Essais sur la régulation de la liquidité bancaire : implications pour les prêts et la prise de risque

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Essays on bank liquidity regulation: implications for lending and risk-taking

Keywords: Bank lending; Basel III; Liquidity regulation; Liquidity Balance Rule; Liquidity Coverage Ratio; Propensity Score Matching; Quasi-natural experiment, risk, stability, global financial crisis.

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General Introduction

"Liquidity requirements can internalize some of the externalities that are generated by the price impact of selling into a falling market."

(Cifuentes et al. 2005)

Bank liquidity has received little to no attention before the 2007-2008 global financial crisis, which many economists and experts consider to be the worst financial crisis since the Great Depression in the 1930s. Many factors led to the outbreak of the financial crisis, and observers disagree on the weight given to individual aspects. There is, however, a broad agreement that liquidity risks and lapses in liquidity risk management[1] were crucial factors leading to the outbreak of this crisis and its expansion.

Liquidity risk is the possibility that a bank may suffer an adverse shock to its liquidity position. The literature classifies bank liquidity into two categories: market and funding liquidity. Funding liquidity refers to the ease with which an institution can attract funding. An institution's funding liquidity is high if it can quickly raise money at reasonable costs. When financial institutions purchase an asset, they often use it as collateral for short-term borrowing. The haircut (the difference between the value of an asset and the amount one can borrow against it) needs to be financed by the institution's equity. Liquidity risk can arise when there are changes in margins and haircuts, cost increases, or massive withdrawal of funding. Thus, funding liquidity risk has a severe adverse impact if assets can only be sold at fire-sale prices. Market liquidity refers to the ease with which an institution can raise money by selling its assets instead of borrowing against them. If market liquidity is low, selling the asset would depress its price. The shock in the real estate market (subprime crisis) has affected both banks' funding

[1] owing to a complex interplay of government policies that encouraged home ownership, providing easier access to loans for subprime borrowers, and by an over-valuation of bundled sub-prime mortgages based on the assumption that housing prices would continue to escalate (Brunnermeier 2009).

and market liquidity. Brunnermeier and Pederson (2009) explain that investors increased haircuts on securitizations used in secured borrowing transactions as they were unsure about their quality. Since banks were already highly leveraged, they could not finance the increasing haircuts with their equity. As a consequence, many banks needed to sell their assets at the same time. These sales depressed prices even further, which led to more sales and a downward spiral. Banks' liquidity risk increased, but they held too little market liquid assets to compensate for it. And this favored the outbreak of the financial crisis.

Adrian and Shin (2010) argue that the 2007-2008 financial crisis has shown how quickly liquidity can evaporate and how rapidly this can transmit stress from one market to other markets. It also revealed the weak points in the previous regulation. Mainly, it showed that capital regulation is not sufficient to mitigate liquidity risks. As a response, the Basel Committee on Banking Supervision (BCBS) revised the regulatory framework to strengthen the global financial system and to reduce future spillovers to the real economy (BCBS, 2011). Among other things, The BCBS' new regulatory framework (Basel III) proposes two liquidity requirements to reinforce the resilience of banks to liquidity risk. The first measure is the Liquidity Coverage Ratio (LCR), a short-term ratio requiring financial institutions to hold enough liquid assets to withstand a 30-day stress period. The second measure, the Net Stable Funding Ratio (NSFR), aims at improving banks' longer-term, structural funding.

The introduction of these two requirements on bank liquidity triggered an intense debate among policymakers, academics, and bankers. Most of the contributions so far are either of a theoretical or political nature, while there is limited empirical analysis regarding the impact of the new standards. This dissertation aims to contribute to this debate by providing an empirical evaluation of the effects of the introduction of liquidity regulation on banks' behavior.

This thesis consists of three chapters. The first two chapters were written as part of the ANR CaLiBank Project (ANR-19-CE26-0002). Each chapter is self-contained and can be read individually. The first and second chapters use the same empirical setting to address specific but related issues. Specifically, the first chapter discusses the impact of the introduction of liquidity regulation on bank lending, while the second chapter assesses the effects on bank risk.

The following chapter (Chapter 3) contributes to the literature on the interaction of bank liquidity and capital.

The first chapter is based on Ananou et al. (2021a). The purpose of this chapter is to assess the impact of the introduction of an LCR-like requirement on bank lending. Much of the salient literature that has emerged following the global financial crisis uses dynamic general equilibrium models to investigate the impact of changes to liquidity rules on lending and real economic activity (Macroeconomic Assessment Group, 2010; Angelini et al., 2011; De Nicolo, Gamba and Lucchetta, 2014; Covas and Driscoll, 2014). In general, these studies conclude that the introduction of liquidity regulations reduces bank lending with a resultant negative impact on the real economy. In this chapter, we provide an empirical analysis of this issue. To achieve this, we use the introduction of a liquidity regulation in the Netherlands, known as the Liquidity Balance Rule (LBR) as a setting. Introduced in 2003, the LBR preceded the Basel III Liquidity Coverage Ratio. According to the LBR, banks are required to hold high-quality liquid assets exceeding or equal to net cash outflows over a 30-day stress period. In contrast to the Liquidity Coverage Ratio, the introduction of the LBR in the Netherlands did not occur following a period of financial instability. It was unlikely to be anticipated in advance by banks and other industry stakeholders (such as shareholders, bondholders, and depositors). The LBR was imposed on Dutch banks and did not apply to other banks operating elsewhere in other Benelux countries (Belgium and Luxembourg) or the rest of the Eurozone. Using this differential regulatory treatment to overcome identification concerns, we investigate the impact of liquidity regulation on the lending activities of Dutch banks. Specifically, we utilize a difference-in-differences framework where we estimate the difference in the behavior of affected banks between the pre-LBR and post-LBR period with the same difference in the conduct of an unaffected control group of banks. Our sample period straddles the introduction of the LBR. It comprises an unconsolidated balance sheet, off-balance-sheet, and income statement data for commercial banks covering 2000 to 2006 for 12 Eurozone member countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain). We examine bank lending behavior at both an aggregated and disaggregated level, including analyzing loan type and maturity. Our setting is most closely related in spirit to that of Banerjee and Mio (2018), who investigate how banks make balance sheet adjustments to comply with the UK ILG regulation[2]. However, unlike with the UK setting used in their study, where the introduction of ILG followed by quantitative easing (QE) policy by the Bank of England, in the present study, we focus on a relatively tranquil period where possible contaminating factors such as QE are absent. Therefore, our setting is ideally suited to a more general assessment of the impact of sudden introductions of liquidity regulation on bank behavior.

The results of our empirical analysis indicate that the introduction of the LBR led Dutch banks to change loan portfolio composition. Specifically, the enactment of the LBR led to an increase in the overall volume of lending and a re-orientation toward corporate borrowing. Further analysis reveals that the impact of liquidity requirements on bank lending is crucially dependent on the availability of stable funding sources. These findings constitute an essential contribution to the literature, given that we provide new evidence suggesting that the introduction of liquidity regulations not only affects the composition of bank loan portfolios but also leads to banks accumulating more stable funding in the form of deposits and equity. This is of significant importance because by increasing the size of banks' balance sheets, liquidity regulation can increase credit supply - an issue neglected by previous studies.

Motivated by the findings of the first chapter, the second chapter draws from Ananou et al. (2021b) and aims to assesses whether introducing liquidity regulations affects bank risk-taking behavior. The results from the first chapter suggest that Dutch banks did not cut lending and have re-orientated their loan portfolio towards more liquid loans, while they were also able to improve their liquid assets. This should therefore translate into their riskiness. Ex-ante, it is unclear whether the introduction of liquidity regulations aimed at reducing the maturity mismatch between banks' illiquid assets and liquid liabilities leads to an increase or decrease in

[2] The UK Individual Liquidity Guidance (ILG) was introduced in 2010. Similarly, to the LBR and the LCR, it requires banks to hold a sufficient stock of high-quality liquid assets (HQLA) to withstand an acute bank specific funding shock lasting 2 weeks and a less acute but more generalised funding shock lasting 3 months.

risk, given that banks have a myriad of ways to manage liquidity (DeYoung and Jang, 2016). Empirically, this chapter uses the same empirical setup as in the first chapter: we consider the introduction of the Liquidity Balance Rule (LBR) in the Netherlands in 2003 and use a difference-in-differences framework. We use accounting-based measures of bank risk comprising the standard deviation of the return on assets and a bank default risk measure along with its asset and leverage risk sub-components. Market-based indicators are also constructed for a sub-sample of listed banks using the standard deviation of bank daily stock returns over a calendar year and a market-based version of the bank default risk measure. The sample period straddles the introduction of the LBR, covering the period 2000 to 2006 for 12 Eurozone member countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain).

The results of our empirical analysis indicate that following the introduction of the LBR, both the risk-taking (either measured by asset risk or stock price volatility) and default risk of Dutch banks decreased in comparison with counterparts not subject to the LBR. Moreover, the decline in bank default risk occurred primarily through a reduction of leverage risk (as the bank became better capitalized). These findings are consistent across both accounting and market-based indicators of bank risk. Although the systematic risk of Dutch banks remained unchanged following the introduction of the LBR, their specific risk decreased relative to other banks not subject to the provisions of the LBR. Going beyond, we find that following the introduction of the LBR, Dutch banks changed their funding structure by increasing capital and deposits. We also document that profitability declined despite reduced funding costs. This is because Dutch banks experienced a decrease in the interests received on their assets following the introduction of the LBR. Specifically, the reduction in the cost of funding that occurred following the introduction of the rule was not enough to offset the negative impact of lower interest on earning assets on profitability. Nevertheless, the effect of LBR on profitability is short-lived and disappears few years following the liquidity regulation change.

The third chapter contributes to the literature investigating the relationship between bank capital and liquidity. Building on previous studies that indicate that capital and liquidity are potentially jointly determined, we consider a vector autoregressive model (VAR) to investigate the interaction of bank capital and liquidity. Specifically, we question whether banks hold less or more capital buffers when they build their liquidity buffers. While most of the studies are based on the period before the financial crisis to understand how the implementation of liquidity regulation can affect capital management, in this chapter, we consider a period where liquidity requirements are implemented.

Our sample consists of 41 large banks[3] established in European countries and constrained by Basel III rules under the Single Supervisory Mechanism (SSM),[4] over the period 2015-2020. We find that a change to a bank's capital buffer induces a permanent positive change in its LCR and NSFR buffer, meaning that liquidity buffers increase significantly and permanently after an increase in the capital buffer. On the contrary, a shift in banks' LCR and NSFR buffers does not significantly affect the capital buffer. These findings suggest that the introduction of liquidity rules, alongside those on capital, does not lead banks to build a liquidity buffer at the expense of their capital buffer.

[3] Banks with total assets higher or equal to 30 billions euros.

[4] The SSM came into force in November 2014 and comprised the European Central Bank and national supervisory authorities of the European countries participating in this framework. The framework is designed to ensure cooperation among the different European countries regarding the supervision of the banking system.

Chapter 1

Liquidity regulation and bank lending*

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* This chapter draws from the contribution of Ananou, Chronopoulos, Tarazi, Wilson, 2021. Liquidity regulation and lending. Journal of Corporate Finance 69(1), co-authored with Amine Tarazi, from Université de Limoges/LAPE; Dimitris Chronopoulous, from University of St Andrews; and John O.S. Wilson, from University of St Andrews. I am thankful to my supervisor Amine Tarazi and my co-authors Dimitirs Chronopoulos and John O.S. Wilson for guidance, advice, and encouragement during the writing of this paper. An earlier version of the article has been presented at (1) 37th International Conference of the French Finance Association, 26-28 May 2021 (Online); (2) at the 2021 ANR CaLiBank Project Workshop, January 25, 2021, Limoges, France; and (3) at the 2021 AAP/ANR Workshop, May 25, 2021, Limoges, France. I have also received very helpful comments and suggestions from Robert DeYoung, Olivier De Jonghe, Christophe Hurlin, Alain Sauviat, Ruth Tacneng, Céline Meslier, Laetitia Lepetit, as well as conference and workshop participants.

Abstract

Bank liquidity shortages during the global financial crisis of 2007-2009 led to the introduction of liquidity regulations, the impact of which has attracted the attention of academics and policymakers. In this chapter, we investigate the impact of liquidity regulation on bank lending. As a setting, we use the Netherlands, where a Liquidity Balance Rule (LBR) was introduced in 2003. The LBR was imposed on Dutch banks only and did not apply to other banks operating elsewhere within the Eurozone. Using this differential regulatory treatment to overcome identification concerns and a difference-in-differences approach, we find that the LBR increased the volume of lending by Dutch banks relative to other banks located in the Eurozone. Increased equity, an inflow of retail deposits and subsequent increase in balance sheet size allowed Dutch banks to increase lending despite having to meet the LBR requirements. The LBR also affected loan composition (with corporate and retail lending increasing more than mortgage lending) and the maturity profile of loan portfolios. Our results have relevance for policymakers tasked with monitoring the impact of liquidity regulations on banks and the real economy.

Classification JEL: G21, G28

Key words: Bank Lending; Basel III; Liquidity Regulation; Liquidity Balance Rule; Liquidity Coverage Ratio; Propensity Score Matching; Quasi-natural experiment.

1.1. Introduction

During the global financial crisis of 2007-2009, governments and regulators intervened extensively to provide liquidity support to banks that were unable to meet short-term obligations. Since then, bank liquidity has attracted considerable attention of academics (Calomiris, Heider, and Hoerova, 2014; De Nicolò, 2016; Chiaramonte and Casu, 2017; Chiaramonte, 2018; Bouwman, 2019) as policymakers have introduced rules requiring banks to hold more liquid assets.[1] Proponents of these new regulations contend that by holding more liquid assets, banks become more resilient to sudden balance sheet shocks, and as a consequence can continue lending to households, small and medium-sized enterprises (SMEs) and corporates even during stressed periods (Schmaltz et al., 2014; Boissay and Collard, 2016; Bressan 2018; Hoerova et al., 2018). However, opponents contend that regulatory compliance with liquidity regulations is costly, and could lead banks to reduce lending to households, SMEs, and corporates (Cecchetti and Kashyap, 2016; Birn, Dietsch, and Durant, 2017). A growing body of evidence documents that credit supply fluctuations affect the real economy (see Berger, Molyneux and Wilson, 2020 for a comprehensive review). Borrowers that are unable to compensate for a decline in bank credit with alternative funding sources are likely to reduce investment and / or employment (Gan, 2007; Berton et al., 2018). Hence, reductions in credit supply, instigated by regulatory policy changes could negatively affect borrowers with resultant declines in real economic activity. Given the paucity of evidence, ongoing empirical controversies, and the importance for real economic outcomes, in this chapter, we investigate the impact of liquidity regulation on bank lending behavior. A priori, it is unclear whether the introduction of liquidity regulations lead to an increase or decrease in bank lending, given that

[1] In 2010, the Basel Committee on Banking Supervision introduced new capital and liquidity regulations (embodied in Basel III), which were to be phased in between 2014 and 2019. Banks are not only required to hold more capital than before, but must also comply with new liquidity standards. The liquidity standards framework specifies a liquidity coverage ratio (LCR) and a net stable funding ratio (NSFR). The LCR requires banks to operate with sufficient high-quality liquid assets to ensure survival of a stress scenario lasting one month. The net stable funding ratio (NSFR) requires banks to operate with enough sufficient stable funding to ensure the continuance of operations over a one-year horizon.

banks have a myriad of ways to manage liquidity. For example, in order to meet stricter liquidity requirements, banks could increase stable funding (via increased deposit taking or by issuing new equity) and balance sheet size, possibly leading to an increase in lending to households, SMEs and corporates. Alternatively, to avoid holding more liquidity, banks could reduce balance sheet size by shrinking assets, leading to a decrease in lending, and resultant negative consequences for the real economy. Banks could also adjust the composition of loan portfolios toward shorter maturities, in order to improve liquidity without changing balance sheet size.

To assess the impact of liquidity regulation on bank lending, we use the introduction of a liquidity regulation in the Netherlands, known as the Liquidity Balance Rule (LBR) as a setting. Introduced in 2003, the LBR preceded the Basel III Liquidity Coverage Ratio introduced by the Basel Committee on Banking Supervision following the global financial crisis. According to the LBR, banks are required to hold high-quality liquid assets exceeding or equal to net cash outflows over a 30-day stress period. In contrast to the Liquidity Coverage Ratio, the introduction of the LBR in the Netherlands did not occur following a period of financial instability, and so was unlikely to be anticipated in advance by banks and other industry stakeholders (such as shareholders, bondholders, and depositors). The LBR was imposed on Dutch banks only and did not apply to other banks operating elsewhere in other Benelux countries (Belgium and Luxembourg) or the rest of the Eurozone. Using this differential regulatory treatment to overcome identification concerns, we investigate the impact of liquidity regulation on the lending activities of Dutch banks.

Assessing the impact of liquidity regulation on bank lending presents a significant empirical challenge. Liquidity regulations are often part of a broader set of regulatory reforms, which are anticipated in advance by industry stakeholders. Moreover, liquidity regulations such as the Basel III Liquidity Coverage Ratio, tend to be phased in gradually over an extended period, during which other significant events can take place. Consequently, isolating the impact of liquidity regulation from other significant events that influence bank lending is not a straightforward task. Our research design, which utilizes an unanticipated policy intervention as a quasi-natural experiment and subsequent empirical analysis, allows us to tackle these issues and investigate the impact of liquidity regulation on bank lending.

In order to assess the impact of the LBR on bank lending, we utilize a difference-in-differences framework where we estimate the difference in the behavior of affected banks between the pre-LBR and post-LBR period with the same difference in the behavior of an unaffected control group of banks. We follow previous literature based on European data (Schepens, 2016) and use a group of matched banks (that share the characteristics of our treated group of Dutch banks prior to the introduction of the LBR to form a control group) drawn from Eurozone countries, where the LBR was not introduced. Specifically, we use propensity score matching in order to avoid potential selection bias (Roberts and Whited, 2013; Atanasov and Black, 2016). In our baseline estimable model, we include bank level characteristics, as well as country time-varying controls that prior literature suggests are important determinants of bank lending. We also ensure our results remain robust to varying the matching parameters. Our sample period straddles the introduction of the LBR, and comprises unconsolidated balance sheet, off-balance sheet and income statement data for commercial banks covering the period 2000 to 2006 for 12 Eurozone member countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain). The results of our empirical analysis indicate that the introduction of the LBR increased the absolute volume of lending by Dutch banks relative to other Eurozone banks not subject to the rule. On average, the volume of loans extended by affected banks increased by 23.2% relative to their counterparts not subject to the provisions of the LBR. This corresponds to an additional €34.3 billion lending in the economy. Further analysis indicates that additional equity, an inflow of retail deposits and subsequent larger increase in balance sheet size compared to other Eurozone banks, allowed Dutch banks to increase lending despite having to meet the LBR requirements. Hence, while the volume of loans significantly increased, the share of loans in banks' balance sheets remained unchanged after the implementation of the LBR. The introduction of the LBR also altered the composition of affected banks' loan portfolios. Specifically, relative to unaffected counterparts, the stock of corporate and retail loans of Dutch banks increased more than mortgage loans. Dutch banks also granted more loans of shorter maturity relative to their unaffected counterparts. These results indicate that the introduction of the LBR led Dutch banks to re-orientate lending toward more liquid loans.

In a series of additional tests, we assess the robustness of our main results. First, we: modify the number of matched banks; include additional bank-level covariates in the estimation of the propensity scores used to match treated and control banks; and restrict the pool of countries used to construct the control group of banks. Our main results are robust to these additional tests. Second, we perform a placebo test by assuming falsely that the LBR was introduced in an earlier period. If banks anticipated the introduction of the LBR, we would expect a change in bank lending during this period. The results of this placebo test do not show any evidence of anticipatory effects via changes in bank lending. Finally, we also re-estimate our baseline model using a sample in which the year 2003 (the year of implementation of the LBR) is excluded. Our results remain consistent with the baseline estimations.

Our study contributes to the literature that has investigated the impact of liquidity regulation on bank behavior. Much of the salient literature that has emerged following the global financial crisis, uses dynamic general equilibrium models to investigate the impact of changes to liquidity rules on lending and real economic activity (Macroeconomic Assessment Group, 2010; Angelini et al., 2011; De Nicolo, Gamba and Lucchetta, 2014; Covas and Driscoll, 2014). In general, these studies conclude that the introduction of liquidity regulations reduce bank lending with a resultant negative impact on the real economy. Additional evidence regarding the link between liquidity regulation and bank behavior is also provided by prior literature that focuses on the Dutch Rule (LBR) and the UK Individual Liquidity Guidance (ILG) regulation. In order to comply with LBR requirements, evidence suggests that banks rely on additional deposit funding (Duijm and Wierts, 2016) and decrease long-term lending on the inter-bank market (Bonner and Eijffinger, 2016). In the UK, the introduction of the ILG reduced cross-border lending to both banks and non-financials (Reinhardt et al, 2020).

Our work is most closely related in spirit to that of Banerjee and Mio (2018) who investigate how banks make balance sheet adjustments to comply with the UK ILG regulation. The authors find that banks adjust the composition of both assets and liabilities by increasing the share of high-quality liquid assets and non-financial deposits, while reducing credit to financial institutions and short-term wholesale funding. Moreover, the ILG did not cause banks to reduce the share of loans granted to non-financial firms. Our study augments and complements the work of Banerjee and Mio along two main dimensions. First, we examine bank lending behavior at both an aggregated and disaggregated level, including an analysis of loan type and maturity. We show that the introduction of the LBR led affected banks to change loan portfolio composition. Specifically, the enactment of the LBR led to an increase in the overall volume of lending, and a re-orientation toward corporate lending. Our findings also show that the impact of liquidity requirements on bank lending is crucially dependent on the availability of stable sources of funding. These findings constitute an important contribution to the literature, given that we provide new evidence suggesting that the introduction of liquidity regulations not only affects the composition of bank loan portfolios, but also leads to banks accumulating more stable funding in the form of deposits and equity. This is of major importance because by increasing the size of banks' balance sheets, liquidity regulation can lead to an increase in credit supply - an issue neglected by previous studies. Second, we complement Banerjee and Mio by using the Netherlands as a setting, where there were no significant stresses on the banking industry immediately before, during or after the introduction of liquidity regulations. This contrasts with the UK setting used by Banerjee and Mio (2018), where the introduction of ILG followed: a regulatory review of liquidity requirements and extensive consultation with industry stakeholders (FSA, 2007, 2008, 2009); a first round of quantitative easing (QE) by the Bank of England, which ceased in January 2010; and preceded the second round of QE, which commenced in October 2011. In contrast, in the present study we focus on a relatively tranquil period where possible contaminating factors such as QE are absent. Our setting is therefore ideally suited to a more general assessment of the impact of sudden introductions of liquidity regulation on bank behavior. Moreover, we document two channels through which liquidity regulation affects bank lending, via an extensive analysis of the structure of bank loan portfolios and funding.

The remainder of the chapter is structured as follows. Section 1.2 discusses relevant literature and presents a set of testable hypotheses. In section 1.3, we describe the institutional background to the Dutch Liquidity Balance Rule and present the empirical methodology. Section 1.4 presents the main results of our baseline model along with the results of a series of robustness tests. Section 1.5 provides a brief summary.

1.2. Related Literature and hypotheses

The global financial crisis highlighted the importance of bank liquidity for financial stability, and as an important factor in determining the volume of credit extended by banks to households, SMEs, corporates, and governments (Berger, Molyneux and Wilson, 2020). Liquidity rules introduced following the financial crisis under Basel III are designed to ensure that banks hold enough liquidity to absorb unforeseen shocks. While there is a paucity of research regarding the impact of liquidity regulations, valuable insights are provided by general literature on bank liquidity. Following a seminal contribution by Diamond and Dybvig (1983) showing how depositor runs can affect even healthy banks, theoretical contributions highlight the need for liquidity regulation given bank vulnerabilities arising from asset-liability liquidity mismatches.2 The remainder of this section reviews prior literature in order to develop testable hypotheses regarding the impact of liquidity regulation on bank lending, loan portfolio composition and funding structure.

Bank lending

Discussions of bank liquidity are relevant to both the liability side and the asset side of the balance sheet. On the liability side of the balance sheet, funding liquidity is a primary concern. Following a liquidity shock, the availability of short-term funding to banks becomes impaired.

[2] De Nicolo (2016) provides an extensive discussion and review of the literature regarding the rationale and benefits and costs of liquidity regulation.

Banks then face a choice between seeking additional funding and/or shrinking assets. The impact of any negative shock depends upon the composition of liabilities, with banks reliant on wholesale funding impacted more relative to counterparts reliant on stable deposit funding. Funding liquidity can interact with asset liquidity. Hanson et al. (2015) highlight synergies between the asset and liability sides of the balance sheet, pointing out that banks can readily sell liquid assets in response to a funding shock. Consequently, the ability of banks to handle a funding shock depends upon holdings of liquid assets, as well as the extent of reliance on wholesale funding. Following a funding shock, banks reliant on wholesale funding or holding a larger share of illiquid assets are expected to curtail lending more than counterparts holding a relatively larger proportion of liquid assets, and reliant on stable deposit funding. The introduction of liquidity rules is likely to cause banks to change the composition of assets and / or liabilities. Banks are likely to reduce illiquid assets and / or increase liquid assets and stable funding sources with resultant implications for bank lending. Prior research documents a positive relationship between liquidity and bank lending, albeit these studies typically investigate this issue through the prism of monetary policy (Kashyap and Stein, 2000; Gambacorta, 2005). Agenor (2019) presents a theoretical model where liquidity requirements enhance financial stability, thus increasing confidence among depositors and acting as an incentive to save. This increased saving has a positive effect on banks' ability to lend. Similarly, Reinhardt et al. (2020) offer empirical evidence for the UK of a moderating effect of deposit funding on the impact on cross-border lending following the introduction of liquidity regulations. The authors assert that a dependence on deposit funding could result in a cross-border expansion in lending, despite more onerous liquidity requirements. Nevertheless, Banerjee and Mio (2018) find no change in bank lending following the introduction of liquidity regulation in the UK banking industry.

A small, but growing literature using dynamic structural models offers differing assessments regarding the impact of liquidity rules on bank behavior and real economic activity. These assessments range from a small and negative (Macroeconomic Assessment Group, 2010; Angelini et al., 2011) to a negative and significant impact of liquidity requirements on bank lending and real economic activity (Institute of International Finance 2011; EBA Banking Stakeholder Group, 2012). Tirole (2011) argues that finite horizon (generally three-period) models of the type used in these aforementioned studies capture key trade-offs in a tractable way. However, infinite horizon models that consider the implied shadow costs faced by banks are likely to deliver more reliable assessments. Building upon this argument, De Nicolo, Gamba and Lucchetta (2014) consider a dynamic partial equilibrium model, in which banks transform insured deposits and short-term collateralized debt into long-term illiquid assets. The results suggest that the introduction of liquidity requirements reduces bank lending, efficiency, and welfare. The authors argue that banks use retained earnings to invest in liquid assets rather than extending loans. Covas and Driscoll (2014) develop a similar model in order to assess the macroeconomic impact of bank liquidity requirements. The authors find that the introduction of liquidity standards leads to a decrease in bank lending, albeit the size of this effect is sensitive to the supply of safe assets. Empirical evidence, using quasi-experimental research designs, lends support to the prediction of a more modest impact of liquidity requirements on bank lending. For the Netherlands, Bonner and Eijffinger (2016) document a negative impact of liquidity requirements on interbank lending but find no impact on lending to non-financial firms. Based upon insights from the aforementioned literature, we offer two alternative hypotheses on the effect of liquidity regulation on bank lending:

H1.a: The introduction of liquidity requirements leads to an increase in bank lending.

H1.b: The introduction of liquidity requirements leads to a decrease in bank lending.

Loan portfolio structure

Banks face a myriad of lending opportunities that range in type and maturity. Given that liquidity regulation aims to address mismatches in the maturity of assets and liabilities, banks are likely to take account of any potential mismatches when allocating credit across a myriad of lending opportunities. Banks facing liquidity pressure are more likely to favor granting short rather than longer-term loans (Bonner and Eijffinger, 2016). Therefore, we anticipate that banks affected by liquidity regulation are likely to adjust the composition of loan portfolios toward shorter maturities. Based upon insights from the aforementioned literature, our second hypothesis, stated in the alternate, is as follows:

H2: The introduction of liquidity requirements leads to an increase in short term bank lending.

Funding structure

Theory predicts a positive association between liquidity regulation and bank deposits. Two explanations are offered to justify this assertion. The first is that, following the introduction of liquidity regulations, banks attract more funds to alleviate any constraints placed upon lending. Webb (2000) argues that if banks have access to sufficient funding, the implementation of liquidity regulation should not constrain lending. That is, banks use various strategies (including capital accumulation and equity issuance, money market borrowing, offering higher interest rates on deposits) to secure additional funds. Therefore, following the enactment of liquidity regulation, banks may engage in a strategy of actively attracting deposits such as providing new or enhanced services or increasing interest rates on savings. Alternatively, depositors may view banks as safer following the introduction of liquidity regulation. Indeed, liquidity regulation causes banks to hold more liquid assets with a resultant decline in liquidity risk and bank fragility (Vives, 2014). That is, banks holding more liquid assets are more resilient to negative balance sheet shocks (Ratnovski, 2013) and less prone to runs (De Bandt, Lecarpentier and Pouvelle, 2021). Consequently, following the enactment of liquidity regulation, banks may experience an inflow of deposits resulting from the belief that they are safer. Based upon insights from the aforementioned literature, our third hypothesis stated in the alternate, is as follows:

H3: The introduction of liquidity requirements leads to an increase in bank deposits.

Theory offers contrasting views regarding the impact of liquidity regulation on bank capital. One view posits that capital and liquidity are to some extent substitutes, where an increase in liquidity requirements could achieve the same outcome as an increase in capital requirements. That is, to the extent that banks hold higher levels of capital as an incentive to avoid accumulating excessive risks on asset portfolios, maintaining high levels of liquid assets has a similar effect (Kashyap, Tsomocos and Vardoulakis, 2014; Calomiris, Heider and Hoerova, 2014; Acharya, Mehran and Thakor, 2016). Therefore, liquidity regulation can induce banks to reduce capital. An alternative view posits that capital and liquidity are complements rather than substitutes, thus suggesting a positive association between liquidity regulation and capital. In general, returns on liquid assets are lower than those on illiquid assets. This implies that bank profits decline as liquidity increases, leading to an increase in insolvency risk (Eisenbach et al., 2014; Konig, 2015). Consequently, following the introduction of liquidity requirements, banks may increase capital to offset the increase in insolvency risk. Furthermore, liquidity and capital could be associated due to the mechanical link between the two. Indeed, higher capital makes banks more liquid because such funding is stable. Therefore, one way of achieving higher liquidity is to increase capital because it reduces the maturity mismatch between assets and liabilities. Higher liquidity also implies that banks need to hold less capital to comply with capital regulation. Regulatory capital ratios compare equity to asset mix, whereas liquidity ratios compare asset mix to funding mix. For instance, because many liquid assets held on bank balance sheets carry low risk weights in capital requirement computations, banks need less capital to comply with the minimum risk-weighted regulatory capital ratio when they hold larger portions of liquid assets. Based upon insights from the aforementioned literature, we offer two alternative hypotheses on the effect of liquidity regulation on bank capital:

H4.a: The introduction of liquidity requirements leads to an increase in bank equity.
H4.b: The introduction of liquidity requirements leads to a reduction in bank equity.

1.3. Background and research design

1.3.1. Identification

To investigate the impact of liquidity regulation on bank lending, we rely on the introduction of the LBR in 2003. The LBR stipulates that banks should hold high-quality liquid assets greater than or equal to net cash outflows over a 30-day stress period. The LBR is defined as: LBR =

AL/RL. AL denotes Actual Liquidity and comprises the sum of the stock of liquid assets and cash inflow scheduled within the next 30 days.[3] RL denotes Required Liquidity and comprises the sum of the stock of liquid liabilities and cash outflow scheduled within the next 30 days. The LBR ratio should be equal to or exceed one. In order to account for market and funding liquidity risks, items included in AL and RL are weighted according to relative liquidity.[4] During a period of stress, market illiquidity dictates that only certain assets can be sold immediately (often at fire sale prices with resultant losses). In such a situation, the probability of withdrawal may differ depending on the nature of the liability.[5] The period between the announcement and implementation of the LBR was relatively short, thus minimizing the possibility of anticipatory effects and subsequent changes in bank behavior prior to implementation. Announced in January 2003, banks had until July 2003 to comply with the terms of the LBR (de Haan and den End 2013). Every Dutch bank was subject to the rule. Branches of banks located in other countries of the European Union were exempt.

The LBR can be considered as a source of exogenous change in the proportion of liquid to total assets across banks. Given that the rule was introduced in January and implemented in July 2003, there was insufficient time for banks to make any major balance sheet adjustments in order to comply with the rule in advance of implementation.[6] Extensive searches of

[3] The LBR is conceptually similar to the Basel III LCR, which requires banks to hold a minimum level of liquid assets to meet a stress scenario of outflows. The main difference is in the weighting scheme and the range of items included in the stock of liquid assets (which is more extensive for the LBR compared to the LCR).

[4] The weight for each item is determined by the regulator (DNB, 2011).

[5] For example, asset-backed securities carry a lower weight than high-quality bonds. Wholesale deposits carry a higher weight than retail deposits. Liquid assets (such as securities, inter-bank assets payable on demand and debts immediately due or payable by public authorities and professional moneymarket participants) are items that can be converted to cash quickly. Demand deposits held with noncredit institutions or non-professional money-market participants are not counted as part of the actual liquidity. Liquid liabilities comprise bank debt (such as deposits without a fixed maturity) that can be called upon immediately.

[6] We also conduct an event study analysis, which confirms that the LBR did not affect banks outside of the Netherlands. That is relative to counterparts located elsewhere in the Eurozone, shareholders of

regulatory reports and commentaries suggest there were no information leaks that alerted banks to the pending announcement and provisions of the LBR.[7] Therefore, it is unlikely that banks could have anticipated the LBR.[8] Moreover, other regulatory changes (such as the publication of the preliminary draft of Basel II requirements) that may have occurred at the regional or international level during the period when the LBR was announced and implemented is not expected to affect our analysis. Indeed, such regulatory changes do normally not influence banks differently. At the national level, there were no other changes that could have affected the ability of banks to increase liquidity or lending (IMF, 2004).

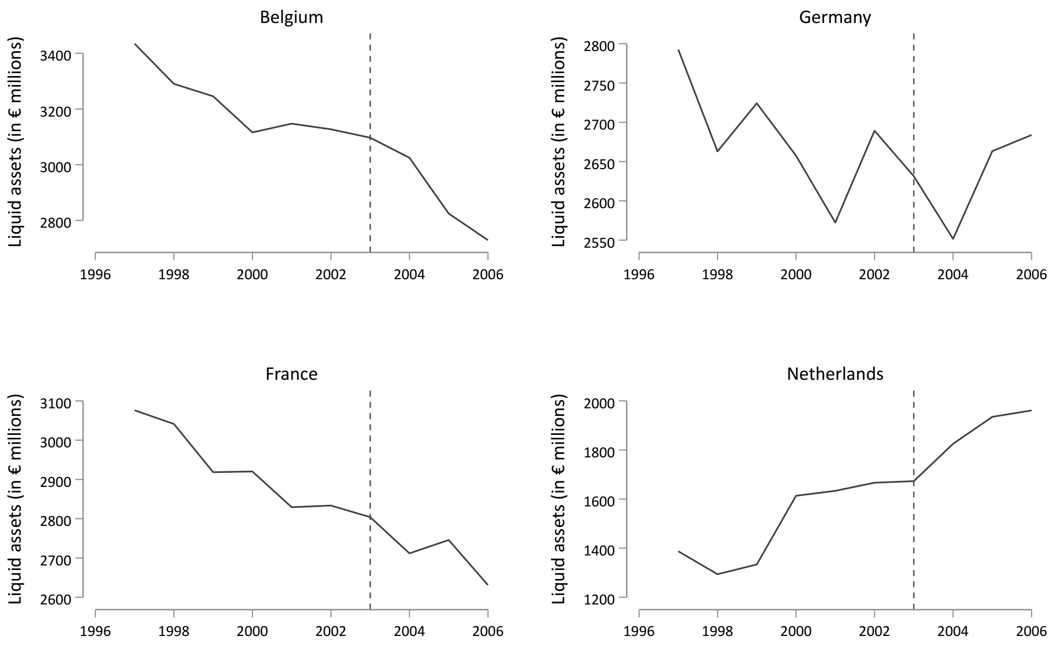
The LBR was unique to the Netherlands. Bank regulators based in other Eurozone countries did not consider this type of rule until the Global Financial Crisis of 20072009, when following international agreement, the Liquidity Coverage Ratio was introduced (Bonner and Hilbers 2015). Figure 1.1 shows that the introduction of the LBR led to an increase in liquidity at Dutch banks as expected. Specifically, we observe a levelling off in the volume of liquid assets held by Dutch banks before 2003. It is also evident, that Dutch banks experience a growth in liquid assets after the introduction of the LBR. Nevertheless, the level of liquid assets held by counterparts in neighboring countries exhibit a general downward trend throughout the period considered. This implies that the introduction of the LBR had a positive impact on the liquidity of Dutch banks, while leaving the liquidity of banks located in other Eurozone countries unaffected. Consequently, banks operating in Eurozone countries outside the Netherlands serve as a sample from which a suitable control group can be chosen.

Dutch banks suffered a greater wealth reduction following the news of the LBR. Nevertheless, these findings rely on a small sample of six publicly listed Dutch banks, which reduces the power of our tests.

[7] The introduction of a new rule often violates this exogeneity assumption because regulators communicate with industry stakeholders prior to announcement and implementation. If banks anticipate the introduction of a regulation, they may take pre-emptive action to comply or lessen any impacts prior to implementation. Consequently, any change in bank behavior following actual implementation would be negligible.

[8] Dutch banks had relatively high levels of liquidity in the pre-treatment period (IMF 2004). Liquid assets had been high enough to cover 50% of short-term liabilities since 1998.

Figure 1.1 – Liquid assets of banks in the Netherlands and neighboring countries from 2000 to 2006



Notes: The figure plots the amount of liquid assets (weighted by bank size) held by banks operating in the Netherlands and in neighboring countries (Belgium, France, and Germany) included in our full sample.

1.3.2. Data

We collect financial statement items from the BankScope produced by Bureau van Dijk. This comprises unconsolidated balance sheet, off-balance sheet, and income statement data of commercial banks from 2000 to 2006 for the Netherlands and the 11 other European countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, and Spain) forming the Eurozone in 2003 (the year of the introduction of the LBR). We restrict our sample to these countries for two reasons. First, to avoid changes in the composition of any possible control group arising from the accession of new countries to the Eurozone. Second, structural differences between countries should be insignificant, and the banking industry in each country would face the same constraints due to regulation. We complement the bank-level data with macroeconomic data, retrieved from the Eurostat database. A full list of variables and accompanying definitions are provided in Table 1.1.

Table 1.1 – Definition of variables.

Variable name	Description	Source	Expected Sign
Dependent variables			
BANKD	Total deposits by banks, including deposits, loans and repos from banks overt total assets (in %)	Bankscope	
CUSTD	Total deposits by customers, including current, saving and term accounts over total assets (in %)	Bankscope	
IMPLICIT	Ratio of interest expense over total deposits (in %)	Computed	
lnLOAN	Natural logarithm of total loans	Computed	
LOANFW	Loans flow defined as the ratio of the year-to-year difference of the sum of net granted loans and unused loan commitments normalized by the sum of total assets and unused loan commitments at the beginning of the period (in %)	Computed	
MAT > 5 years	Ratio of loans with a maturity greater than 5 years to total assets (in %)	Bankscope	
MAT 1-5 year	Ratio of loans with a maturity between 1 to 5 years to total assets (in %)	Bankscope	
MAT 3-12 months	Ratio of loans with a maturity of 3 to 12 months to total assets (in %)	Bankscope	
MAT < 3 months	Ratio of loans with a maturity of less than 3 months to total assets (in %)	Bankscope	
RATLOAN	Ratio of outstanding loans to total assets (in %)	Computed	
SECU	Ratio of the sum of reverse repos, cash collateral, trading securities, derivatives, available for sale securities, held to maturity securities, at-equity investments, and other securities over total assets	Bankscope	
Control variables			
DEPOSITS	Total deposits by customers, money market and short-term funding over total assets of bank (in %)	Bankscope	+
EQUITY	Ratio of total equity to total assets (in %)	Bankscope	+
LIQ	Sum of trading securities, reserve repos, cash collateral, loans and advances to banks, cash and due from banks minus mandatory reserves, over total assets of bank (in %)	Bankscope	+
LLR	Ratio of loan loss reserves to total assets (%)	Bankscope	-
SIZE	Natural logarithm of total assets	Bankscope	+/-
GROWTH	Year-to-year growth rate of real GDP	Eurostat	+
INFLATION	Year-to-year growth rate of harmonized price index	Eurostat	-
Other variables			
COMMIT	Total of any undrawn credit facilities made available by the bank (in millions of euros)	Bankscope	
LOANS	Outstanding loans on bank's balance sheet (in millions of euros)	Bankscope	

Notes: This table presents definitions for all variables used throughout the chapter. The first column shows the name of the variable as used throughout the chapter, the second describes the corresponding definition and the third column gives the source. The final column presents the expected sign for each of the control variables included in the baseline model.

Our initial sample comprises 528 banks per year on average. We exclude 12 banks identified as branches of banks located in other Eurozone countries. This leaves us with a sample of 517 banks. To eliminate the undue influence of outliers, we winsorize all bank-specific variables at the 5th and 95th percentile. In order to reduce the possible impact of mergers and acquisitions that took place during the period, we also discard all bank-year observations where growth in total assets exceeds 25%. To deal with reporting errors, we delete observations with negative assets and loans. Applying these filters, leaves us with a final sample that comprises of 473 banks per year on average. Column 1 of Table 1.2 provides further details on the number of banks by country

Table 1.2 – Distribution of banks in the sample by country

	Number of banks	
Country	Initial sample	Matched sample
	(1)	(2)
Western Europe		
Austria	38	5
Belgium	20	2
France	92	16
Germany	88	11
Ireland	13	3
Italy	81	2
Luxembourg	52	14
Netherlands	26	22
Southern Europe		
Greece	12	1
Portugal	12	2
Spain	31	6
Northern Europe		
Finland	8	0

Notes: This table indicates for each country the number of banks included in the sample

1.3.3. Model Specification

To assess the impact of the LBR on bank lending, we use a difference-in-differences framework, where we estimate the difference in the lending of affected banks between the pre-LBR and post-LBR period with the same difference in the behavior of the unaffected group of banks as follows:

$$Y_{i,t} = \beta(\text{Affected}_i \times \text{Post Event}_t) + \delta X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t} \tag{1.1}$$

where *i* indexes bank and *t* indexes times. $Y_{i,t}$ denotes bank lending, which is measured by lnLOAN, LOANFW and RATLOAN. lnLOAN is the log of total loans (stock of loans). LOANFW is the net flow of loans defined as the change in the stock of loans and unused commitments scaled by total assets and unused commitments as in Cornett et al. (2010). RATLOAN is total loans scaled by total assets. $Affected_i$ is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. $PostEvent_t$ is a dummy variable for the treatment period. It takes the value of one for the years 2003 onwards, and zero otherwise. β is the coefficient of interest, which represents the impact of the LBR on banks' lending.

$X_{i,t-1}$ represents a vector of both bank and country level control variables that prior literature suggests are important determinants of bank lending. In order to avoid simultaneity, we lag each of our control variables by one period. Bank size (SIZE) is measured as the natural logarithm of total assets. The effect of bank size on lending is ambiguous. Large banks may assume more risk than smaller counterparts, given expectations regarding the likelihood of official bailouts (in the event of failure). Moreover, large banks can also diversify asset portfolios, thus holding a lower stock of loans relative to total assets. Consequently, large banks are less likely to reduce loan portfolios in the event of a negative shock (Gambacorta and Marques, 2011; Jiménez et al., 2012; Popov and Van Horen, 2015). In contrast, small banks are likely to specialize in traditional lending activities and are thus more likely to curtail loans in event of a negative shock to liquidity (Petersen and Rajan 1994; Berger and Udell 1995). Loan quality is measured as the ratio of loan loss reserves to total asset (LLR). Prior evidence suggests that there is a significant negative correlation between loan quality and loan growth (Chami et al., 2010; Stepanyan and Guo, 2011; Cucinelli, 2015). Funding is measured by the ratio of deposits to total assets (DEPOSITS). The importance of stable bank funding for credit supply was illustrated aptly during the global financial crisis of 2007-2009 when banks that were more reliant on traditional deposits, maintained lending to households and firms (Cornett, McNutt, and Strahan, 2010; Chami et al., 2010). Consequently, when faced with stricter liquidity requirements, banks more dependent on deposits are more likely to continue lending relative to counterparts more reliant on wholesale funding. Capital (EQUITY) is measured by total equity to total assets ratio. Prior evidence suggests that there is a significant relationship between capital and lending (Berrospide and Edge 2010; Carlson, Shan, and Warusawitharana 2013; Kapan and Minoiu, 2013). Given the ability to efficiently absorb negative shocks to loan portfolios, well capitalized banks are expected to extend more loans when faced with stricter liquidity requirements. Liquidity is measured by the ratio of liquid assets to total assets (LIQ). Liquid assets for purposes of LIQ are defined as the sum of trading securities, reserve repos, cash collateral, loans and advances to banks, cash and due from banks minus mandatory reserves. Prior evidence suggests that more liquid banks tend to lend more than counterparts holding higher proportions of illiquid assets (Cornett, McNutt, and Strahan, 2010; Kim and Sohn, 2017). Hence, we expect a positive relationship between LIQ and lending. Economic conditions and monetary policy are measured by the real GDP growth (GROWTH) and inflation (INFLATION) respectively. Given that economic conditions determine consumption and investment demand (and thus reflect the demand for credit), higher GDP is likely to related to higher credit growth (Frankel and Romer 1999; Takats 2010). Inflation is likely to negatively impact lending, given that financial intermediaries are less willing to fund new projects in an inflationary environment (Bernanke and Blinder 1988). The model also includes bank specific fixed effects, α_i, to control for unobserved bank heterogeneity and time dummies, γ_t, to capture time effects common to all banks. Table 1.3 presents the correlation matrix of all variables. The pairwise correlations suggest that the independent variables included in equation (1.1) are not highly correlated. Consequently, multicollinearity issues are not a concern.

Table 1.3 – Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	9.	10.	11.
1. lnLOAN	1.00									
2. LOANFW	0.12	1.00								
3. RATLOAN	0.17	0.27	1.00							
4. SIZE	-0.19	0.03	-0.19	1.00						
5. DEPOSITS	0.03	-0.18	0.04	-0.15	1.00					
6. LLR	-0.07	-0.04	-0.09	-0.08	0.03	1.00				
7. EQUITY	-0.14	0.07	-0.16	-0.09	-0.44	-0.02	1.00			
8 GROWTH	-0.24	-0.21	-0.24	0.06	0.33	0.15	-0.15	1.00		
9. INFLATION	-0.06	-0.30	-0.06	-0.13	0.27	0.29	-0.18	0.20	1.00	
10. LIQ	-0.63	-0.03	-0.63	0.14	-0.10	-0.21	0.02	0.02	-0.08	1.00

Notes: This table reports the correlation matrix for the outcome variables and control variables used in our analysis.

1.3.4. Propensity score matching

Our sample comprises of 26 Dutch banks and 447 banks from other Eurozone countries. Table 1.4 provides descriptive statistics for the main variables for both Dutch banks and banks from other Eurozone countries spanning the 2000-2006 period.

Table 1.4 – Summary statistics of the full sample

	Dutch banks			Rest of Eurozone				
Panel A: Pre LBR period (2000-2002)								
Variables	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Diff.	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RATLOAN	74	45.46	22.88	1180	46.94	27.1	-1.48	0.47
lnLOAN	74	6.85	1.88	1180	6.14	2.13	0.71	0.00
LOANFW	74	0.06	0.22	1180	0.06	0.17	0.00	0.64
SIZE	74	7.71	1.59	1180	7.26	1.7	0.45	0.02
LIQ	74	32.64	21.95	1180	31.75	23.75	0.89	0.73
DEPOSITS	69	46.58	28.18	1068	50.56	23.72	-3.98	0.25
EQUITY	74	10.19	12.22	1180	9.69	12.47	0.5	0.73
COMMITS	74	338.66	666.12	1180	270.82	742.48	67.84	0.39
LLR	63	0.75	0.61	1068	0.69	0.81	0.06	0.01
GROWTH	3	1.43	0.93	33	2.07	2.07	-0.64	0.00
INFLATION	3	0.47	0.56	33	0.59	0.61	-0.12	0.00
Panel B: Post LBR period (2003-2006)								
RATLOAN	103	42	24.17	1602	45.53	28.08	-3.53	0.00
lnLOAN	103	6.97	2.35	1602	6.36	2.13	0.31	0.00
LOANFW	103	0.03	0.17	1602	-0.06	0.15	0.09	0.00
SIZE	103	7.82	1.38	1602	7.45	1.68	0.37	0.000
LIQ	103	32.98	20.84	1602	31.04	24.18	1.94	0.05
DEPOSITS	103	53.19	27.01	1431	51.82	24.22	1.37	0.64
EQUITY	103	9.5	6.27	1602	9.72	12.39	-0.22	0.49
COMMITS	103	382.73	745.91	1602	368.31	871.57	14.42	0.65
LLR	85	0.95	1.44	1584	0.82	0.72	0.13	0.00
GROWTH	4	1.46	0.4	44	2.09	2.08	-0.63	0.00
INFLATION	4	0.4	0.47	44	0.6	0.63	-0.2	0.27
Panel C: Pre-trend (growth in) (%)								
RATLOAN	74	1.97	3.72	1180	3.53	2.16	-1.56	0.00
lnLOAN	74	-0.58	1.74	1180	-1.32	1.81	0.74	0.00
LOANFW	74	-3.28	3.37	1180	-2.91	6.30	-0.37	0.95
Panel D: Post-trend (growth in) (%)								
RATLOAN	103	-2.53	3.16	1602	-1.21	1.87	-1.32	0.00
lnLOAN	103	2.62	2.79	1602	1.34	2.01	1.28	0.00
LOANFW	103	4.45	1.08	1602	1.91	1.14	2.54	0.00

Notes: Panels A and B report summary statistics for all the outcome and control variables for Dutch banks and non-Dutch banks for the full sample over the pre- and post-treatment period respectively. Panels C and D present trends in the pre- and post-treatment period and the mean comparison of these trends between treated and control banks for the outcome variables. Columns 7 and 8 report the differences and p-values for the difference in means test (t-test) between Dutch and Eurozone banks.

Panel A of Table 1.4 shows that Dutch banks with, on average, assets of € 5.45 billion are larger, have lower loan portfolio quality (measured by LLR; 0.75% versus 0.69%), and extend more loans (lnLOAN 6.85 versus 6.14) than counterparts located in other Eurozone countries. In addition, Dutch banks experience a smaller decrease in loan growth as well as a slower growth in the ratio of loans to total assets relative to counterparts based in other Eurozone countries during the pre-treatment period. This suggests there are some structural differences across Eurozone banking systems.[9] If Dutch banks differ from control banks in the pre-treatment period across a number of observable characteristics, they might exhibit different trends in the outcome variables of interest in the post-treatment period even in the absence of the LBR. Fortunately, propensity score matching (PSM) can be used to construct a valid control group; thus, ensuring comparability between the treatment and control group. In the present study, we follow Roberts and Whited (2013) and Schepens (2016) and use PSM to construct a suitable control group.

Our propensity score matching is executed based upon trends in lending and other balance sheet characteristics as well as national economic conditions in the pre-treatment period (prior to the introduction of the LBR). Specifically, we compute propensity scores using the levels of total assets and total loans. We also use the growth rate in loans; ratio of total deposits to total assets; ratio of total equity to total assets; real GDP and inflation. Hence, we select banks of similar size, portfolio composition, capital structure and facing similar economic conditions in the pre-treatment period. The propensity scores are used to match each Dutch bank with its three nearest neighbors. The matching is executed with replacement. This means that each non-Dutch bank can serve as a control for multiple Dutch banks, thus improving the accuracy of the matching procedure (Smith and Todd, 2005).

[9] Goddard, Molyneux and Wilson (2010, 2015, 2019) provide detailed overviews of the banking systems of EU member states before, during and after the global financial crisis.

1.3.5. Diagnostic of the matching

The matching procedure leads to a final sample of 85 banks, comprising 22 treated banks and 63 control banks.[10] Column 2 of Table 1.2 tabulates the countries where banks in our matched sample are headquartered. The impact of the matching is illustrated in Table 1.5, where summary statistics for the outcome and control variables of the treated and control banks are presented. Panel A of Table 5 shows that the difference in means between Dutch banks and the matched group of banks is not statistically significant for all bank characteristics. Moreover, trends in loans to assets ratio (RATLOAN), total loans (lnLOAN) and loans flow (LOANFW) are similar between Dutch banks and matched banks in the pre-treatment period (Panel C). In addition, Panel D shows that in the post-treatment period the growth in two of the three outcome variables, namely lnLOAN and LOANFW, is significantly higher for Dutch banks compared to control banks. Figure 1.2 provides a graphical illustration of the aforementioned findings. It depicts the evolution of loans, loan flows and loans to total assets for banks in the treatment and control groups. The trends in all outcome variables follow similar paths in the pre-treatment period lending support to the notion that the parallel trends assumption is not violated in our setting (more formal test results are reported in Section 1.4.3). However, from 2003 (the year LBR came into effect), we observe diverging trends for the affected and control banks. This represents tentative evidence that the introduction of the LBR changed the lending behavior of Dutch banks.

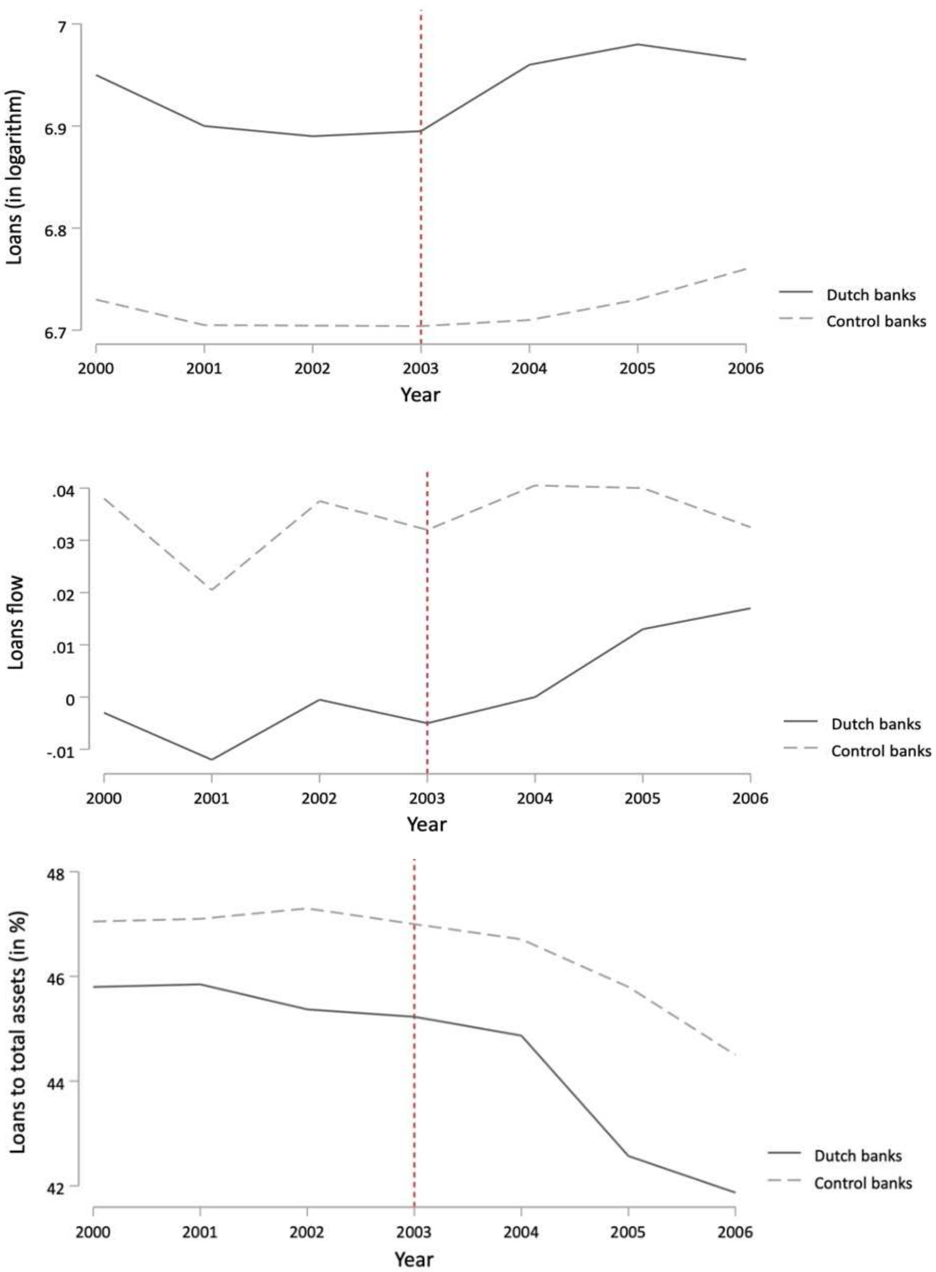
[10] Four Dutch banks are dropped from our matched sample due to missing values for DEPOSITS; a variable used in the propensity score matching exercise.

Table 1.5 – Summary statistics of the matched sample

	Dutch banks			Rest of Eurozone				
Panel A: Pre LBR period (2000-2002)								
Variables	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Diff.	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RATLOAN	57	45.67	21.96	167	46.53	23.77	-0.86	0.55
lnLOAN	57	6.85	1.88	167	6.72	2.17	0.13	0.62
LOANFW	57	0.07	0.22	167	0.05	0.14	0.02	0.45
SIZE	57	7.93	1.37	167	7.81	1.69	0.12	0.54
LIQ	57	31.7	20.91	167	31.56	23.83	0.14	0.69
DEPOSITS	57	46.58	28.18	167	47.45	23.27	-0.87	0.45
EQUITY	57	8.38	4.72	167	8.19	11.67	0.19	0.84
COMMITS	57	335.32	615.27	167	287.15	743.48	48.17	0.19
LLR	57	1.01	0.72	167	0.91	0.68	0.1	0.25
GROWTH	3	1.43	0.93	33	2.07	2.07	-0.64	0.00
INFLATION	3	0.47	0.56	33	0.59	0.61	-0.12	0.00
Panel B: Post LBR period (2003-2006)								
RATLOAN	76	43.29	24.64	248	45.54	22.71	-2.25	0.27
lnLOAN	76	7.51	2.87	248	6.77	2.08	0.74	0.00
LOANFW	76	0.03	0.34	248	0.00	0.12	0.03	0.02
SIZE	76	7.97	1.88	248	7.88	1.67	0.09	0.00
LIQ	76	33.67	23.87	248	31.52	25.26	2.15	0.16
DEPOSITS	76	54.63	27.68	248	48.04	23.69	6.59	0.51
EQUITY	76	9.78	7.56	248	8.25	11.21	1.53	0.23
COMMITS	76	374.27	755.36	248	368.31	751.57	5.96	0.39
LLR	76	1.11	0.84	248	3.259	1.12	-2.149	0.07
GROWTH	4	1.46	0.4	44	2.09	2.08	-0.63	0.00
INFLATION	4	0.4	0.47	44	0.6	0.63	-0.2	0.27
Panel C: Pre-trend (growth in) (%)								
RATLOAN	57	1.63	2.21	167	2.02	2.91	-0.39	0.28
lnLOAN	57	-1.06	2.07	167	-0.93	2.36	-0.13	0.31
LOANFW	57	-3.14	3.87	167	-3.01	1.86	-0.13	0.55
Panel D: Post-trend (growth in) (%)								
RATLOAN	76	-1.94	1.52	248	-1.73	1.23	-0.21	0.81
lnLOAN	76	2.36	2.28	248	0.36	2.68	2.00	0.00
LOANFW	76	3.25	1.27	248	1.23	1.96	2.02	0.03

Notes: Panels A and B report summary statistics for all the outcome and control variables for Dutch banks and non-Dutch banks for the matched sample over the pre- and post-treatment period respectively. Panels C and D present trends in the pre- and post-treatment period and the mean comparison of these trends between treated and matched banks for the outcome variables. Columns 7 and 8 report the differences and p-values for the difference in means test (t-test) between Dutch and matched Eurozone banks.

Figure 1.2 – Evolution of loans, loans flow and loans to total assets from 2000 to 2006



Notes: This figure plots the evolution of loans, loans flow and loans to total assets for both treated and control banks over the period 2000-2006. The dashed vertical line in each graph marks 2003, the year LBR came into effect. The upper graph depicts the mean of loans. The middle graph depicts the mean of loan flows. The bottom graph depicts the mean of loans to total assets. The control group includes all the banks selected via the nearest neighbor matching.

1.4. Results

1.4.1. Regression results: baseline model

Table 1.6 presents the results of estimating equation (1.1). The outcome variables are log of total loans, lnLOAN (column 1); the ratio of loan flows, LOANFW (column 2); and the ratio of total loans to total assets, RATLOAN (column 3). Each model includes bank specific control variables to capture any potential shocks in one of the time-varying determinants of bank lending as well as country-specific variables to capture country level changes in economic conditions or fiscal policy.

Table 1.6 – Regression results: baseline Model

Variables	lnLOAN (1)	LOANFW (2)	RATLOAN (3)
Affected × Post Event	0.213**	0.023**	0.011
	(0.092)	(0.008)	(0.015)
SIZE	1.018***	0.027	0.033
	(0.021)	(0.039)	(0.048)
DEPOSITS	0.0631**	0.090**	0.088*
	(0.0242)	(0.021)	(0.052)
LIQ	0.1216	0.022**	-0.137
	(0.1839)	(0.0072)	(0.245)
EQUITY	0.2982	0.075*	0.013**
	(1.3448)	(0.0394)	(0.006)
LLR	-0.0404	-0.038	-0.036
	(0.0984)	(0.2189)	(0.051)
GROWTH	0.055**	0.034**	0.014*
	(0.021)	(0.012)	(0.006)
INFLATION	-0.023	-0.004	0.027
	(0.039)	(0.005)	(0.039)
Year fixed effects	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Observations	471	471	471
R-squared	0.923	0.392	0.902

Notes: This table analyses the impact of the introduction of the Liquidity Balance Rule in the Netherlands in 2003 on bank lending behavior. The sample consists of 22 Dutch banks and 63 Eurozone banks selected via propensity score matching. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets, loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. *Affected* is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. *Post Event* is a dummy variable that takes the value of one for the years 2003 onwards, and zero otherwise. The dependent variable is the log of total loan volume in Column 1, the year-to-year variation of the sum of total loans and unused commitments over the lagged sum of total assets and unused commitments in Column 2, and the ratio of total loans to total assets in Column 3. The effect of LBR is captured by the coefficient on the interaction term *Affected × Post Event*. Standard errors are clustered at the bank level and presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The coefficient on the interaction term, $\text{Affected}_i \times \text{PostEvent}_t$, (which represents the average treatment effect of the LBR on loans granted by Dutch banks) is positive and statistically significant when lnLOAN and LOANFW are the outcome variables of interest. This indicates that the introduction of the LBR has a positive and significant impact on both the stock and flow of loans. Following the introduction of the LBR, the average stock of loans for Dutch banks was 23.2% higher relative to banks not subject to the provisions of the LBR.[11] With the total sum of credit outstanding in the Netherlands in the pre-treatment period in our sample amounting to €147.9 billion, this translates into an expansion in outstanding credit to €182.2 billion. The flow of loans for Dutch banks was 2.3 percentage points higher relative to banks not subject to the LBR. However, in the estimations using RATLOAN as the outcome variable, the coefficient of interest is positive, but not statistically significant. This indicates that the introduction of the LBR does not affect the loans to total assets ratio. This is in line with prior evidence (Bonner, 2016; Banerjee and Mio, 2018).

Turning to our control variables, the coefficient on SIZE is positive and statistically significant at the 1% for the specification in column 1. This suggests that a 1% increase in SIZE is associated with an average increase of about 1% in the (log) amount of loans (lnLOAN). We also find that better capitalized banks extend more loans (according to specifications in columns 2 and 3). The coefficient on DEPOSITS across all specifications shows that an increase in stable bank funding is associated with growth in loans. For instance, a standard deviation (28.18%) increase in DEPOSITS will increase the stock of loans by 1.77%, while it will also increase the flow of loans and the ratio of loans to total assets by 2.53 and 2.47 percentage points, respectively. We also find that an increase in liquid assets has a positive impact on the flow of loans. This finding is consistent with the view that more liquid banks lend more than counterparts holding a higher proportion of illiquid assets (Cornett, McNutt, and Strahan, 2010; Kim and Sohn, 2017).

[11] For a dummy variable, we cannot directly interpret the coefficient as capturing the impact of the variable on the dependent variable in percentage terms. Therefore, we follow the transformation discussed by Giles (1982): $100 \times [exp(\hat{\beta} - 0.5V(\hat{\beta})) - 1]$, where $\hat{\beta}$ is the estimated coefficient and $V(\hat{\beta})$ represents its variance. In the remainder of the paper, we use the transformed coefficient to discuss the impact of the LBR.

Moreover, the coefficient on LLR shows that increases in the ratio of loan loss reserves to total assets has no impact on the growth of loans. Finally, we find that improved economic conditions are associated with higher credit growth.

Next, we turn our attention to the structure of bank loan portfolios. The results of our empirical investigation indicate that the introduction of the LBR did not affect the share of loans on the balance sheet of Dutch banks. However, banks may adjust the composition of loan portfolios by shifting from long-term to short-term loans. To that end, we obtain data on the maturity of loans granted by both affected and control banks. Specifically, we consider loans classified into four different maturity categories comprising: greater than 5 years, between 1 to 5 years, between 3 to 12 months, and less than 3 months. Subsequently, we normalize the amount of loans in the four maturity categories by total assets. Given the limited availability of data on loan maturities for European banks, we use a smaller sample than that used in the main analysis. We estimate equation (1.1) using this restricted sample, while considering the normalized amount of loans in each maturity category as an outcome variable. Table 1.7 presents the results of this analysis.[12] We find that for the first three maturity categories containing longer-term loans, the coefficient on the interaction term $Affected_i \times PostEvent_t$ is negative and statistically significant at the 1% level. However, the sign of the coefficient turns positive when the shortest maturity loan category is considered. This is consistent with the view that banks switch to shorter maturity loans in response to the imposition of the LBR.

[12] For simplicity, the table mainly shows the coefficient of the interaction term, *Affected × Post Event*. Appendix A1.1 reports the estimations in detail including the control variables

Table 1.7 – Impact of LBR on loan maturity

Variables	MAT > 5 years (1)	MAT 1-5 years (2)	MAT 3-12 months (3)	MAT < 3 months (4)
Affected × Post Event	-0.010***	-0.005***	-0.001***	0.011***
	(0.000)	(0.001)	(0.000)	(0.000)
Controls	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Observations	202	202	202	202
R-squared	0.943	0.932	0.936	0.945

Notes: The table analyses the impact of the introduction of the LBR on loans by maturity. The sample consists of 12 banks from the Netherlands and 21 matched banks over the 2000-2006 period. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets, loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. Affected is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. Post Event is a dummy variable that takes the value of one for the years 2003 onwards, and zero otherwise. Columns (1) reports the results for loans with a maturity higher than 5 years, while column (2) shows the results for loans with a maturity between 1 to 5 years. Columns (3) and (4) report the results for loans with a maturity between 3 to 12 months and less than 3 months, respectively. All outcome variables are normalized by total assets. The effect of LBR is captured by the coefficient on the interaction term Affected × Post Event. Standard errors are clustered at the bank level and presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

As a further test of whether banks restructure loan portfolios in response to the LBR, we dis-aggregate total loans into mortgage, retail, and corporate loans.[13] Subsequently, we re-estimate equation (1.1) using the unrestricted matched sample. We assume that mortgage loans are of longer maturity (DeYoung and Jang 2016), while retail loans and corporate loans are of short to medium-term duration (Cortina, Didier and Schmukler, 2018). The results of this analysis, which are tabulated in Table 1.8[14], show a positive and significant impact of the LBR on retail and

[13] We use the average distribution presented in reports from the Central Bank of each country in cluded in the control group to dis-aggregate the data on loans for each year of the sample.

[14] For simplicity, the table mainly reports the coefficient of the interaction term, *Affected × Post Event*. Appendix A1.2 presents the estimations in detail including the control variables.

particularly on corporate loans. Specifically, in the post-treatment period, the stock of mortgage, retail and corporate loans of Dutch banks were on average, respectively, 0.8%, 1.8% and 26.7% higher relative to banks in the control group. The flow of mortgages was 0.2 percentage points lower for Dutch banks relative to banks in the control group, but the flows of retail and corporate loans were, respectively, 0.5 and 2.9 percentage points higher. These findings suggest that following the introduction of the LBR, the share of mortgage loans declined, while corporate loans increased (as Panel C shows).

Table 1.8 – Impact of LBR on loan categories

Variables	Panel A: lnLOAN			Panel B: LOANFW			Panel C: RATLOAN		
	MORT	RETL	CORP	MORT	RETL	CORP	MORT	RETL	CORP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Affected × Post Event	0.008**	0.018*	0.167**	-0.002**	0.005***	0.029**	-0.001***	0.001	0.003***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)	(0.000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	471	471	471	471	471	471	471	471	471
R-squared	0.772	0.706	0.663	0.598	0.658	0.523	0.663	0.746	0.802

Notes: This table analyses the impact of the introduction of the Liquidity Balance Rule on the main components of loans portfolio (mortgage, retail and corporate). The sample consists of 22 Dutch banks and 63 Eurozone banks selected via propensity score matching over the 2000-2006 period. In Panel A, the outcome variable is the volume of loans classified either into mortgage, retail or corporate loans category. The outcome variables considered in Panel B, are the flows of loan again disaggregated into three categories. Panel C presents results when the outcome variable is one of the three loan categories normalized by total assets. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. The effect of LBR is captured by the coefficient on the interaction term *Affected × Post Event*. Standard errors are clustered at the bank level and presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Overall, the results presented in this section indicate that following the introduction of the LBR, Dutch banks increased lending relative to counterparts not subject to the LBR. The ratio of loans to total assets did not change while the stock of loans and loan flows increased significantly relative to unaffected banks. This implies that the introduction of the LBR led Dutch banks to re-orientate their asset portfolios toward liquid assets, with an insignificant impact on the share of loans in balance sheet totals. Such adjustments would necessitate Dutch banks increasing liquidity. This could be achieved by equity and debt issuance as a means of funding investment in liquid assets (Webb, 2000). We investigate these possibilities in section 1.4.2.

1.4.2. The impact of LBR on the balance sheet

In order to examine the evolution of various asset and liability categories following the introduction of the LBR, we estimate the following equation:

$$Y_{i,t} = \beta(\text{Affected}_i \times \text{PostEvent}_t) + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (1.2)$$

The outcome variables, $Y_{i,t}$, are: the ratio of liquid assets to total assets (LIQ); the ratio of securities to total assets (SECU); the ratio of equity to total assets (EQUITY); the ratio of customers deposits to total assets (CUSTD); the ratio of deposits from banks to total assets (BANKD); and the natural logarithm of total assets (SIZE).

Table 1.9 presents the results of the estimation of equation (1.2). On the asset side of the balance sheet, the LBR has a positive and significant impact on liquid assets and securities. In the post-treatment period, the ratio of liquid to total assets and securities to total assets are higher for affected banks relative to unaffected counterparts. On the liability side of the balance sheet, the LBR has a significant and positive effect on the ratio of customer deposits-to-total assets, and the ratio of bank deposits-to-total assets for Dutch banks. The ratio of customer deposits-to-total assets and the ratio of bank deposits-to-total assets are higher for Dutch banks relative to counterparts not subject to the LBR. These findings are in line with prior research showing that following the introduction of the LBR, deposits increased for Dutch banks (Duijm and Wierts, 2016). As discussed in section 1.2, theory offers two plausible explanations for the observed positive impact of LBR on deposits. One being that affected banks could actively attract deposits in an effort to continue extending credit after the implementation of liquidity regulations (Webb, 2000). This explanation is further investigated in section 1.4.4. The results of this investigation suggest that banks in our sample do not engage in this strategy. Another explanation offered by theory is that banks holding more liquid assets are less fragile, and more resilient to sudden negative balance sheet shocks (Vives, 2014, Ratnovski, 2017, De Bandt, Lecarpentier and Pouvelle, 2021), and as such perceived as safer by depositors. Therefore, the inflow of deposits may have resulted from the belief that the introduction of the LBR made Dutch banks safer.

It also appears that following the introduction of the LBR, Dutch banks increased equity. The ratio of equity to total assets for the average Dutch bank is higher than the average bank in the control group. Holding more liquid assets reduces returns, which leads to an increase in insolvency risk (Eisenbach et al., 2014; Konig, 2015). As such, banks may increase capital in order to offset the increase in insolvency risk induced by increased liquidity requirements. Nevertheless, the positive association between LBR and equity could be the outcome of an increase in capital, given that capital reduces the maturity mismatch between assets and liabilities, and constitutes a more stable funding. Finally, the results in the final column of Table 1.9 suggest that Dutch banks grew faster than counterparts not subject to the LBR. The total assets for the average Dutch bank are higher than the total assets for the average bank in the control group.

Table 1.9 – Impact of LBR on banks' balance sheets

Variables	LIQ	SECU	CUSTD	BANKD	EQUITY	SIZE
	(1)	(2)	(3)	(4)	(5)	(6)
Affected × Post Event	0.017***	0.012***	0.045***	0.004***	0.003***	0.117**
	(0.002)	(0.000)	(0.015)	(0.001)	(0.001)	(0.006)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	471	471	186	186	471	471
R-squared	0.871	0.937	0.983	0.933	0.656	0.932

Notes: This table analyses the impact of LBR on various balance sheet items. Columns 1 and 2 report results for the ratio of liquid assets to total assets (LIQ) and the ratio of total securities to total assets (SECU). Columns 3 and 4 report results for the ratio of customer deposits (CUSTD) and bank deposits (BANKD) relative to total assets. Column 5 presents results for the equity to total assets ratio (EQUITY). Column 6 examines the effect of LBR on the (log of) total assets (SIZE). The sample consists of banks from The Netherlands and their matched non-Dutch banks over the 2000-2006 period. The effect of the LBR is captured by the coefficient of *Affected × Post Event*. Standard errors are clustered at the group level and reported in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

In contrast to prior evidence (Banerjee and Mio, 2018), our results suggest that the introduction of the LBR led Dutch banks to invest in securities as they experienced a growth in deposits and equity relative to counterparts not subject to the liquidity requirements. These adjustments led to an overall increase in the size of balance sheets. Taken together, these results suggest that following the introduction of the LBR, Dutch banks expanded liabilities relative to counterparts not subject to the liquidity requirements. This allowed them to invest in liquid assets without having to reduce the share of loans in overall asset portfolios.

1.4.3. Sensitivity tests

In this section, we examine the robustness of our main results to: variations in the matched sample size; the inclusion of additional independent variables in the matching procedure; restrictions on the geographic coverage of the control group; and the false timing of the introduction of the LBR. Table 1.10 presents the results of these robustness tests, which use the same bank- and country-level controls, as well as fixed effects as described in equation (1.1). For brevity, Table 1.10 reports only the estimated coefficient and relevant standard errors for the interaction term $Affected_i \times PostEvent_t$, and presents them in rows instead of columns.

First, we test whether variations in matching affect our baseline results. We vary the number of matched banks from three nearest neighbors to the nearest neighbor only (see row (1)), and then to the five nearest neighbors (see row (2)) and obtain similar results. Second, we add additional bank-specific variables to the matching procedure in order to test whether the matching procedure is biased due to omitted variables. We augment our baseline specification set of controls (comprising total assets, growth rate of loans, growth rate of total deposits to total assets, growth rate of total equity to total assets, lagged value of loans, GDP growth rate and the rate of inflation) with non-interest income share (measured as the ratio of non-interest income to total assets), non-interest expense share (measured as the ratio of non-interest expense to total assets), and return on assets (measured as the ratio of net profits-to-total assets). The results remain qualitatively similar to those reported in Table 1.6 (see row (3)). Third, we restrict the number of countries from which banks in the control group are selected. Specifically, we consider using Belgium and Luxembourg as the only two countries for the control group. The Netherlands is part of the BENELUX, a historical economic union formed with Belgium and Luxembourg. Countries in close geographic proximity and with long term close economic ties are more likely to share similar characteristics. Consequently, an analysis based on these three countries, is likely to address any omitted variable bias associated with these characteristics.[15] Nevertheless, we are also mindful of the specific nature of the banking system in Luxembourg (which specializes on wealth management) and we conduct a further robustness check using only Belgian banks as our control group.[16] Our results hold (see, respectively, rows (4) and (5)). We also investigate whether our results are driven solely by banks' immediate reaction to the announcement and implementation of the rule in 2003. To this end, we omit observations from year 2003 and use this restricted sample to re-estimate equation (1.1). The results, which are reported in row (6) of Table 1.10, suggest that our main findings hold.

A key identification assumption underlying our identification strategy is that in the absence of treatment the coefficient of interest, β, is zero (the parallel trend assumption). We complement our initial investigation of possible violations of the parallel trend assumption reported in section 1.3.5 (Panel C of Table 1.5 and Figure 1.2) by conducting a placebo test. In order to investigate the effect of a placebo treatment, we assume falsely that the LBR was introduced in 2001 rather than in 2003. We also re-run the matching procedure based on the full sample of 2001. The matching procedure is the same as that used in the baseline analysis with 1998-2000 as the pre-treatment period. The results of this test, which are presented in row (7), suggest that the parallel trend assumption is not violated and the effects on the outcome variable reported in Table 1.6 are associated with the introduction of the LBR.

[15] The matching procedure leads to a final sample of 41 banks, of which 18 treated Dutch banks and 23 control group banks (14 from Luxembourg and 9 from Belgium).

[16] The final sample after running the matching comprises 11 Dutch banks (treated group) and 9 Belgian banks (control group).

Table 1.10 – Impact of LBR on bank lending: sensitivity tests

		Dependent variables		
		lnLOAN	LOANFW	RATLOAN
(1)	Matching with one neighbor	0.167**	0.011**	0.019
		(0.061)	(0.004)	(0.024)
(2)	Matching with five neighbors	0.156**	0.027***	-0.012
		(0.059)	(0.009)	(0.014)
(3)	Additional matching variables	0.148***	0.024**	-0.043
		(0.058)	(0.009)	(0.053)
(4)	Matching with Benelux countries only	0.153**	0.011**	0.031
		(0.056)	(0.004)	(0.041)
(5)	Matching with Belgium only	0.136*	0.019**	0.063
		(0.081)	(0.006)	(0.088)
(6)	Year of LBR introduction omitted	0.196**	0.021***	-0.038
		(0.079)	(0.008)	(0.054)
(7)	Placebo test	-0.087	0.061	-0.038
		(0.112)	(0.077)	(0.054)

Notes: The table presents the sensitivity of the baseline model to variations in the sample size and matching procedure as well as false timing of the introduction of the LBR. The dependent variables are stock of total loans (lnLOAN), loans flow (LOANFW), and the ratio of loans to total assets (RATLOAN). For brevity, we only report the estimated coefficients of the variable of interest *Affected × Post Event* (full table in Appendix A1.3). Standard errors for the same coefficient are clustered at the bank level and reported underneath in parentheses. The bank- and country-level controls as well as fixed effects are identical to those in columns (1), (2) and (3) of Table 1.6. Rows (1) and (2) match each Dutch bank with one and five unaffected banks, respectively. Row (3) saturates the matching procedure with additional bank-specific variables. Rows (4) and (5) restrict the number of countries from which banks in the control group are selected to Benelux (i.e. Belgium and Luxembourg) and Belgium, respectively. Row (6) omits the year 2003 (the year LBR was enacted) from the sample. Row (7) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Finally, we test whether variations in matching affect the estimates derived for the different balance sheet items. Table 1.11 reports the results of the estimations. Again, for brevity we tabulate only the estimated coefficient and relevant standard errors for the interaction term $Affected_i \times PostEvent_t$, and present them in rows instead of columns. The main results still hold.

Table 1.11 – Impact of LBR on banks' balance sheets: sensitivity tests

		Dependent variables					
		LIQ	SECU	CUSTD	BANKD	EQUITY	SIZE
(1)	Matching with one neighbor	0.015**	0.014***	0.053***	0.005***	0.004***	0.139**
		(0.005)	(0.006)	(0.015)	(0.002)	(0.001)	(0.053)
(2)	Matching with five neighbors	0.012***	0.012**	0.047***	0.004***	0.003***	0.115**
		(0.004)	(0.005)	(0.012)	(0.001)	(0.001)	(0.047)
(3)	Additional matching variables	0.007***	0.008**	0.027***	0.003***	0.002***	0.078**
		(0.002)	(0.004)	(0.008)	(0.001)	(0.001)	(0.030)
(4)	Matching with Benelux countries only	0.009**	0.007***	0.037***	0.002***	0.002***	0.089***
		(0.003)	(0.003)	(0.011)	(0.001)	(0.001)	(0.034)
(5)	Matching with Belgium only	0.012**	0.008***	0.019***	0.002**	0.002**	0.061***
		(0.004)	(0.003)	(0.001)	(0.001)	(0.001)	(0.014)
(6)	Year of LBR introduction omitted	0.011***	0.011***	0.032***	0.004***	0.002***	0.114***
		(0.003)	(0.004)	(0.009)	(0.001)	(0.001)	(0.032)
(7)	Placebo test	-0.005	0.005	-0.018	-0.001	0.001	-0.054
		(0.016)	(0.018)	(0.029)	(0.002)	(0.002)	(0.082)

Notes: The table presents the sensitivity of the results regarding the impact of LBR on the banks' balance sheets to variations in the sample size and matching procedure as well as false timing of the introduction of the LBR. The dependent variables are the ratio of liquid assets to total assets (LIQ), the ratio of securities to total assets (SECU), the ratio of customer deposits to total assets (CUSTD), ratio of bank deposits to total assets (BANKD), the ratio of equity to total assets (EQUITY), and the log of total assets (SIZE). For brevity, we only report the estimated coefficients of the variable of interest *Affected × Post Event.* Standard errors for the same coefficient are clustered at the bank level and reported underneath in parentheses. The fixed effects are identical to those in columns (1) to (6) of Table 1.8. Rows (1) and (2) match each Dutch bank with one and five unaffected banks, respectively. Row (3) saturates the matching procedure with additional bank-specific variables. Rows (4) and (5) restrict the number of countries from which banks in the control group are selected to Benelux (i.e., Belgium and Luxembourg) and Belgium, respectively. Row (6) omits the year 2003 (the year LBR was enacted) from the sample. Row (7) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

1.4.4. Did banks follow an active policy to attract deposits?

The introduction of the LBR led Dutch banks to increase securities holdings, equity capital and deposits. This suggests that Dutch banks made significant balance sheet adjustments. While the increase in securities investments and equity are the direct result of the deliberate actions of banks, the growth in deposits can occur either passively or following a deliberate price or non-price strategy designed to increase market share. However, if the implementation of the LBR improved confidence, deposits may increase regardless of any deliberate actions on the part of Dutch banks. To investigate whether Dutch banks have engaged actively in strategies to attract deposits, we examine the impact of the LBR on the deposit rates offered by banks. We assume that an increase in deposit rates would be indicative of an active strategy to attract deposits.[17] To assess the impact of the LBR on deposit rates, we estimate the following equation:

$$Y_{i,t} = \beta(\text{Affected}_i \times \text{PostEvent}_t) + \alpha_i + \lambda_t + \varepsilon_{i,t} \tag{1.3}$$

The outcome variable, $Y_{i,t}$, is the implicit deposit rate measured as the ratio of interest expense on deposits to total deposits (IMPLICIT). The model is estimated over the 2000-2006 period. Table 1.12 reports the results.

Table 1.12 – Impact of LBR on the implicit interest rates of deposits

Variables	IMPLICIT
Affected × Post Event	-0.0256
	(0.031)
Year fixed effects	Yes
Bank fixed effects	Yes
Observations	342
R-squared	0.908

Notes: The table analyses the impact of the LBR on the implicit interest rate of bank deposit measured as the ratio of interest expense on deposits to total deposits in a difference-in-difference set up. The sample consists of banks from The Netherlands and the matched non-Dutch banks over the 2000-2006 period. The effect of the LBR is captured by the coefficient of the interaction term *Affected × Post Event*. Standard errors are clustered at the bank level and reported in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

[17] The fact that banks may actively engage in strategies to attract deposits does not exclude the potential incentive effect of the introduction of the LBR. However, we assume that the effect of the former would be stronger. Given that the design and implementation of the LBR rule was not discussed publicly prior to its introduction, we assume that bank customers do not have full access to information. Hence, we can expect that depositor behaviour does not change in the short term. Moreover, Bonner and Eijffinger (2016) indicate that Dutch banks that were below the required level of liquidity charged lower interest on interbank loans, but paid higher interest on unsecured interbank funding, compared to banks operating above the required level of liquidity. Hence, we expect banks to offer higher rate on deposits as a means to raise funding.

The coefficient of the interaction term is negative, but not statistically significant. This indicates that the introduction of the LBR did not impact deposit rates offered by the average Dutch bank. Hence, Dutch banks have not engaged in active pricing strategies in order to attract deposits. The implementation of the LBR may have improved depositor confidence, which contributed to higher deposit growth. In turn, this allowed Dutch banks to increase their level of lending.

1.5. Conclusion

This chapter investigates the impact of bank liquidity regulation on lending using as a setting, the introduction of the so-called Liquidity Balance Rule (LBR) implemented in the Netherlands in 2003. Using a difference-in-differences approach and propensity score matching techniques (to form an appropriate control group of banks to act as a benchmark for our treated banks), our results indicate that following the introduction of the LBR, Dutch banks increased lending relative to unaffected banks. On average, the net flows of loans were 2.3 percentage points higher than what would have been observed in the absence of the LBR. This led to a significant increase in the total stock of loans for affected banks, relative to counterparts not subject to the regulation. The volume of loans was 23.2% higher relative to counterparts not subject to the LBR. By loan category, Dutch banks modified the structure of their respective loan portfolios. Specifically, Dutch banks extended considerably more loans to the corporate sector, while the increase in retail and mortgage loans, relative to unaffected banks was rather moderate. Corporate loans for Dutch banks on average increased by 30% relative to an average Eurozone bank not subject to the LBR. Dutch banks also made significant adjustments to the liability side of balance sheets by increasing equity. They also experienced a significant inflow of customer deposits, relative to an average Eurozone bank not subject to the LBR. Hence, Dutch banks could maintain lending despite stricter liquidity requirements.

Overall, the results of this study suggest that the imposition of stricter liquidity requirements increased bank lending. Moreover, these stricter regulations appear to have contributed to higher depositor confidence, resulting in overall deposit growth at Dutch banks relative to unaffected banks. Given the similarity between the Dutch LBR and the Basel III Liquidity Coverage Ratio, our results have obvious relevance for policymakers tasked with monitoring the impact of liquidity regulations on banks and the real economy. Specifically, the similarity between the LBR and the Basel III Liquidity Coverage Ratio suggests that the post-crisis liquidity regulations may not be detrimental for bank lending activities and the real economy, as many commentators and bank lobbyists have argued. Taken together with prior evidence regarding the impact of liquidity requirements on bank behavior, our results suggest that banks can rely on diverse strategies to comply with the Basel III Liquidity Coverage Ratio. Banks can increase liquidity by altering balance sheet size or modify the composition of assets and liabilities. Most importantly, our results suggest that a reduction in bank lending appears unlikely regardless of the strategy banks follow in order to comply with Basel III liquidity coverage requirements.

Chapter 2

Liquidity regulation and bank risk*

* This chapter draws from the working paper (Ananou, Chronopoulos, Tarazi, Wilson, 2021b. Liquidity regulation and bank risk) co-authored with Dimitris Chronopoulous, from University of St Andrews; Amine Tarazi, from Université de Limoges/LAPE, and John O.S. Wilson, from University of St Andrews. I am grateful to my supervisor Amine Tarazi and my co-authors Dimitirs Chronopoulos and John O.S. Wilson for guidance, advice, and encouragement during the writing of this paper. The paper has been accepted for presentation at the 34th AFBC, December 15-17, 2021.

Abstract

In this chapter, we investigate the impact of liquidity requirements on bank risk. We take advantage of the implementation of the Liquidity Balance Rule (LBR) in the Netherlands in 2003 and analyze its impact on bank default risk. The LBR was imposed on Dutch banks only and did not apply to other banks operating elsewhere within the Eurozone. Using this differential regulatory treatment to overcome identification concerns, we find that following the introduction of the LBR, the risk of Dutch banks declined relatively to counterparts not affected by the rule. Concomitantly, despite the lower cost of funding driven by the LBR, the profitability of Dutch banks decreased in comparison with other banks in Europe, as a result of a decrease in income accruing from interest-bearing activities. Our findings also indicate that relatively to unaffected banks, Dutch banks might not have tried to offset their loss in interest income by increasing interest rates of loans. However, better financing conditions allowed Dutch banks to increase the shares of deposits and capital on the liability side of their balance sheets.

Classification JEL: G21, G28

Key words: Banking, liquidity regulation, Netherlands, propensity score matching, quasi-natural experiment, risk, stability.

2.1. Introduction

Until the liquidity shortages that occurred upon the onset of the global financial crisis, little attention had been paid to the importance of bank liquidity and its implications for bank risk. Since then, coordinated international agreements under the auspices of Basel III have required banks to enhance liquidity via adherence to: a Liquidity Coverage Ratio (LCR), which requires that banks hold enough high-quality liquid assets to survive a stress scenario spanning a one month duration; and a Net Stable Funding Ratio (NSFR) which requires banks to hold a minimum amount of stable deposit funding to withstand a closure of wholesale funding markets (Basel Committee on Banking Supervision, 2009, 2013). Given the paucity of relevant empirical research and the importance of liquidity for individual banks and the wider banking industry, in this study we investigate the impact of liquidity regulation on bank risk.

Ex ante, it is unclear whether the introduction of liquidity regulations aimed at reducing the maturity mismatch between banks' illiquid assets and liquid liabilities leads to an increase or decrease in risk given that banks have a myriad of ways to manage liquidity (DeYoung and Jang, 2016).[1] On the one hand, liquidity regulation that requires banks to hold higher levels of liquid assets as a buffer against liquidity shocks leads to a subsequent decline in risk and the probability of bank runs (Diamond and Kashyap, 2016). Moreover, liquidity regulation similar in format to that introduced under Basel III Liquidity Coverage Ratio allows banks to comply with regulatory requirements via increases in capital (Hartlage, 2012). Thus, bank resilience to negative balance sheet shocks is also improved (Hoerova et al., 2018). Banks can also swap funding from sources (such as wholesale funding) that are less favored by capital regulation with sources (such as retail deposits) attracting more favorable regulatory treatment. In doing so, banks can reduce the cost of capital, increase profitability, and build up capital buffers to withstand external shocks to balance sheets. On the other hand, attracting more retail deposits may increase bank risk in the

[1] Bonner et al. (2015) use data from 30 different countries and find that the correlations of bank liquidity buffers to deposit liabilities, market concentration, and bank size are substantially weaker in countries with bank liquidity regulations. The authors contend that liquidity regulations act as substitutes for active liquidity management and limit excessive risk-taking by banks.

presence of safety net guarantees, such as deposit insurance schemes (Lambert et al. 2017). Liquidity regulation may force banks to increase investments in more liquid, but lower yielding assets, which leads to a subsequent decline in profitability. Faced with declining profitability, banks may invest remaining funds in riskier investments to boost returns (Hoerova et al., 2018; Bosshardt and Kakhbod, 2020). Consequently, the introduction of liquidity regulation can lead to an increase in bank risk.

Assessing the impact of liquidity regulations on bank risk is not straightforward given that such rules are often introduced and phased in alongside other safety and soundness regulation. In the present study, we overcome these challenges via a research design that uses an unanticipated policy intervention as a quasi-natural experiment to investigate the impact of liquidity regulation on bank risk. We use the Netherlands at a setting, where in 2003 a Liquidity Balance Rule (LBR) was introduced. Under the terms of the LBR, banks are required to hold high-quality liquid assets that exceed or are equal to net cash outflows over a 30-day stress period. The introduction of the LBR in the Netherlands did not occur following a period of financial system instability and was not anticipated in advance by banks and other industry stakeholders. The LBR only applied to Dutch banks and did not apply to other banks operating elsewhere in the Eurozone. Consequently, we use this differential regulatory treatment to overcome identification concerns and investigate the impact of liquidity regulation on the risk of Dutch banks. We use accounting-based measures of bank risk comprising the standard deviation of the return on assets and a bank default risk measure along with its asset and leverage risk sub-components. Market-based indicators are also constructed for a sub-sample of listed banks using the standard deviation of bank daily stock returns over a calendar year and a market-based version of the bank default risk measure. The sample period straddles the introduction of the LBR. Our data set comprises unconsolidated balance sheet, off-balance sheet and income statement data for commercial banks covering the period 2000 to 2006 for 12 Eurozone member countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain).

To assess the impact of the LBR on bank risk, we use a difference-in-differences approach where we estimate the difference in the riskiness of affected banks between the pre-LBR and post-LBR period with the same difference in the riskiness of a control group of banks. In order to avoid possible selection bias, and following prior literature based on European data (Schepens, 2016, Ananou et al 2021a), we use propensity score matching to form a control group of similar banks drawn from Eurozone countries where the LBR was not introduced. Our baseline model includes bank level characteristics, as well as country time-varying controls that prior literature considers as important determinants of bank risk.

The main results of our empirical analysis indicate that following the introduction of the LBR both the risk-taking (either measured by asset risk or stock price volatility) and default risk of Dutch banks decreased in comparison with counterparts not subject to the LBR. Moreover, the decline in bank default risk occurred primarily through a reduction of leverage risk (as bank became better capitalized). These findings are consistent across both accounting and market-based indicators of bank risk. Although the systematic risk of Dutch banks remained unchanged following the introduction of the LBR, their specific risk decreased relative to other banks not subject to the provisions of the LBR.

In a series of additional tests, we investigate the impact of the introduction of the LBR on bank profitability, cost of funding and funding structure. Our findings suggest that, following the introduction of the LBR, Dutch banks changed their funding structure by increasing capital and deposits. We also document that profitability declined despite reduced funding costs. We find that this is because Dutch banks experienced a decrease in the interests received on their assets following the introduction of the LBR. Specifically, the decrease in the cost of funding that occurred following the introduction of the rule was not enough to offset the negative impact of lower interest on earning assets on profitability. Nevertheless, the impact of LBR on profitability is short lived and disappears four years following the liquidity regulation change.

Our baseline results are not sensitive to variations in the matching procedure including the number of countries used to match treated and control banks, the control variables included in the estimation of the propensity score, or the number of matched banks included in the sample.

The internal validity of our findings is satisfied by insignificant placebo tests that confirm the causal interpretation of our results.

Our study contributes to the recent literature on the impact of liquidity regulation on bank behavior. This literature suggests that liquidity regulation has a significant impact on domestic and cross border bank lending (De Nicolo et al., 2014; Covas and Driscoll, 2014; Reinhardt et al, 2020). Moreover, some studies show that the imposition of liquidity regulation requires banks to adjust their balance sheet mix by increasing the share of high-quality liquid assets and by reducing reliance on short-term wholesale funding (Duijm and Wierts, 2016; Banerjee and Mio, 2018). In the case of the Netherlands itself, prior evidence suggests that the introduction of the LBR led affected banks to change the volume and composition of lending. Specifically, the enactment of the LBR led to an increase in the overall volume of lending and a re-orientation toward corporate lending as well as to the accumulation of more stable deposit and equity funding (Ananou et al, 2021). A decline in inter-bank lending is also evident (Bonner and Eijffinger, 2016). Complementing this literature, our difference-in-differences approach used in the empirical analysis allows us to identify the causal impact of differences in liquidity requirements across banks on risk and the pricing of assets and liabilities.

Our findings also contribute to research that explores the determinants of bank risk. Prior evidence suggests that macroeconomic conditions (Athanasoglou et al. 2008; Albertazzi and Gambacorta 2009), competition (Beck et al., 2013; Liu et al, 2013; Goetz, 2018), ownership (Iannotta et al., 2007; Barry et al, 2011); size (De Haan, and Poghosyand, 2012); funding structure (Demirguc-Kunt and Huizinga, 2010; Vazquez and Federico, 2015; Khan et al., 2017), capital (Berger, 1995; Giordana and Schumacher, 2017), diversification (Demsetz and Strahan, 1997; DeYoung and Roland, 2001; Lepetit et al, 2008), corporate governance (Berger et al., 2016; Anginer et al, 2018); loan growth (Foos et al, 2002) and business models (Altunbas et al., 2011; Kohler, 2015) pursued by banks impact risk. We also contribute to a literature examining the importance of various types of liquidity for bank risk. Wagner (2007) finds that increases in bank liquidity reduces the likelihood of bank runs and thus leads banks to increase risk-taking. Kohler (2015) finds that retail-oriented banks are riskier as their share of non-deposit to total funding increases. Using a sample of US commercial banks, Hong et al., (2014) find that the NSFR and the LCR did not predict bank failures. Rather systemic liquidity risk was a major contributor to the US bank failures observed immediately following the global financial crisis. For a sample of European banks, Chiaramonte and Casu (2017) find that banks with higher structural liquidity (values of the Basel III NFSR) are less likely to default. The authors find that the LCR is not related to bank default risk. We augment this literature by documenting that a change in asset liquidity requirements induces a long-lasting reduction in risk of affected banks. Specifically, the reduction in default risk is driven by a reduction in leverage risk (i.e., improved capitalization to cover asset risk).

The remainder of the chapter is organized as follows. Section 2.2 describes the empirical methodology and presents the data and summary statistics of the sample. In section 2.3, we present the results of our empirical analysis. Section 2.4 provides additional evidence, which corroborates that liquidity requirements reduce the level of bank risk. Sensitivity checks are described in Section 2.5. Section 2.6 concludes.

2.2. Research design

2.2.1. Data and sample

Our sample comprises commercial banks based in the 12 European countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain) forming the Eurozone by 2003 over the 2000–2006 period. We retrieve accounting data from the BankScope database compiled by Bureau van Dijk. All the banks in our sample (European banks) report annual financial statements with fiscal year ending December 31. For each bank, we use unconsolidated data if available; otherwise, we use consolidated statements. For the period and countries covered by this study, we identify commercial banks that have at least three consecutive years of observations for net income, total equity, and total assets.[2] To minimize the effect of outliers, we remove banks by eliminating extreme observations (5% lowest and highest values) for each financial variable of interest. To reduce the possible impact of mergers and

[2] This criterion enables us to compute rolling-window standard deviations to construct our risk indicators.

acquisitions that took place during the sample period, we also discard all bank-year observations where growth in total assets exceeds 25%. Our final sample comprises 400 commercial banks including 16 Dutch banks.

In our analysis, we also construct a subsample dataset of listed banks. We retrieve daily market data from the Bloomberg database. The subsample is restricted to banks with continuously daily traded stocks between the 1st of January 2000 and 31st December 2006. We obtain a final subsample of 117 listed banks. Columns (1) and (3) of Table 2.1 presents information regarding the geographic distribution of the initial sample of banks.

Table 2.1 – Distribution of banks in the sample by Country

Country	Broad sample of banks		Subsample of listed banks	
	Full sample	Matched sample	Full sample	Matched sample
	(1)	(2)	(3)	(4)
Austria	38	5	8	0
Belgium	20	3	4	1
Finland	3	0	4	1
France	90	9	26	3
Germany	86	9	23	4
Greece	11	0	1	0
Ireland	5	1	0	0
Italy	20	1	10	1
Luxembourg	60	8	14	0
Netherlands	16	16	4	4
Portugal	11	3	7	1
Spain	40	3	16	2

Notes: This table indicates for each country, the number of commercial banks included in the full sample

2.2.2. Measures of bank risk

To measure bank risk, we use the standard deviation of the return on assets (SDROA) computed on a rolling window of three years. We also consider the Z-Score as a proxy for bank default risk. We compute a variable named ZSCORE as proposed by Boyd and Graham (1986):

$$ZSCORE = (MROA+EQUITY)/SDROA$$

where MROA is the three-year rolling window average return on assets, defined as the ratio of net income to total assets, and EQUITY is the ratio of total equity to total assets. SDROA denotes the standard deviation of the return on assets computed on a rolling window of three years.

We follow Goyeau and Tarazi (1992) and Lepetit et al. (2008) and decompose the ZSCORE into its constituent components, defined as Z1SCORE and Z2SCORE.[3] Z1SCORE measures asset risk, while Z2SCORE is a measure of leverage risk. These two measures allow us to capture whether a change in ZSCORE is driven by a change in asset and/or in leverage risk. For robustness, we consider SDROA using a four-year rolling window and a five-year rolling window. ZSCORE is then computed with these alternative definitions of SDROA.

Given that accounting-based variables may not accurately capture sudden changes in bank risk, we complement these measures with market-based indicators for a subsample of listed banks. Risk is measured using the standard deviation of bank daily stock returns within a calendar year (SDRETURN).[4] To assess default risk, we calculate a market-based Z-Score (MZSCORE) defined as:

$$MZSCORE = (1+RETURN)/SDRETURN$$

where RETURN is the average of bank daily stock returns within a calendar year. We also consider systematic risk as measured by BETA and the bank specific risk (IVOL). BETA and IVOL are obtained by estimating the market model, for each year:

$$R_{i,t} = a_i + \beta_i R_{m,t} + \varepsilon_{i,t}$$

[3] ZSCORE = Z1SCORE + Z2SCORE = MROA/SDROA + EQUITY/SDROA

[4] Bank daily stock return is computed as the logarithm of the ratio of two adjacent daily stock prices (i.e., $\ln(Price_t/Price_{t-1})$)

where $R_{i,t}$ is bank *i*'s daily stock return, and $R_{m,t}$ is the daily return of a market portfolio *m*. We use the Euro Overnight Index Average rate as proxy for the market portfolio. BETA takes the values of the estimated coefficient β_i and IVOL is obtained as the standard deviation of the residuals from the regression. For robustness, we also compute SDRETURN, MZSCORE, BETA and IVOL using bank daily stock returns over the last three months of each year from 2000 to 2006.

2.2.3. Methodology

The research design employed in the current study allows us to identify the causal impact of liquidity regulation on bank risk. To that end, we rely on the introduction of the LBR in the Netherlands in 2003, which provides an exogenous variation in the liquid assets held by Dutch banks.[5] The regulation was announced in January 2003, and Dutch banks had until July 2003 to comply with its terms (de Haan and den End, 2013), thus minimizing the possibility of anticipatory effects and subsequent changes in bank behavior prior to implementation. Also, the LBR was unique to the Netherlands. Bank regulators based in other Eurozone countries did not consider this type of rule until the Global Financial Crisis of 20072009, when following international agreement, the Liquidity Coverage Ratio was introduced (Bonner and Hilbers 2015). Moreover, other regulatory changes (such as the publication of the preliminary draft of Basel II requirements) that may have occurred at the regional or international level during the period when the LBR was announced and implemented would affect banks in the Eurozone the same way. Hence, the introduction of the LBR can be considered as an exogenous change in the liquid assets held by Dutch banks.

[5] The LBR is conceptually similar to the Basel III LCR, which requires banks to hold a minimum level of liquid assets to meet a stress scenario of outflows. The main difference is in the weighting scheme and the range of items included in the stock of liquid assets which is more extensive for the LBR compared to the LCR.

The LBR stipulates that Dutch banks should hold high-quality liquid assets greater than or equal to net cash outflows over a 30-day stress period. The LBR is defined as:

LBR=AL/RL

where the numerator, AL denotes Actual Liquidity and comprises the weighted sum of the stock of liquid assets and cash inflow scheduled within the next 30 days such as such as securities, inter-bank assets payable on demand and debts immediately due or payable by public authorities and professional money-market participants.[6] The denominator, RL denotes Required Liquidity and comprises the weighted sum of the stock of liquid liabilities and cash outflow scheduled within the next 30 days such as any bank debt that can be call upon immediately (e.g., deposits without a fixed maturity). In order to comply with the regulation, the ratio of a given bank should be equal to or exceed one. The items included in AL and RL are weighted relatively to their degree of liquidity in order to account for market and funding liquidity risks. These weights are determined by the regulator (DNB, 2011). For example, asset-backed securities carry a lower weight than high-quality bonds. Wholesale deposits carry a higher weight than retail deposits.

Our analysis is based on propensity score matching combined with difference-indifferences estimation, which compares the change in risk of Dutch banks between the pre-LBR and post LBR period, with the change in risk of a similar group of European banks for which the LBR did not apply. The baseline model is as follows:

$$Y_{i,t} = \beta(\text{Affected}_i \times \text{PostEvent}_t) + \delta X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t} \qquad (2.1)$$

where *i* indexes bank and *t* indexes time. $Y_{i,t}$ is a measure of bank risk. We proxy bank risk using SDROA and ZSCORE as well as its constituent components Z1SCORE and Z2SCORE for the full sample, whereas for the sub-sample of listed banks only, we use their market-based equivalents SDRETURN, BETA, IVOL and MZSCORE. Affected_i is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. PostEvent_t is a dummy variable for

[6] Demand deposits held with non-credit institutions or non-professional money-market participants are not counted as part of the actual liquidity

the treatment period, equal to one for the years 2003 onwards, and zero otherwise. $X_{i,t-1}$ represents a vector of bank-level control variables that vary across banks and over time, which prior literature considers as important determinants of bank risk. These variables are defined in section 1.2.4 below. To control for changes in the domestic economic environment, we also include the real GDP growth rate and inflation. To avoid simultaneity, we lag each of our control variables by one period. The model also includes bank specific fixed effects, α_i, to control for unobserved bank heterogeneity, and time dummies γ_t, to capture time effects common to all banks. The list of all the variables considered in the analysis is given in Table 2.2.

Table 2.2 – Variable definitions

Variable	Description	Source	Expected sign
Dependent variables			
BETA	Systematic risk computed by regressing bank daily stock return on a benchmark market excess return within a calendar year. BETA is the coefficient associated with the market excess return	Author computed	
IINC	Ratio of interest income to total assets (%)	Author computed	
INT	Ratio of total interest income on to total earning assets (%)	Author computed	
IVOL	Bank specific risk computed as the annualized standard deviation of the residuals of the regression of bank daily returns on a benchmark market excess return.	Author computed	
COST	Ratio of total interest expenses on to total liabilities (%)	Author computed	
MZSCORE	Market based Z-Score defined as (100+RETURN)/SDRETURN where RETURN and SDRETURN are expressed in percentages.	Author computed	
NII	Ratio of non-interest income to total assets (%)	Author computed	
NIM	Net interest margin defined as the difference between INT and COST	Author computed	
ROA	Return on assets defined as the ratio of net income to total assets (%)	Bankscope	
SDRETURN	Market based bank risk defined as the geometric standard deviation of daily stock returns within a calendar year (%)	Bloomberg	
SDROA	Three-year rolling window standard deviation of ROA (%)	Author computed	
ZSCORE	Bank default risk. ZSCORE = (MROA + EQUITY)/SDROA, where EQUITY is the ratio of total equity to total assets; and MROA is the three-year rolling window average of ROA	Author computed	
ZSCORE1	First component of ZSCORE. ZSCORE1 = MROA/SDROA	Author computed	
ZSCORE2	Second component of ZSCORE. ZSCORE2 = EQUITY/SDROA	Author computed	
Control variables			
COSTINCOME	Cost to income ratio (%)	Bankscope	-
DEPOSITS	Ratio of customer deposits to total assets (%)	Bankscope	+
EQUITY	Ratio of total equity to total assets (%)	Bankscope	+/-
GROWTH	Year-to-year growth rate of real GDP	Eurostat	
INFLATION	Year-to-year growth rate of harmonized price index	Eurostat	
LOANS	Ratio of net loans to total assets (%)	Bankscope	+/-
NNI	Ratio of net noninterest income to net operating income (%)	Bankscope	-
SIZE	Natural logarithm of total assets	Bankscope	+/-

Notes: This table presents definitions for all variables used throughout the chapter. The first column shows the name of the variable as used throughout the chapter, the second describes the corresponding definition and the third column gives the source

Table 2.3 – Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11
Panel 1. Broad sample of banks											
1. SDROA	1.00										
2. ZSCORE	-0.37	1.00									
3. ZSCORE1	-0.40	0.73	1.00								
4. ZSCORE2	-0.36	0.97	0.70	1.00							
5. NII	0.12	-0.17	-0.06	-0.17	1.00						
6. COSTINCOME	0.14	-0.11	-0.28	-0.10	0.17	1.00					
7. DEPOSITS	-0.03	-0.02	0.07	-0.02	0.08	0.20	1.00				
8. EQUITY	0.31	0.18	-0.05	0.19	-0.03	-0.14	-0.16	1.00			
9. SIZE	-0.23	-0.06	0.12	-0.07	-0.04	-0.11	-0.26	-0.42	1.00		
10. LOANS	-0.13	0.07	0.14	0.06	-0.35	0.06	0.18	-0.15	-0.02	1.00	
11. LLR	0.13	-0.11	-0.02	-0.11	-0.04	0.18	0.17	-0.07	-0.15	0.28	1.00
Panel 2. Subsample of listed banks											
1.SDRETURN	1.00										
2. MZSCORE	-0.35	1.00									
3. BETA	0.44	-0.18	1.00								
4. IVOL	0.99	-0.34	0.06	1.00							
5. NII	-0.01	0.02	0.08	-0.03	1.00						
6. COSTINCOME	0.22	-0.10	0.18	0.21	0.11	1.00					
7. DEPOSITS	0.13	-0.03	-0.14	0.16	0.09	0.11	1.00				
8. EQUITY	-0.11	0.09	-0.14	-0.08	-0.12	-0.19	-0.23	1.00			
9. SIZE	-0.01	-0.17	0.64	-0.12	-0.01	0.21	-0.27	-0.07	1.00		
10. LOANS	-0.04	0.10	-0.02	-0.03	-0.06	0.00	0.20	0.17	-0.20	1.00	
11. LLR	-0.02	0.05	-0.22	0.03	-0.09	-0.12	-0.04	0.15	-0.34	0.43	1.00

Notes: This table reports the correlation matrix for the outcome variables and control variables used in our analysis.

Key to our identification strategy is the assumption that in the absence of treatment the coefficient of interest β_1 is zero. This is also known as the parallel trend assumption. To ensure that the coefficient β_1 captures the effect of the LBR rather than a sample selection effect, we use a propensity score matching procedure to construct a control group of European banks such that treated, and control banks share similar trends in terms of risk (Roberts and Whited, 2013; Schepens, 2016). Therefore, we compute propensity scores based upon trends in the ZSCORE over the pre-treatment period for the full sample (and the MZSCORE for the subsample of listed banks) and other balance sheet characteristics as well as national economic conditions in the pre-treatment period (prior to the introduction of the LBR).[7] Specifically, the propensity scores are computed using the growth rate in ZSCORE (respectively MZSCORE); ratio of total deposits to total assets; ratio of total equity to total assets; ratio of liquid assets to total assets, return on assets, real GDP growth and inflation, and the levels of total assets and the lagged value of ZSCORE (MZSCORE). Hence, we select banks of similar size, portfolio composition, capital structure, liquid assets, income and facing similar economic conditions in the pre-treatment period. The propensity scores are used to match each Dutch bank with its three nearest neighbors for the full sample and five nearest neighbors for the subsample of listed banks.[8] The matching is executed with replacement. This means that each non-Dutch bank can serve as a control for multiple Dutch banks. This improves the accuracy of the matching procedure (Smith and Todd, 2005).

The matching procedure leads to a control group that comprises 42 banks drawn from other Eurozone countries for the broad sample of banks. For the subsample of listed banks, we end up with a control group that comprises 13 banks drawn from other Eurozone countries.[9] The impact of the matching procedure is illustrated in Table 2.4. The table provides summary statistics for the main variables of interest for the three years prior to the introduction of the LBR and the three years after the introduction. The table also reports mean differences test between Dutch and the wider sample of eurozone banks from which the control group of banks are selected.

The summary statistics show that the parallel trend assumption is violated when using the full sample of non-Dutch banks as control group. Banks operating in Netherlands differ in various characteristics, compared to other European banks. For example, Dutch banks are on

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[7] We consider trends in ZSCORE (MZSCORE) for the full sample (for the subsample of publicly listed banks) because all the risk measures are highly correlated, as shown in the correlation matrix in table 3. We are therefore confident that the other measures of risk employed in our analysis follow a similar trend. For robustness (section 5), we use trends in SDROA and SDRETURN to run the matching and our findings remain identical with these measures.

[8] We choose 5 neighbours for the listed banks to gain more observations necessary to compute statistical tests.

[9] Columns (2) and (4) of table 2 present the distribution of banks in the control group by country.

average larger and have significantly a higher risk of default during the pre-treatment period. The success of the matching is illustrated in the last three columns of the table. The difference in means between Dutch banks and the matched group of banks is not statistically significant for all bank characteristics. Furthermore, the growth rates of bank risk measures are similar for banks in both groups.

Figure 2.1 depicts the evolution of two of the bank risk measures considered in our analysis (namely ZSCORE and MZSCORE) over the period 2000 to 2006. Both variables follow similar paths in the pre-treatment period lending support to the notion that the parallel trends assumption is not violated in our setting. However, from 2003, we observe diverging trends for the affected and control banks. This is suggestive evidence that the introduction of the LBR has had an impact on Dutch banks' risk.

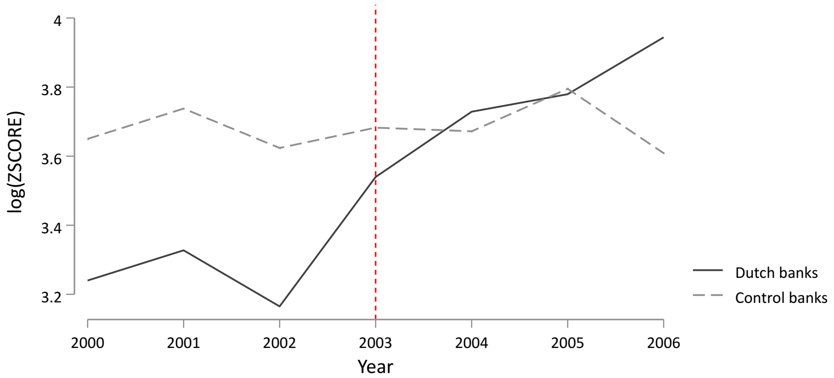
Table 2.4 – Summary statistics

	Dutch banks		Full control group			Matched control group		
	Mean	Std. Dev.	Mean	Std. Dev.	Diff	Mean	Std. Dev.	Diff
Panel A: Pre LBR period								
SDRETURN	1.970	1.105	1.841	1.546	0.129	2.182	0.861	-0.211
MZSCORE	50.219	4.621	91.679	6.554	-41.460***	54.091	4.195	-3.872
MZSCOREGW	-6.496	8.536	22.042	4.892	-28.539**	-6.155	6.184	0.058
BETA	0.562	0.596	0.196	0.335	0.365**	0.443	0.458	0.119
IVOL	1.600	0.738	1.757	1.516	-0.157	1.983	1.917	-0.383
ROA	1.111	1.592	0.600	1.217	0.512**	0.842	1.501	0.271
SDROA	0.610	0.727	0.377	0.574	0.233**	0.453	0.674	0.156
ZSCORE	49.796	9.349	76.265	13.543	-26.469***	66.887	6.458	-19.443*
ZSCOREGW	29.057	12.036	53.466	7.72	-24.409***	26.883	12.831	2.174
ZSCORE1	3.804	4.293	5.054	5.795	-1.249*	4.985	5.761	-1.182
ZSCORE2	46.105	8.854	71.126	2.541	-25.022***	64.180	6.791	-18.075*
NNI	27.782	16.799	37.649	23.420	-9.866***	24.744	24.109	2.600
COSTINCOME	53.401	18.444	62.532	22.166	-9.131***	51.726	24.152	1.680
DEPOSITS	48.647	28.726	51.370	24.879	-2.727	45.685	20.208	2.962
EQUITY	11.415	11.435	9.733	12.955	1.681	10.280	9.644	1.135
SIZE	8.115	1.776	7.403	1.991	0.711***	7.869	2.242	0.245
LOANS	46.579	24.552	46.602	27.689	-0.592	48.729	27.041	-2.718
LLR	0.631	0.489	1.999	2.302	-1.363***	0.863	2.061	-0.232
GROWTH	1.350	0.656	2.009	1.894	-0.659***	2.009	1.894	-0.659***
INFLATION	0.329	0.172	0.599	0.617	-0.269***	0.599	0.617	-0.269***
Panel B : Post LBR period								
SDRETURN	0.923	0.588	1.209	1.830	-0.286	1.079	2.825	-0.157
MZSCORE	83.851	5.282	129.318	12.775	-45.467***	74.275	6.883	10.611***
MZSCOREGW	31.508	20.718	12.761	3.776	18.474	27.774	9.498	3.734***
BETA	0.534	0.566	0.231	0.389	0.303*	0.542	0.417	0.007
IVOL	0.754	0.155	1.161	0.106	-0.407**	0.971	0.438	-0.216
ROA	0.857	1.625	0.742	1.211	0.146	1.034	0.701	-0.178*
SDROA	0.407	0.549	0.362	0.581	0.0004	0.517	0.768	0.111
ZSCORE	67.871	8.932	79.054	2.680	-11.182	71.488	7.076	-3.292
ZSCOREGW	33.021	10.977	60.891	9.96	-27.872*	25.198	9.349	8.171***
ZSCORE1	4.486	3.414	5.342	5.661	-0.856	5.180	5.615	-0.694
ZSCORE2	63.295	8.513	73.405	2.547	-10.110	66.233	6.696	-2.784
NNI	26.904	18.875	39.828	23.494	-12.925***	39.207	25/841	-8.894*
COSTINCOME	52.348	16.445	59.879	21.944	-7.530***	57.743	24.205	-5.394**
DEPOSITS	52.468	28.410	52.448	25.142	0.020	45.584	20.917	6.883**
EQUITY	11.940	10.432	9.662	12.874	1.431	9.682	12.363	1.358
SIZE	8.425	1.849	7.653	2.020	0.772***	7.571	2.391	0.854**
LOANS	47.993	26.154	48.026	28.738	-0.908	50.421	28.271	-3.203
LLR	1.481	2.259	2.099	2.160	-0.617	1.261	1.286	0.221
GROWTH	1.521	0.555	1.996	1.894	-0.474***	1.996	1.894	-0.474***
INFLATION	0.566	0.852	0.598	0.606	-0.032	0.598	0.606	-0.032

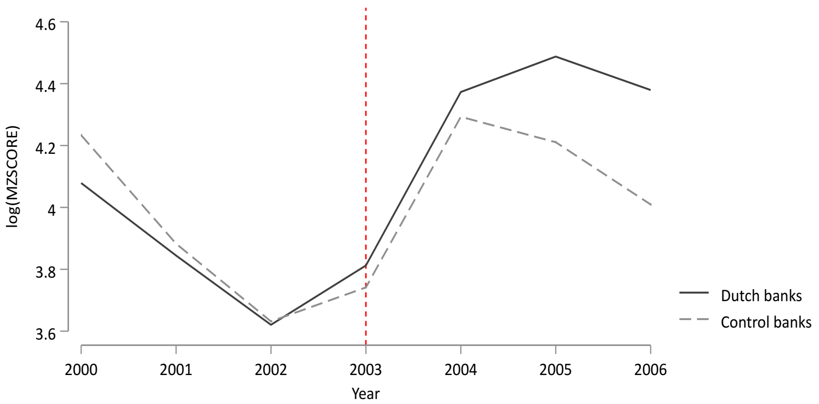
Notes: This table reports summary statistics of the outcome variables and the control variables for Dutch banks and non-Dutch banks in the pre-treatment (Panel A) and post treatment (Panel B) periods. MZSCOREGW and ZSCOREGW respectively describe the growth rates of MZSCORE and ZSCORE. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively for the difference in means test (t-test) between Dutch and Eurozone banks.

Figure 2.1 – ZSCORE and MZSCORE for Dutch banks and control banks from 2000 to 2006

Panel 1. ZSCORE



Panel 2. MZSCORE



2.2.4. Control variables

All our regressions include a set of control variables, which are expected to affect bank risk. This comprises the natural logarithm of bank total assets (SIZE) and the ratio of equity to total assets (EQUITY) to respectively account for bank size and capitalization. Larger banks have greater ability to diversify their activities and should be less risky (Demsetz and Strahan, 1997). But because of the presence of too-big-to-fail policies, they might also have higher incentives to take more risk (Galloway et al., 1997). The effect of bank capitalization on default risk is expected to be negative. However, its effect on risk-taking is not clear. Banks with higher capital ratios (on a market-value basis) are safer and take less risk, due to the moderating effect of charter values

(Keeley, 1990). However, higher capital ratios due to more stringent capital regulation can encourage banks to take on more risk to maintain the expected return to shareholders (Koehn and Santomero, 1980; Kim and Santomero, 1988).

Bank funding is captured by the ratio of deposits to total assets (DEPOSITS). Banks with higher deposits-to-assets ratio are expected to be riskier. Demirguc-Kunt and Detragiache (2002), Demirguc-Kunt and Kane (2002) and Barth et al. (2004) indicate that when deposits are insured, depositors lack the incentives to monitor banks activities, thus leading bank to excessive risk-taking. We also introduce the ratio of total loans to total assets (LOANS). Its impact on risk is expected to be negative because loans are usually more stable than non-traditional intermediation activities (Iannotta et al., 2007). Lending is part of banks' traditional activity. Through the screening of their clients, they would be able to offset the impact of an increase in lending on their default risk. However, the literature consistently finds that excessive rates of loan growth led to greater risk-taking (Foos et al., 2010).

To control for differences in banks' business models, we include the ratio of net noninterest income to net operating income (NNI). Greater reliance on non-interest income activities is generally found to be associated with higher risk (Stiroh, 2004; Lepetit et al., 2008, Demirgüc-Kunt and Huizinga 2010, Altunbas et al. 2011). Liikanen (2012) indicates that income from non-interest activities is more volatile, which can negatively affect the stability of a bank.

To account for operational efficiency, we consider the cost to income ratio (COSTINCOME), which should have a positive effect on risk. Under the "bad management" hypothesis by DeYoung (1997), banks operating with low levels of efficiency have higher costs largely due to inadequate credit monitoring and inefficient control of operating expenses (which is reflected in lower cost efficiency almost immediately). Declines in cost (and revenue) efficiency will temporally precede increases in banks' risk due to credit, operational, market and reputational problems. Shehzad et al., (2010); Barry et al., (2011), Saramiento and Galan (2017) found evidence which support this argument.

2.3. Results

In this section, we discuss the results of our regression analysis, which assesses the possible impact of the introduction of the LBR on bank risk. Table 2.5 presents the results of estimating equation (2.1). We follow the recent literature analyzing bank-risk measures such as Z-Score or the standard deviation of returns and apply a log transformation to all the outcome variables.[10] The estimated models include bank-specific control variables to capture any potential shocks in one of the time-varying determinants of bank risk. We also include year fixed effects to capture effects common to all banks, and bank fixed effects to account for any unobservable time invariant bank characteristics.

In all regressions, using either an accounting or a market-based risk measures of risk as outcome variable, the coefficient on the interaction term of interest is negative and significant for SDROA, SRETURN and positive and significant for ZSCORE, Z2SCORE and MZSCORE. This implies that following the introduction of the LBR, Dutch banks' risk-taking became lower leading to a lower probability of default, as captured by the Z-score measures, relative to counterparts not subject to the LBR. For instance, the standard deviation of return on assets of the average Dutch bank was reduced by 45% relatively to an average bank not subject to the LBR. For the average Dutch bank, the ZSCORE increased by 51% relative to the average non-Dutch bank not subject to the LBR. The results also show that these changes occur mainly through a reduction in leverage risk. Specifically, we observe a positive impact of the introduction of the LBR on Z2SCORE; the impact on Z1SCORE is not significant. The results also reveal that on average, for Dutch banks, specific risk decreased relatively to other banks not subject to the provision of the

[10] Lepetit and Strobel (2015) indicate that log-transformed Z-scores may be more appropriate in applied work due to the skewness of Z-scores in levels. They add that the log of the Z-score can additionally be shown to be negatively proportional to the log odds of insolvency, giving it a sound probabilistic foundation. For comparability, we harmonize all the variables by applying a log transformation

LBR. This is in line with the view that the introduction of liquidity requirements would lead to a decline in risk and the probability of bank runs (Diamond and Kashyap, 2016, Hoereva et al. 2018).

Turning to our control variables, we focus our discussion on the specification with ZSCORE as an outcome variable (column 1) in Table 2.5. Regarding the bank-level variables SIZE enters the regression with a positive coefficient that is statistically significant at the 1% level. This suggests that a one percent increase in SIZE is associated with a 0.6 percent increase in ZSCORE. This is line with the view that larger banks have greater ability to diversify their activities and hold more diversified loan portfolios which is effective in reducing risk (Demsetz and Strahan, 1997). We also find that better capitalized banks (EQUITY) are associated with lower default risk, as expected. Interestingly, when the outcome variable is SDROA (column 4) better capitalized banks are found to take higher asset risk which is consistent with the view that higher capitalization allows banks to fund riskier projects without jeopardizing their solvency. DEPOSITS and COSTINCOME enter the regression with positive, but insignificant coefficients, while LOAN and NNI enter the regression with a negative, but insignificant coefficient. These variables are non-significant in any of the other regressions with different outcome variables. Finally, GROWTH enters the regression with a negative, but marginally significant coefficient, while the coefficient on INFLATION is negative and statistically insignificant. Growth only shows a significant coefficient in column 4 where the outcome variable is SDROA. In periods of booms, our results hence show that banks tend to increase the riskiness of their asset portfolio which is consistent with the findings of previous studies (Bohachova, 2008; Altunbas et al. 2010; Madaloni and Peydro, 2010; Haq and Heaney, 2012).

Table 2.5 – Impact of the introduction of LBR on bank risk

Variables	Panel 1 : Broad sample of banks				Panel 2 : sub sample of listed banks			
	ZSCORE	Z1SCORE	Z2SCORE	SDROA	SDRETURN	BETA	IVOL	MZSCORE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Affected x PostEvent	0.434***	0.380	0.430***	-0.579**	-0.329**	-0.881	-0.301**	0.329**
	(0.190)	(0.641)	(0.189)	(0.196)	(0.115)	(0.934)	(0.107)	(0.133)
DEPOSITS	0.001	0.031**	-0.001	0.007	-0.002	-0.012	-0.023	0.021**
	(0.005)	(0.013)	(0.005)	(0.007)	(0.008)	(0.021)	(0.076)	(0.008)
EQUITY	0.041**	-0.025**		0.017**	-0.019**	-0.004	-0.024**	0.019**
	(0.009)	(0.011)		(0.009)	(0.009)	(0.031)	(0.008)	(0.009)
SIZE	0.661***	0.316***	0.651***	-0.116***	-0.151**	0.021	-0.149***	0.151**
	(0.105)	(0.087)	(0.106)	(0.104)	(0.056)	(0.024)	(0.062)	(0.067)
LOANS	-0.005	-0.015**	-0.005	0.005	0.082	0.003**	0.083	-0.083
	(0.006)	(0.099)	(0.006)	(0.006)	(0.311)	(0.001)	(0.283)	(0.312)
NNI	-0.004	-0.001	0.004	-0.0001	0.001	-0.000	0.000	-0.001
	(0.005)	(0.006)	(0.005)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
COSTINCOME	0.005	-0.035***	0.004	0.003	0.004	0.001**	0.003	-0.004
	(0.005)	(0.008)	(0.004)	(0.004)	(0.006)	(0.000)	(0.006)	(0.007)
LLR	-0.013**	-0.029**	-0.013**	-0.020	-0.151**	-0.328*	-0.150**	0.151**
	(0.007)	(0.094)	(0.007)	(0.228)	(0.067)	(0.201)	(0.052)	(0.057)
GROWTH	-0.043*	0.059*	-0.045	0.022**	-0.054**	-0.008	-0.052*	0.053**
	(0.027)	(0.036)	(0.053)	(0.004)	(0.019)	(0.071)	(0.043)	(0.020)
INFLATION	-0.055	0.012***	-0.052	-0.108	0.062	-0.033**	0.078**	-0.062
	(0.074)	(0.000)	(0.074)	(0.101)	(0.072)	(0.011)	(0.034)	(0.039)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	294	294	294	294	86	86	86	86
R-squared	0.974	0.826	0.973	0.904	0.978	0.903	0.982	0.978

Notes: The table analyses the impact of the introduction of the Liquidity Balance Rule in the Netherlands on bank risk in a difference-in-differences setup. The sample consists of banks from the Netherlands and the matched non-Dutch banks over the 2000-2006 period. In Panel 1, all the regressions are performed on a sample of 58 commercial banks. In Panel 2, all regressions are performed on a sample of 18 listed banks. ZSCORE is a measure of bank default risk, Z1SCORE is a measure of bank asset risk; Z2SCORE is a measure of bank leverage risk. SDRETURN is the standard deviation of daily stock returns within a calendar year. BETA is a measure of systematic risk and IVOL is a measure of idiosyncratic risk. MZSCORE is a market-based Z-Score defined as (100+RETURN)/SDRETURN. All the dependent variables were log transformed. AFFECTED is a dummy is equal to 1 when the bank is a Dutch bank and 0 otherwise. POSTEVENT is a dummy equal to 1 for the years 2003 to 2006 and 0 otherwise. The model is estimated using OLS. The control variables comprise: SIZE defined as the natural logarithm of total assets, EQUITY defined as the ratio of total equity to total assets, DEPOSITS defined as the ratio of total customer deposits to total assets. LOANS is defined as of net loans to total assets. COSTINCOME is the ratio of operating expense over total operating income. LLR is the ratio of loan loss reserves to total assets, GROWTH is the real GDP growth and INFLATION is the inflation rate. The effect of LBR is captured by the coefficient on the interaction term Affected × Post Event. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Overall, our results show that the introduction of the LBR has reduced both the risk-taking and default risk of banks subject to the rule. However, an important issue is whether such an impact is transitory or long-lived. Indeed, to comply with the rule banks need to make quick adjustments by increasing the share of liquid assets on the liability side of their balance sheet or by reducing the share of non-stable funding in their liabilities. However, once they have adjusted to the new requirements, banks could also react by increasing the riskiness of their non-liquid assets to maintain their profitability. To investigate this issue, we follow Jorda (2005) and Favara and Imbs (2015) to determine the dynamic effect of liquidity regulation on bank risk. Specifically, we employ local projections, which consist of running a sequence of predictive regressions of a variable of interest (e.g., risk or profitability) on a regulatory shock (e.g., LBR) for different horizons to obtain impulse response functions. In the context of our analysis, the impulse response functions correspond to a sequence of estimates β^j obtained from the estimations of:

$$Y_{i,t+j} = \beta^j(\text{Affected}_i \times \text{PostEvent}_t) + \delta X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (2.2)$$

where each β^j captures the effect of the introduction of the LBR at horizon j, with j=1, ..., 5. Also, other regulatory changes (such as the publication of the preliminary draft of Basel II requirements) that may have occurred at the regional or international level during the period when the LBR was announced and implemented would affect banks in the Eurozone the same way. Thus, our analysis is unlikely to be influenced by such changes and the IRF will capture the long run effect of the introduction of the LBR. Figure 2.2 plots the impulse response functions. For both the ZSCORE and SDRETURN, the impulse response function shows a significant impact until the fifth year, although the magnitude of the impact diminishes over the years.[11] This suggest that the introduction of the LBR has an immediate but not short-lived effect on bank risk.

Overall, we find that following the introduction of the LBR, Dutch banks became less risky relative to counterparts not subject to the rule. The observed impact is not simply statistically

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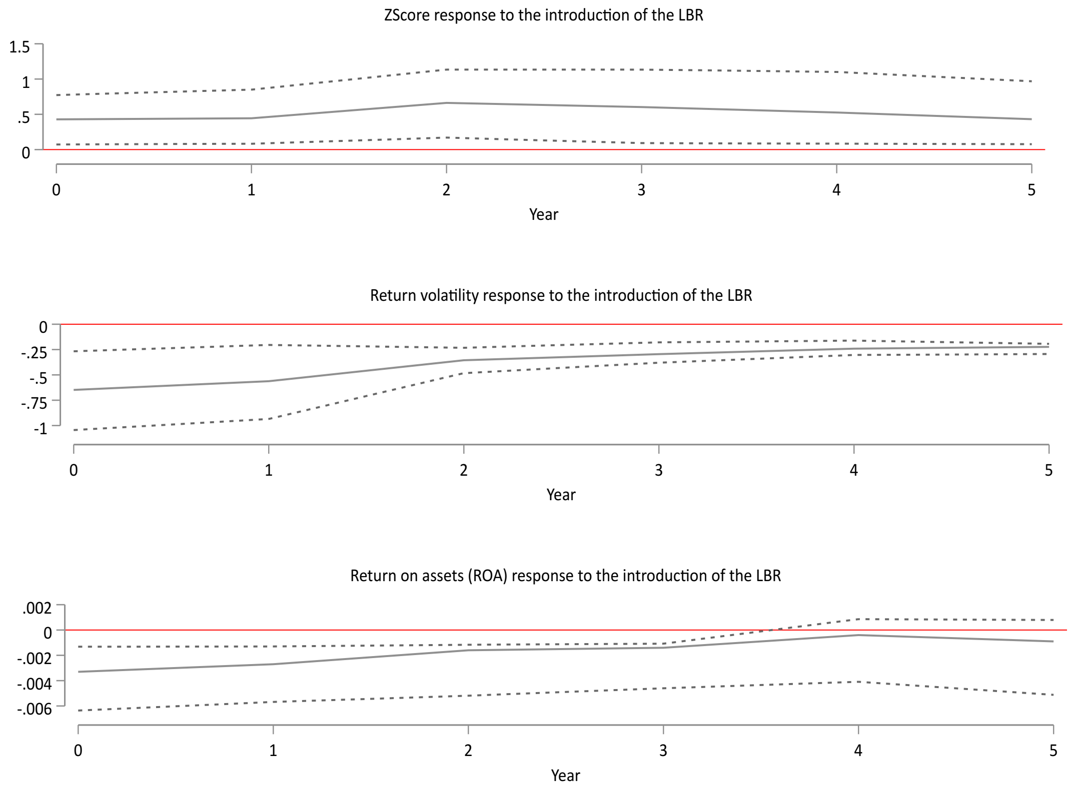
[11] The estimated coefficients that we used to lay out Figure 2.2 are reported in Appendix A2.1.

significant, but also economically significant. On average, ZSCORE increased by approximately 51%, while SDROA decreased by around 45%, compared to counterparts not subject to the rule. As such, it appears that the introduction of the LBR leads banks to take lower risk and become less vulnerable to default.

Figure 2.2 – Bank risk and profitability response to the introduction of the LBR



Notes: This figure plot the impulse responses of bank risk (ZSCORE and SDRETURN) and profitability (ROA) to the introduction of the LBR. The IRFs are computed following the method proposed by Jorda (2005). Doted lines are the 95 percent confidence bands.

2.4. Impact on bank profitability, income, cost of funding and funding structure

In this section, we examine the impact of the introduction of the LBR on bank profitability and on their cost of funding and funding structure. Hoereva et al (2018) indicate that banks face a tradeoff between risk and profitability when facing liquidity constraints. Thus, a decrease in bank risk should be accompanied by a decline in profitability, given that the return on liquid assets is likely to be lower than the return on illiquid assets. They argue that funding cost matters for bank profitability and risk, particularly in an environment where banks are subject to an LCR-like standard. They emphasize that when the return on liquid assets is lower than funding cost, banks may have incentives to invest in riskier assets to offset the negative impact on their profitability of holding larger portions of liquid assets. Banks can also adjust to the loss in income driven by the constraint of holding larger shares of liquid assets by adjusting their lending rates. This implies that banks can actively engage in a pricing policy to limit the negative impact on their income, but such a strategy will be dependent on the degree of competition on the loan market. Banks could also collude in ways that the increase in lending rates is beneficial to all the players in the banking industry but detrimental to borrowers. Giordana et al (2017) also argue that any impact of an increase in liquid assets on profitability is crucially dependent on the structure of bank liabilities. Our results indicate that following the implementation of the LBR, Dutch banks became less vulnerable to default and took less risk. A priori, we also expect to observe a negative or insignificant impact of the introduction of the LBR on profit, and a significant effect on bank funding structure and costs of Dutch banks. To investigate these issues, we consider the reduced form of a DiD model as follows:

$$Y_{i,t} = \beta(\text{Affected}_i \times \text{PostEvent}_t) + \alpha_i + \lambda_t + \varepsilon_{i,t} \qquad (2.3)$$

where *i* indexes bank and *t* indexes time. Affected_i is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. PostEvent_t is a dummy variable for the treatment period. It takes the value of 1 for the years 2003 onwards, and zero otherwise. β is the coefficient of interest, which represents the impact of the LBR on one of our outcome variables: profitability, cost of funding and, funding structure variables. The model also includes bank specific fixed effects, α_i, to control for unobserved bank heterogeneity, and time dummies γ_t, to capture time effects common to all banks.

2.4.1. Bank profitability, interest margins and non-interest income

To assess the effect of the introduction of the LBR on bank profitability and interest margins and other income components, we consider the return on assets (ROA) and various components of bank income comprising: the ratio of total interest income to total assets (IINC); and the ratio of non-interest income to total assets (NII). We further investigate the structure of bank revenue by analyzing the impact of the introduction of the LBR on components of non-interest income comprising the ratio of net gain/loss from trading activities to total non-interest income (TRADEGAIN); ratio of net fees and commissions to total non-interest income (COM); and the ratio of other non-interest income to total non-interest income (EXTRA). The results of the estimations are presented in Table 2.6. As expected, the LBR has a negative and significant impact on bank profitability. This is driven mainly by a reduction in income generated by interest bearing activities as opposed to non-interest income. However, the effect is not permanent. The last row of Figure 2.2 shows the impulse response function of ROA to the introduction of the LBR. It indicates that four years after the introduction of the LBR, the effect of LBR becomes insignificant. Nevertheless, closer inspection of non-interest income reveals a heterogenous impact of the LBR. Specifically, following the introduction of the LBR, income generated by trading activities declines; other non-interest income increases; and income from fees and commissions remains unchanged. This suggests a shift from trading to other non-interest generating activities of Dutch banks.

Table 2.6 – Impact of LBR on bank profitability and income

Variables	ROA (1)	IINC (2)	NII (3)	TRADEGAIN (4)	COM (5)	EXTRA (6)
Affected x PostEvent	-0.004**	-0.019**	-0.006	-0.123**	0.823	0.076**
	(0.002)	(0.010)	(0.009)	(0.007)	(1.824)	(0.002)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	406	258	258	95	95	95
R-squared	0.769	0.908	0.744	0.515	0.942	0.896

Notes: The table analyses the impact of the introduction of the Liquidity Balance Rule in the Netherlands on bank profit, equity, and deposits in a difference-in-differences setup. The sample consists of banks from the Netherlands and the matched non-Dutch banks over the 2000-2006 period. ROA is a measure of bank's profitability, IINC is the ratio of interest income to total assets, NII is the ratio of non-interest income to total assets, TRADEGAIN is the ratio net gain/loss from trading activities to total non-interest income, COM is the ratio of net fees and commissions to total non-interest income and EXTRA is the ratio of other non-interest income to total non-interest income. AFFECTED is a dummy is equal to 1 when the bank is a Dutch bank and 0 otherwise. POSTEVENT is a dummy equal to 1 for the years 2003 to 2006 and 0 otherwise. The model is estimated using OLS. The effect of LBR is captured by the coefficient on the interaction term Affected × PostEvent. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Overall, the results suggest that the introduction of the LBR lead to a reduction in Dutch banks' income possibly due to the requirement of holding larger shares of less profitable liquid assets. Alternatively, following Hoereva et al (2018), another potential explanation to this result could be that Dutch banks face higher funding costs because they hold riskier assets in reaction to the introduction of the LBR. If depositors and other types of debt holders effectively discipline banks, then they would indeed actually require a higher rate of return on their holdings. Banks could also adjust to the new regulatory environment by increasing the interest rate charged on illiquid assets which could have a detrimental effect if it leads to credit rationing by hoarding out the safest borrowers (Stiglitz and Weiss, 1981). We investigate this issue in the next section.

2.4.2. Cost of funding and loan pricing

To investigate the impact of the LBR on bank funding cost and loan pricing, we consider the difference (NIM) between the implicit interest rate charged, INT (measured by the ratio of total interest income to total earning assets) and paid, COST (measured by the ratio of total interest expenses to total liabilities). The results are presented in Table 2.7. We find that the coefficient of the interaction term (Affected$_i$ x PostEvent$_t$) enters the regression with a negative and statistically significant coefficient at the 5% level. The magnitude of the coefficient suggests that Dutch banks suffer from a reduction in their interest margin (NIM) by 40 basis points on average, following the introduction of the liquidity regulation. Further analysis of the components of NIM suggests that both the implicit interest rate charged by banks on their assets (INT) and that paid on their liabilities (COST) decreased following the introduction of the LBR. However, INT declines by more than COST, leading to the observed narrowing of NIM for the Dutch banks. Overall, it appears that Dutch banks might not have actively try to offset their loss in income as they did not charge higher interest on their assets, relatively to nonaffected banks. They also benefit from better financing conditions which should allow them to increase the shares of deposits and capital on the liability side of their balance sheets, which are helpful for compliance (Hartlage 2012) and to offset insolvency risk arising from a decline in profitability. We investigate this issue in the next section.

Table 2.7 – Impact of LBR on bank interest margin, interest charged and funding cost

Variables	NIM (1)	INT (2)	COST (3)
Affected x PostEvent	-0.004**	-0.021**	-0.016**
	(0.004)	(0.009)	(0.000)
Year fixed effects	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Observations	261	261	261
R-squared	0.848	0.913	0.819

Notes: The table analyses the impact of the introduction of the Liquidity Balance Rule in the Netherlands on bank profit, equity and deposits in a difference-in-differences setup. The sample consists of banks from the Netherlands and the matched non-Dutch banks over the 2000-2006 period. COST is the ratio of total interest expenses to total liabilities, INT is the ratio of total interest income to total earning assets, and NIM is the difference between INT and COST (NIM = INT-COST). AFFECTED is a dummy is equal to 1 when the bank is a Dutch bank and 0 otherwise. POSTEVENT is a dummy equal to 1 for the years 2003 to 2006 and 0 otherwise. The model is estimated using OLS. The effect of LBR is captured by the coefficient on the interaction term Affected × PostEvent. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

2.4.3. Funding structure

To assess the impact on banks' funding structure, we consider EQUITY and DEPOSITS as outcome variables. The results of the estimation are presented in Table 2.8.

Table 2.8 – Impact of LBR on bank funding structure

Variables	DEPOSITS (5)	EQUITY (6)
Affected x PostEvent	0.009**	0.019**
	(0.000)	(0.000)
Year fixed effects	Yes	Yes
Bank fixed effects	Yes	Yes
Observations	364	406
R-squared	0.963	0.927

Notes: The table analyses the impact of the introduction of the Liquidity Balance Rule in the Netherlands on bank profit, equity and deposits in a difference-in-differences setup. The sample consists of banks from the Netherlands and the matched non-Dutch banks over the 2000-2006 period. DEPOSITS is the ratio of total customer deposits to total assets and EQUITY is the ratio of total equity to total assets. AFFECTED is a dummy is equal to 1 when the bank is a Dutch bank and 0 otherwise. POSTEVENT is a dummy equal to 1 for the years 2003 to 2006 and 0 otherwise. The model is estimated using OLS. The effect of LBR is captured by the coefficient on the interaction term Affected × PostEvent. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The results indicate that Dutch banks have experienced an inflow of deposits, but also an increase in equity. A potential explanation is that Dutch banks may have increased equity to offset the increased insolvency risk arising from a decline in profitability. Eisenbach et al. (2014) and Konig (2015) argue that when bank profits decline because of an increase in liquid assets, insolvency risk also increases. Therefore, by increasing capital, banks can offset any negative impact on their stability.

2.5. Robustness and sensitivity analysis

In this section, we examine the robustness of our main results. To ensure that our results are not affected using overlapping periods (rolling-windows), we compute our accounting-based risk variables on the basis of 4-year and 5-year rolling windows. For the subsample of listed banks, we consider the last three months of the year to compute the market-based risk indicators. We re-estimate equation (2.1) using these measures. The results of the estimations are presented in row (1), (2) and (3) of Table 2.9. The results remain qualitatively similar to those reported in Table 2.5.

Next, we test whether variations in our matching procedure affects our results. First, we run the matching using the trends in SDROA and SDRETURN, instead of ZSCORE and MZSCORE. In the baseline analysis, we assume that the evolution of all the outcome variables should be similar to ZSCORE and MZSCORE, given the strong correlation between all these indicators. The results of the estimation of equation (2.1) using this alternative matching are presented in row (4) of Table 2.9. The results hold, and the magnitude of the coefficient are in line with our baseline results. We also vary the number of matched banks from three nearest neighbors to the nearest neighbor only and then to the five nearest neighbors and obtain similar results (see rows 5 and 6). Finally, we restrict the number of countries from which banks in the control group are selected. We use Belgium and Luxembourg for the control group, given that along with the Netherlands these countries are part of the historical BENELUX economic union. An analysis based on these three countries is likely to address any omitted variable bias. Given the specific nature of the banking system in Luxembourg (which specializes on wealth management), we conduct a further robustness check using only Belgian banks as our control group. The results remain unchanged qualitatively (see rows 7 and 8).

Finally, we test for the parallel trend assumption by performing a placebo test. In order to investigate the effect of a placebo treatment, we assume that the LBR was introduced in 2001, rather than in 2003. We then re-run the matching using the growth rate of ZSCORE and MZSCORE. The matching procedure is the same as that used in the baseline analysis. The estimations are presented in row (9) of Table 2.9 and suggest that the parallel trend assumption is not violated, and thus the identification strategy is valid.

Table 2.9 – Robustness analysis and sensitivity tests

		Panel 1. Broad sample of banks				Panel 2. Subsample of listed banks			
		ZSCORE	Z1SCORE	Z2SCORE	SDROA	SDRETURN	BETA	IVOL	MZSCORE
(1)	4 Year rolling window	0.362***	0.442	0.335***	-0.556**				
		(0.105)	(0.572)	(0.104)	(0.209)				
(2)	5 Year rolling window	0.345**	0.337	0.339**	-0.498**				
		(0.130)	(0.502)	(0.135)	(0.187)				
(3)	Last 3 months					-0.263**	-0.934	-0.255**	0.319**
						(0.099)	(1.394)	(0.112)	(0.124)
(4)	Alternative matching	0.305**	0.571	0.296**	-0.356**	-0.262**	-0.522	-0.244**	0.262**
		(0.116)	(0.738)	(0.119)	(0.133)	(0.094)	(0.771)	(0.091)	(0.098)
(5)	1 neighbor	0.451***	0.618	0.413***	-0.832*				
		(0.115)	(0.824)	(0.113)	(0.498)				
(6)	5 neighbors	0.484**	0.462	0.472**	-0.547**				
		(0.181)	(0.689)	(0.173)	(0.204)				
(7)	Benelux only	0.305**	0.562	0.296**	-0.547**				
		(0.113)	(0.837)	(0.119)	(0.204)				
(8)	Belgium only	0.332**	0.320	0.276**	-0.687***				
		(0.201)	(0.468)	(0.179)	(0.157)				
(9)	Placebo test	0.193	0.647	0.176	-0.687***	-0.157	-0.021	-0.190	0.162
		(0.264)	(0.766)	(0.264)	(0.157)	(0.175)	(0.024)	(0.213)	(0.182)

Notes: The table presents the sensitivity of the baseline model to variations in the definition of the outcome variable, the sample size and matching procedure as well as false timing of the introduction of the LBR. For brevity, we only report the estimated coefficients of the variable of interest *Affected × Post Event*. Appendix A2.2 and A2.3 presents the results of the estimation for ZSCORE, and MZSCORE. The bank- and country-level controls as well as fixed effects are identical to those in Table 6. In rows (1) and (2), ZSCORE, Z1SCORE, Z2SCORE and SDROA are measured using a four-year rolling and five-year rolling window. Row (3) uses the last three months of the year to compute SDRETURN, BETA, IVOL and MZSCORE. Row (4) use alternative variables for the matching procedure. Instead of the growth rate in ZSCORE and MZSCORE, the growth rates of SDROA and SDRETURN is used. Row (5) and (6) match each Dutch bank with one and five unaffected banks, respectively. Rows (7) and (8) restrict the number of countries from which banks in the control group are selected to Benelux (i.e., Belgium and Luxembourg) and Belgium, respectively. Row (9) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

2.6. Conclusion

In this study we conduct an extensive investigation into how liquidity regulation impacts bank risk. To identify the impact of bank liquidity regulation on bank risk we use the Liquidity Balance Rule, which was introduced in the Netherlands in 2003, and required Dutch banks to hold high-quality liquid assets greater than or equal to net cash outflows over a 30-day stress period.

We conduct an extensive difference in differences empirical analysis at the bank level, where we compare the riskiness of Dutch banks between the pre-LBR and post-LBR period with the same difference in the riskiness of a control group of European banks not subject to the provision of the LBR. Our analysis produces two major findings. First, we show that following the introduction of the LBR Dutch banks became less risky, but their profitability was negatively impacted. Second, we find that the introduction of the LBR led Dutch banks to change their funding structure by increasing capital and deposits. The decrease in the cost of funding following the introduction of the LBR possibly explains such a change.

Our findings have implications for public policy and government agencies monitoring the impacts of the recently phased in Liquidity Coverage Ratio on the banking industry. Given prior evidence (including the global financial crisis) shows that a lack of bank liquidity can have implications for the safety and soundness of banks, the results presented in the present study suggest that the introduction of liquidity regulation reduces bank risk and the likelihood of default. Our findings do not lend support to the views that the introduction of liquidity requirements could be counterproductive by encouraging banks to take on more risk to avoid the negative impact of such rules on bank profitability. However, because the introduction of the LBR has led to a decline in bank profitability, bank stability could be a concern. Bank managers and supervisors should be cautious about banks’ solvency levels which can more likely be maintained with equity issuance rather than with reserves generated by non-distributed income.

Chapter 3

On the relationship between capital and liquidity requirements: a vector autoregression approach*

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Abstract

This study investigates the relationship between bank regulatory capital buffer and bank regulatory liquidity buffers. Building on previous studies that indicate that bank capital and liquidity are jointly determined, we employ a panel VAR approach that applies to a sample of European banks part of the Single Supervision Framework (SSM) over 2015-2020. The VAR approach addresses the problem of endogeneity by allowing endogenous interaction between system variables. Our results suggest that banks increase their regulatory liquidity when they increase their regulatory capital. In contrast, an increase in liquidity does not affect capital. Our findings suggest that the introduction of liquidity rules, alongside those on capital, does not lead banks to build a liquidity buffer at the expense of their capital buffer.

Classification JEL: G21, G28

Key words: Bank regulatory capital, Liquidity, Bank regulation.

3.1. Introduction

In response to the financial crisis of 2007-2009, the Basel Committee on Banking Supervision has proposed a new set of constraints for banks, embodied in Basel III. Banks are not only required to hold more capital than before. They also need to comply with new liquidity ratios: the liquidity coverage ratio (LCR) to ensure they have enough high-quality liquid assets to sustain liquidity shocks over a one-month horizon. The net stable funding ratio (NSFR) limits their maturity transformation. These new rules have been designed to improve the resiliency of banks during a stress period and prevent further crises. The benefits of the reforms also stem from the interaction among the regulatory requirements. Nevertheless, the interactions between the revised capital requirements and the newly proposed liquidity standards can also lead to tensions that warrant attention (Borio et al., 2020).

The Basel III requirements are expected to strengthen banks' buffers to ensure that banks have sufficient absorption capacity to face either solvency shock and/or liquidity shock. The main question is whether the introduction of liquidity rules, which required banks to hold liquidity buffers, would affect how they manage both their capital and liquidity. The banks' desired levels of capital and the liquidity of their assets are interrelated in ways that are not yet fully understood by regulators and researchers. The addition of liquidity requirements adds further complexity to the understanding of this relationship. The existing literature on the interrelations of bank capital and bank liquidity thus far reached few firm conclusions. It has been established in the literature that banks manage jointly their unregulated liquidity and regulated capital (Roulet et al 2013, Walther 2016, Boissay et al 2016, DeYoung et al. 2018, Ascotha-Smith et al 2019, Gomez and Vo 2020) depending on their business model and size, which has led to question whether the joint regulation of capital and liquidity was necessary. For example, Gomez and Vo (2012) have shown that banks will maintain an adequate level of liquid assets to shield themselves from liquidity shocks if and only if they are well-capitalized, suggesting that banks view capital and liquidity as complements. DeYoung et al. (2018) and Roulet et al (2013) reach the same conclusion for large international banks but stress that small U.S. banks, that often hold a high level of liquid assets, view capital and liquidity as substitutes.

The main lesson from this literature is that banks have a desired level for liquidity and capital and manage their balance sheet accordingly and cautiously to sustain any negative shock.[1] Given that until the 2007-2008 financial crisis, the focus was on banks' capital; this might have shaped the way banks viewed and managed their capital and liquidity. The introduction of liquidity requirements could potentially affect this relationship, as banks are now required to hold a buffer for capital and liquidity. In such a context, their desired level for liquidity is influenced by the required ratios, which could affect how they managed their capital as well. Would banks prefer holding capital or liquidity buffer? Or would they maintain a precautious behavior by bearing or strengthen their capital or liquidity buffer?

To investigate this issue, we take advantage of the fact that Basel III rules constrained some European banks under the Single Supervisory Mechanism (SSM). The SSM came into force in November 2014 and comprised the European Central Bank and national supervisory authorities of the 19 European countries participating in this framework. The framework is designed to ensure cooperation among the different European countries regarding the supervision of the banking system. We collected the supervisory data including NSFR, LCR, the Capital Adequacy Ratio for these banks from BankFocus. To account for the existence of liquidity requirements, we consider the capital and liquidity buffers, defined as the difference between the required ratio and the bank position, instead of the regulatory capital and liquidity ratios. To overcome the reverse causality problem that arises from banks, choosing capital and liquidity positions simultaneously, we use a vector autoregression (VAR) framework. This method is developed by Sims (1980) and has been widely used in macroeconomics. The technique is now receiving attention in the banking and finance literature (Garretsen and Swank 1998, Juri and Quagliariello 2008, DeGraeve and Karas 2012, Hoggart et al. 2015 Li et al 2020) to study the interactions between a few endogenously determined variables.[2] This is because VAR models have

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[1] However, the recent financial crisis has shown that this was not sufficient, justifying the introduction of further requirements.

[2] Canova and Ciccarelli (2013) extensively survey these tools and discuss their benefits for banking analysis.

advantages over other methods. First, compared to theoretical works that try to assume the exogeneity of several factors to limit the model's dimensionality, VAR models allow all variables to be determined endogenously and use lagged values of the variables as IVs (instrumental variables). GMM (generalized method of moments) is used to estimate the coefficients of the lagged endogenous variables. It also uses a recursive identification strategy to identify the transmission of shocks between the system's variables. Therefore, VAR can overcome the endogeneity problem and isolate the response of a given variable to others respectively. Second, compared to the standard regression approach, the results of VAR models can shed light on which theoretical models align more closely with empirical reality. Third, using a VAR approach avoids the potential bias resulting from the misspecification caused by the assumed exogeneity in simultaneous equation models (Sims, 1989). It has the merit of avoiding a complete specification of the models (Bagliano and Favero, 1998). Therefore, it is a suitable technique to study the interactions between the Basel III requirements. Our results fall in line with previous studies that capital and liquidity are jointly determined. All the variables are explained by their last realization and the prior realization of other variables. We further use a Granger causality test to evaluate the joint determination of capital and liquidity ratios. We find that the regulatory liquidity ratios are influenced significantly by the regulatory capital ratio. We also use orthogonalized impulse response functions (OIRFs) to visualize how a shock to the buffer on CAR, LCR, or NSFR affects the others. We find that a change to a bank's capital buffer induces a permanent positive change in its LCR and NSFR buffer, meaning that liquidity buffers increase significantly and permanently after an increase in the capital buffer. On the contrary, a shift in banks' LCR and NSFR buffers does not significantly affect the capital buffer.

To test the robustness of our results, we extended the system of equations to be estimated by introducing other variables identified in the literature as factors that could affect banks' capital and liquidity. We also change the recursive order of the variables in the initial setup. These changes do not make a qualitative difference to our results. We also compare our results to the estimates of a single equations model. The results suggest that single equations without controlling the other variable as a system generate biased estimates. The bias is even persistent when we control for the other variables in the single equation, without considering the interaction effect.

We contribute to the literature in several ways. To be consistent with recent empirical studies showing that banks' capital and liquidity might be interrelated, we used a VAR approach. With the Granger causality test, we have also established that banks' capital has a significant influence on their liquidity, whereas liquidity does not significantly influence banks' capital. This is important for future studies related to bank capital and liquidity. Considering models such as VAR to analyze this relationship might be worthy. It helps in solving the endogeneity issue and to assess whether this relationship is short or long-lived – an aspect that has not been yet addressed in the existing literature. Also, we provide evidence which indicates that, in presence of liquidity requirements, an increase in banks' capital induces an increase in their liquidity. This suggest that the introduction of liquidity rules, alongside those on capital, does not lead banks to build a liquidity cushion at the expense of their capital cushion

The remainder of the chapter is organized as follows. Section 3.2 reviews the literature linking banks' capital and liquidity. Section 3.3 presents our empirical strategy. Section 3.4 presents and discusses the empirical results. Section 3.5 discusses the robustness of our results. Section 3.6 concludes.

3.2. Related literature

This study is related to the literature linking bank capital and liquidity. From a theoretical perspective, the seminal work of Berger and Bouwman (2009) provides two hypotheses to understand the relationship between a bank's capital and liquidity. The first one is related to the intermediary function of banks. They collect funds from depositors and lend to borrowers. To optimize this intermediary function, they monitor borrowers and obtain private information that gives them an advantage in assessing their profitability. They indicate that this informational advantage creates an agency problem. Banks might therefore extort rents from the depositors by requiring a more significant share of the loan's income. Bank could withhold monitoring if depositors refuse to pay the higher cost. But depositors also know that banks could abuse their trust, becoming reluctant to put their savings in the bank. Consequently, banks need to win depositors' confidence by keeping a large share of liquid deposits by adopting a fragile financial structure. A contract between banks and depositors can help mitigate this hold-up problem, as depositors can run on the banks if they threaten to withhold efforts. Thus, financial fragility favors liquidity creation in that it allows the bank to collect more deposits and grant more loans. However, higher capital tends to mitigate the financial fragility and enhance the bank's bargaining power, which hampers the credibility of its commitment to depositors. Thus, higher capital tends to decrease liquidity creation. The second one is related to banks' risk absorption capacity. They explain that higher capital enhances the ability of banks to create liquidity. Bank capital allows the bank to absorb greater risk (Repullo, 2004; Von Thadden 2004). Thus, the higher is the bank's capital ratio, the higher is its liquidity creation. They empirically test these hypotheses using a sample of US commercial banks from 1993 to 2003. They construct an indicator for liquidity creation and test how it relates to capital. The relationship is positive for large banks when liquidity creation includes off-balance sheet activities and not significant when liquidity creation only accounts for on-balance sheet activities. The relationship is significantly negative for small banks considering both liquidity creation measures.

Following the announcement of Basel III requirement, the issue has received more attention from researchers. Several studies attempt to understand banks' liquidity holding behavior and how it interacts with capital. Acosta-Smith et al. (2019) construct a model to analyze the impact of banks' capital ratios on the extent to which banks choose to engage in liquidity transformation. In their model, banks that face uncertainty about the timing of deposit withdrawals choose their liquid asset holdings to insure themselves against the risk of failure due to a liquidity shortage. They note that banks' capital level positions have two effects on their liquidity holdings. First, they explained that an increase in a bank's capital ratio means a more stable liability structure, which implies a lower need for liquidity holdings and may cause a bank to reduce its holding of liquid assets. Second, an increase in a bank's capital ratio also means that shareholders face higher losses and a higher cost if the bank is forced into an early liquidation due to insufficient liquidity holdings. In such a context, a bank must hold more liquidity. From the perspective of the second effect, an increase in banks' capital ratios will lead to a decrease in the degree of liquidity transformation (an increase of liquidity holdings). In contrast, the first effect implies that the bank could decrease its liquidity holdings. Using numerical analysis, they conclude that overall, an increase in banks' capital ratios would lead banks to engage in minor liquidity transformation (increase holding of liquidity) and make them less vulnerable to liquidity shocks. Gomez and Vo (2020) reach a similar conclusion at the individual bank level when considering a baseline setting in which banks hold liquidity just for precautionary reasons. They find that banks will maintain an adequate level of liquid assets to shield themselves from liquidity shocks if and only if they are well-capitalized. DeYoung et al. (2018) study the relationship between bank capital and bank liquidity for a sample of US banks before the introduction of Basel III. Their identification strategy relies on a negative shock to bank capital (if a bank is already operating below its internal capital ratio target, and then it experiences an additional reduction in its capital ratio that moves it even further below its internal target). Given that this reduction would be involuntary for banks, the shock is assumed to be an exogenous shock to bank capital. Their findings suggest that US banks have historically treated capital and liquidity as substitutes. Eisenbach et al. (2014) build a framework to analyze how bank capital and liquidity ratios affect bank resilience. In their model, a bank is financed by short-term debt and long-term debt and equity. It invests these resources into liquid and illiquid assets. Short-term debt holders could decide to withdraw their funds before maturity. Depending on the return on illiquid assets, the bank can be either fundamentally insolvent or conditionally solvent but illiquid or fundamentally solvent. Eisenbach et al. (2014) indicate that if the return on illiquid assets is higher than the return on liquid assets, a bank's insolvent probability increases if its liquidity ratio increases. The intuition is that when illiquid assets pay more than liquid assets, higher liquidity holdings reduce the bank's revenues and weaken its solvency position. In this sense, capital complements liquidity since an increase in liquid asset holdings requires an increase in capital for the bank to maintain the same level of stability. De-Bandt et al. (2021) also construct a model to study the interaction between solvency and liquidity constraints. In their setup, the bank is funded by equity and demandable deposits, which are invested into loans and marketable securities. In their setup, the bank is assumed to behave as a mean-variance investor. They reach the same conclusions as Eisenbach et al (20214), that increasing the liquidity requirement can reduce the bank's profit and thus weaken its solvency.

3.3. Empirical strategy

3.3.1. The model

This chapter aims to test whether the introduction of liquidity requirements affect the relationship between banks' capital and liquidity. Previous studies show that bank capital and liquidity are jointly determined, which poses some endogeneity issues. To overcome this, we employ a system equation model, precisely a panel-data vector autoregressive method (Panel VAR). The VAR methodology was developed by Sims (1980) and has been widely used in macroeconomics. The technique is now receiving attention in the banking and finance literature (Garretsen and Swank 1998, Juri and Quagliariello 2008, DeGraeve and Karas 2012, Hoggart et al. 2015 Li et al 2020) to study the interactions between endogenously determined variables. This is because VAR models have some advantages over other methods. First, compared to theoretical works that try to assume the exogeneity of several factors to limit the model's dimensionality, VAR models allow all variables to be determined endogenously and use lagged values of the variables as IVs (instrumental variables). GMM (generalized method of moments) is used to estimate the coefficients of the lagged endogenous variables. It also uses a recursive identification strategy to identify the transmission of shocks between the system's variables. Therefore, VAR can overcome the endogeneity problem and isolate the response of a given variable to others respectively. Second, compared to the standard regression approach, the results of VAR models can shed light on which theoretical models align more closely with empirical reality. Third, using a VAR approach avoids the potential bias resulting from the misspecification caused by the assumed exogeneity in simultaneous equation models. Sims (1980) argues that the standard hypotheses implicit in identifying simultaneous equation systems are too strong to be of practical use.

Combining the VAR approach with the panel structure offers two things that are of interest for our identification. On the one hand, the panel VAR approach treats all the variables in the system as endogenous. On the other hand, it relies on the traditional panel-data techniques, thus enabling unobserved heterogeneity by introducing fixed effects. Thus, with this approach, we overcome the endogeneity issue. We will also be able to identify a causal relationship between bank capital and liquidity. The VAR model also allow us to draw impulse response functions that describe how an average bank absorbs one standard-deviation of one of the variables (shock) and how it affects the others.

As banks are required to meet a minimum standard on capital and liquidity, their leeway will relate to the buffer they hold. Thus, we will consider the regulatory buffer on capital and liquidity for our investigation, instead of the actual ratios. The regulatory buffer is defined as the amount of capital or liquidity a bank holds in excess of the minimum required to meet regulatory standards.

The empirical model is given as follow (subscripts i and t denoting bank and period, respectively):

$$\mathrm{Y_{i,t}} = \mathrm{A(L)} \times \mathrm{Y_{i,t}} + \alpha_\mathrm{i} + \varepsilon_\mathrm{i,t} \tag{3.1}$$

where $Y_{i,t}$ is a (1,3) dimension vector of *KGap*, *LCRGap* and *NSFRGap*. $A(L)$ is a matrix of polynomial in the lag operator, with $A(L) = A_1L^1 + A_2L^2 + ... + A_pL^p$. α_i is a vector of bank specific fixed effects and $\varepsilon_{i,t}$ is a vector of idiosyncratic errors.

KGap, *LCRGap* and *NSFRGap* describe regulatory buffers as defined below[3]:

- *KGap* is measured by the difference between the total regulatory capital ratio (i.e., the ratio of Tier 1 and Tier 2 capital to risk weighted assets) and a constant (8%)[4],

[3] Appendix A3.1 provides the detailed definitions of all the variables used in our analysis.

[4] For robustness check, we consider different thresholds (10%) instead of 8% to account for Basel III Pillar 2 requirements. The micro-prudential framework adjusts capital according to the individual bank's risk exposure. These additional capital requirements, known as Pillar 2, are designed to ensure that risks not fully covered under Pillar 1 are accounted for in the total capital requirement. Banks are then required to have in place the internal capital adequacy assessment process (ICAAP) that involves the use of elaborate internal models and stress tests to quantify all the risks the bank bears and estimate the amount

- *LCRGap* is the difference between the LCR and the required ratio of 100%,

- and *NSFRGap* is the difference between the NSFR and the required ratio of 100%.

The model is estimated by the generalized method of moments (GMM) using lagged regressors as instruments. Estimating a single equation of the dynamic system by OLS or the fixed effects method leads to biased and inconsistent estimates due to the endogeneity in lagged dependent variables and in the other independent variables (Blundell and Bond, 1998; Antoniou et al., 2008). Abrigo and Love (2016) indicate that the GMM generates consistent estimates for autoregressive models. Abrigo and Love (2016) propose using the Helmet transformation (forward orthogonal deviations) to eliminate the bank fixed effects. We follow these suggestions in estimating equation (3.1).

We perform several tests to check the validity of the VAR model. Following Enders (2015), we conduct an over-identification test with the null hypothesis that the VAR model is not over-identified and stable. Abrigo and Love (2016) indicate that the model stability is a pre-condition for a correct interpretation of the impulse response function analyses. We also check whether the lag structure of our SVAR model is appropriate. Thornton and Batten (1985) and Holtz-Eakin et al. (1988) highlight the importance of using an appropriate lag structure in a VAR model, indicating that an inappropriate choice leads to misspecifications and misleading results from the Granger causality tests. We follow Andrews and Lu (2001) and use the model and moment selection criteria to check the lag structure of our model. The results of these tests are discussed in section 3.3.3.

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of capital appropriate to that risk profile. Bank supervisors review ICAAP as a component of an in-depth bank evaluation, as a result, the appropriate level of Pillar 2 capital add-on is determined. Since this additional layer is based on individual bank risk profile, we consider using a threshold of 10% (corresponding to an additional layer of 2%) to reflect the binding effect of Pillar 2.

3.3.2. Data

This study uses bank group-level data for a sample of banks in Europe's Single Supervisory Mechanism (SSM). The SSM came into force in November 2014 and comprised the European Central Bank and national supervisory authorities of the European countries participating in this framework. The framework is designed to ensure cooperation among the different European countries regarding the supervision of the banking system. Under the SSM framework, several banks are under control using the Basel III principles. It comprises 115 significant institutions (SIs) directly supervised by the ECB, all selected based on their size.[5] We retrieve the list of all the significant institutions included in this framework from the ECB-SSM website, as of 2020.

We collect annual consolidated financial statements and supervisory data from BankFocus for the period 2015 to 2020, for all banks and bank holding companies established in all the European countries concerned by the SSM framework.[6] We then merge the list of the banking institutions available from BankFocus with the list of the SIs retrieved from the ECB-SSM website. We restrict the sample to commercial banks only and further discard all banks that do not have the available information for total assets all over the period. Applying these filters leave us with a sample of 65 so-called SIs commercial banks.[7] Table 3.1 presents the distribution of banks by country and the representativeness of the SIs included in our sample. In column (3), we compare aggregate total assets of banks identified as SI with the aggregate total assets of the whole banking system as covered by Bankfocus. Over the period 2015-2020, the so-called Sis represent on average over 20% in their respective country. This indicates that the SSM framework has focused on the largest banks in each country.

[5] The minimum total assets for banks considered as Significant Institutions is 30 billions euros.

[6] Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovenia, and Spain.

[7] Some banks were left out because they are not covered by BankFocus.

Table 3.1 – Distribution of banks and representativeness of the final sample

Country	(1) Total banks available in BankFocus	(2) SSM Significant institutions available in BankFocus	(3) Total assets of SI/total assets of the banking system (%)	(4) Final sample	(5) Total assets of banks in final sample/total assets of SI (%)
Austria	50	1	7.24	1	100
Belgium	33	7	16.68	2	62.52
Cyprus	28	3	31.26	2	88.82
Finland	24	1	30.71		
France	90	8	23.12	5	83.12
Germany	49	7	13.79	4	85.54
Greece	11	3	33.51	3	100
Ireland	12	3	22.68	1	31.29
Italy	81	8	19.65	7	98.99
Luxembourg	47	2	10.05	1	64.19
Malta	8	2	60.97	2	100
Netherlands	19	4	24.53	2	78.91
Portugal	22	4	26.88	4	100
Slovenia	8	1	16.56	1	100
Spain	37	11	18.91	6	84.78
Total	519	65	24.1	41	88.68

To ensure that our dataset is suitable to carry out a VAR analysis, we discard banks that do not have the available information on NSFR, LCR and the regulatory capital ratio subsequently over the period 2015-2020.[8] To minimize the effect of outliers, we remove banks by eliminating extreme observations (5% lowest and highest values) for each variable of interest. Applying this filter leaves us with a balanced panel sample of 41 banks over 2015-2020. Column (4) of Table 3.1 presents the distribution of the banks included in our final sample, and column (5) compare the aggregate total assets of the banks included in our final sample to the initial sample of SIs. The final sample represents more than 88% of the total assets of the initial sample of SIs. Table 3.2 presents some general descriptive statistics of key balance sheets and income statement items for the final sample and the initial sample of SIs. The statistics of these two samples are very similar. On average, loans and deposits represent more than 50% of total assets. In term of

[8] Obtaining a balanced sample is a requirement for the empirical method.

capitalization, the average equity to total assets is around 8%. In term of performance, the income accruing from interest bearing activities represent more that 40% of the average bank total income, and the average return on assets in the sample reaches 0.3%.

Table 3.2 – Summary statistics on selected accounting and income information for the initial and final sample

	Total assets (in billions euros)	Total loans/total assets	Total deposits /Total assets	Equity /Total assets	Return on assets	interest income /Total income	loan loss provisions /Total loans
Panel A. Initial sample of SIs							
mean	228.554	51.778	57.621	8.201	0.291	43.700	0.591
std. Dev	322.811	21.021	20.961	3.557	0.802	11.682	0.739
min	37.037	6.886	5.773	1.016	-3.776	4.202	-2.728
median	66.139	55.619	62.342	7.108	0.404	45.040	0.356
max	975.314	85.881	85.678	17.279	1.857	63.772	1.887
Panel B. Final sample							
mean	236.316	53.438	59.486	8.941	0.223	45.639	0.630
std. Dev	329.813	14.616	17.723	3.185	0.886	6.818	0.664
min	37.037	6.886	5.773	1.016	-3.776	4.202	-2.728
median	71.574	56.478	62.825	6.891	0.362	45.334	0.457
max	975.314	85.881	85.678	17.279	3.854	63.773	1.828

Note: This table compares the descriptive statistics of balance sheet and income items in our sample and in the raw sample of SIs. All variables are expressed in percentage, except Total assets. Total assets in billion euros; Total loans/total assets: (commercial loans + consumer loans + other loans)/total assets; Total deposits/total assets: (demand deposits + saving deposits + time deposits + other time deposits)/total assets; Loan loss provisions/total loans: loan loss provisions/(commercial loans + consumer loans + other loans); Equity/total assets: total equity/total assets; ROA: net income/total assets; Total interest income/total income: (interest income from loans + resale agreements + interbank investments + other interest income or losses)/total income.

We now focus on our final sample, and specifically on our variables of interest. Table 3.3 shows the distribution of the banks in our final sample based on whether they hold a buffer on liquidity and capital. Almost all banks in our sample meet the minimum capital requirement, LCR, and NSFR, over the period under study. In 2015 and 2016, some banks were not fully compliant with the LCR (4 banks) and NSFR (2 banks) rules, but this should not affect the results. The data suggest that the banks in our sample are cautious. Indeed, the statistics presented in Table 3.4 indicate that the average buffer for capital is 11.05 percentage points, 112.39 for the LCR, and 31.68 for NSFR. 80% of banks have a capital buffer between 5 to 18 percentage points, which is high above the requirement, enabling them to cope with any additional provision on capital. Also, 65% of the banks in our sample have a buffer of 25 to 148 percentage points for LCR; 90% have a pad of 51 percentage points or less for NSFR. In addition, the distribution of the buffer on capital and NSFR appears to be less dispersed than LCR, as shown by the value of the standard deviation and the difference between the mean and the median.

Table 3.3 – Number of banks in the sample with positive buffers

	KGap	LCRGap	NSFRGap
2015	41	37	39
2016	41	37	39
2017	41	41	41
2018	41	41	41
2019	41	41	41
2020	41	41	41

Notes: This table reports, per year, the number of banks in the sample for which the value of KGap, LCRGap and NSFRGap is positive or null.

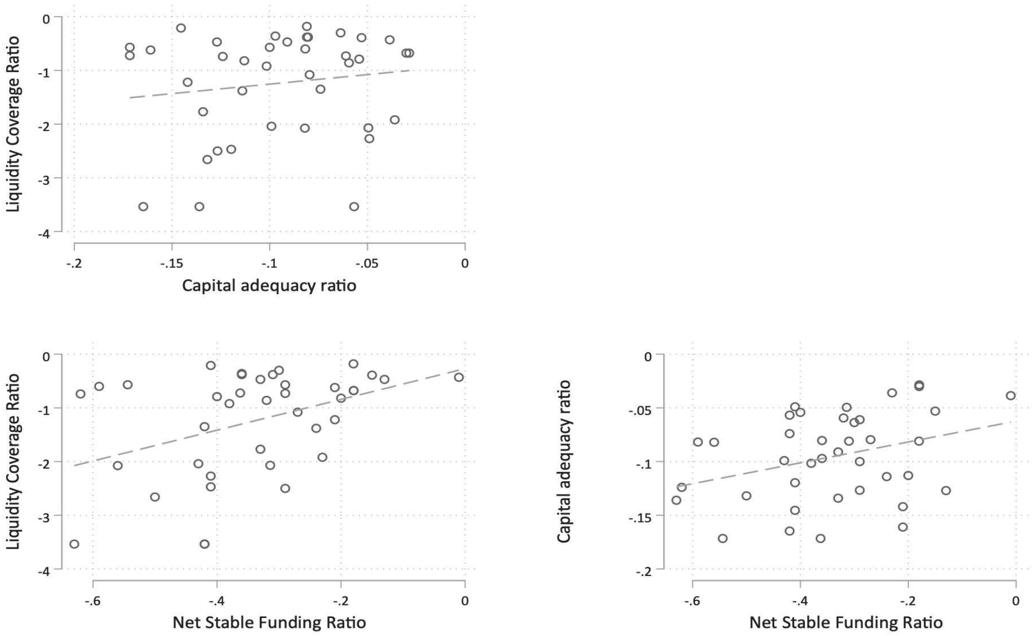
Table 3.4 – Summary statistics of regulatory ratios buffers

Variables	mean	std. dev.	Min.	p10	q25	median	q75	p90	max.	HT
Kgap	11.05	4.54	0.24	5.19	7.40	11.01	14.10	18.30	19.66	0.893***
LCRGap	112.39	100.68	-2.90	25.00	42.00	75.00	148.00	308.00	353.70	0.791***
NSFRGap	31.68	15.74	-17.00	12.00	21.00	31.00	42.00	51.00	69.50	0.779***

Notes: This table reports summary statistics of the outcome variables and the results of the Harris-Tzavalis unit root test.

In Figure 3.1, we plot the capital and liquidity buffers against each other for the year 2019. It shows a positive correlation between all the variables, suggesting that the rules interact with each other. However, the significant dispersion of the points indicates that a potential relationship between the different requirements is not systematic.

Figure 3.1 – NSFR, LCR and Capital ratio in 2009



Notes: The figure plots the distance to compliance for NFR, LCR and CAR against each other.

3.3.3. Specification tests

One of the main concerns when performing time series analysis is the stationarity of the variables (Baltagi et al. 2007), to guarantee the stability of the estimation. We, therefore, check the stationarity of our variables. We perform the Harris Tavarlis unit root test. Given the limited period (6 years), this test is appropriate. It also allows for different fixed effects in the intercepts, accounting for the heterogeneity among the individuals. The results of the test are presented in the last column of Table 3.4 and indicate that all the variables included in the system are stationary in levels, at the 5% level of significance, and thus guarantee that we can run a VAR model.

We also compute several tests for the selection and the validity of the panel VAR, including the optimal lag selection and the panel VAR stability test. Results in Table 3.5 are supportive of the choice of first-order panel VAR (one lag). VAR analysis is based on the choice of the optimal lag order in the VAR specification and the moment condition. Based on Hansen's (1982) J-statistic of overidentifying restrictions, Andrews and Lu (2001) proposed consistent moment and model selection criteria (MMSC) for GMM models. The selection of the optimal lag is based on MBIC, MAIC and MQIC; the optimal lag being the one with the smallest value for two of these statistics. The results from the test suggest that the model using the first order generates the smallest value for model selection criteria. Therefore, we will consider the first-order model.

The last two rows of Table 3.6 provide the statistics regarding the validity of the model and its stability. The reported Hansen J-statistic is 18.928, showing that we cannot reject the null hypothesis. This result suggests that our model satisfies the overidentification requirement. The reported maximum modulus (0.703) is less than one, which fulfills the stability condition that all the moduli should be less than the unity (Enders, 2015).[9]

Table 3.5 – Lag order selection statistics.

lags	CD	J	J Pvalue	MBIC	MAIC	MQIC
1	0.972	22.415	0.716	- 76.500*	-31.584*	-47.699*
2	0.983	19.027	0.390	- 46.917	-16.972	-27.716
3	0.987	4.825	0.849	-28.147	-13.175	-18.547

Notes: This table presents the results of the MMSC for the PVAR model. Each row corresponding to a lag (1-3) reports the CD (Coefficient of Determination), Hansen J-Statistics, and p-values. MBIC, MAIC and MQIC show the results under different selection criteria. * Indicates the best selection.

3.4. Results

This section presents the results of the estimation of equation (3.1). Table 3.6 presents the estimated coefficients of the PVAR model. All the variables are positively associated with their previous occurrence, suggesting that dynamic effects play an essential role. We can also observe that each variable is explained by the other two, indicating interdependence.

[9] Stability suggests that the PVAR model is time-invariant and that the dynamic processes do not explode.

Table 3.6 – Vector autoregression estimation results.

	(1)	(2)	(3)
	KGap	LCRGap	NSFRGap
KGap₋1	0.592***	5.144**	0.885***
	(0.065)	(1.984)	(0.276)
LCRGap₋1	0.001	0.315***	0.017*
	(0.002)	(0.071)	(0.009)
NSFRGap₋1	0.022	-0.244	0.547***
	(0.015)	(0.494)	(0.068)
Hansen J-stat			18.928
Maximum moduli			0.703

Notes: This table presents the regression results of PVAR model in equation (1). The model is based on the first-order model (p = 1). **, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Hansen J-statistic reports the over-identification test results. Maximum modulus reports the model stability test results, with a value below one indicating stability.

The coefficients associated with LCRGap and NSFRGap in the equation of KGap are positive but non-significant. This suggests that liquidity buffers do not affect the capital buffer. In the equation of NSFRGap, the coefficient associated with the KGap is positive and significant at the 1% level while the coefficient of LCR is positive and significant at the 10% level. This indicates that LCR buffer and capital buffer are positively associated with NSFR buffer. This means that when a bank increases its LCR or regulatory capital ratio, its NSFR would also increase. In the equation of LCR, only KGap shows a significant coefficient, suggesting that capital buffer and LCR buffer are positively associated.

To evaluate the other variables joint explanatory power in each variable's dynamic, we use the Granger causality test. The null hypothesis of this test is that the coefficients of all the lags of a given variable are jointly equal to zero. Acceptance of the null hypothesis indicates the absence of Granger causality. Table 3.7 presents the results of the test. The results indicate that KGap is not Granger caused by either NSFRGap or LCRGap. NSFRGap is Granger caused by KGap and LCRGap. And LCRGap is Granger caused by KGap. The last row of the table reports the results by testing whether each variable is Granger caused by all the other jointly. The results indicate that, except KGap, neither LCRGap nor NSFRGap is independently determined. This means that an increase in the capital buffer would positively affect the liquidity buffers. In contrast, an increase in liquidity buffers does not significantly determine whether a bank's capital buffer increases (or decreases).

Table 3.7 – Granger causality matrix.

	(1) KGap	(2) LCRGap	(3) NSFRGap
KGap	0.589	4.044**	4.629**
LCRGap	0.283	-	5.182*
NSFRGap	0.001	0.032	-
All variables	0.357	4.990	10.820**

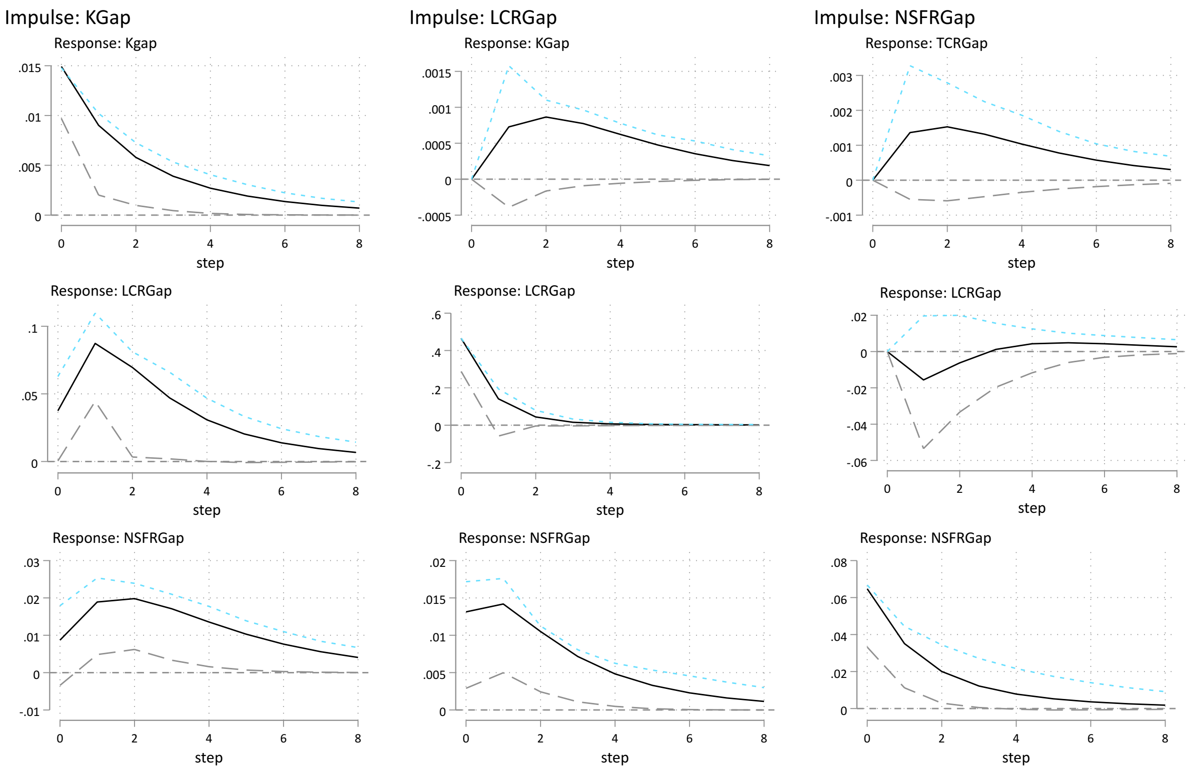
Notes: This table presents the Granger causality matrix. Each cell shows whether the column variable is Granger caused by the row variable. The last row presents a joint test of whether the column variable is Granger caused by all the row variables. Each cell reports the Chi- square statistics. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

To further analyze the relationship between the different buffers, we use the Orthogonalized Impulse Response functions (OIRFs) to measure how an orthogonal shock to one of the variables affects the others. The OIRFs are constructed based on the estimated coefficient of the model. OIRFs describes how an average individual absorbs a one-standard-deviation of a positive shock to one of the variables in the system and how it affects the others, and whether and how long it takes to revert to the previous situation. Figure 3.2 shows how an average bank absorbs one standard-standard deviation of one of the variables (shock) and how it affects the others. In the specific context of our investigation, we are interested in assessing how a deviation of a bank position concerning the required ratio on capital affects its position on LCR and NSFR and whether the potential impact is persistent.[10] In other words, how would a bank's liquidity buffers react if its capital buffer changes? Figure 3.2 shows that NSFRGap and LCRGap respond positively and significantly to an increase (decrease) of KGap. An increase of LCRGap leads to a positive and persistent response in NSFRGap. However, a positive shock to NSFR does not significantly affect

[10] The effect is persistent if the impact is significant (confidence interval does not include 0) and conserves its significance over a long period. And it means that a structural change occurs as the variable moves from a given position to another position. If the effect is not persistent, then the variable will revert to its initial position.

KGap and LCRGap. This means that when the difference between a bank's CAR and the regulatory threshold improves (deteriorates), the difference between its NSFR (respectively LCR) and the regulatory threshold also improves (deteriorates). For instance, figure 2 shows that, on average, a standard deviation increase (decrease) of CAR will lead to an increase (decrease) of around 1% of the difference between the NSFR buffer and of about 4% for the LCR buffer. The positive effect conserves its significance over a long period, which indicates a permanent change.[11]

Figure 3.2 – Impulse response functions.



Notes: This figure illustrates the impulse responses to a one-standard deviation of shock to either KGap, NSFRGap and LCRGap. The dot lines denote the 95% confidence interval calculated by 2000 Monte Carlo draws from the PVAR Model estimated in equation (1). The X-axis shows the steps of the forecast horizons in years, and the Y-axis shows the magnitude of the response. The doted lines are the 95% confidence bands.

[11] The terms "shocks" and "steady-state" comes from the macroeconomics literature. The steady-state can be interpreted as the equilibrium level desired by the bank. Thus, a permanent change means a new equilibrium in which a bank NSFR, LCR or CAR has changed and is different from the level the bank would prefer.

Overall, our results suggest that although banks jointly manage capital and liquidity, they prioritize capital over liquidity. We also find that introducing liquidity rules alongside the existing capital rules does not incentivize a bank to substitute capital buffer for liquidity buffers. On the contrary, they remain cautious in managing the liquidity position and are willing to simultaneously hold a comfortable level of capital and liquidity buffers. This finding falls in line with the view that well-capitalized banks should be able to maintain a high level of liquidity to shield themselves against liquidity shocks (Gomez and Vo 2020, Borio et al 2020).

3.5. Robustness check

In this section, we check the robustness of our results against changing the recursive order of the variables, the introduction of other variables identified in the literature as crucial factors that could influence a bank's capital and/or liquidity and, changing the definition of some variables. Our main results hold, suggesting that our findings are not limited to our base model as a particular setting.

First, we change the recursive order of the variables to see whether our results hold. The recursive order of employed variables is essential because it identifies the transmission of shocks within the firm and changing it may lead to different results in the OIRF analyses (Bernanke, 1986). Therefore, we check whether our results are sensitive to the change of the recursive order by using some random orderings. In our initial setup, we consider this order: KGap, LCRGap, and NSFRGap. We initially follow this order because rules on capital have been in place long before those on liquidity. Priority has been given to LCR over NSFR in practice by the regulators. Alternatively, we consider different ordering. First, we place the variable related to capital (KGap) in the last row of the system and consider the liquidity-related measures first, which correspond to the vector (LCRGap, NSFRGap, KGap). Second, we change LCRGap and KGap, corresponding to the vector (LCRGap, KGap, NSFRGap). The OIRFs associated with these changes are presented in Panel 1 of Figures 3.3. The results show that these changes do not make a qualitative difference to the impulse response functions.

Secondly, we extend the vector to other variables identified as factors that might affect a bank's capital and liquidity. This includes bank size as measured by the logarithm of total assets (SIZE), risk as measure by the ratio of loans loss reserves to total loans (LLR), funding structure as measured by the ratio of subordinated debts to total debts (FUND), and dividend payout ratio measured as the ratio of total common dividends to the difference between net income and minority interests plus preferred dividends (DIV). The impulse response functions (Panel 2 of Figure 3.3) associated with our variables of interest (KGap, LCRGap, and NSFRGap) remain qualitatively similar to those in our initial setup.

Finally, we modify the definition of KGap. We use a threshold of 10% instead of 8% for the minimum required capital ratio. We consider this additional layer to 2% to account for Pillar 2. Pillar 2 under Basel III is designed to ensure that risks not fully covered under Pillar 1 (total capital ratio) are accounted for in the entire capital requirement. Banks are required to have in place the internal capital adequacy assessment process (ICAAP) that involves the use of elaborate internal models and stress tests to quantify all the risks the bank bears and estimate the amount of capital appropriate to that risk profile. Using this evaluation, the regulator can require additional capital. This capital add-on is specific to each bank. However, given that we do not have the particular information for each bank, we consider a maximum additional layer of 2%. The results (Panel 3 of Figure 3.3) are similar to those obtained using a threshold of 8%.

Figure 3.3 – Robustness: Impulse response functions

Panel 1. Alternative ordering of the variables

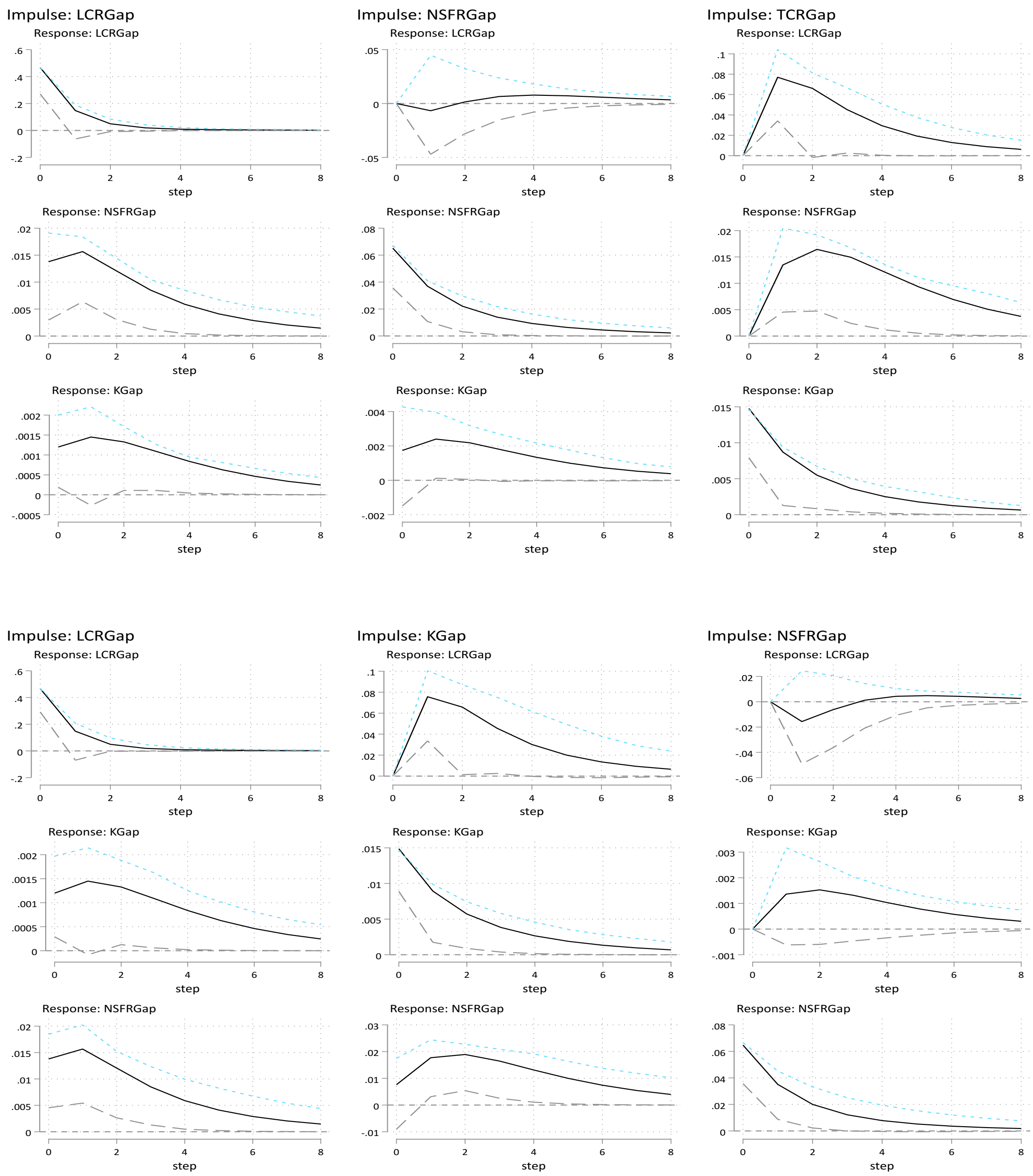
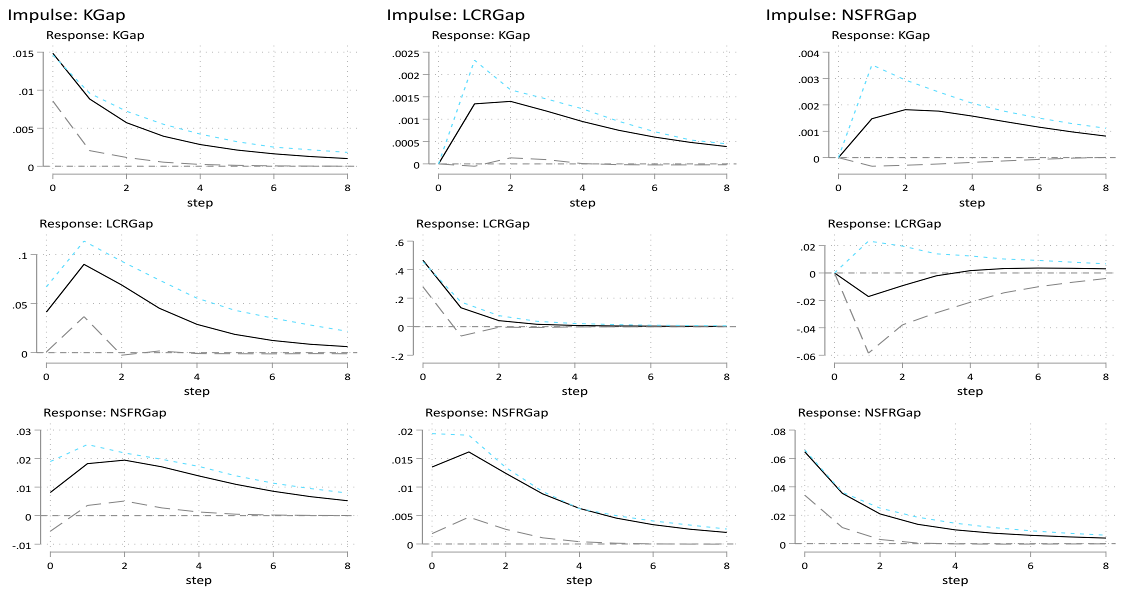
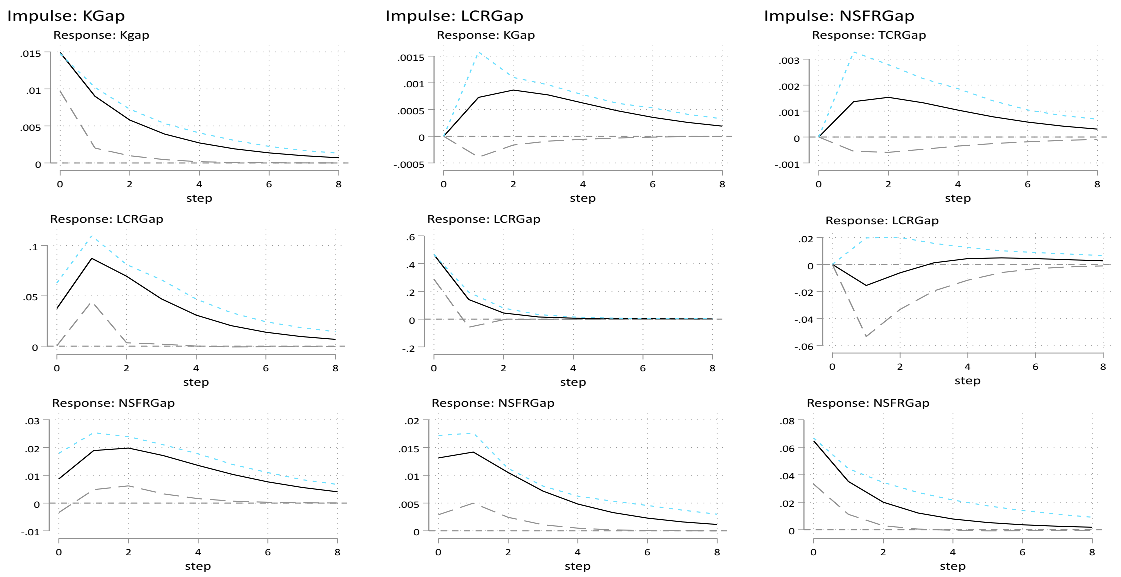


Figure 3.3 – Robustness: Impulse response functions (continued)

Panel 2. Extension of the vector of variables



Panel 3. Change to the definition of KGap



Notes: This figure presents the sensitivity of the impulse responses to change in the recursive ordering of the variables (Panel 1), to extension of the VAR system to other variables (Panel 2) and change to the definition of KGap, using a threshold of 10%. The dot lines denote the 95% confidence interval calculated by 2000 Monte Carlo draws from the PVAR Model estimated in equation (1). The X-axis shows the steps of the forecast horizons in years, and the Y-axis shows the magnitude of the response.

To show how the VAR model performs and constitute a suitable approach to analyzing the relationship between a bank's capital and liquidity, we compare the estimations of the VAR model to different specifications. First, we regress each variable of the system on its own lags in a single equation setting and then compare the coefficients with those from the VAR model. We use one-year lagged variables because our VAR model is based a first-order model. The results of the estimation are presented in column 1 of Table 3.8. Secondly, we regress each variable on its own lag and the other variables' lagged values in a single equation setting. The results of the estimation are presented in column 2 of Table 3.8. Columns 3 and 4 report and test the difference between the estimates of the VAR model and the single equations. In the estimation of the single equations, we control for bank and year-fixed effects so that the results are comparable with those from the VAR model. The results show that there is a statistically significant difference between the estimates from the VAR model and the three single equations. Single equation models suggest that their past realization explains each variable's dynamic, and that capital does not significantly affect the liquidity-related variables. Except in the equation of LCRGap, almost all the coefficients in the single equation model appear to be overestimated when we consider only the past realization as independent variables but underestimate when we include the lagged value of the other variables. This suggests that a single equation model without controlling the other variables as a system generates biased estimates.

Table 3.8 – Testing VAR model against single equations.

		(1)	(2)	(3)	(4)	(5)
Dependent variables	independent variables	Single equation with own lag	Single equation with own lag and other variables lag	VAR model	(1) - (3)	(2) - (3)
KGap	KGap	0.626***	0.573***	0.592***	0.034	-0.019**
		(0.057)	(0.064)	(0.065)	(0.044)	(0.007)
	LCRGap		0.001	0.001		0.000
			(0.002)	(0.002)		(0.000)
	NSFRGap		0.013	0.022		-0.009***
			(0.016)	(0.015)		(0.002)
LCRGap	KGap		3.744*	5.144**		-1.389**
			(2.051)	(1.984)		(0.469)
	LCRGap	0.341***	0.337***	0.315***	0.026**	0.022**
		(0.067)	(0.069)	(0.071)	(0.009)	(0.008)
	NSFRGap		-0.461	-0.244		-0.217***
			(0.494)	(0.494)		(0.055)
NSFRGap	KGap		0.392	0.885***		-0.493***
			(0.260)	(0.276)		(0.135)
	LCRGap		0.015*	0.017*		-0.002
			(0.008)	(0.009)		(0.003)
	NSFRGap	0.649***	0.454***	0.547***	0.102***	-0.093***
		(0.067)	(0.062)	(0.068)	(0.029)	(0.025)

Notes: This table presents the results of testing the estimates of the VAR model against single equations. Column (1) presents the results by using single equations with own lags as the only explanatory variables. Column (2) includes the lags of the other variables. To estimate the coefficient reported in columns (1) and (2), we include bank and year fixed effects. Column (3) reports the same results as in Table 3.5. Columns (4) – (5) display and test the difference in the estimates from single equation models and those in the VAR model. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.6. Conclusion

This study investigates the interaction of bank regulatory capital and bank regulatory liquidity under Basel III rules. Building on previous studies that indicate that capital and liquidity might be jointly determined, we apply a panel VAR approach consider to a sample of (large) European commercial banks, part of the Single Supervisory Mechanism (SSM) initiated by the European Central Bank and constrained by Basel III rules. Specifically, we question whether hold less or more capital buffers when they build their liquidity buffers.

The results confirm that capital and liquidity requirements are strongly related. To further analyze the relationship, we use the Orthogonalized Impulse Response functions (OIRFs) to measure how an orthogonal shock to one of the variables affects the others. We perform additional tests that show that our results are robust and that the VAR model captures the relationship between a bank's capital and liquidity. Our results show that banks increase their regulatory liquidity buffers when they increase their regulatory capital buffer. In contrast, an increase in liquidity buffers does not affect the capital buffer. Overall, the results suggest that the introduction of liquidity rules, alongside those on capital, does not incentivize banks to build a liquidity cushion at the expense of their capital cushion

Our findings are relevant for researchers and regulators. Future studies might consider using a system of equations to account for the relationship between bank capital and liquidity. Our results support the view that banks are cautious about their level of capital and would probably ensure that they hold enough liquidity and capital all the time to guarantee their resilience against shocks.

However, the study is limited in some ways: first, we only consider relatively large banks in Europe, which might raise concerns about whether the findings are consistent with small banks. Second, we focus on commercial banks only. Finally, according to theory, our study did not differentiate banks based on their business model, which might influence banks' adjustment process.

General Conclusion

Since the outbreak of the global financial crisis in 2007, the regulation and supervision of banks have intensified. The crisis revealed weak points in the previous regulation framework of banks. The losses, which banks were not able to absorb, resulted « in a massive contraction of liquidity and credit availability » (BCBS, 2011), requiring the intervention of central banks and governments across the world to support the financial system with liquidity, capital, and guarantees (BCBS, 2011). As a consequence of this financial turmoil, the Basel Committee on Banking Supervision (BCBS) revised the regulatory framework to strengthen the global financial system and reduce future spillovers to the real economy (BCBS, 2011). The revised Basel III framework required banks to hold more capital and introduced two new liquidity standards.

Although the literature on the impact of financial regulation, especially regarding liquidity, on bank behavior is growing, it is still relatively new. Most of the contribution so far is theoretical or political, leaving several questions unanswered. This thesis aims to support theory by providing empirical evidence regarding the impact of liquidity regulation on bank behavior. It seeks to assess whether the implementation of liquidity regulations helps achieve its purpose (i.e., reduce excessive risk-taking by banks) and affects banks' contribution to the real economy.

In the first chapter, we investigate the impact of bank liquidity regulation on bank lending behavior. To achieve this, we use the introduction of a liquidity regulation in the Netherlands, known as the Liquidity Balance Rule (LBR), as a setting and analyze the effect of the introduction on bank lending at both an aggregated and disaggregated level, including an analysis of loan type and maturity. In addition, we look into how banks' balance sheets evolved broadly following the introduction of liquidity requirements. Our aim in this chapter was to assess the impact on bank lending and to test some of the hypotheses put forward by theory to explain why the introduction of liquidity requirements would affect lending.

Using a difference-in-differences approach and propensity score matching techniques to form an appropriate control group of banks to act as a benchmark for our treated banks, our study shows that the imposition of stricter liquidity requirements is not detrimental for bank lending. Our findings highlight that banks rely on diverse strategies to comply with the Basel III Liquidity Coverage Ratio. They can increase liquidity by altering balance sheet size or modifying the composition of assets and liabilities. We also find evidence suggesting that the introduction of liquidity requirements could contribute to higher depositor confidence, resulting in the growth of bank funding, which is essential for bank lending.

In the second chapter, we examine the effect of the introduction of liquidity regulation on bank risk-taking behavior using, as a setting, the introduction of the Liquidity Balance Rule (LBR) implemented in the Netherlands in 2003. The results of the difference-in-differences setting suggest that following the introduction of the LBR, Dutch banks became less risky. Going beyond, we find that their profitability was also negatively impacted. The impact is, however, short-lived as it faded over few years. We also find that the introduction of the LBR led Dutch banks to change their funding structure by increasing capital and deposits. They benefited from a favorable financing condition (decrease in the cost of funding following the introduction of the LBR possibly). These results fall in line with the view that impact of liquidity regulations on bank risk taking behavior is crucial depending on whether banks face higher financing conditions than the return on (liquid) assets.

The third chapter is motivated by the need to understand how bank capital and liquidity interact when both are regulated. It takes from previous studies indicating that liquidity and capital are jointly determined and uses a vector autoregression model, applied to a sample of large European banks regulated under Basel III, to investigate whether the presence of liquidity regulation incentives banks to hold less or more capital buffers. The presented results suggest that banks increase their regulatory liquidity buffers when they increase their regulatory capital buffer. In contrast, an increase in liquidity buffers does not affect the capital buffer. Overall, our results suggest that the introduction of liquidity rules, alongside those on capital, does not incentivize banks to build a liquidity cushion at the expense of their capital cushion.

All in all, the findings of this dissertation complement the existing literature on the impact of the implementation of liquidity requirements on banks. First, the results highlight that the post-crisis regulations may not be detrimental for bank lending activities and the real economy, as many commentators and bank lobbyists have argued. This is because banks have a myriad of ways to cope with the regulation. They could mix different strategies, which affect their balance sheet and lending behavior is yet to be documented theoretically. Most importantly, the regulation could also improve the confidence in the banking system; an aspect neglected in analysis discussing the impact of the reformed regulation for banks. Second, the results presented in this dissertation do not support the view that the introduction of liquidity requirements could be counterproductive by encouraging banks to take on more risk to avoid the negative impact of such rules on bank profitability. Our results thus provide evidence supporting the view that liquidity requirements would improve the soundness and safety of banks and would not negatively affect their contribution to the real economy. However, because the introduction of the LBR has led to a decline in bank profitability, bank stability could be a concern. Although there are no clear indications to suggest that banks would neglect their capital in the presence of liquidity requirements, bank managers and supervisors should be cautious about banks' solvency levels.

The literature on the impact of financial regulation, especially regarding liquidity, on bank behavior, is still at its early stages. While this dissertation provides some answers to some empirical questions, there is broad scope for further work. The analysis in chapter 1 and 2 do not distinguish between banks for which the rule is binding and those for which the rule is not (or less) binding. With banks now reporting the required liquidity ratios, the gradual implementation of the Liquidity Coverage Ratio offers some quasi-experiments that could help better understand the impact of the liquidity requirements on banks' lending and risk-taking. Another critical area for further research would be to account for differences in banks' business models. Researchers and observers argue that the regulatory framework, as it stands, requires all banks to comply with the same requirements without considering if a bank pursues a low or high-risk business strategy.

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Appendix

Appendix A1.1 – Impact of LBR on loan maturity

Variables	MAT > 5 years (1)	MAT 1-5 years (2)	MAT 3-12 months (3)	MAT < 3 months (4)
Affected × Post Event	-0.010***	-0.005***	-0.001***	0.011***
	(0.000)	(0.001)	(0.000)	(0.000)
SIZE	0.013	0.006	0.008	0.017
	(0.014)	(0.014)	(0.014)	(0.023)
DEPOSITS	0.028**	0.021**	0.019	0.001*
	(0.012)	(0.012)	(0.031)	(0.001)
LIQ	-0.017	-0.102	-0.028	-0.011
	(0.045)	(0.245)	(0.043)	(0.034)
EQUITY	0.003**	0.000**	0.001**	0.007**
	(0.000)	(0.000)	(0.000)	(0.000)
LLR	-0.003	-0.015	-0.013	-0.008**
	(0.051)	(0.073)	(0.061)	(0.001)
GROWTH	0.001**	0.007**	0.004*	0.012
	(0.000)	(0.000)	(0.000)	(0.000)
INFLATION	0.002	0.021	0.003**	0.004**
	(0.039)	(0.061)	(0.001)	(0.001)
Year fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Observations	202	202	202	202
R-squared	0.943	0.932	0.936	0.945

Notes: The table analyses the impact of the introduction of the LBR on loans by maturity. The sample consists of 12 banks from the Netherlands and 21 matched banks over the 2000-2006 period. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets, loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. Affected is a dummy variable equal to one for banks affected by the LBR (Dutch banks) and zero otherwise. Post Event is a dummy variable that takes the value of one for the years 2003 onwards, and zero otherwise. Columns (1) reports the results for loans with a maturity higher than 5 years, while column (2) shows the results for loans with a maturity between 1 to 5 years. Columns (3) and (4) report the results for loans with a maturity between 3 to 12 months and less than 3 months, respectively. All outcome variables are normalized by total assets. The effect of LBR is captured by the coefficient on the interaction term Affected × Post Event. Standard errors are clustered at the bank level and presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A1.2 – Impact of LBR on loan categories

Variables	Panel A : lnLOAN			Panel B : LOANFW			Panel C : RATLOAN		
	MORT	RETL	CORP	MORT	RETL	CORP	MORT	RETL	CORP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Affected × Post Event	0.008**	0.018*	0.167**	-0.002**	0.005***	0.029**	-0.001***	0.001	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)	(0.000)
SIZE	0.033***	0.071***	0.793***	0.002	0.005	0.0324	0.003	0.003**	-0.007*
	(0.012)	(0.020)	(0.211)	(0.003)	(0.004)	(0.039)	(0.005)	(0.005)	(0.048)
DEPOSITS	0.023**	0.041**	0.049**	0.007**	0.009**	0.117**	0.007**	0.007*	0.034**
	(0.009)	(0.014)	(0.024)	(0.003)	(0.004)	(0.021)	(0.003)	(0.007)	(0.025)
LIQ	0.005	0.016	0.094	0.002**	0.006**	0.042**	-0.0124	-0.0124	-0.053*
	(0.084)	(0.018)	(0.134)	(0.001)	(0.002)	(0.008)	(0.032)	(0.032)	(0.034)
EQUITY	0.012	0.034	0.234	0.006*	0.008*	0.063*	0.002**	0.002*	0.013
	(0.017)	(0.098)	(0.344)	(0.004)	(0.004)	(.0394)	(0.000)	(0.000)	(.016)
LLR	-0.002	-0.004	-0.413	-0.003	-0.003	-0.038	-0.002	-0.002	-0.026
	(0.009)	(0.004)	(0.842)	(0.021)	(0.021)	(0.236)	(0.004)	(0.004)	(0.051)
GROWTH	0.002**	0.005**	0.042**	0.003**	0.004**	0.043**	0.002**	0.002*	0.006*
	(0.000)	(0.001)	(0.021)	(0.001)	(0.001)	(.012)	(0.000)	(0.000)	(0.006)
INFLATION	-0.001	-0.003	-0.015	0.001	0.001	0.004	0.003	0.003	0.015**
	(0.004)	(0.006)	(0.031)	(0.000)	(0.000)	(0.005)	(0.004)	(0.004)	(0.005)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	471	471	471	471	471	471	471	471	471
R-squared	0.772	0.706	0.663	0.598	0.658	0.523	0.663	0.746	0.802

Notes: This table analyses the impact of the introduction of the Liquidity Balance Rule on the main components of loans portfolio (mortgage, retail and corporate). The sample consists of 22 Dutch banks and 63 Eurozone banks selected via propensity score matching over the 2000-2006 period. In Panel A, the outcome variable is the volume of loans classified either into mortgage, retail, or corporate loans category. The outcome variables considered in Panel B, are the flows of loan again disaggregated into three categories. Panel C presents results when the outcome variable is one of the three loan categories normalized by total assets. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. The effect of LBR is captured by the coefficient on the interaction term *Affected × Post Event*. Standard errors are clustered at the bank level and presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A1.3 – Impact of LBR on bank lending: robustness check and sensitivity tests

Variables	Matching with one neighbor	Matching with five neighbors	Additional matching variables	Matching with Benelux countries only	Matching with Belgium only	Year of LBR introduction omitted	Placebo test
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A : Total loans (in log) lnLOAN							
AffectedxPostEvent	0.167**	0.156**	0.148***	0.153**	0.136*	0.196**	-0.087
	(0.061)	(0.059)	(0.058)	(0.056)	(0.081)	(0.079)	(0.092)
SIZE	0.785***	0.871***	0.978***	0.610***	0.587**	1.018***	.118**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.012)	(0.021)	(0.054)
DEPOSITS	0.013**	0.053**	0.013**	0.037**	0.032**	0.0631**	0.018**
	(0.008)	(0.024)	(0.008)	(0.014)	(0.008)	(0.024)	(0.014)
LIQ	0.071	0.021	0.121	0.015	0.011	0.121	0.344**
	(0.084)	(0.039)	(0.183)	(0.039)	(0.039)	(0.189)	(0.183)
EQUITY	0.245	0.272	0.298	0.1904	0.198	0.298	0.082
	(0.344)	(1.344)	(1.344)	(1.184)	(1.012)	(1.344)	(0.123)
LLR	-0.091	-0.144*	-0.04	-0.101**	-0.087*	-0.04	-0.011
	(0.143)	(0.098)	(0.098)	(0.064)	(0.076)	(0.098)	(0.009)
GROWTH	0.005**	0.000**	0.055**	0.000**	0.05**	0.055**	0.002**
	(0.002)	(0.000)	(0.021)	(0.000)	(0.001)	(0.021)	(0.000)
INFLATION	-0.073	-0.123	-0.023	-0.123	-0.003	-0.023	0.000
	(0.091)	(0.139)	(0.039)	(0.139)	(0.039)	(0.039)	(0.000)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204	531	373	236	93	471	403
R-squared	0.943	0.93	0.961	0.974	0.942	0.968	0.954
Panel B : Loans flow (LOANSFW)							
AffectedxPostEvent	0.011**	0.027***	0.024**	0.011**	0.019**	0.021***	0.061
	(0.004)	(0.009)	(0.009)	(0.004)	(0.006)	(0.008)	(0.077)
SIZE	0.015	0.027	0.027	0.027	0.022	0.027	0.053**
	(0.024)	(0.039)	(0.039)	(0.039)	(0.029)	(0.039)	(0.039)
DEPOSITS	0.043**	0.090**	0.089**	0.090**	0.074**	0.089**	0.120*
	(0.012)	(0.051)	(0.032)	(0.048)	(0.041)	(0.032)	(0.095)
LIQ	0.009**	0.022**	0.032**	0.022**	0.019**	0.032**	0.122**
	(0.007)	(0.008)	(0.018)	(0.011)	(0.008)	(0.018)	(0.053)
EQUITY	0.034*	0.065*	0.075*	0.055**	0.062**	0.075*	0.025
	(0.034)	(0.039)	(0.039)	(0.029)	(0.045)	(0.039)	(0.039)
LLR	-0.038	-0.018	-0.024	-0.037	-0.032	-0.024	0.019
	(0.218)	(0.111)	(0.218)	(0.211)	(0.157)	(0.218)	(0.019)
GROWTH	0.013**	0.034**	0.004**	0.024**	0.019*	0.004**	0.004**
	(0.007)	(0.012)	(0.002)	(0.012)	(0.012)	(0.002)	(0.002)
INFLATION	-0.001	-0.004	-0.003	-0.001	-0.004	-0.003	0.000
	(0.005)	(0.005)	(0.005)	(0.003)	(0.005)	(0.005)	(0.001)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204	531	373	236	93	471	403
R-squared	0.67	0.432	0.469	0.506	0.534	0.554	0.612

Appendix A1.3 – Impact of LBR on bank lending: robustness check and sensitivity tests (continued)

Panel C: ratio of loans to total assets (RATLOANS)							
AffectedxPostEvent	0.019	-0.012	-0.043	0.031	0.063	-0.038	-0.038
	(0.024)	(0.014)	(0.053)	(0.041)	(0.088)	(0.053)	(0.053)
SIZE	0.057	0.033	0.066	0.073	0.033	0.066	0.066
	(0.068)	(0.048)	(0.126)	(0.148)	(0.048)	(0.126)	(0.126)
DEPOSITS	0.152**	0.088*	0.112**	0.128***	0.053**	0.092**	0.142**
	(0.052)	(0.052)	(0.036)	(0.024)	(0.025)	(0.036)	(0.036)
LIQ	-0.186	-0.137	-0.087	-0.187	-0.171	-0.087	-0.087
	(0.245)	(0.245)	(0.134)	(0.245)	(0.145)	(0.134)	(0.134)
EQUITY	0.022**	0.013**	0.053***	0.013**	0.003**	0.053***	0.037***
	(0.008)	(0.006)	(0.006)	(0.006)	(0.001)	(0.006)	(0.006)
LLR	-0.061	-0.036	-0.123	-0.036	-0.006	-0.123	-0.123
	(0.09)	(0.051)	(0.071)	(0.051)	(0.037)	(0.071)	(0.071)
GROWTH	0.002	0.014*	0.072**	0.034*	0.003**	0.068**	0.057**
	(0.006)	(0.006)	(0.006)	(0.016)	(0.000)	(0.032)	(0.026)
INFLATION	0.041	0.002	0.002	0.033	0.029	0.027	0.027
	(0.039)	(0.004)	(0.004)	(0.065)	(0.039)	(.039)	(0.039)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204	531	373	236	93	471	403
R-squared	0.973	0.969	0.988	0.982	0.917	0.976	0.984

Notes: The table presents the sensitivity of the baseline model to variations in the sample size and matching procedure as well as false timing of the introduction of the LBR. The dependent variables are stock of total loans (lnLOAN), loans flow (LOANFW), and the ratio of loans to total assets (RATLOAN). Standard errors for the same coefficient are clustered at the bank level and reported underneath in parentheses. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: log of total assets, total deposits to total assets, liquid assets to total assets, equity to total assets loan loss reserves to total assets, real GDP growth and inflation rate, all lagged by one period. Columns (1) and (2) match each Dutch bank with one and five unaffected banks, respectively. Column (3) saturates the matching procedure with additional bank-specific variables. Columns (4) and (5) restrict the number of countries from which banks in the control group are selected to Benelux (i.e., Belgium and Luxembourg) and Belgium, respectively. Column (6) omits the year 2003 (the year LBR was enacted) from the sample. Column (7) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A2.1 – Long-term effect of LBR on bank risk and profitability

Variables	ZSCORE (1)	SDRETURN (2)	ROA (3)
Year 0	0.429***	-0.647**	-0.003**
	(0.127)	(0.168)	(0.000)
Year 1	0.444***	-0.562**	-0.003**
	(0.135)	(0.145)	(0.000)
Year 2	0.662***	-0.355***	-0.002**
	(0.196)	(0.092)	(0.000)
Year 3	0.603***	-0.295**	-0.001**
	(0.174)	(0.076)	(0.000)
Year 4	0.526**	-0.241**	0.000
	(0.195)	(0.062)	(0.001)
Year 5	0.431**	-0.223**	-0.001
	(0.160)	(0.058)	(0.001)

Notes: The table analyses the long-term impact of the introduction of the Liquidity Balance Rule in the Netherlands on bank risk and profitability. The table reports the estimated coefficients of the variable of interest Affected × Post Event. The estimated coefficients are based on equation (2.2). Column (1) reports the estimated coefficients for ZSCORE. Columns (2) presents the results for the market-based variable, SDRETURN and column (3) reports the coefficients for ROA. All models are estimated using ordinary least squares and include bank and year fixed effects as well as time-varying bank- and country-level controls: SIZE defined as the natural logarithm of total assets, EQUITY defined as the ratio of total equity to total assets, DEPOSITS defined as the ratio of total customer deposits to total assets. LOANS is defined as of net loans to total assets. COSTINCOME is the ratio of operating expense over total operating income. LLR is the ratio of loan loss reserves to total assets, GROWTH is the real GDP growth and INFLATION is the inflation rate. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A2.2 – Robustness check and sensitivity analysis - full sample of banks

Variables	4 Year rolling window	5 Year rolling window	Alternative matching	Matching with one neighbor	Matching with five neighbors	Matching with Benelux countries only	Matching with Belgium only	Placebo test
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Affected x PostEvent	0.362***	0.345**	0.305**	0.451***	0.484**	0.305**	0.332**	0.193
	(0.105)	(0.130)	(0.116)	(0.115)	(0.181)	(0.113)	(0.201)	(0.264)
DEPOSITS	0.001	0.000	0.001	0.000	0.000	-0.001*	-0.001*	0.000**
	(0.005)	(0.000)	(0.007)	(0.006)	(0.007)	(0.000)	(0.001)	(0.000)
EQUITY	0.039**	0.027**	0.001***	0.037***	0.029*	0.001**	0.001**	0.063**
	(0..009)	(0.009)	(0.000)	(0.005)	(0.019)	('0.000)	(0.001)	(0.011)
SIZE	0.584***	0.566***	0.848**	0.674***	0.327**	0.848**	0.822*	0.163***
	(0.105)	(0.103)	(0.436)	(0.105)	(0.087)	(0.436)	(0.645)	(0.035)
LOANS	-0.004	-0.001	-0.012	-0.005	-0.000	-0.001	-0.000	-0.005
	(0.006)	(0.003)	(-0.067)	(0.006)	(0.006)	(0.067)	(0.009)	(0.015)
NNI	-0.004	-0.004	-0.012*	-0.004	-0.004	-0.012**	-0.004	-0.004
	(0.005)	(0.005)	(0.018)	(0.005)	(0.005)	(0.001)	(0.005)	(0.005)
COSTINCOME	0.005	0.007*	-0.087	0.005	0.005	-0.087	-0.061	0.005
	(0.005)	(0.005)	(0.087)	(0.005)	(0.005)	(0.087)	(0.087)	(0.005)
LLR	-0.009**	-0.013**	-0.000*	-0.013**	-0.006**	-0.000**	-0.000*	-0.078**
	(0.007)	(0.005)	(0.000)	(0.007)	(0.007)	(0.000)	(0.001)	(0.014)
GROWTH	-0.043*	-0.082	-0.024*	-0.043*	0.008	-0.024*	-0.024*	-0.043*
	(0.027)	(0.123)	(0.027)	(0.027)	(0.034)	(0.027)	(0.027)	(0.027)
INFLATION	-0.055	-0.005	-0.006	-0.055	0.003*	-0.006	-0.006	-0.035
	(0.074)	(0.039)	(0.008)	(0.074)	(0.002)	(0.009)	(0.009)	(0.086)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	294	294	294	148	541	214	206	294
R-squared	0.881	0.773	0.748	0.961	0.907	0.748	0.824	0.671

Notes: The table presents the sensitivity of the baseline model to variations in the definition of the outcome variables, the sample size and matching procedure as well as false timing of the introduction of the LBR. The table presents the estimates for ZSCORE as the outcome variable. In rows (1) and (2), ZSCORE is measured using a four-year rolling and five-year rolling window. Row (3) use alternative variables for the matching procedure. Instead of the growth rate in ZSCORE, the growth rates of SDROA is used. Row (4) and (5) match each Dutch bank with one and five unaffected banks, respectively. Rows (6) and (7) restrict the number of countries from which banks in the control group are selected to Benelux (i.e., Belgium and Luxembourg) and Belgium, respectively. Row (8) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A2.3 – Robustness check and sensitivity analysis - sample of listed banks

Variables	Last 3 months	Alternative matching	Placebo test
	(1)	(2)	(3)
Affected x PostEvent	0.319**	0.262**	0.162
	(0.124)	(0.098)	(0.182)
DEPOSITS	0.021**	0.001*	0.000**
	(0.008)	(0.000)	(0.000)
EQUITY	0.011**	0.001*	0.001*
	(0.009)	(0.000)	(0.000)
SIZE	0.093**	0.123**	0.163**
	(0.045)	(0.056)	(0.035)
LOANS	-0.083	-0.012	-0.066
	(0.312)	(-0.067)	(0.015)
NNI	-0.001	-0.012*	-0.004
	(0.001)	(0.009)	(0.005)
COSTINCOME	-0.004	-0.001	0.005
	(0.007)	(0.001)	(0.005)
LLR	0.151**	-0.000*	-0.078**
	(0.057)	(0.000)	(0.014)
GROWTH	0.053**	-0.024*	-0.043*
	(0.020)	(0.006)	(0.027)
INFLATION	-0.062	-0.006	-0.035
	(0.039)	(0.008)	(0.086
Year fixed effects	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Observations	86	294	294
R-squared	0.878	0.948	0.549

Notes: The table presents the sensitivity of the baseline model to variations in the definition of the outcome variables, the sample size and matching procedure as well as false timing of the introduction of the LBR. The table presents the estimates for MZSCORE as the outcome variable. In rows (1), MZSCORE is measured using the last three months of the year. Row (2) use alternative variables for the matching procedure. Instead of the growth rate MZSCORE, the growth rates of SDRETURN is used. Row (3) conducts a placebo test by falsely assuming the LBR was implemented in 2001 rather than 2003. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix A3.1– Definition of variables

Variables	Definitions	Source
KGap	Difference between the regulatory threshold of 8% bank's Capital Adequacy Ratio (CAR)	Bankfocus and author computed
NSFRGap	Difference between the regulatory threshold of 100% and bank's Net Stable Funding Ratio (NSFR)	Bankfocus and author computed
LCRGap	Difference between the regulatory threshold of 100% and bank's Liquidity Coverage Ratio (LCR)	Bankfocus and author computed
SIZE	Natural logarithm of total assets	Bankfocus
LLR	Ratio of loans loss reserves to total loans (%)	Bankfocus
FUND	Ratio of subordinated debts to total debts (%)	Bankfocus
DIV	Ratio of total common dividends to the difference between net income and minority interests plus preferred dividends (%)	Bankfocus

Notes: This table presents definitions for all variables used throughout the paper. The first column shows the name of the variable as used throughout the paper, the second describes the corresponding definition and the third column gives the source.

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Abstract

This thesis aims to evaluate the impact of the introduction of liquidity regulation on banks' contribution to the economy and their risk-taking behavior. In the first chapter, we investigate the effect of liquidity regulation on bank lending, using the introduction of a liquidity rule in the Netherlands in 2003 as a setting. Our results suggest that introducing liquidity requirements similar to the Liquidity Coverage Ratio would not affect bank lending. Moreover, we find that increased equity, an inflow of retail deposits, and a subsequent increase in balance sheet size may allow banks to increase lending despite meeting the liquidity requirements. The second chapter uses the same setting as in the first chapter and examines bank risk-taking behavior. Our results indicate that introducing liquidity requirements similar to the Liquidity Coverage Ratio would restrict banks from taking excessive risk. However, they might experience a decrease in their profitability due to reduced income accruing from interest-bearing activities. The third chapter investigates the relationship between bank regulatory capital and bank regulatory liquidity. Our results suggest that banks increase their regulatory liquidity when they increase their regulatory capital. In contrast, an increase in liquidity does not affect capital. Our findings indicate that the introduction of liquidity rules, alongside those on capital, would not lead banks to build a liquidity cushion at the expense of their capital cushion.

Résumé

L'objectif de cette thèse est d'évaluer l'impact de la mise en place de la réglementation portant sur la liquidité des banques, sur leur contribution à l'économie, et leur comportement de prise de risque. Dans le premier chapitre, nous nous sommes intéressés à l'impact sur le crédit bancaire. En nous appuyant sur l'expérience des Pays-Bas, où une règle portant sur la liquidité des banques a été introduite en 2003, nous avons montré que l'introduction d'exigences sur la liquidité bancaire n'affecterait pas le crédit bancaire. De plus, nous constatons qu'une augmentation des fonds propres, un afflux de dépôts et une augmentation subséquente du bilan peuvent permettre aux banques d'augmenter leurs prêts (en volume) malgré le fait qu'elles doivent satisfaire aux exigences de liquidité. Le deuxième chapitre s'appuie aussi sur l'expérience néerlandaise pour étudier l'impact de l'introduction d'exigences sur la liquidité bancaire sur la prise de risque des banques. Nos résultats indiquent que l'introduction d'exigences de liquidité similaires à celle prévue dans Bale III (notamment le Ratio de Couverture de Liquidité) amèneraient les banques à limiter leurs investissements dans des actifs risqués. Elles pourraient, cependant, connaître une baisse de leur rentabilité, en raison d'une diminution des revenus provenant des activités génératrices d'intérêts. Le troisième chapitre examine la relation entre le capital et la liquidité bancaire, dans un contexte où coexistent des exigences conjointes sur le capital et la liquidité. Nos résultats suggèrent que les banques augmentent leur liquidité lorsqu'elles augmentent leurs fonds propres. En revanche, une augmentation de la liquidité n'entraine pas systématiquement une augmentation des fonds propres. Ce résultat suggère que l'introduction de règles de liquidité, aux côtés des celles sur les fonds propres, ne conduit pas les banques à se constituer un coussin de liquidité au détriment de leur coussin de fonds propres