are statistically significant for the period after 2007 (Column 2) and for different sub-periods excluding the year 2014 to control for the introduction of macroprudential policy measures (Columns 3 and 4). Yet, the size of the estimated coefficients of the bank levy dummy and of the interaction term with CIT is smaller in more recent years when compared to the baseline result. This finding is in line with previous results suggesting that bank levies are most effective in reducing leverage depending on the CIT in countries implementing levies relatively early.

To test whether the composition of banks and countries matters for our results, we account for the fact that in many countries, smaller banks face exemptions from the levy; e.g. in Austria (balance sheet size smaller than 1 billion Euros) and Germany (tax base smaller than 300 million Euros). Similarly, positions within entities belonging to a bank holding company often face a special levy treatment. These banks might thus have no or different incentives to adjust their capital structure in order to lower levy payments. Excluding bank holding companies (Column 5) or small banks with assets below the 25th percentile (Column 6) leaves the key mechanism unaffected, even though the direct effect of the CIT rate turns statistically insignificant. This is also the case when restricting the sample to Euro area countries,[12] and thus reducing confounding factors due to a different stance of monetary policy, in Column (7) – probably because the variation in CIT rates is significantly smaller among these countries than for the entire EU.

3.5 Conclusion

The goal of this paper is to analyze how the introduction of bank levies can reduce leverage of European banks, depending on the prevailing corporate income tax (CIT) rate. While corporate income taxes introduce a debt bias, bank levies can have opposite effects on banks' capital structure if, for example, equity is excluded from the tax base. Given substantial changes in the regulatory framework in Europe, including the introduction of a European bank levy to finance the Single Resolution Fund, understanding such interaction effects among regulatory and corporate income taxes is of utmost importance.

Our analysis reveals that bank levies promote a more stable bank capital structure with potentially positive effects for financial stability. However, this favorable effect is weaker, the higher the CIT rate that a bank is subject to and, hence, the stronger the debt bias of taxation. For EU-countries charging very high CIT rates, the leverage-reducing effect of bank levies turns ineffective because the incentives to use debt financing that result from the CIT system outweigh the opposite incentives set by the levies. Thus, there are non-negligible interaction effects between regulatory taxes and corporate taxes that should be taken into consideration when thinking about the goals and effectiveness of changes in one tax or the other.

[12] The Euro area (EA) dummy varies across time and includes the 18 countries that joined the EA prior to 2015.

We also show that the effectiveness of the levies as a tool to decrease leverage depends crucially upon levy design. Again, the leverage-reducing effect of bank levies taxing liabilities weakens with a higher debt bias of taxation. Not surprisingly, bank levies that tax bank liabilities reduce leverage, whereas levies with different tax bases like total assets, deposits, or minimum equity requirements do not show systematic effects upon bank capital structure. The latter tax schemes, hence, tend to serve primarily the goal of filling resolution funds only. Our analysis reveals that, ceteris paribus, a reduction of systemic risk due to less wholesale financing and a better capital base is most likely in case bank levies target the liability side and are implemented in an environment of limited debt bias of taxation.

This result has the important policy implication that financial regulators should also have an eye on the specific design of regulatory levies and the interaction with other taxation schemes. In a broader context, our results imply that before introducing new regulation to target a specific outcome in banks' behavior, regulators have to assess possible interaction effects with (non-)regulatory measures that are found to impact the targeted variable. Otherwise, regulatory effectiveness cannot be guaranteed.

Appendix B

B.1 Data description

Variable	Description	Source
Bank-specific variables		
Total liabilities to total assets (in %)	Total liabilities relative to total assets	Bankscope
Ln total assets	Log of total assets (in US$ million)	Bankscope
Return on assets (in %)	Operating profit relative to average assets	Bankscope
Impaired loans (in %)	Impaired loans relative to gross loans	Bankscope
Country-specific variables		
Bank levy (0/1 dummy)	Dummy variable that is 1 if a bank levy is in place and 0 otherwise	Based on Devereux et al. (2015), ECB's Macroprudential Policies Evaluation Database by Budnik and Kleibl (2018), Kogler (2018), Twarowska (2016), Ernest and Young (2016)
Bank levy tax base: L-D (0/1 dummy)	Dummy variable that is 1 if the bank levy in place uses the difference of liabilities (=total assets - equity) and deposits as tax base to calculate the levy	
Bank levy tax base: deposit based (0/1 dummy)	Dummy variable that is 1 if the bank levy in place uses deposits as tax base to calculate the levy	
Bank levy tax base: RWA or minimum equity requirement (0/1 dummy)	Dummy variable that is 1 if the bank levy in place uses risk-weighted assets or minimum equity requirements as tax base to calculate the levy	
Bank levy tax base: total assets (0/1 dummy)	Dummy variable that is 1 if the bank levy in place uses total assets as tax base to calculate the levy	
Increasing levy rate (0/1 dummy)	Dummy variable that is 1 if the bank levy rate was increased after the introduction	ECB's Macroprudential Policies Evaluation Database by Budnik and Kleibl (2018)
Corporate tax rate (in %)	Sum of federal tax rate, local tax rate taking into account surcharge and deductibility of local taxes	Oxford University Centre for Business Taxation, KPMG (2014), Devereux et al. (2015)
GDP growth (in %)	Annual growth of GDP	International Financial Statistics, IMF
Inflation (in %)	Annual inflation rate	
Supervisory forbearance discretion (0-4)	Whether the supervisory authorities may engage in forbearance when confronted with violations of laws and regulation or other imprudent behavior (0-4, with higher values indicate less supervisory discretion)	Barth et al. (2013)
Factors mitigating moral hazard (0-4)	The degree to which moral hazard exists (0-4, higher values indicate greater mitigation of moral hazard)	Barth et al. (2013)
Euro area (0/1 dummy)	Dummy variable that is 1 if the country is a member state of the Euro area in a given year	

B.2 Country sample and tax base

This table presents the country samples depending on the tax base applied for the levy. Countries in **bold font** are those that introduced a levy, while the other countries did not have a levy in place during our sample period (2006–2014). In the second column, the L-D sample is shown including only countries in which the tax base is "Liabilities (=total assets – equity) – deposits (L-D)" and countries without a levy. The third column shows the year when the levy was implemented. The broad definition of the tax base is indicated in the fourth column. The final column shows the source of the information in those cases we draw on information beyond the one provided in Devereux et al. (2015) and the ECB's Macroprudential Policies Evaluation Database by Budnik and Kleibl (2018).

Baseline sample	*L-D sample*	*Implementation*	*Tax base*	*Source (if additional to:* Devereux et al., 2015; Budnik and Kleibl, 2018)
Austria	**Austria**	**2011**	**L-D**	
Belgium	**Belgium**	**2012**	**L-D**	
Bulgaria	Bulgaria	No levy	No levy	
Cyprus	-	**2011**	**Deposits**	
Czech Republic	Czech Republic	No levy	No levy	
Denmark	Denmark	No levy	No levy	
Estonia	Estonia	No levy	No levy	
Finland	-	**2013**	**Risk-weighted assets**	Twarowska (2016)
France	-	**2011**	**Minimum equity requirement**	
Germany	**Germany**	**2011**	**L-D**	
Greece	Greece	No levy	No levy	
Hungary	-	**2010**	**Total assets**	
Ireland	-	**2014**	**Deposits**	
Italy	Italy	No levy	No levy	
Latvia	**Latvia**	**2011**	**L-D**	
Luthuania	Luthuania	No levy	No levy	
Luxembourg	Luxembourg	No levy	No levy	
Malta	Malta	No levy	No levy	
Netherlands	**Netherlands**	**2012**	**L-D**	
Poland	Poland	No levy	No levy	
Portugal	**Portugal**	**2011**	**L-D**	
Romania	**Romania**	**2011**	**L-D**	
Slovakia	**Slovakia**	**2012**	**L-D**	
Slovenia	-	**2011**	**Total assets**	
Spain	-	**2014**	**Deposits**	http://www.elexica.com/en/legal-topics/tax/09-spain-new-tax-on-bank-deposits
Sweden	**Sweden**	**2009**	**L-D**	
United Kingdom	**United Kingdom**	**2011**	**L-D**	

B.3 Additional robustness checks

This table shows regression results based on the empirical specification of equation (3.3). The dependent variable is total liabilities relative to total assets (in %). Bank levy is a country-level dummy variable that is one if a bank levy is in place and zero otherwise. Corporate tax rate is a continuous variable, also defined at the country level. For Column (1) and Columns (5)-(7), the estimation period covers the years 2006-2014. Columns (2)-(4) show estimates for alternative sample periods. In Column (5), all banks that are indicated by Bankscope as bank holdings and holding companies are excluded from the sample. Column (6) shows estimates for a sample that excludes banks with total assets below the 25th percentile of the baseline sample. The estimates shown in Column (7) are based on banks in Euro area countries only. All models include bank-level and country-level controls, as well as bank and time fixed effects. Bank-level controls are included with a lag and standard errors are clustered at the bank level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1) Baseline	(2) after 2007	(3) until 2013	(4) 2010 - 2013	(5) w/o bank holdings	(6) excl. small banks	(7) Euro area countries
Bank levy$_t$	-4.520***	-2.911***	-4.462***	-1.852*	-4.547***	-3.888***	-3.490***
	(0.867)	(0.875)	(0.865)	(0.948)	(0.873)	(0.844)	(1.066)
Corporate tax rate$_t$	0.097**	0.322***	0.069	0.295**	0.098**	-0.001	-0.051
	(0.043)	(0.083)	(0.046)	(0.127)	(0.043)	(0.04)	(0.046)
Corporate tax rate$_t$ $*$ Bank levy$_t$	0.135***	0.082***	0.141***	0.074***	0.136***	0.120***	0.135***
	(0.027)	(0.028)	(0.029)	(0.027)	(0.027)	(0.027)	(0.039)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	10,774	9,769	8,509	5,715	10,748	8,080	9,274
R-squared	0.068	0.072	0.081	0.045	0.079	0.066	0.067
Number of banks	2,771	2,727	2,581	2,464	2,765	2,106	2,470

Chapter 4

Does liquidity regulation impede the liquidity profile of collateral?

Abstract: *We analyze the pledging behavior of Euro area banks during the introduction of the liquidity coverage ratio (LCR). The LCR considers only a subset of central bank eligible assets and thereby offers banks an arbitrage opportunity to improve their regulatory ratio by altering their collateral pledging with the European Central Bank. We use the existence of national liquidity requirements to proxy for banks' incentives to exploit this differential treatment of central bank eligible assets. Using security-level information on collateral pledged with the central bank, we find that banks without a preceding national liquidity requirement pledge more and less liquid collateral than banks with a preceding national liquidity requirement after the LCR introduction. We attribute the difference across banks to a preparation effect of the liquidity regulation on the national level.*

4.1 Introduction

Following the global financial crisis 2007/2008, the need for profound changes in financial supervision was addressed by the introduction of new regulatory measures. Given the central role of liquidity during the crisis, these measures include standards on liquidity. The liquidity coverage ratio (LCR) was introduced in October 2015 as the first of two quantitative liquidity standards. The LCR measures the liquidity resilience of institutions for the next 30 days in case of a stress scenario by setting the liquidity buffer in relation to the expected net cash outflow.

In this paper, we examine whether the introduction of the LCR had adverse effects on the liquidity profile and the quantity of collateral pledged with the European Central Bank (ECB) to secure its refinancing operations. Whereas the collateral framework of the ECB is one of the broadest among central banks world wide, the LCR framework takes into account only the most liquid of these ECB eligible assets. Such differential treatment of ECB eligible assets creates the possibility to improve the LCR by simply pledging assets as collateral that are considered illiquid according to the LCR, while withholding assets eligible for the LCR. Assets are only included in the LCR calculation if they are not encumbered via any kind of banking activity. Hence, banks face the trade-off to use a liquid asset eligible under the LCR framework for the LCR or within the scope of another banking activity, for example to secure a refinancing operation. In addition to the differential treatment of ECB eligible assets, the LCR framework directly favors central bank funding over other refinancing sources by assigning a zero percent outflow rate. Because this regulatory design creates an incentive to increase central bank funding and to complement the estimation on the collateral liquidity profile, we also consider quantity effects of the LCR introduction on collateral pledged with the central bank.

Investigating whether banks exploit the arbitrage opportunity via the central bank to improve their LCR is crucial for the policy evaluation of the liquidity requirement. The LCR is meant to promote banks' resilience to liquidity shocks and to reduce the reliance on the central bank. However, if banks use the arbitrage opportunity to alter their LCR value rather than to improve their liquidity risk profile, the arbitrage possibility could leave the LCR being ineffective or increase reliance on the central bank. Hence, this research bears important implications for policy makers regarding the potential risk mitigating effect of the regulation.

We use a proprietary dataset with bank-level information on central bank collateral. These collateral data are based on security-level information and are complemented by regulatory data at the bank level. To identify the effect of the LCR introduction on pledged collateral, we exploit the existence of national liquidity requirements in some Euro area countries. These national regulations preceded the EU-level LCR and have resemblance to it. We hypothesize that banks without preceding national liquidity requirement alter their pledging behavior more extensively than banks with a preceding national liquidity requirement in reaction to the LCR introduction. The conjecture is that in the presence of a preceding national liquidity regulation, the need to alter the pledging behavior in response to the LCR introduction is expected to be less pronounced because those banks already made adjustments to comply with their national liquidity regulation. Thus, we have less reason to expect that these banks with a national requirement exploit the differential regulatory treatment in terms of pledging less liquid collateral or making use of the preferential treatment of central bank funding by increasing the refinancing through the central bank.

To measure a potential reaction in the pledging behavior of banks, we use the natural logarithm of the collateral value as a quantity measure. Whereas we exclude the haircut for the quantity measure, we use it to estimate collateral liquidity by calculating the weighted average haircut of pledged collateral. The haircut depends on the price volatility and uncertainty associated with the valuation of the collateral.[1] Therefore, haircuts are smaller for more liquid assets like those considered within the LCR. Because only marketable assets are potentially LCR eligible, we subdivide the total of pledged collateral into marketable and non-marketable assets. Marketable assets include securities, while non-marketable assets comprise, for example, credit claims.

Empirically, we find evidence that banks react to the LCR implementation by altering their pledging behavior with the central bank. The two main findings are that banks without a national liquidity requirement decrease the liquidity profile and increase the quantity of pledged collateral relative to banks that already faced a national liquidity regulation before the introduction of the EU-level LCR. For the collateral liquidity profile we find two opposing effects. While the average liquidity profile for marketable collateral decreases by over 30% for banks without national liquidity requirement, the liquidity of non-marketable assets increases by 8.4%. The decrease in marketable collateral liquidity supports the hypothesis that banks without

[1] Bindseil et al. (2017)

national liquidity requirement have a higher incentive to exploit the regulatory friction by substituting liquid with less liquid collateral. Given that non-marketable collateral is LCR ineligible, an improvement in its average liquidity is no contradiction to our hypothesis but could be driven by the corresponding increase in pledged non-marketable collateral. Banks without a national liquidity requirement increase the collateral value of pledged non-marketable assets by 6% in comparison to banks with a preceding national liquidity regulation. Given that non-marketable assets are not considered under the LCR framework, this result suggests that banks either increased their central bank funding with LCR ineligible assets or increased their overcollateralization. For marketable assets, we find no statistically significant results concerning the quantity of pledged collateral.

To our knowledge, this paper is the first to consider the effect of liquidity regulation on central bank collateral. It is also one of the first to consider the effect of the LCR implementation at the EU level. Our work is closest to Fuhrer et al. (2017)'s study on the LCR introduction in Switzerland. Whereas we focus on the effect on banks' pledging behavior with the central bank, Fuhrer et al. (2017) provide empirical evidence of a security price premium for assets considered under the LCR framework as suggested by Stein (2013). They examine the friction of assets considered by the LCR framework and all other assets on the market, whereas we concentrate on the differentiation of LCR eligible and ineligible assets within the collateral framework. Their theoretical analysis hints that the premium is driven by additional demand for these assets, the elasticity of the asset supply, and the possibility of banks to reduce net cash outflows.

Another side effect of liquidity regulation is considered by Bonner and Eijffinger (2016), who find for the Dutch interbank market that liquidity requirements seem to increase long-term borrowing, lending rates and long-term interbank loans. These findings support Bech and Keister (2017)'s theoretical model on the externalities of liquidity regulation, which stresses the influence of liquidity regulation on market conditions and the interest rate and by that affects monetary policy implementation. However, since the introduction of the full allotment policy in 2008, Bech and Keister (2017)'s model no longer applies to the monetary policy transmission of the Euro area given that the policy rate is no longer implemented through the interbank market. As we show, this shift in the regime to implement monetary policy does not imply that liquidity regulation has no effect on monetary policy.

We also contribute to the rather small literature on central bank collateral pledging. Within this strand of literature this paper is closest to Drechsler et al. (2016) and Fecht et al. (2016). Like them, we consider the collateral pledged with the central bank. Whereas we consider the effect of the LCR introduction, Drechsler et al. (2016) and Fecht et al. (2016) study the implementation of the full allotment policy of the ECB in 2008. In contrast to our country-level identification, they provide evidence that weaker banks use lower quality collateral and demand disproportionally more central bank funding. Fecht et al. (2016) highlight the possibility of an implicit support of weaker banks and the limited use of lower quality collateral outside of Eurosystem operations as reasons for using lower quality collateral for central bank operations. One of these reasons is the default risk of the lender as stressed by Ewerhart and Tapking (2008). In a repurchase transaction, the lender is protected against the default of the borrower via the provision of collateral. To minimize the risk that the transaction is too low collateralised due to price fluctuations of the underlying collateral, appropriate haircuts are applied. However, in case the lender defaults, the borrower faces the problem that very high haircuts were applied and the loss of the collateral is higher than the principal amount of the transaction. Our finding, that the LCR induces banks to pledge lower quality collateral indicates another source of asymmetric opportunity costs of pledging collateral with the central bank. Also for the pre-crisis period, Bindseil et al. (2009) find evidence that opportunity costs differ across collateral types when studying the main refinancing operations of the ECB for a 1-year period in 2000/2001. Hence, asymmetric opportunity costs do not seem to be per se a phenomenon of the unconventional monetary policy of the ECB. Cassola and Koulischer (2019) propose a theory of collateral choice to assess how changes in collateral policy of the central bank influence the collateral type pledged by banks and banks' funding choice. The results suggest that an increase in haircuts applied to collateral belonging to a specific asset class reduces the use of this particular group of assets.

The perspective of the central bank is described by Bindseil and Lamoot (2011), who stress the trade-off between the social benefits due to a broad collateral framework versus the social costs potentially associated with it. While Choi et al. (2017), Cassola and Koulischer (2019), and Koulischer and Struyven (2014) highlight the positive effect of a broad collateral framework on market functionality, De Roure (2016) finds an premium of securities eligible as central bank collateral. Similar to Fuhrer et al. (2017)'s approach for LCR eligible assets, De Roure (2016) provides empirical evidence for the distortion of markets due to the collateral policy of the central bank. Also Kacperczyk et al. (2017) show that central bank eligibility itself is a determinant of a safe asset. Such effects on money and asset markets may reduce market discipline and can create distortions in the real economy like the overproduction of illiquid real assets (Nyborg, 2016; Nyborg, 2017). We focus on the interaction effects of the regulatory LCR framework and the collateral framework which is no externality of the collateral framework per se but the result of the differential treatment of assets by the two frameworks.

The remainder of this paper is organized as follows. Section 4.2 provides information on the institutional background relevant for this paper. It describes the set up of the LCR and ECB's refinancing operations and emphasizes the friction between the relevant frameworks. Also the identification strategy is described. In Section 4.3, we present the measurement and data, as well as the empirical specifications to estimate the effect of the LCR introduction on bank's pledging behavior. We discuss our results in Section 4.4 and present robustness checks in Section 4.5. We conclude in Section 4.6.

4.2 Institutional setting

4.2.1 Liquidity coverage ratio

The liquidity coverage ratio (LCR) determines the amount of banks' liquidity buffer relative to their expected net cash outflows for the next 30 days. It was introduced with a minimum of 60% in October 2015, followed by an increase to 70% in January 2016, and 80% in January 2017. Banks need to adhere to the final minimum requirement of 100% by January 2018. The regulation applies to all EU credit institutions.[2]

In the context of the LCR the liquidity buffer is referred to as the sum of high quality liquid assets (HQLA) held by the respective bank:

$$\text{Liquidity Coverage Ratio} = \frac{\text{High Quality Liquid Assets}}{\text{E[Net cash outflow]}_{\text{30days}}}.$$

HQLA are defined in the legal framework of the LCR and include assets like reserves, marketable government, and central bank securities, but also corporate debt securities of non-financial institutions and covered bonds.[3] The amount of HQLA is calculated based on the market values of the individual assets which are adjusted by respective haircuts. To calculate the expected net cash outflow, liquidity inflows and outflows are evaluated for a 30 day stress period. Outflows and inflows are calculated by multiplying balance sheet and off-balance sheet holdings with a maturity lower than 30 days with inflow/outflow rates assigned to them.[4] These rates are also defined in the LCR framework. They are based on a combination of idiosyncratic and market wide stress scenarios. To improve their LCRs, banks can consequently either increase their HQLA holdings by altering their asset side or opt for funding sources with lower outflow rates.

It is important to note that HQLA are only considered for regulatory purposes if they are not encumbered via any kind of banking activity. Hence, with the introduction of the LCR, banks face the trade-off to use a liquid

[2]Commission Delegated Regulation (CDR) (EU) 2015/61 of 10 October 2014
[3]For more details consider title 2, chapter 2 of the CDR (EU) 2015/61.
[4]For more details consider title 3 of the CDR (EU) 2015/61.

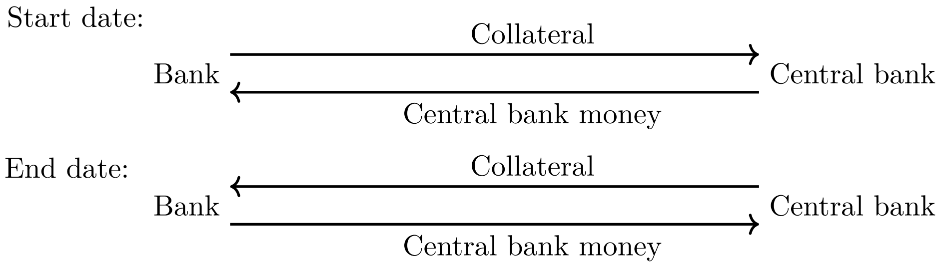
asset eligible under the LCR framework as HQLA or within another banking activity, for example to secure a refinancing operation.

4.2.2 Central bank refinancing operations

Since the introduction of the full allotment policy in October 2008, European financial institutions can receive unlimited amounts of liquidity at the main refinancing rate and against adequate collateral during the weekly auctions of the ECB. Like in an ordinary repurchase transaction the borrower (bank) must provide a sufficient amount of collateral to the lender (central bank) at the start date. At the end date of the transaction the borrowed amount plus interest payments are returned to the lender, while the collateral is returned to the borrower (see Figure 4.1).

FIGURE 4.1: Refinancing operations with the central bank

The figure shows the transactions of a central bank refinancing operation. From the start date onwards, the bank has to provide central bank eligible collateral to the central bank to secure the amount of central bank money received from the same. On the end date, the bank is free to withdraw its collateral after repaying the principal amount and the interest obligations to the central bank.



Within the Eurosystem, all assets pledged as collateral with the central bank belong to the collateral pool of the respective bank. Put differently, banks do not pledge one particular asset to secure a certain amount of funding, but the value of the collateral pool has to cover the face value of central bank refinancing operations.

Assets pledged with the central bank as collateral need to be eligible for the collateral framework. The collateral value of asset i is the asset price at date t times one minus the assigned haircut.[5] In contrast to the asset price, haircuts are not revalued every business day but are fairly stable over

[5] $\text{Collateral value}_{it} = \text{asset price}_{it} * (1 - \text{haircut}_{it})$

time. The haircut is a percentage discount to account for the risk of loss that the asset possess and is applied to protect the Eurosystem against financial losses in case the collateral has to be realized due to an default of the counter-party. Counter-party risk is not considered in haircut considerations but is indirectly included by applying counter-party eligibility criteria (Bindseil et al., 2017).[6]

The asset price is the price of the business day preceding the valuation day. For marketable assets, like ECB debt certificates and other marketable debt instruments, the asset price is usually the most reliable market price.[7] However, for non-marketable assets like credit claims, retail mortgage-backed debt instruments and fixed-term deposits from eligible counter-parties either a theoretical model calculates the asset price or the outstanding amount is used as such.[8]

Bindseil et al. (2017), Nyborg (2016), Nyborg (2017), BIS Markets Committee and others (2013), and Eberl and Weber (2014) provide detailed discussions on ECB's collateral framework and risk mitigation procedures.

4.2.3 Friction and identification

Our research question is motivated by the friction of the ECB's collateral framework and the assets considered as HQLA within the LCR framework. While the collateral framework covers a broad range of marketable assets and non-marketable assets, the LCR framework considers only the most liquid marketable assets as HQLA.

The differentiation of assets in HQLA and non-HQLA creates additional regulatory value for HQLA (Fuhrer et al., 2017). Given that the distinction is also present within the collateral framework, the increase in regulatory value also affects banks' pledging behavior with the central bank. Instead of using HQLA to secure central bank operations, banks have an incentive to keep HQLA unencumbered to let them be counted into the LCR. While the LCR

[6] For details: `https://www.ecb.europa.eu/ecb/legal/pdf/celex_32016o0032_en_txt.pdf`.

[7] For details: `http://www.ecb.europa.eu/paym/coll/standards/marketable/html/index.en.html`.

[8] For details: `http://www.ecb.europa.eu/paym/coll/standards/nonmarketable/html/index.en.html`.

regulation framework punishes the switch to less liquid collateral with other counter-parties by increasing the outflow rate, and therefore the denominator of the LCR, the outflow rate for central bank operations is independent of the underlying collateral.[9] Therefore, it is reasonable to expect that with the introduction of the LCR banks are more likely to pledge non-HQLA instead of HQLA to secure central bank operations.

In addition to this friction induced mechanism there is another potential channel affecting the pledging behavior of banks with the central bank. Regulators consider central bank funding as 100% stable and therefore assign an outflow rate of 0%. In contrast, other refinancing sources considered secure like stable retail deposits, have an outflow rate of at least 5% and outflow rates for operational deposits are not below 25%. Hence, the introduction of the LCR and the variation in outflow rates across different funding sources can induce banks to switch from high-outflow-rate-funding sources to funding sources with lower outflow rates and by that increasing its LCR via reducing the denominator of the ratio. The substitution of funding sources would have an direct effect on the quantity of collateral pledged with the central bank and could have an indirect effect on the liquidity profile of collateral.

Summing up, the introduction of the LCR in the context of the ECB's collateral framework can influence the pledging behavior of banks with the central bank via the incentive to substitute HQLA with non-HQLA and the substitution of funding sources.

These arbitrage opportunities undermine the effectiveness of liquidity regulation, given that the intention of liquidity regulation is to reduce the reliance on central bank funding in times of economic stress. The reason for this issue is the problematic distinction between structural and regulatory liquidity needs. Turning to the central bank to demand funding, a bank might want to satisfy regular funding needs due to business activities, not to exploit the arbitrage opportunity of the LCR framework. Treating central

[9]If a bank switches its collateral from HQLA to non-HQLA to secure non-central bank funding source, the applied outflow rate increases to 100 %. Short-term funding secured by HQLA has outflow rates of only 0% to 50%. For further details on the exact outflow rates consider Article 28 of the Commission Delegated Regulation (EU) 2015/61.

bank funding stricter within the LCR framework is also not reasonable as it is a secure funding source especially in times of distress. Hence, to avoid that banks face even more costs due to liquidity regulation, central bank funding is preferentially treated.[10] Bindseil and Lamoot (2011) give an extensive description and discussion of the separate treatment of liquidity regulation and the central bank's operational framework and the unwanted interactions stemming from it.

To identify the potential effect of this friction, we exploit the fact that in 12 out of 19 Euro area countries the EU-wide LCR was preceded by a national liquidity requirement comparable to the EU-level counterpart (Figure C.2 in the appendix). The national regulation either has or had a time horizon of 30 days or a similar calculation of liquid assets, cash outflows, and inflows. We assume that in the presence of a preceding national liquidity regulation the need to alter the pledging behavior in response to the LCR introduction is less pronounced because those banks already made adjustments, for example reducing their liquidity risk profile or altering the pledging behavior, to comply with their national liquidity regulation. Thus, we have less reason to expect that these banks with national liquidity requirement exploit the differential regulatory treatment.

Although national liquidity requirements are not exogenous to the liquidity holdings of the national banking sector, they are far less endogenous than individual liquidity indicators like the LCR value itself. To control for effects of differences in the regulatory design of the liquidity requirements, we control for the regulatory toughness and the intensity of the LCR introduction in Section 4.4.3.

[10] In the theoretical literature, Stein (2013) suggests to use central bank funding to cap the tax of liquidity regulation. However, the author does not comment on the consequences.

4.3 Method and data

4.3.1 Measurement and data

We obtain data of banks' pledging behavior from the ECB. At weekly frequency, we observe which bank pledged what kind of asset on the security level. These information are combined with regulatory bank-level data of the Single Supervisory Mechanism (SSM).

To evaluate the pledging behavior of banks, we consider the liquidity profile and the quantity of the collateral pool. Similar to Fecht et al. (2016) and Drechsler et al. (2016), we measure the liquidity profile of collateral using the weighted average haircut for each bank's collateral pool in time t. The advantage of using the weighted average haircut is that it is available for marketable and non-marketable collateral. Given that haircuts are meant to reduce the probability of losses in case the borrower defaults and the collateral has to be liquidated, less liquid assets like non-HQLA have higher haircuts than more liquid assets like HQLA.

The quantity of pledged collateral is measured by the natural logarithm of the total value of the collateral pool, which is the sum of all assets pledged as collateral excluding haircuts. The collateral value is not the exact amount of requested central bank funding, but is closely connected to it. Disparity arises because banks tend to pledge more collateral than needed to secure the principal amount of the central bank loan. In the private market so called overcollateralization is used to reduce refinancing costs. In the context of central bank funding, overcollateralization has no effect on the required interest rate, but is likely done to account for variations in the daily valuations of the pledged collateral. Also fluctuations in the demand for central bank funding can lead to overcollateralization, if the respective bank does not adjust its pledged collateral accordingly.[11] Collateral pledged with the central bank is legally encumbered. As mentioned in Section 4.2.1, encumbered assets cannot be sold until the debt is satisfied or used to

[11]For example, banks with a significant demand for intraday credit are likely to hold substantial end-of-day overcollateralization.

secure other transactions. Hence, banks have an incentive to limit their overcollateralization. Also the legal framework of the LCR claims that HQLA can not be encumbered. Despite this legal requirement, in practice, assets pledged with the central bank in excess to the required amount of collateral are included in the calculation of the LCR, provided these assets are HQLA. Thereby, non-HQLA are considered first and only if this amount is not sufficient to secure the credit claim of the central bank, HQLA are considered as collateral. This practice can limit the incentive of banks to substitute their HQLA within the collateral pool with non-HQLA due to the LCR introduction. They can simply add a sufficient amount of non-HQLA and by that increase overcollateralization to the extend that the HQLA included in the collateral pool is not needed to secure the refinancing operation with the central bank. Whether this practice is reasonable in the sense of an efficient use of assets could be questioned, however, it can not be ruled out with certainty. Hence, the quantity of collateral is no exact proxy for the quantity of central bank funding because we can not distinguish whether a change in the amount of pledged collateral value is due to a change in central bank funding or a change in overcollateralization. However, in both cases the effect of the LCR introduction on the quantity of collateral is of interest for us because it either indicates whether banks take advantage of the preferential treatment of central bank funding or complements the results for collateral liquidity profile. An increase in overcollateralization because non-HQLA is added but HQLA is not withdrawn, can lead to an underestimation of the effect of the LCR introduction with the remaining HQLA in the collateral pool diluting the change in the weighted average liquidity. In general, the estimates on the quantity of pledged assets complement our results because a change in the quantity offers alternative explanations for the change in the collateral liquidity profile next to the substitution of collateral. For example, the liquidity profile decreases when banks withdraw the most liquid assets first, or add less liquid assets to their collateral pool.

We distinguish the collateral pool into the sub-categories marketable and non-marketable collateral because non-marketable collateral is never considered to be a HQLA, while marketable collateral can be both. Hence, considering marketable and non-marketable collateral separately disentangles potentially contrary effects.

Our sample covers 77 banks supervised by the SSM that hold a collateral pool to back their borrowings during our sample period. Since our covariates are end of quarter measures, we use the latest available weekly observation within the respective quarter. The amount of collateral pledged by our sample banks covers approximately 47% of collateral value pledged with the ECB for the two sample periods.[12] This magnitude is reasonable given that only the largest and most significant banks of the Euro area are supervised by the SSM. Our baseline specification considers two cross-sections, the second quarter of 2015 and the first quarter of 2016. We exclude the intermediate period, Q3 and Q4 2015, to control for anticipation effects, which are likely because of the end-of-period set up of our data. Q3 2015 is likely to show anticipation effects as the regulation came into force on the 1st of October 2015.[13] Therefore, it is likely that banks already adjusted their pledging behavior end of September. The period Q4 2015 is excluded because it is likely to show anticipation effects of the first LCR increase in January 2016, when the minimum threshold was increased from 60% to 70%.[14] To avoid the uncertainty that estimated effects are due to the LCR introduction or due to anticipation effects of the following increase in the LCR requirement, we consider both events as one treatment and consider Q1 2016 as the first post-treatment period.

We restrict our baseline sample to two cross-sections to reduce the possibility of confounding events. In Section 4.5 we test how sensitive our estimates are regarding the sample period by extending the two cross-sections to a panel as well as including the treatment period. Furthermore we include bank-level controls from the harmonized reporting standards, the common

[12]Our end of quarter aggregate divided by the average of the three end of month observations over the respective quarter. The aggregate data are available here: `https://www.ecb.europa.eu/paym/coll/charts/html/index.en.html`.

[13]Article 39, Commission Delegated Regulation (EU) 2015/61

[14]Article 38, Commission Delegated Regulation (EU) 2015/61

solvency reporting (COREP) and the financial reporting (FINREP), of the SSM.

As stressed in Section 4.2.3, banks are defined in two groups: banks with *no national liquidity requirement* (NNLR) and banks with national liquidity requirement. Table 4.1 presents mean and standard deviation for each group per pre- and post-treatment period as well as the difference, and the statistical significance of the difference of the pre- and post-period. For the two pre-treatment samples, we find no significant differences in the covariates. For the post-treatment period, covariates remain to be not significantly different except for capital ratio and deposits of financial institutions. For the left-hand side variables, we find that in the pre-treatment period only marketable collateral value is significantly different for NNLR and non-NNLR banks, while all the liquidity profile measures are significantly different in the post-treatment-period. More details on individual variable definitions are provided in the appendix by Table C.8.

TABLE 4.1: Summary statistics

This table reports bank-level statistics for the pre-LCR-introduction-period Q2 2015 and post-LCR-introduction-period Q1 2016 by groups. The indicator variable NNLR is 1 if the bank was not exposed to a national liquidity regulation similar to the LCR preceding to the EU-level LCR introduction. The sample comprises a subset of SSM banks participating in ECB refinancing operations. The reported p-values are two sided. Covariates are lagged by one quarter. Variables are further described by Table C.8 in the appendix.

		Pre-LCR-introduction-period						Post-LCR-introduction-period					
		NNLR = 1		NNLR = 0				NNLR = 1		NNLR = 0			
	Variable	Mean	Std. dev.	Mean	Std. dev.	△(0-1)	P-value	Mean	Std. dev.	Mean	Std. dev.	△(0-1)	P-value
LHS	Haircut	13.09	12.85	10.75	10.90	-2.34	0.39	13.46	7.63	11.83	11.99	-1.63	0.50
	Marketable haircut	4.52	2.56	5.35	7.55	0.83	0.54	7.20	2.82	6.03	7.68	-1.18	0.40
	Non-marketable haircut	36.61	15.92	29.92	14.25	-6.69	0.11	33.41	14.04	29.65	14.91	-3.76	0.36
	Collateral value	8.31	1.85	7.87	2.06	-0.44	0.33	8.69	1.30	7.86	1.92	-0.84	0.03
	Marketable collateral value	8.26	1.49	7.40	2.56	-0.86	0.08	8.40	1.46	7.39	2.45	-1.01	0.04
	Non-marketable collateral value	6.76	1.90	6.77	1.70	0.02	0.97	7.41	1.28	6.53	1.73	-0.88	0.05
RHS	Log of total assets	25.00	1.23	24.83	1.79	-0.17	0.64	25.10	1.14	24.76	1.76	-0.34	0.34
	Capital ratio	13.63	7.62	15.11	4.23	1.48	0.29	13.98	5.99	16.71	4.93	2.73	0.04
	ROA	0.14	0.18	0.13	0.15	-0.01	0.84	-0.01	0.29	-0.09	0.56	-0.08	0.44
	Loan ratio	67.18	11.35	64.44	13.58	-2.74	0.35	66.17	9.89	63.59	12.76	-2.58	0.34
	Debt instruments	17.45	9.65	19.30	10.37	1.84	0.43	17.64	7.87	19.48	10.11	1.85	0.39
	Interest Income	0.64	0.31	0.75	0.28	0.11	0.12	0.58	0.20	0.62	0.55	0.04	0.72
	Deposits of fin. Institutions	7.46	6.17	10.94	11.53	3.48	0.11	5.76	4.37	9.75	10.39	4.00	0.04
	Household deposits	31.77	12.70	30.86	23.24	-0.91	0.84	33.83	13.06	31.28	22.85	-2.55	0.57
	Interest expense	0.28	0.16	0.34	0.24	0.07	0.17	0.23	0.11	0.26	0.36	0.04	0.56
	Number of banks/obs.	36		40				34		40		Total 150 obs./77 banks	

4.3.2 Empirical specification

With the implementation of the LCR, we hypothesize that banks have an incentive to alter their collateral pledging behavior with the central bank as it offers the possibility to improve the regulatory ratio and thereby ease the regulatory burden. To identify the effect of the EU-wide introduction on banks' pledging behavior we use country-level information on national liquidity requirements preceding to the EU-wide LCR implementation and employ a difference-in-difference set up. To evaluate the pledging behavior of banks, we consider the average weighted haircut of pledged securities for bank i of country j in period t and the natural logarithm of the amount of collateral after haircuts pledged by bank i of country j in period t as dependent variable (Y_{ijt}).

$$\begin{aligned} Y_{ijt} = {} & \alpha_i + \alpha_t + \gamma X_{it-1} \\ & + \beta_1 NoNationalLiquidityRequirement_j * PostLCR_t + \epsilon_{ijt} \end{aligned} \tag{4.1}$$

The binary dummy variable $NoNationalLiquidityRequirement_j$ is one if country j did not have some kind of liquidity requirement comparable to the EU-level LCR and zero if there was or still is a national liquidity regulation in place. The main coefficient of interest, β_1, is showing the differential effect of the LCR introduction ($PostLCR_t$) on banks without national liquidity requirement ($NoNationalLiquidityRequirement_j$). $PostLCR_t$ is a time dummy, which is equal to one for the post-treatment period(s). We control for bank fixed effects, α_i, time fixed effects, α_t, and cluster standard errors at the bank level. All covariates (X_{it-1}) are lagged by one period to reduce simultaneity concerns. Because this does not solve the issue of possible reverse causality, our estimates should be interpreted as correlations.

In a second step, we control for country and bank-specific effects by extending the interaction term with a third indicator variable. As a placeholder, this variable is named $Treated_{i/j}$. It is either defined on the bank level i or the country level j.

$$
\begin{aligned}
Y_{it} = \alpha_i + \alpha_t + \gamma X_{it-1} + \beta_1 PostLCR_t * Treated_{i/j} \\
+ \beta_2 PostLCR_t * NoNationalLiquidityRequirement_j \\
+ \beta_3 PostLCR_t * Treated_{i/j} * NoNationalLiquidityRequirement_j + \epsilon_{ijt}
\end{aligned} \tag{4.2}
$$

As for the baseline specification, we include bank and time fixed effects and cluster standard errors at the bank level.

4.4 Results

Due to the differential treatment of identical assets under the collateral framework and the LCR regulation, as well as the preferential treatment of central bank operations within the LCR framework, banks have the opportunity to reduce the regulatory burden of the LCR implementation by altering their pledging behavior with the central bank.

4.4.1 Do banks alter the liquidity profile of pledged collateral?

Using the pre-treatment period Q2 2015 and the post-treatment period Q1 2016 to estimate the effect of the EU-wide LCR introduction, we first consider the liquidity measure as dependent variable. The results are shown by Table 4.2.

We find no macro-level evidence of the LCR introduction by regressing only the treatment dummy, $PostLCR_t$, on the collateral haircut. Column (1) shows that for the haircut no statistically significant effect of the LCR introduction can be estimated. The same applies to the group indicator, $NNLR_i$, (Column 2). When estimating the difference-in-difference specification of equation (4.1) without controlling for observables or unobservables, the individual effects of the two indicators, as well as the interaction term remain insignificant (Column 3). However, the low (within) R-squared of this model indicates a high level of noise within the data. Therefore, we extend our analysis by controlling for bank-specific characteristics in Column (4) and by including bank and quarter fixed effects in Column (5). The regression model shown by Column (4) controls for bank size, capital ratio, returns on assets, loan ratio, debt instruments, interest income, deposits of financial institutions, household deposits, and interest expenses.[15] For the specification with bank controls the coefficient of the LCR-introduction indicator is statistically significant. The effect of 3 percentage points accounts on average to a rise of 25% in the weighted average haircut (Column 4). An increase in the weighted average haircut represent a decrease in the collateral liquidity profile. The interaction coefficient of the NNLR indicator and the treatment dummy remains insignificant in Column (4) and continues to have no statistical relevance, also when we control for unobservables by including bank and time fixed effects (Column 5 and 6). Unobservables like asset purchase programs (APPs) or changes in the collateral framework affect banks' asset holdings and, therefore, are very likely to have an effect on banks' pledging behavior with the central bank. Hence, it is reasonable to account for them in our estimation.

When disaggregating the overall collateral liquidity measure in marketable haircut and non-marketable haircut and including bank-level controls, we estimate a highly significant correlation of the LCR introduction indicator for the haircut of marketable collateral (Column 7). This result suggests that the average haircut of marketable collateral increased after the LCR introduction. However, the national liquidity regulation indicator

[15]While the literature provides ambiguous results concerning the relevance of bank size on banks' liquidity holdings (Deléchat et al., 2014; Kashyap et al., 2002; Aspachs et al., 2005), Drechsler et al. (2016) provide strong evidence for the significance of banks' capitalization for the magnitude of central bank funding as well as the quality of pledged collateral. Controlling for return on assets, we follow the lender of last resort literature and the argumentation that central banks should lend to "illiquid but solvent" banks (Choi et al., 2017; Rochet and Vives, 2004; Deléchat et al., 2014). Given that alternative adjustment strategies can reduce the need to alter the pledging behavior of a bank, we control for changes in banks asset holdings by including loan ratio, debt instruments, and interest income. To control for changes in the quality of bank holdings is also important because collateral liquidity could be directly affected by changes of the same. Besides increasing their relative HQLA holdings, banks can reduce the denominator of the ratio by decreasing the expected outflows. Therefore, we include deposits of financial institutions, household deposits, and interest expenses, to control for changes in refinancing sources considered stable (household deposits) or unstable (deposits of financial institutions) within the LCR framework (Bindseil, 2013; Cornett et al., 2011). For a detailed definition of the variables refer back to Table C.8 in the appendix.

Table 4.2: Liquidity profile of pledged collateral

This table examines the effect of the EU-level LCR introduction on the weighted average haircut of collateral pledged with the ECB. The reported effects are estimated based on the empirical specification of equation (4.1) for the two cross-sections Q2 2015 and Q1 2016. Haircut is the weighted average haircut of all assets included in the collateral pool of the individual bank (Columns 1-6). Marketable (Columns 7-9) and non-marketable (Columns 10-12) haircut are the respective measures for the two sub-categories of the haircut aggregate. PostLCR is an indicator variable for the period after the EU-level LCR introduction. NNLR is one for countries with no preceding national liquidity requirement. Included bank controls are the logarithm of total assets, capital ratio, return on assets, loan ratio, debt instruments, interest income, deposits of financial institution, household deposits and interest expense. All covariates are lagged by one quarter. Standard errors are clustered at the bank level and are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Haircut						Marketable haircut			Non-marketable haircut		
PostLCR	0.721		1.079	3.003**			2.418***			-2.431		
	(0.910)		(0.750)	(1.185)			(0.727)			(1.582)		
NNLR		1.978	2.337	1.658				0.052			0.668	
		(2.360)	(2.758)	(3.006)				(1.095)			(4.817)	
PostLCR#NNLR			-0.707	-1.810	0.802	0.905			1.767***			-2.722***
			(1.863)	(1.826)	(0.829)	(0.770)			(0.600)			(0.996)
R-squared	0.00	0.01	0.01	0.27	0.12	0.36	0.32	0.29	0.54	0.31	0.30	0.35
Bank controls	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	No	No	No	No	Yes	Yes	No	No	Yes	No	No	Yes
Time FE	No	No	No	No	Yes	Yes	No	No	Yes	No	No	Yes
Number of banks	77	77	77	77	77	77	76	76	76	54	54	54
Number of obs. NNLR=1	70	70	70	70	70	70	69	69	69	51	51	51
Observations	150	150	150	150	150	150	149	149	149	104	104	104
Dependent variable												
Mean	12.21	12.21	12.21	12.21	12.21	12.21	5.76	5.76	5.76	32.39	32.39	32.39
Std. dev.	11.03	11.03	11.03	11.03	11.03	11.03	5.89	5.89	5.89	14.90	14.90	14.90

seems to be of no statistical relevance (Column 8). Estimating the difference-in-difference specification with time and bank fixed effects, we find evidence that banks with no preceding national liquidity requirement increased their marketable haircut by nearly 1.8 percentage points more than banks with a preceding national liquidity regulation after the LCR implementation (Column 9). With respect to the mean of the sample, the estimated effect accounts to an increase of over 30% in the marketable haircut. This estimate is in line with our hypothesis that NNLR banks have a higher incentive to switch to less liquid collateral, exploiting the arbitrage opportunity of central bank collateral pledging. For the haircut of non-marketable collateral, we find no macro-level effect of the LCR introduction or the national regulation indicator (Column 10 and 11). For the specification of equation (4.1), we estimate a decrease of -2.7 percentage points (Column 12). With a mean of more than 32 percentage points, this result accounts to a decrease of 8.4% in the average non-marketable haircut. The high mean of the non-marketable haircut is not necessarily due to a lower overall quality of non-marketable collateral compared to marketable collateral but is instead due to the valuation (nominal amount for non-marketable assets) method and the lower liquidity of non-marketable assets in general.

These estimates support the hypothesis that the LCR introduction creates an incentive for banks to pledge less liquid collateral. The findings are also in line with the assumption that banks without preceding national liquidity requirement are more responsive than banks with preceding national regulation. While the finding of the drastic decrease in the liquidity of marketable collateral of NNLR banks is straight forward, the improvement of the average liquidity of non-marketable collateral is not. However, given that non-marketable assets are never HQLA, we can state that the improvement in the liquidity of non-marketable collateral is no contradiction of the hypothesis.

4.4.2 Do banks alter the quantity of pledged collateral?

We repeat our estimations for the liquidity profile of pledged collateral with the natural logarithm of the amount of pledged collateral after haircuts as dependent variable to evaluate whether the introduction of the LCR had an effect on collateral quantity.

We find no macro-level evidence for an effect of the LCR introduction, $PostLCR_t$, on the total collateral value as shown in Column (1) of Table 4.3. Also the absence of a preceding national liquidity requirement, $NNLR_i$, is not of statistical significance for the quantity measure (Column 2). When also including the interaction term of the two indicator variables, the individual terms, as well as the interaction term remain insignificant as shown by Column (3). Like for the liquidity measure, the estimated (within) R-squared is very small. To control for the noise in the data, we again include the bank controls used for collateral liquidity profile. The estimates in Column (4) show that the interaction term and the individual terms of the two indicators remain insignificant when including bank controls. However, the estimate for the interaction term is highly significant for the regression with the fixed effects shown in Column (5). Including time and bank fixed effects, as well as covariates, the interaction term remains highly significant.

As for the liquidity profile of collateral, we distinguish between marketable and non-marketable collateral. We find no macro-level effect of the LCR introduction on the marketable collateral value (Column 7), but a significant effect of the national regulation indicator (Column 8). This result suggests that NNLR banks seem to pledge on average approximately 9% more marketable collateral than banks with a preceding national liquidity requirement. Given that we do not control for unobservables, this estimate should not be overstated. However, it supports our assumption that banks with preceding national regulation already made adjustments in response to the national regulation, either in their liquidity risk profile or by altering their pledging behavior.

TABLE 4.3: Quantity of pledged collateral

This table examines the effect of the EU-level LCR introduction on the collateral value pledged with the ECB. The reported effects are estimated based on the empirical specification of equation (4.1) for the two cross-sections Q2 2015 and Q1 2016. Collateral value is the natural logarithm of the total collateral minus the respective haircut (Columns 1-6). Marketable (Columns 7-9) and non-marketable (Columns 10-12) collateral value are the respective measures for the two sub-categories of the collateral aggregate. PostLCR is an indicator variable for the period after the EU-level LCR introduction. NNLR is one for countries with no preceding national liquidity requirement. Included bank controls are the logarithm of total assets, capital ratio, return on assets, loan ratio, debt instruments, interest income, deposits of financial institution, household deposits and interest expense. All covariates are lagged by one quarter. Standard errors are clustered at the bank level and are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Collateral value						Marketable collateral value			Non-marketable collateral value		
PostLCR	0.163		-0.010	0.115			0.069			0.278*		
	(0.131)		(0.142)	(0.093)			(0.093)			(0.142)		
NNLR		0.635	0.445	0.188				0.671**			-0.061	
		(0.391)	(0.449)	(0.287)				(0.334)			(0.417)	
PostLCR#NNLR			0.392	0.179	0.154***	0.143**			0.084			0.426***
			(0.271)	(0.175)	(0.051)	(0.061)			(0.069)			(0.089)
R-squared	0.00	0.03	0.04	0.79	0.11	0.18	0.51	0.53	0.21	0.62	0.62	0.48
Bank controls	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	No	No	No	No	Yes	Yes	No	No	Yes	No	No	Yes
Time FE	No	No	No	No	Yes	Yes	No	No	Yes	No	No	Yes
Number of banks	77	77	77	77	77	77	76	76	76	54	54	54
Number of obs. NNLR=1	70	70	70	70	70	70	69	69	69	51	51	51
Observations	150	150	150	150	150	150	149	149	149	104	104	104
Dependent variable												
Mean	8.16	8.16	8.16	8.16	8.16	8.16	7.83	7.83	7.83	6.85	6.85	6.85
Std. dev.	1.83	1.83	1.83	1.83	1.83	1.83	2.12	2.12	2.12	1.69	1.69	1.69

For the marketable collateral value, we find no statistically significant effect of the interaction of the NNLR indicator and the LCR-introduction indicator when estimating the specification of equation (4.1) (Column 9). For non-marketable collateral value as dependent variable, the LCR introduction dummy is statistically significant, while the group indicator is not (Column 10 and 11). These estimates suggest that banks increased the value of non-marketable collateral on average by over 4% in response to the LCR introduction, but that there is no fundamental difference for NNLR and non-NNLR banks. As mentioned before, given that we do not control for time and bank specific fixed effects, the estimates of the individual coefficients of the indicator variables should be considered with care. Column (12) shows that estimating the specification of equation (4.1), we find that the interaction coefficient is highly significant for non-marketable collateral value.

The estimates in Column (6), (9), and (12) indicate that NNLR banks increased the collateral value pledged with the ECB in comparison to non-NNLR banks during the LCR introduction. This increase in collateral value seems to be driven by non-marketable collateral. In terms of economical significance, banks increase the non-marketable collateral value pledged with the central bank by approximately 6% more than banks with a preceding national liquidity requirement. The results complement our estimations for the liquidity measure of pledged collateral. The estimated improvement in the weighted average liquidity of the non-marketable collateral could be driven by the increase in pledged collateral. Because we can not distinguish whether the increase in pledged collateral is driven by an increase in central bank funding or overcollateralization, we can not be sure that the preferential treatment of central bank funding within the LCR framework has enhanced the demand for central bank funding backed by non-HQLA. If the estimated increase in the quantity of pledged collateral is due to overcollateralization, this would have implications for the results on the collateral liquidity profile. With HQLA remaining in the collateral pool, the estimated effect of the added non-HQLA on the weighted average liquidity of the collateral pool is weaker, compared to if the HQLA are withdrawn and substituted by non-HQLA. Therefore, the estimated effect of the LCR introduction on the liquidity profile of pledged (and required) collateral could be underestimated with an increase in overcollateralization. Both cases, the increase in overcollateralization and the increase in central bank funding, do not stand in contrast to our hypothesis.

Concerning the preparation effect of the national liquidity requirement, we find evidence that banks with a preceding national liquidity requirement pledge less marketable collateral compared to NNLR banks.

4.4.3 Heterogeneities

Since certain countries were more exposed than others to the financial crisis and the sovereign debt crisis, we extent our analysis by controlling for the so called GIIPS countries, Greece, Ireland, Italy, Portugal, and Spain. While time fixed effects control for uniform factors across banks, the GIIPS indicator accounts for differences across the two country groups, GIIPS and non-GIIPS. Such a group specific confounding factor is for example the unconventional monetary policy of the ECB, especially the APPs. Table 4.4 reports the estimates for marketable, and non-marketable haircut and the marketable and non-marketable collateral value.

For the marketable haircut we estimate no significant GIIPS specific effect of the LCR introduction and the LCR-introduction-NNLR interaction estimate is in line with the baseline result (Column 1). Column (2) shows that the previously estimated relative reduction in the non-marketable haircut of NNLR banks in response to the LCR introduction is driven by NNLR-GIIPS banks. This is not surprising given that more than 40% of the observations are from NNLR-GIIPS banks (Italy, Portugal, or Spain). Only for marketable collateral (Column 3), we find a weakly significant effect of the triple interaction but no statistically significant effect for the non-marketable collateral value (Column 4). These results contrast with our baseline results which indicate an increase in non-marketable collateral value.

TABLE 4.4: Country heterogeneity: GIIPS

This table examines the effect of the EU-level LCR introduction on haircut and collateral value of assets pledged with the ECB, while controlling for a specific group of countries. The reported effects are estimated based on the empirical specification of equation (4.2) for the two cross-sections Q2 2015 and Q1 2016. PostLCR is zero for the earlier period and one for the later period. NNLR is one for countries with no preceding national liquidity requirement. GIIPS is one if the bank originates in Greece, Ireland, Italy, Portugal or Spain. All columns include bank and time fixed effects, as well as bank controls. All covariates are lagged by one quarter. Standard errors are clustered at the bank level and are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

VARIABLES	(1) Marketable haircut	(2) Non-marketable haircut	(3) Marketable collateral value	(4) Non-marketable collateral value
PostLCR#NNLR#GIIPS	-2.078	-5.283**	0.400*	0.246
	(1.714)	(2.352)	(0.236)	(0.220)
PostLCR#NNLR	2.190**	0.443	-0.071	0.186
	(1.063)	(1.798)	(0.154)	(0.135)
PostLCR#GIIPS	1.780	1.879	-0.227	0.053
	(1.305)	(1.180)	(0.168)	(0.164)
R-squared	0.55	0.40	0.26	0.51
Bank controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Number of banks	76	54	76	54
Number of obs. NNLR=1	69	51	69	51
Number of obs. GIIPS=1	68	56	68	56
Observations	149	104	149	104
Dependent variable				
Mean	5.76	32.39	7.83	6.85
Std. dev.	5.89	14.90	2.12	1.69

Until the final minimum requirement was reached in January 2018, member states could maintain or introduce national liquidity regulations in addition to the LCR.[16] To control for this, we specify an indicator called toughness (TH). TH is equal to one if the bank faces a national liquidity requirement even after the LCR was introduced. Table C.9 in the appendix provides further details on which country kept/reviewed to keep its national liquidity requirements. Since we are not aware of a country to have introduced a new national regulation for the implementation period of the LCR, the triple interaction term of equation (4.2) drops out. The estimated results are reported by Table 4.5. For all dependent variables, the estimated LCR-introduction-NNLR interaction effects are consistent with the baseline results. Only for the non-marketable haircut, we estimate a (weakly) significant negative effect of the LCR introduction for banks with an additional national liquidity requirement (Column 2). Although the finding for the non-marketable haircut is difficult to rationalize, the estimates

[16]Paragraph 5, article 412, CRR 2013

provide no evidence that the retention of a national liquidity requirement is of high relevance for banks reaction to the LCR introduction.

TABLE 4.5: Regulatory design: toughness

This table examines the effect of the EU-level LCR introduction on haircut and collateral value of assets pledged with the ECB, while considering whether the national liquidity regulation is still in place during the transition period. The reported effects are estimated based on the empirical specification of equation (4.2) for the two cross-sections Q2 2015 and Q1 2016. PostLCR is zero for the earlier period and one for the later period. NNLR is one for countries with no preceding national liquidity requirement. TH is one if the country where the bank originates keeps the national liquidity requirement in place parallel to the LCR. All columns include bank and time fixed effects, as well as bank controls. All covariates are lagged by one quarter. Standard errors are clustered at the bank level and are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

VARIABLES	(1) Marketable haircut	(2) Non-marketable haircut	(3) Marketable collateral value	(4) Non-marketable collateral value
PostLCR#NNLR	2.300***	-5.485***	0.037	0.543***
	(0.694)	(1.761)	(0.058)	(0.148)
PostLCR#TH	0.705	-3.514*	-0.063	0.149
	(0.735)	(1.786)	(0.071)	(0.155)
R-squared	0.54	0.42	0.21	0.49
Bank controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Number of banks	76	54	76	54
Number of obs. NNLR=1	69	51	69	51
Number of obs. TH=1	64	43	64	43
Observations	149	104	149	104
Dependent variable				
Mean	5.76	32.39	7.83	6.85
Std. dev.	5.89	14.90	2.12	1.69

Besides their national liquidity regulation, countries have the discretion to introduce the LCR immediately with 100% rather than opting for the step wise introduction.[17] Introducing the LCR with 100% is called front-loading and can be considered a harsher implementation strategy as it puts additional burden on affected banks. We control for the potential effect of front-loading by introducing the indicator FL. FL is one if a country requires a LCR minimum of 100% from its banks from October 2015 onwards. Table C.9 (appendix) provides country specific details. The estimates reported in Table 4.6 show that front-loading seems to have no NNLR-LCR-introduction specific effect on the liquidity profile or the quantity of pledged collateral. The estimated effects for the LCR-introduction-NNLR interaction term are consistent with the baseline results. Only for the non-marketable haircut,

[17] Paragraph 1, article 38 of the Commission Delegated Regulation (EU) 2015/61. For details regarding the step wise introduction see Figure C.6 in the appendix.

we estimate a positive and significant effect of the LCR-introduction-front-loading interaction (Column 2). This result supports the hypothesis that front-loading puts additional pressure on affected banks.

TABLE 4.6: Regulatory design: front-loading

This table examines the effect of the EU-level LCR introduction on haircut and collateral value of assets pledged with the ECB, while controlling for the intensity of the LCR introduction. The reported effects are estimated based on the empirical specification of equation (4.2) for the two cross-sections Q2 2015 and Q1 2016. PostLCR is zero for the earlier period and one for the later period. NNLR is one for countries with no preceding national liquidity requirement. FL is one if the country where the bank originates introduces the LCR with 100% instead of 60%. All columns include bank and time fixed effects, as well as bank controls. All covariates are lagged by one quarter. Standard errors are clustered at the bank level and are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

VARIABLES	(1) Marketable haircut	(2) Non-marketable haircut	(3) Marketable collateral value	(4) Non-marketable collateral value
PostLCR#NNLR#FL	1.449	1.656	-0.155	-0.427
	(2.034)	(2.931)	(0.362)	(0.310)
PostLCR#NNLR	1.597**	-2.512***	0.094	0.439***
	(0.624)	(0.940)	(0.079)	(0.102)
PostLCR#FL	-0.316	5.038**	-0.019	-0.012
	(1.236)	(1.932)	(0.079)	(0.142)
R-squared	0.54	0.48	0.22	0.50
Bank controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Number of banks	76	54	76	54
Number of obs. =1	69	51	69	51
Number of obs. FL=1	23	7	23	7
Observations	149	104	149	104
Dependent variable				
Mean	5.76	32.39	7.83	6.85
Std. dev.	5.89	14.90	2.12	1.69

While the results of marketable collateral are very consistent, the findings for non-marketable collateral show that multiple effects are at work.

4.5 Robustness

To test whether certain countries drive the results, we include one country specific-LCR-introduction dummy at a time in the empirical specification. We find that the estimates of the LCR-introduction-NNLR-interaction coefficient are in line with the baseline results for marketable haircut, non-marketable haircut, marketable collateral value and non-marketable collateral value (Table C.10 in the appendix). The coefficient estimates of the respective country specific LCR-introduction-NNLR-interaction is only occasionally significant. The results are also robust when excluding one country after another from the sample (Table C.11 in the appendix) except for the specification with the non-marketable haircut as dependent variable when Italy is excluded. In this case the interaction effect is no longer significant but remains negative. This result is likely due to the substantial reduction in observations from 104 to only 80 observations.

The possibility to improve the LCR by exploiting the friction of the collateral framework and assets considered as HQLA is open to every bank with access to the Eurosystem's refinancing operations. However, the incentive to do so might differ for the individual bank. Fecht et al. (2016) and Drechsler et al. (2016) provide evidence that especially weaker banks exploit the credit-risk loophole of central bank refinancing operations by requesting a greater quantity of funding and by pledging riskier collateral.

With the introduction of the LCR the relative opportunity costs to pledge HQLA instead of non-HQLA increases. The magnitude of this change in evaluations depends on the individual situation of the bank. A less solvent or liquidity constraint bank might be more heavily hit by the regulatory shock of the LCR implementation, while a collateral scarce bank might not have the opportunity to exploit the friction of the two frameworks in the first place. Figure C.3, C.4, and C.5 in the appendix show the marginal effects of the triple interaction term $PostLCR$-NNLR-$Treated$ when $Treated$ is defined based on the bank characteristics z-score, risk adjusted returns, or risk density.[18] The three figures show that our baseline results are unlikely to be driven by banks with certain bank characteristics like a high risk to default (low z-score), low financial stability (low risk adjusted returns), or a high liquidity need/low ratio of central bank eligible assets (high risk density).

In our estimations we solely consider two cross-sections to avoid confounding events. Potential confounding factors are changes in the collateral framework, APPs, targeted longer-term refinancing operations (TLTROs), and other regulatory or monetary policy events. Confounding factors which

[18]To limit the number of graphs, we consider only the collateral value and the haircut of marketable and non-marketable collateral as dependent variables.

equally affect all sample banks are captured by the included time fixed effects. However, bank specific differences in the effect of those factors are not considered. Concerning the collateral framework, we are aware of only one change during our sample period. Since November 2015 non-marketable debt instruments backed by eligible credit claims can be used to secure refinancing operations with the ECB.[19] This particular change in the collateral framework affects the eligibility of non-marketable collateral and therefore can only influence our estimates concerning the total and non-marketable collateral measures. Other than this change, we are not aware of any changes in the collateral framework, and also of no change concerning the applied haircuts or the evaluation techniques. Like changes in the collateral framework, APPs affect the amount and composition of central bank eligible asset holdings of banks. Considering that our sample covers only very large banks, we can expect that all sample banks are affected by the APPs and that these uniform effects are captured by time fixed effects. A likely difference in the effect of APPs on sample banks is between crisis and non-crisis banks. For such a GIIPS specific effect of the APPs, we control in Section 4.4.3. A similar argumentation can be applied to banks' participation in TLTROs. TLTROs could affect our results because they provide an incentive to increase central bank funding due to their long maturity (up to four years) and attractive interest rates. TLTROs were first introduced in September 2014 and from then on were exercised with a quarterly frequency throughout our sample period. In addition to time fixed effects, we control for bank specific differences in regard to the TLTROs by including the loan share in banks' balance sheets within our regressions. Doing so is relevant because the amount that banks can borrow is linked to the amount of loans they provide to non-financial corporations and households. In addition, Bock et al. (2018) provide evidence that TLTRO funding was used to replace other, shorter maturity refinancing operations like the longer-term refinancing operations

[19] Alvarez et al. (2017) and Bindseil et al. (2017)

and not so much to increase central bank funding.[20] Furthermore, we are not aware of other regulatory events occurring during the sample period and affecting banks' asset holdings or their decision on what to pledge with the central bank.

Another source of possible bias concerning our estimations is the practice of pledging too much collateral. Overcollateralization is already mention in Section 4.3.1 in regard to the informative value of the variable collateral value. We expect excess collateral to reduce the volatility of the liquidity profile and the quantity of pledged collateral. In this regard, the change in the weighted average haircut is likely to be underestimated, given that banks are more likely to pledge less liquid collateral in excess already. The change in quantity of pledged collateral could also be underestimated because the magnitude of excess collateral could be reduced if the overall demand of central bank funding increases.

To test how sensitive our results are concerning the sample period, we extend our sample period to multiple pre- and post-treatment periods. The pre-treatment period can be extended by one additional quarter and consequently varies between Q1 2015 and Q2 2015. The post-treatment period can be extended until Q4 2016. Hence, the post-treatment period covers up to four quarters. Table 4.7 reports only the interaction results of the LCR introduction indicator and the NNLR indicator for the total, marketable, and non-marketable haircut, and collateral value. The respective and varying sample periods used for the estimations are specified in the lower part of the table. The baseline estimates with the pre-treatment period Q2 2015 and the post-treatment period Q1 2016 are shown in Column (2). The specification with the longest sample period is Column (7), employing the two quarters Q1 and Q2 2015 as pre-treatment period and the entire year 2016 as post-treatment period. Table 4.7 shows that all estimates are consistent with our baseline results. The interaction effect on the total haircut is positive and partly significant (Part A). For the marketable haircut, we find positive and

[20] Chart 9 in Bock et al. (2018) shows the aggregate evolution and composition of ECB's refinancing operations. With regard to our (post) sample period, the 6th and 7th operation of TLTRO-I are most relevant.

highly significant interaction effects for all sample period variations (Part B), while the interaction coefficient for the non-marketable haircut is highly significant and negative (Part C). For the total collateral value, we find positive and highly significant effects (Part D). The coefficient of interest is positive but not significant for the marketable collateral value (Part E), except when using Q1 and Q2 2015 as pre-treatment period and Q1 2016 as only post-treatment quarter (Column 1). Part (F) shows that the interaction coefficient is highly significant for all sample period variations for the non-marketable collateral value. The magnitude of the estimated effects is also very stable.

The estimations shown in Table 4.7 exclude the treatment periods Q3 and Q4 2015. To consider the effect of the treatment period on our results, we rerun our estimations including the two quarters. Given that the LCR was introduced in October 1st, 2015, Q3 2015 is considered within the pre-treatment period, while Q4 2015 is included in the post-treatment period. In this set up, the start of the pre-treatment period varies between the first quarter of 2015 until the third quarter of 2015, while the end of the post-treatment period varies from Q4 2015 until Q4 2016. The results confirm our earlier findings. The interaction term coefficient for the aggregate haircut remains insignificant but highly significant and negative for the non-marketable haircut. For the marketable haircut the estimated interaction term is positive and significant, unless only Q4 2015 is considered as post-treatment period. These results strongly indicate that there was an anticipation effect. Also the results for collateral quantity support previous estimates with the interaction term for total collateral remaining positive and mostly significant. The difference in difference effect for marketable collateral remains insignificant and positive, as well as highly significant for non-marketable collateral. Results are reported by Table C.13 in the online appendix.

Table 4.7: Panel

This table reports the interaction effect of estimating the empirical specification of equation (4.1) for different sample periods. The respective sample period is indicated in the lower part of the table. Like for the baseline specification the treatment period Q3 and Q4 2015 are excluded in all estimations. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2) Baseline	(3)	(4)	(5)	(6)	(7)	(8)
(A)					Haircut			
PostLCR#NNLR	0.743	0.905	1.139	1.489*	1.765*	2.142**	1.621	1.446
	(0.742)	(0.770)	(0.788)	(0.816)	(0.985)	(1.013)	(1.186)	(1.333)
Observations	222	150	296	224	370	298	444	372
R-squared	0.14	0.36	0.08	0.15	0.08	0.09	0.09	0.07
Dependent var.								
Mean	12.41	12.21	12.31	12.15	12.35	12.23	12.42	12.35
Std. dev.	11.56	11.03	11.10	10.56	10.82	10.35	10.70	10.29
(B)					Marketable haircut			
PostLCR#NNLR	1.469**	1.767***	1.966***	2.380***	2.473***	2.792***	2.746***	2.955***
	(0.620)	(0.600)	(0.681)	(0.717)	(0.824)	(0.892)	(0.948)	(1.030)
Observations	220	149	294	223	368	297	442	371
R-squared	0.38	0.54	0.17	0.17	0.15	0.13	0.14	0.12
Dependent var.								
Mean	5.60	5.76	5.75	5.91	5.91	6.06	6.04	6.19
Std. dev.	5.88	5.89	5.41	5.25	5.16	4.97	5.08	4.90
(C)					Non-marketable haircut			
PostLCR#NNLR	-2.338**	-2.722***	-2.801**	-2.709**	-3.337***	-2.862***	-2.834**	-3.143**
	(1.086)	(0.996)	(1.117)	(1.050)	(1.163)	(0.983)	(1.266)	(1.358)
Observations	157	104	209	156	259	206	310	257
R-squared	0.21	0.35	0.20	0.24	0.18	0.24	0.16	0.15
Dependent var.								
Mean	32.83	32.39	32.53	32.13	32.39	32.05	32.24	31.94
Std. dev.	15.04	14.90	14.87	14.70	14.80	14.65	14.71	14.57
(D)					Collateral value			
PostLCR#NNLR	0.207***	0.143**	0.276***	0.220***	0.290***	0.238***	0.342***	0.325***
	(0.066)	(0.061)	(0.069)	(0.068)	(0.088)	(0.086)	(0.104)	(0.114)
Observations	222	150	296	224	370	298	444	372
R-squared	0.19	0.18	0.16	0.11	0.15	0.11	0.17	0.14
Dependent var.								
Mean	8.15	8.16	8.17	8.18	8.15	8.15	8.12	8.12
Std. dev.	1.87	1.83	1.86	1.83	1.90	1.89	1.92	1.91
(E)					Marketable collateral value			
PostLCR#NNLR	0.151**	0.084	0.125	0.047	0.125	0.059	0.151	0.094
	(0.072)	(0.069)	(0.114)	(0.126)	(0.140)	(0.147)	(0.154)	(0.157)
Observations	220	149	294	223	368	297	442	371
R-squared	0.15	0.21	0.03	0.02	0.02	0.02	0.03	0.04
Dependent var.								
Mean	7.80	7.83	7.84	7.87	7.82	7.84	7.80	7.81
Std. dev.	2.24	2.12	2.16	2.05	2.15	2.07	2.14	2.07
(F)					Non-marketable collateral value			
PostLCR#NNLR	0.475***	0.426***	0.474***	0.416***	0.482***	0.385***	0.492***	0.442***
	(0.101)	(0.089)	(0.106)	(0.093)	(0.128)	(0.106)	(0.143)	(0.143)
Observations	157	104	209	156	259	206	310	257
R-squared	0.36	0.48	0.32	0.38	0.25	0.28	0.18	0.18
Dependent var.								
Mean	6.86	6.85	6.86	6.86	6.88	6.89	6.89	6.90
Std. dev.	1.70	1.69	1.73	1.73	1.73	1.73	1.72	1.72
Startperiod	Q1 2015	Q2 2015	Q1 2015	Q2 2015	Q1 2015	Q2 2015	Q1 2015	Q2 2015
Endperiod	Q1 2016	Q1 2016	Q2 2016	Q2 2016	Q3 2016	Q3 2016	Q4 2016	Q4 2016

4.6 Conclusion

In this paper, we study whether the introduction of the LCR had adverse effects on the liquidity profile and the quantity of collateral provided by banks to secure central bank refinancing operations. The change in the liquidity profile of collateral is triggered by a differential treatment of assets by the LCR framework and the collateral framework. Whereas, the change in the quantity of collateral either indicates an increase in central bank funding motivated by the preferential treatment of central bank funding over other funding sources or an increase in overcollateralization due to the calculation practice of the LCR. We use the existence of national liquidity requirements to proxy for banks' incentives to exploit these differential treatments.

For banks without national liquidity requirement, the weighted average haircut of marketable collateral increases by more than 30% after the LCR introduction compared to banks with national liquidity requirement. For non-marketable collateral, we find a decrease of 8.4% in the weighted average haircut, which could be driven by the corresponding increase in non-marketable collateral value of 6%. These results support our hypothesis that banks without preceding national liquidity requirement have a higher incentive to exploit the differential treatments in response to the LCR introduction and also indicate that banks take advantage of the differential treatments to improve their LCR value, without altering their liquidity risk profile or by just increasing their reliance on the central bank. This is a relevant finding given that such a development reduces the regulatory effectiveness of the LCR.

Our estimates are robust when controlling for one-country-specific effects and when extending the sample period from the two cross sections of the baseline specification to a panel, including and excluding the treatment period. We find no strong indications that our results are driven by less solvent banks. Also controlling for the regulatory design does not affect our previous results. However, we can not exclude the possibility that our results are affected by the APPs, TLTROs, or other changes affecting banks' asset holdings. Changes in the collateral framework are unlikely to exert a confounding effect, given that there was only a minor change for non-marketable collateral.

Appendix C

C.1 Figures

FIGURE C.2: National liquidity requirements

Countries with no national liquidity requirement (NNLR) were not exposed to a national liquidity requirement with features comparable to the LCR. Similarities to the LCR could be regarding the time horizon of the ratio or the calculation of the ratio components HQLA, outflow or inflows.

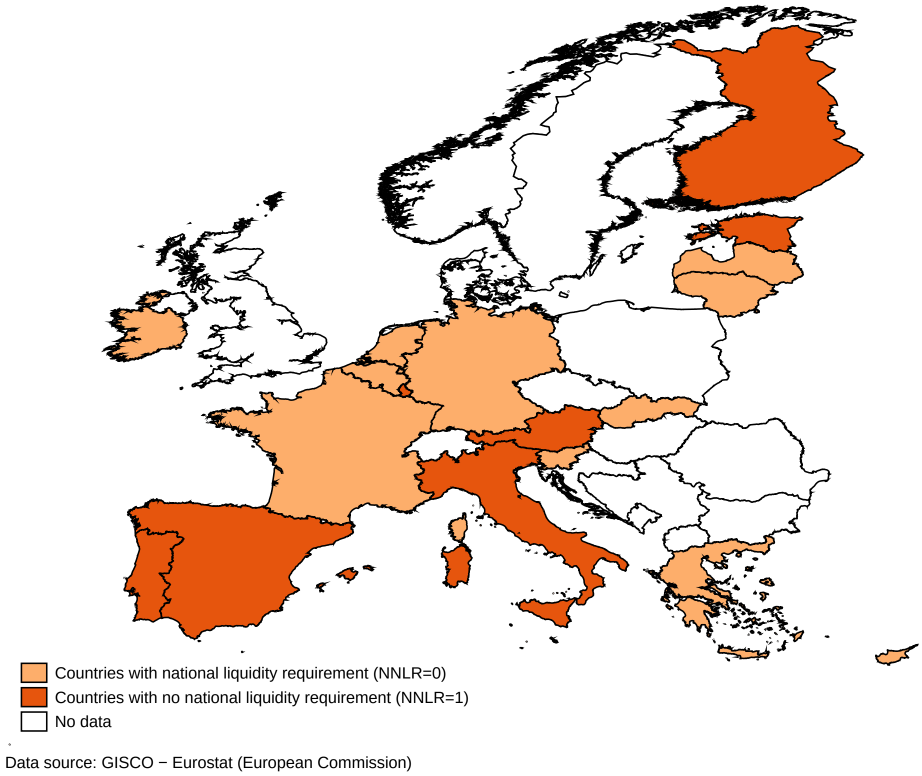


Figure C.3: Marginal effect of triple interaction on liquidity and quantity measures for different percentile thresholds of Treated based on z-score

These graphs show the estimated marginal effects of the PostLCR-NNLR-Treated interaction on the respective collateral measure (left y-axis). Treated is estimated based on an threshold value determined by the percentile of the x-axis. The respective threshold is shown by the right y-axis. A bank is considered to be Treated=1, if its pre-sample period z-score (Q3 2014 until Q1 2015) is **smaller or equal** to the Xth percentile of the pre-sample period sample. The estimates are generated including bank and time fixed effects, as well as bank controls following equation (4.2). For each of the 81 estimates the respective 95% confidence interval is shown.

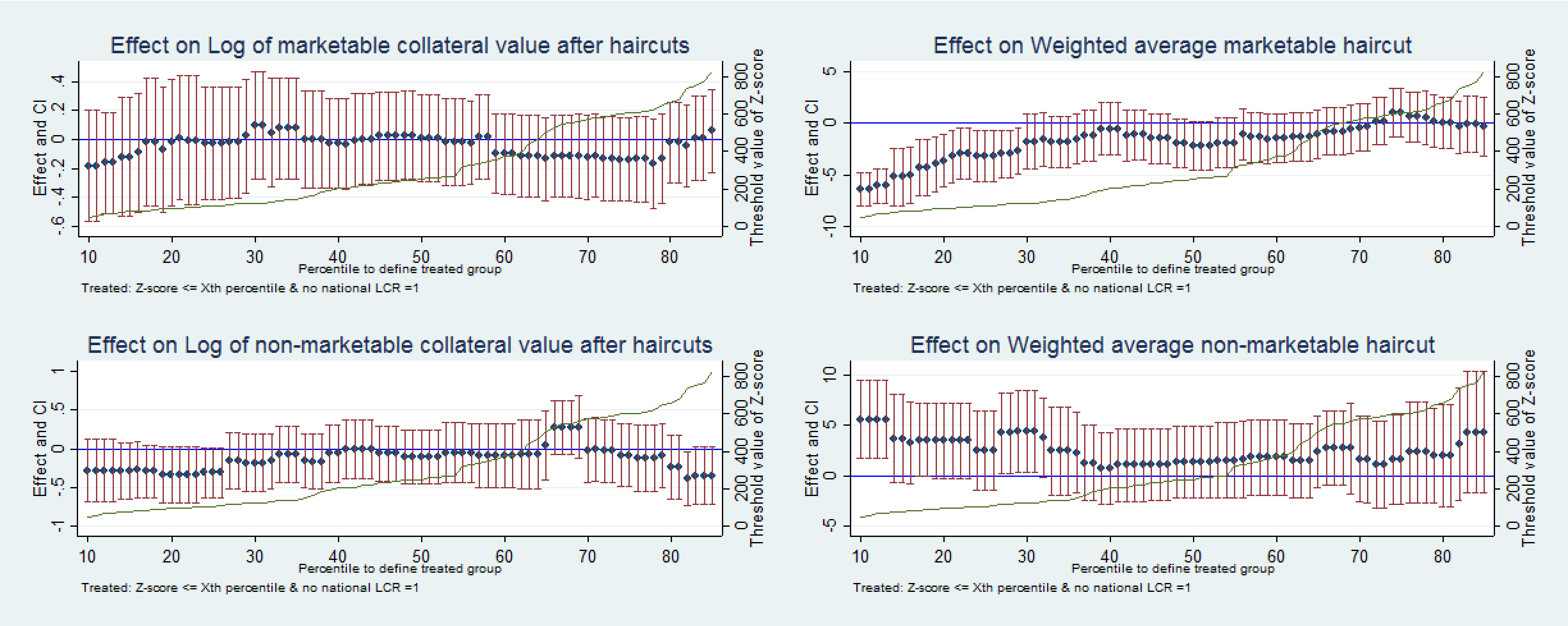


FIGURE C.4: Marginal effect of triple interaction on liquidity and quantity measures for different percentile thresholds of Treated based on risk adjusted returns

These graphs show the estimated marginal effects of the PostLCR-NNLR-Treated interaction on the respective collateral measure (left y-axis). Treated is estimated based on an threshold value determined by the percentile of the x-axis. The respective threshold is shown by the right y-axis. A bank is considered to be Treated=1, if its pre-sample period risk adjusted returns (Q3 2014 until Q1 2015) is **smaller or equal** to the Xth percentile of the pre-sample period sample. The estimates are generated including bank and time fixed effects, as well as bank controls following equation (4.2). For each of the 81 estimates the respective 95% confidence interval is shown.

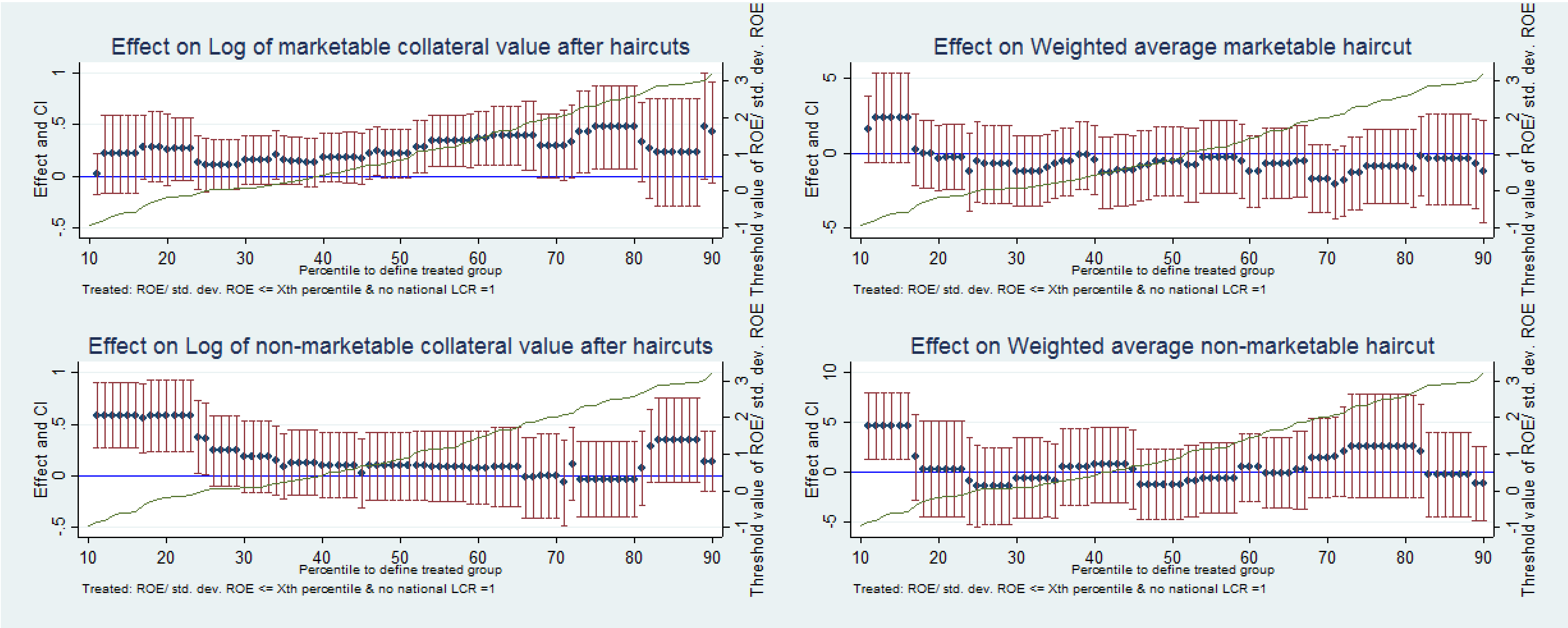


Figure C.5: Marginal effect of triple interaction on liquidity and quantity measures for different percentile thresholds of Treated based on risk density

These graphs show the estimated marginal effects of the PostLCR-NNLR-Treated interaction on the respective collateral measure (left y-axis). Treated is estimated based on an threshold value determined by the percentile of the x-axis. The respective threshold is shown by the right y-axis. A bank is considered to be Treated=1, if its pre-sample period risk density (Q3 2014 until Q1 2015) is **larger** than the Xth percentile of the pre-sample period sample. The estimates are generated including bank and time fixed effects, as well as bank controls following equation (4.2). For each of the 81 estimates the respective 95% confidence interval is shown.

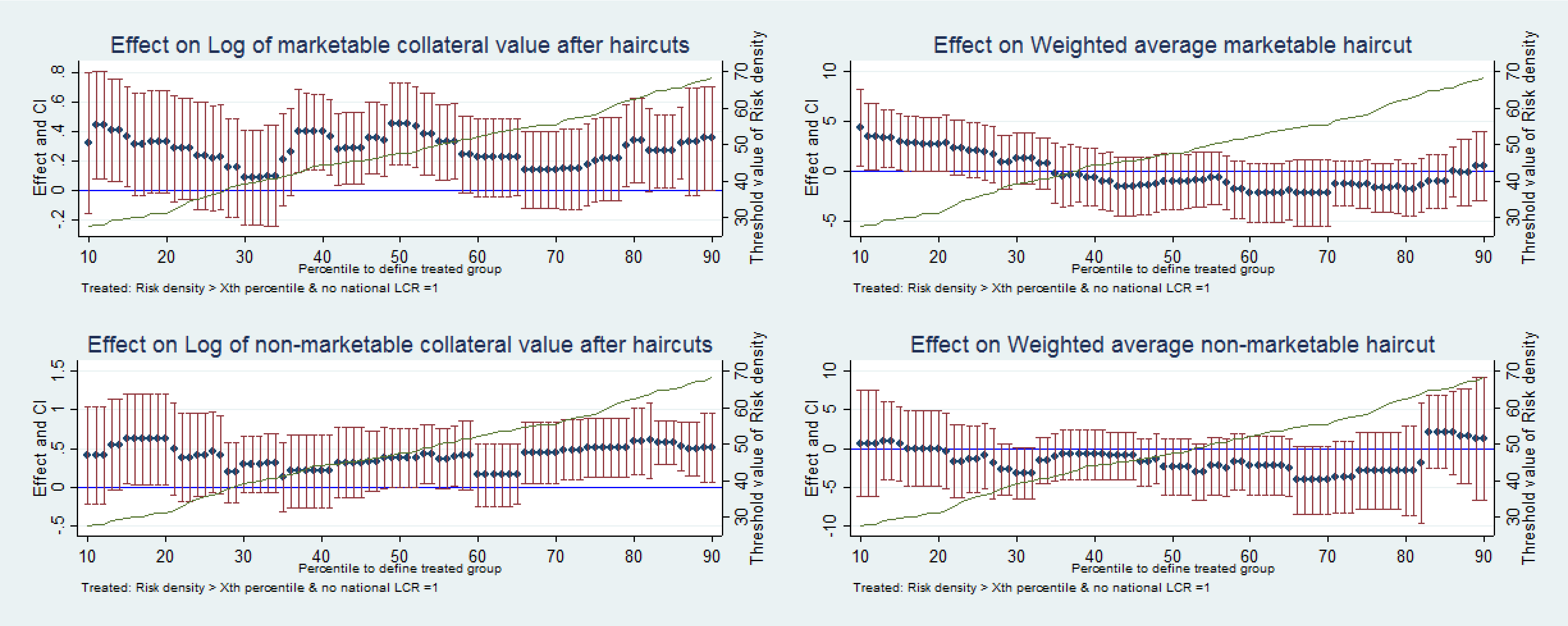
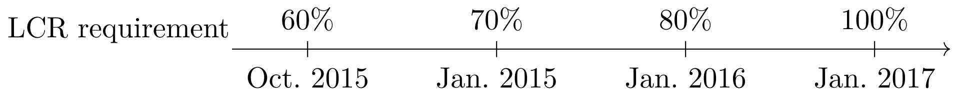


Figure C.6: Timeline of LCR introduction in EU

As described by paragraph 1, article 38 of the Commission Delegated Regulation (EU) 2015/61, the LCR introduction followed a step-wise implementation. Countries could also opt for a so called front-loading approach by introducing the LCR directly with 100% in October 2015. These countries are listed by Table C.9.



C.2 Tables

Table C.8: Data appendix

Notes: MV = market value, CV = collateral value, market value reduced by haircut; haircut formula deviation: CV = MV(1-haircut) ⇒ haircut = 1 - CV/MV = (MV - CV)/MV; $\text{Treated}_{i/j}$, as included in equation 4.2, is a placeholder for FH TH GIIPS. In Section 4.5, Treated_i is also a 0/1 dummy variable and based on values of risk density, z-score or risk adjusted returns.

Variable	Description	Data source
Dependent variables		
Haircut	$[\frac{\sum_{i=c}\text{MV}_{ijt}-\sum_{i=c}\text{CV}_{ijt}}{\sum_{i=c}\text{MV}_{ijt}}]_{jt}$, with c = every asset included in the collateral pool from bank j in time t	Market Operations Department, ECB
Marketable haircut	$[\frac{\sum_{i=c}\text{MV}_{ijt}-\sum_{i=c}\text{CV}_{ijt}}{\sum_{i=c}\text{MV}_{ijt}}]_{jt}$, with c = every marketable asset included in the collateral pool from bank j in time t	
Non-marketable haircut	$[\frac{\sum_{i=c}\text{MV}_{ijt}-\sum_{i=c}\text{CV}_{ijt}}{\sum_{i=c}\text{MV}_{ijt}}]_{jt}$, with c = every non-marketable asset included in the collateral pool from bank j in time t	
Collateral value	$\text{Log}[\sum_{i=c}\text{MV}_{ijt}(1-\text{haircut}_{it})]_{jt}$, with c = every asset included in the collateral pool of bank j in time t	
Marketable collateral value	$\text{Log}[\sum_{i=c}\text{MV}_{ijt}(1-\text{haircut}_{it})]_{jt}$, with c = every marketable asset included in the collateral pool of bank j in time t	
Non-marketable collateral value	$\text{Log}[\sum_{i=c}\text{MV}_{ijt}(1-\text{haircut}_{it})]_{jt}$, with c = every non-marketable asset included in the collateral pool of bank j in time t	
Covariates		
Log of total assets	Calculated based on FINREP data, sheet 01.01 x=10 y=380	
Capital ratio	Tier 1 capital ratio (in %), calculated based on COREP data, sheet 01.00 x=10 y=15	SSM, ECB
ROA	Profit or loss to total assets (in %) Calculated based on FINREP data, sheet 02.00 x=10 y=670	SSM, ECB
Loans	Loans to total assets (in %), calculated based on FINREP data, sheet 01.01 x=10 y=40,90,130,170, 200, 230	SSM, ECB
Debt instruments	Debt instruments to total assets (in %), calculated based on FINREP data, sheet 01.01 x=10 y=80,120,160,190,220	SSM, ECB
Interest income	Interest income to total assets (in %), calculated based on FINREP data, sheet 02.00 y=10 x=10	SSM, ECB
Interest expense	Interest expense to total assets (in %), calculated based on FINREP data, sheet 02.00 y=10 x=90	SSM, ECB
Household deposits	Household deposits to total assets (in %), calculated based on FINREP data, sheet 08.01 y=310 x=10,20,30,34,35	SSM, ECB
Deposits of fin. institutions	Deposits of financial institutions to total assets (in %), calculated based on FINREP data, sheet 08.01 y=160 x=10,20,30,34,35	SSM, ECB
Dummies		
PostLCR	Dummy variable (0/1) =1 for all time periods from Q4 2015 onwards	
NNLR	Dummy variable (0/1) =1 if EU-wide LCR was not preceded by national liquidity requirement with features similar to the EU-wide counterpart, see Figure C.2 for details	
FH	Front-loading dummy, dummy variable (0/1) =1 if EU-wide LCR is introduced with 100% by country, see Table C.9 for details	
TH	Toughness dummy, dummy variable (0/1) =1 if national liquidity requirement is still in place or under review, see Table C.9 for details	
GIIPS	Dummy variable (0/1) =1 if bank is Greece, Italian, Irish, Portuguese or Spanish	
Others		
Risk density	Calculated based on COREP data, sheet 01.00 x=10 y=15	SSM, ECB
Z-score	$\left[\mu(\text{ROA}) + \text{capital assets ratio}\right]/\left[\sigma(\text{ROA})\right]$, μ and σ based on period Q4 2014 till Q4 2016 ROA = quarterly returns times 4/ total assets, FINREP data, sheet 01.03 x=10 y=10, FINREP data, sheet 02.00 x=10 y=670	SSM, ECB
Risk adjusted returns	ROE/σ (ROE), σ based on period Q4 2014 till Q4 2016, FINREP data, sheet 01.03 x=10 y=300, FINREP data, sheet 02.00 x=10 y=670	SSM, ECB

TABLE C.9: Categorization of countries

Notes: * indicates whose national liquidity requirements are still in place/ currently under review and will be maintained until 2018, ° indicates which country introduces the EU-wide LCR with 100% in October 2015 instead of using the step wise introduction.

With preceding national liquidity regulation	Without preceding national liquidity regulation
NNLR = 0	NNLR = 1
Belgium°	Austria°
Cyprus*°	Estonia°
Germany*	Finland
France	Italy
Greece*	Luxembourg
Ireland*	Portugal
Latvia*	Spain
Lithuania°	
Malta*	
Netherlands*°	
Slovenia*	
Slovakia*	

TABLE C.10: Country-specific LCR introduction effect

This table reports the interaction effects of estimating the empirical specification of equation (4.2) with Treated=1 for one country at a time. The triple interaction drops out due to collinearity. Row (1) repeats the baseline results from Table 4.3 and 4.2. *** p<0.01, ** p<0.05, * p<0.1.

	VARIABLES	(1) Marketable haircut	(2) Non-marketable haircut	(3) Marketable collateral value	(4) Non-marketable collateral value
(1)	PostLCR#NNLR	1.767***	-2.722***	0.084	0.426***
		(0.600)	(0.996)	(0.069)	(0.089)
(2)	PostLCR#Austria^D	1.002	7.458***	-0.249	-0.441**
		(2.159)	(2.214)	(0.446)	(0.193)
	PostLCR#NNLR	1.711***	-2.954***	0.098	0.440***
		(0.605)	(1.005)	(0.061)	(0.093)
(3)	PostLCR#Belgium ^{D}	-2.683***	7.989***	0.092	0.049
		(0.577)	(1.159)	(0.098)	(0.115)
	PostLCR#NNLR	1.577**	-2.280**	0.091	0.429***
		(0.604)	(0.921)	(0.073)	(0.094)
(4)	PostLCR#Cyprus ^{D}	1.660		-0.102	
		(2.415)		(0.081)	
	PostLCR#NNLR	1.927***		0.075	
		(0.599)		(0.072)	
(5)	PostLCR#Estonia^D	1.639		0.199	
		(2.214)		(0.323)	
	PostLCR#NNLR	1.725***		0.079	
		(0.605)		(0.072)	
(6)	PostLCR#Finland^D	0.827	1.011	-0.257**	-0.253
		(2.392)	(1.237)	(0.108)	(0.168)
	PostLCR#NNLR	1.690***	-2.858***	0.108	0.460***
		(0.616)	(1.024)	(0.071)	(0.093)
(7)	PostLCR#France^D	0.411	1.412	0.094	-0.203
		(0.704)	(2.018)	(0.083)	(0.238)
	PostLCR#NNLR	1.817***	-2.537**	0.096	0.400***
		(0.647)	(1.077)	(0.073)	(0.090)
(8)	PostLCR#Germany^D	-0.505	-2.865**	-0.007	0.155
		(0.793)	(1.402)	(0.092)	(0.125)
	PostLCR#NNLR	1.635**	-3.782***	0.083	0.484***
		(0.641)	(1.019)	(0.077)	(0.103)
(9)	PostLCR#Greece^D	1.543	2.311	-0.203	-0.316
		(1.219)	(1.887)	(0.190)	(0.202)
	PostLCR#NNLR	1.805***	-2.478**	0.079	0.393***
		(0.603)	(1.014)	(0.069)	(0.094)
(10)	PostLCR#Ireland^D	1.707	0.772	-0.220	0.333***
		(1.754)	(1.119)	(0.223)	(0.093)
	PostLCR#NNLR	1.915***	-2.670**	0.065	0.449***
		(0.581)	(1.023)	(0.069)	(0.091)
(11)	PostLCR#Italy^D	-1.181	-0.778	0.171**	0.212**
		(1.009)	(1.228)	(0.078)	(0.090)
	PostLCR#NNLR	2.208***	-2.298*	0.020	0.311***
		(0.639)	(1.158)	(0.078)	(0.091)
(12)	PostLCR#Latvia^D	0.427		0.588***	
		(0.538)		(0.085)	
	PostLCR#NNLR	1.783***		0.106	
		(0.616)		(0.068)	
(13)	PostLCR#Lithuania^D	-0.412	2.589	-0.086	-0.169
		(1.296)	(1.842)	(0.168)	(0.216)
	PostLCR#NNLR	1.745***	-2.650**	0.080	0.422***
		(0.619)	(1.002)	(0.071)	(0.093)
(14)	PostLCR#Luxembourg^D	-1.361		-0.024	
		(0.831)		(0.197)	
	PostLCR#NNLR	1.867***		0.086	
		(0.644)		(0.071)	
(15)	PostLCR#Malta^D	-2.093*	-1.243	-0.239*	-0.865***
		(1.166)	(1.282)	(0.129)	(0.087)
	PostLCR#NNLR	1.665***	-2.787***	0.073	0.381***
		(0.614)	(1.042)	(0.071)	(0.079)
(16)	PostLCR#Netherlands^D	-0.686		0.123**	
		(0.436)		(0.050)	
	PostLCR#NNLR	1.747***		0.088	
		(0.610)		(0.070)	
(17)	PostLCR#Portugal^D	0.621	-2.592**	-0.046	0.027
		(1.551)	(1.254)	(0.085)	(0.164)
	PostLCR#NNLR	1.707***	-2.601**	0.089	0.425***
		(0.609)	(0.997)	(0.071)	(0.090)
(18)	PostLCR#Slovenia^D	0.370	0.016	-0.151	0.053
		(1.322)	(1.243)	(0.158)	(0.099)
	PostLCR#NNLR	1.790***	-2.720**	0.075	0.432***
		(0.615)	(1.048)	(0.071)	(0.097)
(19)	PostLCR#Slovakia^D	-0.752	-0.370	0.299	0.234
		(0.788)	(1.684)	(0.315)	(0.169)
	PostLCR#NNLR	1.686***	-2.751**	0.117*	0.445***
		(0.635)	(1.085)	(0.066)	(0.098)
(20)	PostLCR#Spain^D	0.758	0.175	-0.045	-0.124
		(0.808)	(1.449)	(0.090)	(0.103)
	PostLCR#NNLR	1.552**	-2.764**	0.097	0.457***
		(0.720)	(1.115)	(0.074)	(0.096)

Table C.11: Excluding individual countries

This table reports the interaction effect of estimating the empirical specification of equation (4.1) for different samples. Row (1) reports the estimated interaction effects of the baseline sample already presented by Table 4.3 and 4.2. Row (2) to (20) report the estimates when the indicated country is excluded from the estimation sample. *** p<0.01, ** p<0.05, * p<0.1.

VARIABLES		(1) Marketable haircut	(2) Non-marketable haircut	(3) Marketable collateral value	(4) Non-marketable collateral value
Baseline	PostLCR#NNLR	1.767***	-2.722***	0.084	0.426***
(1)		(0.600)	(0.996)	(0.069)	(0.089)
	Observations	149	104	149	104
W/o Austria	PostLCR#NNLR	1.665***	-2.954***	0.088	0.440***
(2)		(0.601)	(1.002)	(0.064)	(0.092)
	Observations	145	101	145	101
W/o Belgium	PostLCR#NNLR	1.575**	-2.280**	0.091	0.429***
(3)		(0.602)	(0.917)	(0.073)	(0.094)
	Observations	145	102	145	102
W/o Cyprus	PostLCR#NNLR	1.784***		0.063	
(4)		(0.608)		(0.071)	
	Observations	143		143	
W/o Estonia	PostLCR#NNLR	1.725***		0.079	
(5)		(0.604)		(0.072)	
	Observations	146		146	
W/o Finland	PostLCR#NNLR	1.769***	-2.839***	0.110	0.467***
(6)		(0.612)	(1.025)	(0.071)	(0.094)
	Observations	145	100	145	100
W/o France	PostLCR#NNLR	1.819***	-2.533**	0.096	0.411***
(7)		(0.647)	(1.071)	(0.073)	(0.090)
	Observations	141	98	141	98
W/o Germany	PostLCR#NNLR	1.655**	-4.205***	0.086	0.474***
(8)		(0.648)	(1.053)	(0.078)	(0.095)
	Observations	125	82	125	82
W/o Greece	PostLCR#NNLR	1.725***	-2.283**	0.073	0.394***
(9)		(0.596)	(0.997)	(0.069)	(0.097)
	Observations	141	96	141	96
W/o Ireland	PostLCR#NNLR	1.926***	-2.662**	0.073	0.448***
(10)		(0.579)	(1.024)	(0.066)	(0.091)
	Observations	143	100	143	100
W/o Italy	PostLCR#NNLR	2.243***	-1.821	0.014	0.284***
(11)		(0.633)	(1.225)	(0.079)	(0.089)
	Observations	125	80	125	80
W/o Latvia	PostLCR#NNLR	1.783***		0.106	
(12)		(0.614)		(0.068)	
	Observations	146		146	
W/o Lithuania	PostLCR#NNLR	1.714***	-2.650**	0.082	0.422***
(14)		(0.623)	(0.997)	(0.070)	(0.093)
	Observations	145	102	145	102
W/o Luxembourg	PostLCR#NNLR	1.874***		0.079	
(13)		(0.651)		(0.070)	
	Observations	145		145	
W/o Malta	PostLCR#NNLR	1.674***	-2.787***	0.071	0.381***
(15)		(0.613)	(1.038)	(0.072)	(0.078)
	Observations	145	102	145	102
W/o Netherlands	PostLCR#NNLR	1.747***		0.088	
(16)		(0.608)		(0.070)	
	Observations	147		147	
W/o Portugal	PostLCR#NNLR	1.718***	-2.591**	0.087	0.426***
(17)		(0.608)	(0.991)	(0.071)	(0.090)
	Observations	141	99	141	99
W/o Slovakia	PostLCR#NNLR	1.678***	-2.751**	0.110*	0.445***
(18)		(0.634)	(1.080)	(0.065)	(0.098)
	Observations	143	102	143	102
W/o Slovenia	PostLCR#NNLR	1.783***	-2.718**	0.076	0.432***
(19)		(0.613)	(1.046)	(0.071)	(0.096)
	Observations	144	99	144	99
W/o Spain	PostLCR#NNLR	1.651**	-2.887**	0.096	0.489***
(20)		(0.728)	(1.185)	(0.074)	(0.105)
	Observations	127	89	127	89

C.3 Online appendix

Table C.12: Correlation matrix

This table reports the correlation matrix for our baseline sample, the cross-sections Q2 2015 and Q1 2016. The covariates used in our estimations are here also included being lagged.

	Collateral value	Marketable collateral value	Non-marketable collateral value	Haircut	Marketable haircut	Non-marketable haircut	Log of total assets	Capital ratio	Loan ratio	Debt instruments	Interest Income	Deposits of fin. Institutions	Household deposits	Interest expense	ROA
Collateral value	1.00														
Marketable collateral value	0.80	1.00													
Non-marketable collateral value	0.79	0.33	1.00												
Haircut	0.03	-0.11	0.23	1.00											
Marketable haircut	-0.01	0.00	0.29	0.51	1.00										
Non-marketable haircut	0.05	0.10	0.16	0.65	0.03	1.00									
Log of total assets	0.86	0.68	0.72	0.07	-0.07	0.04	1.00								
Capital ratio	-0.45	-0.38	-0.30	-0.29	-0.16	-0.43	-0.35	1.00							
Loan ratio	-0.22	-0.05	-0.12	0.15	0.09	0.16	-0.26	0.10	1.00						
Debt instruments	-0.10	-0.12	-0.21	-0.32	-0.26	-0.18	-0.15	-0.13	-0.61	1.00					
Interest Income	0.08	0.13	0.11	0.17	0.19	0.08	0.04	-0.08	0.29	-0.13	1.00				
Deposits of fin. Institutions	0.07	0.08	-0.14	0.02	-0.11	-0.21	0.17	0.02	0.04	-0.09	0.05	1.00			
Household deposits	-0.36	-0.24	-0.23	-0.01	0.18	0.05	-0.39	0.10	0.32	0.00	0.08	-0.57	1.00		
Interest expense	0.29	0.30	0.23	0.15	0.11	0.06	0.30	-0.18	0.14	-0.08	0.78	0.37	-0.26	1.00	
ROA	-0.13	-0.15	0.03	-0.10	-0.03	-0.30	-0.08	0.22	0.03	0.11	0.24	0.07	0.03	0.18	1.00

Table C.13: Panel incl. treatment period

This table reports the interaction effect of estimating the empirical specification of equation (4.1) for different sample periods. The sample period is indicated in the lower part of the table. In contrast to Table 4.7, the treatment periods Q3 and Q4 2015 are included in the estimations. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
								Haircut							
PostLCR#NNLR	-0.933	-0.822	-0.588	0.017	0.172	0.345	0.690	0.788	0.808	1.174	1.255*	1.103	0.965	0.816	0.370
	(0.586)	(0.617)	(0.658)	(0.587)	(0.623)	(0.629)	(0.569)	(0.554)	(0.631)	(0.721)	(0.728)	(0.788)	(0.956)	(1.014)	(1.207)
Observations	297	225	149	371	299	223	445	373	297	519	447	371	593	521	445
R-squared	0.06	0.08	0.27	0.09	0.15	0.19	0.04	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.05
								Marketable haircut							
PostLCR#NNLR	-0.086	0.166	0.472	0.822*	1.033**	1.112**	1.427***	1.618***	1.673***	1.866***	1.975***	1.835***	2.130***	2.153***	1.926**
	(0.403)	(0.426)	(0.485)	(0.441)	(0.462)	(0.434)	(0.515)	(0.530)	(0.520)	(0.645)	(0.662)	(0.648)	(0.768)	(0.784)	(0.760)
Observations	294	223	148	368	297	222	442	371	296	516	445	370	590	519	444
R-squared	0.12	0.09	0.17	0.27	0.31	0.36	0.13	0.13	0.11	0.12	0.11	0.09	0.11	0.10	0.09
								Non-marketable haircut							
PostLCR#NNLR	-2.598***	-2.446***	-2.003***	-2.485***	-2.284***	-1.874***	-2.637***	-2.395***	-2.069***	-2.821***	-2.442***	-2.146***	-2.808***	-2.809***	-2.645***
	(0.725)	(0.627)	(0.502)	(0.755)	(0.655)	(0.589)	(0.813)	(0.733)	(0.652)	(0.832)	(0.755)	(0.675)	(0.945)	(0.978)	(0.979)
Observations	209	156	103	260	207	154	312	259	206	362	309	256	413	360	307
R-squared	0.18	0.29	0.45	0.20	0.27	0.31	0.20	0.24	0.29	0.17	0.21	0.23	0.12	0.13	0.13
								Collateral value							
PostLCR#NNLR	0.074*	0.042	0.020	0.125***	0.082**	0.066*	0.187***	0.142***	0.126***	0.212***	0.172***	0.178***	0.275***	0.251***	0.275***
	(0.044)	(0.043)	(0.045)	(0.043)	(0.039)	(0.038)	(0.049)	(0.047)	(0.046)	(0.063)	(0.060)	(0.055)	(0.082)	(0.085)	(0.093)
Observations	297	225	149	371	299	223	445	373	297	519	447	371	593	521	445
R-squared	0.12	0.07	0.11	0.10	0.07	0.07	0.12	0.08	0.08	0.12	0.11	0.12	0.13	0.11	0.11
								Marketable collateral value							
PostLCR#NNLR	0.101	0.073	0.045	0.109**	0.068	0.055	0.089	0.046	0.038	0.088	0.047	0.062	0.108	0.071	0.084
	(0.063)	(0.063)	(0.058)	(0.048)	(0.046)	(0.049)	(0.078)	(0.079)	(0.075)	(0.106)	(0.107)	(0.101)	(0.123)	(0.121)	(0.114)
Observations	294	223	148	368	297	222	442	371	296	516	445	370	590	519	444
R-squared	0.10	0.09	0.16	0.10	0.08	0.08	0.03	0.03	0.05	0.03	0.03	0.07	0.04	0.04	0.07
								Non-marketable collateral value							
PostLCR#NNLR	0.203***	0.164***	0.125**	0.311***	0.255***	0.213***	0.338***	0.285***	0.244***	0.344***	0.281***	0.245***	0.379***	0.336***	0.310***
	(0.061)	(0.057)	(0.050)	(0.067)	(0.060)	(0.060)	(0.075)	(0.065)	(0.065)	(0.089)	(0.076)	(0.073)	(0.106)	(0.103)	(0.103)
Observations	209	156	103	260	207	154	312	259	206	362	309	256	413	360	307
R-squared	0.11	0.16	0.46	0.18	0.20	0.24	0.20	0.21	0.20	0.17	0.18	0.16	0.15	0.15	0.14
Startperiod	Q1 2015	Q2 2015	Q3 2015	Q1 2015	Q2 2015	Q3 2015	Q1 2015	Q2 2015	Q3 2015	Q1 2015	Q2 2015	Q3 2015	Q1 2015	Q2 2015	Q3 2015
Endperiod	Q4 2015	Q4 2015	Q4 2015	Q1 2016	Q1 2016	Q1 2016	Q2 2016	Q2 2016	Q2 2016	Q3 2016	Q3 2016	Q3 2016	Q4 2016	Q4 2016	Q4 2016

Chapter 5

Obstacles of monetary policy's stealth recapitalization

Abstract: *Unconventional monetary policy measures like asset purchase programms aim to reduce the yield of certain securities and thereby alter the investment behavior of financial institutions. This increases the market value of securities already held by the institutions and adds to their equity positions. This paper highlights that the extent of this recapitalization effect crucially depends on the securities' accounting, valuation methods, and country level capital regulation. Securities meant to be held until maturity are measured at amortized costs and do not transmit changes in market prices to the institution's balance sheet. This restricts the recapitalization effect to assets measured at fair value. The effect is further reduced by so called prudential filters which neutralize the effect of unrealized gains of certain securities on banks' regulatory capital.*

5.1 Introduction

In response to the financial crisis, central banks introduced unconventional monetary policy measures like asset purchase programms to counter the corresponding downturn of the economy and to overcome the issue of the zero lower bound. These measures put upward pressure on security prices and affect financial institutions in two ways: They generate gains by increasing the value of securities already held by them, and they make targeted securities less profitable investments by reducing their yield.

The reduction in the yield of high quality securities puts downward pressure on interest rates, thereby improving borrowing and financing conditions for the real economy. This channel of unconventional monetary policy is investigated among others by Cycon and Koetter (2015), Gagnon et al. (2011), Grosse-Rueschkamp et al. (2017), and Koetter (2019).

The gain in value of securities held by financial institutions adds to the capitalization of these institutions. It is therefore referred to as stealth recapitalization, a term coined by Brunnermeier and Sannikov (2016), who provide a theoretical framework for the channel. Empirical evidence for the recapitalization effect is provided for example by Chakraborty et al. (2019), Chodorow-Reich (2014), and Rodnyansky and Darmouni (2017) for the United States, and by Acharya et al. (2019) and Andrade et al. (2016) for the EU. They also investigate the transmission of the effect to the real economy.

This paper highlights two aspects so far not considered in context with the recapitalization effect. Replicating Acharya et al. (2019)'s estimates of the recapitalization effect of ECB's Outright Monetary Transactions (OMT) announcements in 2012, we show that the recapitalization gain is reduced by 20 to 98% compared to the previously estimated gain when security valuation and national capital regulations in form of prudential filters are factored in. Following these estimates the literature should consider the valuation method and the effect of prudential filters in context with stealth recapitalization to avoid a systematic overestimation of the recapitalization gain and to estimate potential effects of it to the real economy.

The security valuation method applied when measuring the value of securities on banks' balance sheets depends on the purpose of the security and its accounting class. If a security is bought to be held until it matures, it is classified into the held-to-maturity (HtM) portfolio and assessed at amortized cost. If a security is meant to be traded in the short term, it is sorted into the held-for-trading (HfT) class and measured at fair value. In case the purpose is not clear yet, the bank can choose the hybrid category available-for-sale (AfS) whose assets are also evaluated at fair value. Following this taxonomy, only securities categorized as HfT or AfS mirror an increase in the security price. Table 5.1 provides an overview of the accounting categories and the corresponding valuation methods.[1]

[1]For simplicity, the category "designated at fair value through profit or loss" (dFV) is not considered in detail. It usually includes derivatives and shares all relevant features

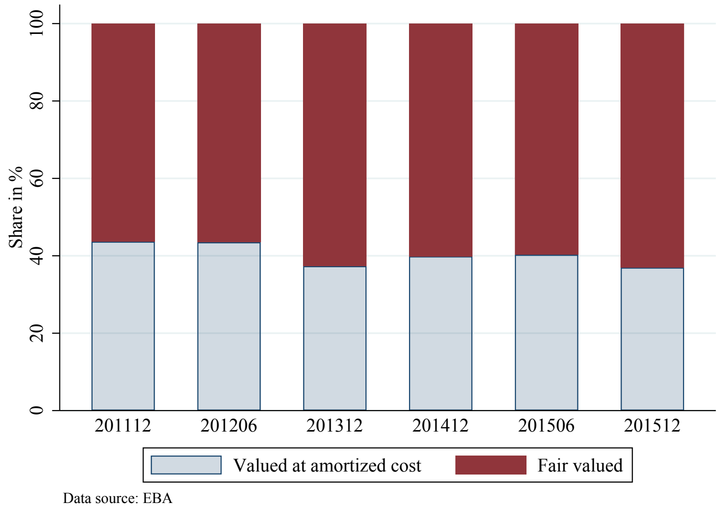
Table 5.1: Security accounting, valuation, and G&L recognition

Accounting category	Subsequent measurement	Recognition of unrealized gains and losses
Held for trading	Fair value	Income statement
Held to maturity	Amortized cost	Income statement
Available for sale	Fair value	Other comprehensive income

Figure 5.1 shows that only around 60% of banks' EU government debt holdings are continuously valued.

Figure 5.1: EU government debt holdings by security valuation method

EU government holdings by valuation method from banks considered in the capital exercise 2011 (65 banks), the stress test 2014 (123 banks), the transparency exercise 2015 (105 banks), and the stress test 2016 (51 banks) provided by the European Banking Authority (EBA).



Reclassifying securities from the HtM category to other classes is limited to insignificant amounts.[2] In case of a violation, the bank taints its HtM portfolio on the group level for two financial years. This step exposes the bank to market developments like a rise in interest rates and therefore, can be considered a credible threat.

The second aspect not yet considered by the recapitalization literature are prudential filters. Prudential filters remove unrealized gains and losses of AfS securities from banks' other comprehensive income (OCI). Under Basel II this was meant to reduce volatility and uncertainty from bank's

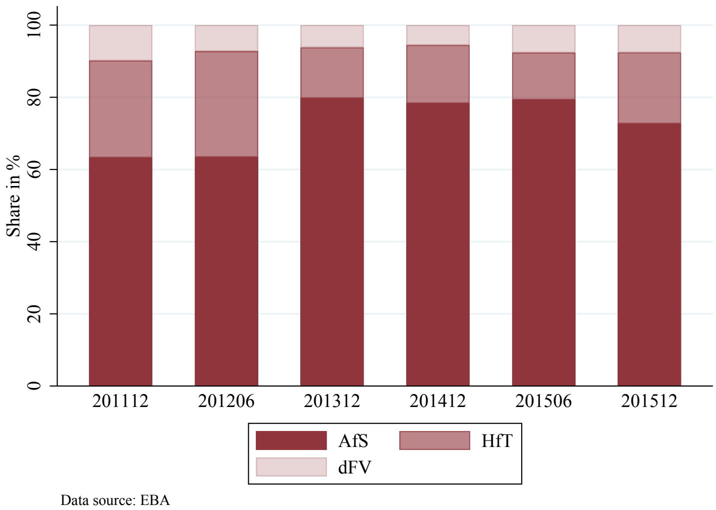
with the HfT class. In the following, assets considered as dFV are included in the HfT category.

[2]In rare circumstances like the financial crisis banks are allowed to reclassify larger amounts (Fiechter, 2011; Bischof et al., 2012).

regulatory capital which includes OCI (Allen and Carletti, 2008; Chisnall, 2001; Heaton et al., 2010). Following the CEBS[3] guidelines, EU countries could opt between two approaches. The asymmetric approach fully subtracts unrealized losses of AfS debt securities from capital and adds unrealized gains only partially to Tier2 capital. The neutralization approach recognizes neither unrealized gains nor unrealized losses (CEBS, 2007). Hence, depending on the country specific approach, banks can not or only partially benefit from unrealized gains originating from AfS securities. For a varying sample of significant banks, Figure 5.2 shows, that up to 80% of fair valued EU government debt is categorized as AfS. Even though Basel III/CRR removes national prudential filters step by step from 2014 onwards, prudential filters will remain relevant because countries are able to opt to keep prudential filter in place for central government debt.[4]

FIGURE 5.2: Fair valued EU government debt holdings by accounting class

Share of fair valued EU government holdings by accounting category from banks considered in the capital exercise 2011 (65 banks), the stress test 2014 (123 banks), the transparency exercise 2015 (105 banks), and the stress test 2016 (51 banks) provided by the European Banking Authority (EBA).



By highlighting the relevance of fair value accounting for the recapitalization effect, we also contribute to the discussion on securities valuation method. On one hand, the historic cost regime is criticized to be inefficient

[3]The Committee of European Banking Supervisors (CEBS) preceeded the European Banking Authority (EBA).

[4]`http://www.eba.europa.eu/supervisory-convergence/supervisory-disclosure/options-and-national-discretions`

because it ignores price signals. On the other hand, fair value measurement can distort the informational content of prices by adding a non-fundamental component to price fluctuations (Laux and Leuz, 2009; Plantin et al., 2008).

To the prudential filter literature we contribute by describing its interaction effect with unconventional monetary policy. While prudential filters reduce the volatility of regulatory capital (Argimón et al., 2018), they also exclude unrealized gains which could be considered more stable because they originate from central banks' market interventions as highlighted by the recapitalization literature.

In the following the effects of security valuation and prudential filters on the recapitalization effect are quantified considering Acharya et al. (2019)'s work on the OMT announcements by ECB president Mario Draghi in 2012. The study is especially suited because it quantifies the effect using freely available data. If not noted otherwise, we follow Acharya et al. (2019). Differences to the study are summarized in appendix D.2.

5.2 Data and methodology

We use the detailed breakdown of banks' sovereign debt holdings from EBA's 2011 capital exercise. In addition, we employ bond price data from Datastream and bank-level information from Bureau van Dijk's Bankscope.[5] In a first step we replicate the so called OMT windfall gain, the recapitalization effect of the OMT announcement, using all EU government debt holdings.[6] We sum the bond price changes of the three OMT announcement days (July 26, August 2, and September 6 of 2012) and multiply them for each maturity, m, and country, c, with the respective bank-level sovereign debt holdings ($\text{SovereignDebt}_{bcm}$). Summing the country-specific

[5] Acharya et al. (2019) use bank-level data from SNL.

[6] In summer 2012, ECB president Mario Draghi announced the introduction of the OMT program. With the program being activated by a specific country, ECB is allowed to buy a potentially unlimited amount of government bonds from the respective country in the secondary market. In connection with the announcement, Draghi also stated, "[...] the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough". This and following statements had significant effects on government bond prices as shown by Altavilla et al., 2014, Krishnamurthy and Vissing-Jorgensen, 2011, and Szczerbowicz et al., 2015.

gains from all EU sovereigns and dividing the total by the bank's total equity (TotalEquity_b), results to the bank-level OMT windfall gain:

$$\text{OMTWindfallGain}_b = \frac{\sum_{cm} \text{SovereignDebt}_{bcm} * \text{AccBondPriceChanges}_{cm}}{\text{TotalEquity}_b} \tag{5.1}$$

We extend Acharya et al. (2019)'s work by repeating the calculation using only the fair valued sovereign debt holdings. The effect of prudential filters is also considered by reviewing the effect separately for AfS and HfT securities.

In a second step, we estimate whether the change in magnitude has an effect on the estimation results.

$$\begin{aligned} \Delta\text{Loans}_{bmt+1} &= \beta_1 * \text{OMTWindfallGain}_b * \text{PostOMT}_t + \gamma * X_{bt} \\ &+ \text{Firm Cluster}_m * \text{Quarter-Year}_{t+1} + \text{Firm Cluster}_m * \text{Bank}_b + \text{u}_{bmt+1} \end{aligned} \tag{5.2}$$

The regression tests whether banks with higher OMT windfall gains (OMTWindfallGain_b) extended more credit after the OMT announcement (PostOMT_t). We concentrate on Acharya et al., 2019's preferred version of the model and consider the effect on existing borrowers (intensive margin), measured with the change in log loan volume of bank b in quarter t to firm cluster m (Δ Loans_{bmt+1}). We include firm cluster-time fixed effects, firm cluster-bank fixed effects, and bank controls (X_{bt}). The annual frequency of the bank controls is adjusted to the quarterly frequency of the sample using linear exploration. Standard errors are clustered on the bank level.

5.3 Results

Following equation (5.1), we estimate the OMT windfall gains. Like Acharya et al. (2019), we report the mean of the estimated OMT windfall gains for the subsets of non-GIIPS and GIIPS banks (Panel A of Table 5.2). Column (1) shows the estimates using the total sovereign debt holdings. For non-GIIPS banks we estimate a slightly negative recapitalization effect of -0.41% of equity. For GIIPS banks we measure a gain of 8.80% of equity. The negative effect for non-GIIPS banks originates mostly from German and British banks and the fact that Bund and Gilt prices slightly decreased after the announcement. Column (2) records the recapitalization estimates considering only fair valued securities. For GIIPS banks, the gain is reduced by nearly a third to 6.04% of equity compared to the previously estimated effect. The gain for non-GIIPS banks increases slightly to 0.02% of equity. This is most likely because German and British banks, but also other banks hold large shares of their home sovereign debt exposure in their HtM portfolios (see Table D.5 in the appendix). The difference in the windfall gain between non-GIIPS and GIIPS banks is significant for both calculations which is likely due to the significant difference in total and fair valued-GIIPS sovereign holdings (Panel B). For GIIPS banks the difference between the two windfall gain versions (total and fair value) is significant too (Column 3). Consequently, the valuation of securities should be considered when calculating the actual recapitalization effect.

Prudential filters also have the potential to reduce the recapitalization effect. Given that the estimated windfall gain is concentrated within GIIPS banks, we focus on the three remaining GIIPS countries: Italy, Portugal, and Spain.[7] All three countries employ the neutralization approach, which means that neither unrealized losses nor unrealized gains of AfS debt securities are included in regulatory capital. Panel A of Table 5.3 disentangles the fair value-windfall gain (Column 1) into the two fair value categories AfS and HfT (Column 2 and 3). It shows that the estimated (fair value) windfall gain originates mostly in the AfS portfolio of the GIIPS banks (>90%). This is because the majority of sovereign debt is categorized as AfS, rather than HfT, as shown by Panel B and Figure 5.2.

[7] Irish and Greek banks are dropped by Acharya et al. (2019) because their local sovereign bonds were not actively traded at the time of the OMT announcement and local sovereign bonds made up the majority of the banks' sovereign debt holdings. Therefore, they concluded that a calculation of an OMT windfall gain was not possible.

TABLE 5.2: OMT windfall gain and sovereign bond holdings: total vs. fair valued

Column (1) and (2) of Panel A report the OMT windfall gain estimates based on equation (5.1). Standard errors are reported in parentheses. For Column (1) we use the total of bank-level EU sovereign debt holdings and for Column (2) only the fair valued debt is considered. Column (3) of Panel A reports the t-values for the difference of the values in Column (1) and (2). Panel B reports the bank specific sovereign debt holdings of GIIPS countries (in %). Column (1) shows the total of GIIPS holdings, while Column (2) reports only fair values GIIPS holdings. Column (3) reports the t-value for the different values of GIIPS holdings. The sample includes 13 GIIPS banks and 36 non-GIIPS banks. In the appendix D.2, we provide a comparison of our estimates in Panel A, Column (1) to the results of Acharya et al. (2019).

A. OMT windfall gain (in %)

	(1) A la Acharya et al. (2019)	(2) Fair valued only	(3) *t-test*
Non-GIIPS banks	-0.41	0.02	*1.50*
	(2.25)	(0.70)	
GIIPS banks	8.80	6.04	*-4.65*
	(8.62)	(7.73)	
t-test	*-3.81*	*-2.80*	

B. Sovereign bond holdings (in %)

	Total GIIPS / Assets	Fair valued GIIPS / Assets	*t-test*
Non-GIIPS banks	0.66	0.24	*2.57*
	(1.13)	(0.53)	
GIIPS banks	9.13	6.20	*4.90*
	(3.39)	(3.62)	
t-test	*-8.85*	*-5.91*	

However, prudential filters only apply to unrealized gains and losses. If the bank decides to realize the accumulated gain/loss of a certain AfS security, it can simply sell the respective AfS security. In this case the realized gain/ loss is recognized via the income statement and affects regulatory capital. Because of this possibility, and given that countries using the asymmetrical approach partially include unrealized gains from AfS debt securities, one can not entirely exclude a recapitalization effect via AfS securities.[8] Hence, the actual recapitalization effect lies somewhere between the HfT only effect and the effect measured for all fair valued securities.

To collect further empirical evidence, we estimate equation (5.2). Table 5.4 reports the estimates for the OMT windfall gain-PostOMT dummy

[8]From our sample Austria, Denmark, Finland, and Sweden use the asymmetric approach. In contrast to Belgium, France, Germany, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, and the United Kingdom using the neutralization approach.

TABLE 5.3: OMT windfall gain and sovereign bond holdings: AfS and HfT

Panel A reports the OMT windfall estimates based on equation (5.1) using the respective amounts of government debt. Column (1) is based on all EU government debt measured at fair value. Column (2) and (3) use the EU government debt classified as AfS and HfT. Panel B shows the respective GIIPS government debt holdings by fair value measurement (Column 1), AfS accounting category (Column 2), and HfT accounting category (Column 3). The HfT class also includes effects/ holdings from assets categorized as dFV. The sample includes 13 GIIPS banks and 36 non-GIIPS banks. Standard errors are in parentheses.

A. OMT windfall gain (in %)

	(1) Fair valued only	(2) AfS only	(3) HfT only
Non-GIIPS banks	0.02	0.11	-0.10
	(0.70)	(0.60)	(0.35)
GIIPS banks	6.04	5.63	0.41
	(7.73)	(7.71)	(0.49)

B. Sovereign bond holdings (in %)

	Fair valued GIIPS / Assets	AfS GIIPS / Assets	HfT GIIPS / Assets
Non-GIIPS banks	0.24	0.21	0.03
	(0.53)	(0.53)	(0.08)
GIIPS banks	6.20	5.46	0.74
	(3.62)	(3.22)	(0.90)

interactions. We include the bank-level controls logarithm of total assets, return to assets, equity to assets, and non performing loans to equity. Due to data availability, we cannot control for firm specific features like rating as done by Acharya et al. (2019). In Column (1) and (2), we use firm's country of incorporation and industry to form firm clusters. Following the least restrictive specification we include firm-cluster fixed effects, quarter-year fixed effects and bank fixed effects. For both interactions we estimate positive and significant results. As expected, the effect for the fair value effect is larger, indicating that the estimate for the OMTWindfallGain^{Total} is driven by fair valued securities. These results remain robust when including the average of the pre-OMT interest premium on Libor/Euribor to proxy for firms' rating when forming firm clusters. The estimate for the OMTWindfallGain^{Total} in Column (3) is comparable with the effect estimated by Acharya et al. (2019), amounting to a 1.25% increase in loan volume per 1 percentage point of OMT windfall gain. The interaction effect for OMTWindfallGain^{FV} indicates an increase in 1.51% in newly allocated loan volume per percentage point of the recapitalization effect (Column 4).

Table 5.4: Loan volume regression

This table examines the effect of the OMT windfall gain on banks lending behavior following Acharya et al. (2019)'s work. It presents a modified Khwaja and Mian (2008) bank lending channel regression with firm cluster-bank-quarter-year as the unit of observation. The change in log loan volume from a bank to a firm cluster is the dependent variable. We cover the time period 2009 to 2014. The T-statistic in the last row tests for the 95th percentage level. Standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01

	(1) Δ Loans	(2) Δ Loans	(3) Δ Loans	(4) Δ Loans	(5) Δ Loans	(6) Δ Loans
PostOMT × OMTWindfallGain^{Total}	0.0933**		0.227***		0.0136	
	(0.0450)		(0.0668)		(0.0238)	
PostOMT × OMTWindfallGain^{FV}		0.215**		0.474***		0.0552
		(0.0974)		(0.138)		(0.0346)
R^2	0.118	0.118	0.143	0.143	0.897	0.897
N	56,701	56,701	45,615	45,615	45,615	45,615
Bank-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cluster fixed effects	Yes	Yes	Yes	No	No	No
Time fixed effects	Yes	Yes	Yes	Yes	No	No
Bank fixed effect	Yes	Yes	Yes	Yes	No	No
Firm-cluster-bank fixed effects	No	No	No	No	Yes	Yes
Firm-cluster-time fixed effects	No	No	No	No	Yes	Yes
Firm cluster based on:	country of incorporation, industry		country of incorporation, industry, average pre-OMT interest rate premium			
T-statistic (H_0: OMTWindfallGain^{Total} - OMTWindfallGain^{FV}=0)	*-349.99*		*-344.08*		*-235.88*	

Both OMT effects lose their significance when we switch to Acharya et al. (2019) most restrictive model using firm-cluster-bank fixed effects and firm-cluster-time fixed effects. Other than that, the point estimates remain consistent with the previous results. As for the previous two specifications, the coefficient for the total OMT gain is significantly smaller than for the fair value estimate (Column 5 and 6).

While our results are insightful, they are not necessarily comparable to Acharya et al. (2019)'s estimates given that they control for more firm and bank-specific factors, and have a much smaller sample (see appendix D.2 for a comparison). However, our estimates highlight that fair valued securities instead of the total of respective securities should be considered to measure the potential recapitalization effect. Due to prudential filters the gain could be further reduced which could lead to a systematic overestimation of the recapitalization gain.

5.4 Conclusion

This paper highlights two relevant factors affecting the magnitude of the recapitalization effect of unconventional monetary policy. Only securities mirroring the market price transmit the increase in security prices to financial institutions' balance sheets. Therefore, the valuation method of securities determined by the accounting category have to be considered when estimating the magnitude of the effect. The effect is further reduced by so called prudential filters which (partly) exclude the unrealized gains and losses from fair valued AfS securities from banks' regulatory capital.

Due to this taxonomy, the actual recapitalization effect can be reduced essentially as shown with the example of Acharya et al. (2019)'s work on the OMT announcements in 2012. Applying the highlighted restrictions, we find that the average recapitalization effect most likely varies between 0.04% and 1.62% of equity, instead of the previously estimated average of 2.02% of equity of the sample banks. To avoid a systematic overestimation of the potential recapitalization gain and to estimate potential effects of it to the real economy, the literature should consider the valuation method and the effect of prudential filters in context with stealth recapitalization.

Appendix D

D.1 Tables

TABLE D.5: EU government holdings and home exposure

Notes: Based on 49 banks in Q2 2012 covered by the EBA capital exercise 2011 and considered by Acharya et al. (2019), for simplicity HfT also includes assets part of the category dFV. Standard errors are reported in parentheses.

	All banks	Non-GIIPS banks	GIIPS banks
EU government debt to total assets (in %)			
Total	8.83	8.49	9.77
	(6.25)	(7.06)	(3.11)
Fair valued	4.21	3.34	6.61
	(3.11)	(2.48)	(3.50)
AfS	2.97	1.98	5.74
	(2.79)	(1.86)	(3.13)
HfT	1.23	1.36	0.88
	(1.74)	(1.95)	(0.91)
Home exposure to total assets (in %)			
Total	6.33	5.47	8.72
	(5.31)	(5.71)	(3.02)
Fair valued	2.95	1.90	5.87
	(2.88)	(1.88)	(3.22)

D.2 Comparison to Acharya et al. (2019)

To test whether our replication deviates significantly from Acharya et al. (2019)'s estimates, we run a t-test for the mean of the sample, as well as the subsamples (see Table D.6). For the entire sample and the GIIPS subsample we find no significant difference between the means (on the 95th significance level). However, our estimates for the non-GIIPS's windfall gain seem to be significantly lower. This could be due to multiple reasons. One source of difference could be the bond price series. We might use different series than Acharya et al. (2019). Even if we use the same series, they could have been updated since Acharya et al. (2019) collected them. Other differences are that for bank-specific information we use Bankscope, while Acharya et al. (2019) use SNL data.

TABLE D.6: OMT windfall gain (in %)

Acharya et al., 2019 report the means of the OMT windfall gain for the subsamples of GIIPS (13 banks) and non-GIIPS (36 banks). In a working paper version, *CERP discussion paper 12005*, they list the individual OMT effects, therefore we can consider the mean for the entire sample (49 banks). Standard deviations are reported in parentheses.

	(1) Acharya et al. (2019)	(2) Own calculations	(3) t-test for difference
Non-GIIPS banks	1.14	-0.43	3.63
	(1.71)	(2.25)	
GIIPS banks	7.95	8.80	-0.47
	(4.00)	(8.62)	
All banks	2.94	2.02	1.58
	(3.92)	(6.26)	

Chapter 6

Concluding remarks

The financial crisis and the European debt crisis triggered substantial changes in banking regulation and monetary policy. While the rise in regulation aimed to increase the resilience of the financial sector against future shocks, central bankers introduced new policy instruments, initially to tackle already existing financial stability concerns and later also due to the zero lower bound. The fundamental changes in both areas created a great need of analysis. This thesis contributes to the evaluation of monetary policy during the post crisis period, as well as to the understanding of interactions between macroeconomic policies and banking regulation.

Chapter 2 investigates whether a decreasing deposit facility rate is an effective tool to reduce banks' incentives to hold reserves at the central bank. We find that banks with a more interest-sensitive business model are more likely to reduce their reserve holdings in response to a decreasing deposit facility rate. We also find evidence that the liquidity is re-allocated to loans, contributing to monetary policy transmission. However, this effect is driven by non-GIIPS countries, which highlights the limited effectiveness of conventional monetary policy and the need for further - unconventional - instruments.

Chapter 3 puts light on the interaction effect of bank levies and corporate income taxes on bank leverage. We find evidence that bank levies have a positive effect on banks' capitalization. However, this effect is weaker the more elevated corporate income taxes are. In countries with very high corporate income taxes, the positive effect on banks' capitalization becomes ineffective. These findings are valuable for regulators and fiscal policy makers especially in regard to financial stability. While financial stability might be only a minor aspect in the considerations for corporate income taxes, regulators have to be aware of them when choosing a bank levy to affect bank leverage.

Chapter 4 considers whether Euro-area banks have adjusted their collateral pledging behavior with the central bank in response to the introduction of the liquidity coverage ratio (LCR). An altered pledging behavior could indicate that banks exploit an arbitrage possibility via the central bank to improve their LCR value. Using the existence of preceding national liquidity requirements to proxy for the incentive of exploiting the arbitrage possibility, I find evidence that banks have reduced the liquidity profile of marketable assets pledged with the central bank. This result indicates that banks made use of the arbitrage possibility, which reduces the risk mitigating effect of the regulation. Supervisors and regulators should take this finding into consideration when evaluating banks' liquidity risk profile and the effect of the regulation.

Chapter 5 highlights that banks' security valuation and country-level capital regulation, which both depend on the accounting category of the security, reduce the recapitalization effect of unconventional monetary policy. For central bankers and researchers this finding is important to avoid a systematic overestimation of the recapitalization gain and to properly estimate potential effects of it to the real economy.

This thesis provides useful insights for the ongoing regulatory debate, as well as for the conduct of monetary policy. It highlights how macroeconomic policies, especially monetary policy, and banking regulation interact. In the evaluation and decision making process this needs to be considered.

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