DOCTOR OF PHILOSOPHY

Exploring the Unexplored: An Assessment of the Implications of Low and Negative Interest Rates for the Banking Sector

Reghezza, Alessio

Award date:
2020

Awarding institution:
Bangor University

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Abstract

The aim of this doctoral thesis is to study whether protracted periods of low and negative interest rates have unintended effects on the banking sector. Specifically, by investigating a completely new event in the central banking community: the introduction of the Negative Interest Rate Policy (NIRP), this thesis studies the effect of nominal negative interest rates on bank margins and profits, and lending for a large sample of European banks over 2012-16. Moreover, by employing granular data on the Italian banking sector, this thesis investigates the effect of low interest rates on Italian bank business model over 2007-17. Overall, I find that negative interest rates reduce margins and profits as deposit rates are sticky downward. However, this depends on bank- and country-specific characteristics. If NIRP compresses margins and profits, capital accumulation via retained earnings is limited. Consequently, I also find that NIRP negatively affects lending. Again, this depends on bank- and country-specific characteristics. Finally, I show that banks try to keep up profits in a low and negative interest rate environment by switching from traditional intermediation activity to a more 'services-oriented' business model.

ACKNOWLEDGEMENTS

It is my duty to thank all the people that have helped me in completing this doctoral dissertation. First of all, I would like to thank my supervisor and colleague Professor Jon Williams that guided me through the impervious world of the academia where not only ideas but precision and attention to details are fundamental tools for researchers. Second, a big thank is due to my old supervisors Professor Philip Molyneux and Dr Ru Xie. Although our face-to-face experience has been short, they have always helped me. I have never felt on my own during this experience. A huge thank goes to the Business School that is like a big family to me. They welcomed and raised me since my first day in the University in 2015. I also thank my colleagues and friends at the European Central Bank and, in particular, Costanza Rodriguez d'Acri and Martina Spaggiari that helped me to understand the link between academic research and policy making.

This thesis is dedicated to my family.

TABLE OF CONTENT

Acknowledgments……. 6

Table of Contents…….. 7

List of Tables…….....……. 8

List of Figures……... 10

List of Boxes……. 11

List of Tables in the Appendixes……... 12

List of Figures in the Appendixes…….. 11

Chapter 1: A General Introduction to the Negative Interest Rate Policy…….. 14

Chapter 2: Bank Margins and Profits in a World of Negative Rates…… 38

Chapter 3: Banks' Non-Interest Income and Securities Holdings in a Low Interest Rate Environment: The Case of Italy……. 98

Chapter 4: Did Negative Interest Rates Improve Bank Lending or Fuel Bank Risk-Taking?..... 124

Appendix: Mitigating Misleading Implications for Policy: Treatment of Outliers in a Difference-in-Differences Framework?..... 166

Chapter 5: Conclusion and Limitations…… 176

List of Tables

Table 1: NIRP-affected countries and adoption date 13

Table 2.1: Macroeconomic and institutional variables descriptive statistics divided into the treatment and control groups (percentage values)……... 61-63

Table 2.2: Descriptive statistics of control and treatment group prior and after NIRP. 65-66

Table 2.3: The effect of NIRP on NIM and ROA…… 73

Table 2.4: Propensity score estimation: Probit model……. 76

Table 2.5: Difference-in-differences - PSM results……. 76

Table 2.6: The influence of NIRP on NIM and ROA by splitting the sample in four percentiles based on bank size……. 79

Table 2.7: The influence of NIRP on non-interest income and fees and commissions by splitting the sample in four percentiles based on bank size…….. 81

Table 2.8: The effect of NIRP on banks that: strongly (weakly) hedge against interest rate risk; have diversified lending; operate in more (less) competitive markets; in countries where floating (fixed) rates predominate; and for levels of bank capital……... 82

Table 2.9: NIRP, NIM and ROA for surplus/deficit countries……. 85

Table 2.10: Bank activity restrictions index…… 86

Table 2.11: NIRP, NIM and ROA for banks subjected to weak/strong activity restrictions……... 87

Table 2.12: NIRP and bank specialisation……... 89

Table 2.13: Robustness checks 90-91

Table 3.1: Variable name, units of measurement, definition and source…….. 108

Table 3.2: Descriptive Statistics…….. 109

Table 3.3: NIMs, FEEs and Securities holdings in a low interest rate environment…. 113

Table 3.4: Management, brokerage and consultancy fees; cash receipts and payments fees; and current account fees in a low interest rate environment…… 115

Table 3.5: Available for sale, held for trading and held to maturity securities in a low interest rate environment……... 117

Table 3.6: Robustness checks…….. 119

Table 3.7: Robustness checks…….. 122

Table 4.1: Descriptive statistics: treatment and control groups……... 144-145

Table 4.2: Average bank lending measured by gross loans, mortgage loans and C&I loans before and after NIRP at country level…… 146-147
Table 4.3: Propensity score estimation: Probit model……. 147-148
Table 4.4: Baseline Regression……... 148-149
Table 4.5: Robustness Checks……. 152
Table 4.6: NIRP and bank lending, bank capitalization, funding structure and business model…… 154-155
Table 4.7: Difference-in-differences- PSM……. 155-156
Table 4.8: Robustness checks……. 159-160
Table 4.9: NIRP and Z-score……... 161
Table 4.10: Risky assets, capitalisation, size and competition before and after NIRP. 164

List of Figures

Figure 1.1 European Lending Rates: 2010-2017…….. 20

Figure 1.2. European Deposit Rates: 2010-2017……. 21

Figure 1.3. Ten year government bonds spread (German Bund= benchmark)…….. 26

Figure 1.4. GDP in countries that introduce NIRP in 2014……. 28

Figure 1.5. European Central Bank Policy Rate and Money Market Rates: 2010-2016……... 29

Figure 1.6. Euro Area Inflation Forecast over 2000 – 2015…….. 30

Figure 1.7. Swedish interest and money market rates over 2012 – 2017……... 31

Figure 1.8. Denmark National Bank Interest Rates 2007-2017……. 32

Figure 1.9. Swiss National Bank Interbank Libor Rate: 2007-2017…….. 33

Figure 1.10. Norway Interbank Libor Rate: 2007-2017…… 35

Figure 1.11. Japan Inflation Rate: 2011-2016……... 36

Figure 2.1. Average NIM and ROA among treated banks (blue line) and non-treated banks (red line) from 2011 – 2016……. 66

List of Tables in the Appendixes

Table A1. Correlation Matrix……. 93

Table A2. Macroeconomic indicators and Pearson correlation test for the control and treatment group during the period 2007-2015……... 94

Table A3. This table displays variables, units, description and source of the variables used in the sample……... 95-96

Table B1. Correlation matrix among the variables used in the baseline regression…… 122

Table D4. Winsor Problem Detection in Min and Max Descriptive Statistics….. 172

Table D5. Descriptive Statistics: Control and Treatment groups…… 173

Table D6. Winsorization Techniques and DD Methodology…….. 173

Table D7. Rejection Rate Winsor Techniques…… 174

List of Figures in the Appendixes

Figure D1. Normal density function (no-Winsor)…….. 168

Figure D2. Normal density function (Winsor)…… 169

Figure D3. Normal Density Function (Winsor by group)……... 170

CHAPTER 1: A GENERAL INTRODUCTION TO NEGATIVE INTEREST RATE POLICY

1.1 Introduction

The aim of this doctoral thesis is to study whether the low and negative interest rate environment that followed the 2008 global financial crisis (GFC hereafter) has an impact on the banking sector. After an introduction that explains the transmission channels of negative and/or low interest rates, the thesis is divided into three different papers.

This chapter is divided in 2 sections and several sub-sections. In the first section, I introduce the overall thesis. In the second section, I explain the transmission channels and the transmission problems of NIRP. Furthermore, I describe how NIRP has been implemented by different countries. Section 2 is divided in different sub-sections. Sub-section 1 describes the interest rate channel. Sub-section 2 the credit channel, which is divided in a lending and a balance sheet channel. Sub-section 3 explains the portfolio rebalancing channel and the risk-taking channel of NIRP. Sub-section 4 describes the exchange rate channel under NIRP whilst sub-section 5 the reflation channel. As section 1, section 2 is divided in numerous sub-sections. Specifically, sub-section 1 explains the implementation of NIRP in Europe. Sub-section 2 refers to NIRP implementation in Sweden. Sub-section 3 describes the implementation in Denmark. Sub-section 4 refers to the implementation of NIRP in Switzerland. Sub-section 5 describes NIRP implementation in Norway, whilst sub-section 6 in Japan. Table 1 reports the countries that have been subjected to negative interest rates and NIRP adoption date.

Table 1. NIRP-affected countries and adoption date

Country	NIRP adoption date
Austria	June 2014
Belgium	June 2014
Denmark	July 2012
Estonia	June 2014
Finland	June 2014
France	June 2014
Germany	June 2014
Greece	June 2014
Hungary	March 2014
Ireland	June 2014
Italy	June 2014
Luxembourg	June 2014
Netherlands	June 2014

Norway	September 2015
Portugal	June 2014
Slovakia	June 2014
Slovenia	June 2014
Spain	June 2014
Sweden	February 2015
Switzerland	January 2015

In the first paper (chapter 2), I will focus on the impact of the negative interest rate policy (NIRP) on bank profitability and margins. This research question is of pivotal importance for policy makers in terms of both financial stability and monetary transmission. If NIRP results in a decline in margins and, consequently, profits, this can erode bank capital bases through a reduction of retained earnings. Since capital is vital for bank lending, a reduction of the latter can ultimately curtail lending to the real economy hampering the monetary transmission mechanism. Low profits may also raise financial stability concerns among policy makers as banks operating in countries affected by low or negative interest rates are those that have been struggling to maintain respectable levels of profitability because of slow economy recovery, legacy asset problems (high stock of non-performing loans) and a post global financial crisis as well as sovereign debt crisis deleveraging phase. However, identifying the link between NIRP and bank profitability is challenging as interest rates affect both the asset and the liability side of bank balance sheet. For instance, a cut in interest rates into negative territory may increase bank profitability if: (a) there is significant loan growth and margins are unaffected; (b) banks boost fees and commissions income; (c) they hold a sizeable amount of fixed income securities in the trading book and; (d) negative interest rates reduce borrowers' probability of default reducing loan loss provisions. If banks are unable to reduce deposit rates to the same extent as loan rates then margins will be compressed, and if there is limited loan growth and/or cross-selling of fee and commission services then profits will likely fall.

To capture the effect of NIRP on margins and profits, I employ a bank-level dataset comprising 7,352 banks in 33 OECD countries over the period 2012-16 and difference-in-differences (DiD hereafter) methodology. The DiD methodology enables me to draw conclusions on whether NIRP has squeezed bank NIM and profitability in NIRP adopter countries after the implementation of negative rates. Moreover, it permits me to analyse the effectiveness of the pass-through mechanism of NIRP under different macroeconomic and bank-specific environments.

The first paper addresses this serious concern. It examines whether or not, after the introduction of NIRP, bank margins and profits have been negatively affected. Furthermore, I investigate whether bank- (size, funding structure, business model, assets repricing and product-line specialisation) and country-specific characteristics (degree of competition, prevalence of fixed/floating interest rate) amplify or weaken the effect of NIRP on bank margins and profits. Again, identifying banks and countries that can be more or less affected by the policy is fundamental for policy makers monitoring as well as supervisory activities.

For instance, banks that rely on wholesale funding may benefit from NIRP in terms of cheaper funding costs compared to those that depend mainly on retail deposits that are 'sticky' downward. Similarly, banks with a business model focused on non-interest income ('service oriented') may be less affected by NIRP than banks that focus mostly on traditional intermediation activities. Large banks that have greater international reach, potential to increase lending abroad and more diversified portfolios are better equipped to hedge against interest rate risk and to switch to non-interest focused business models when margins are compressed. Bank with specific product-line specialisation (e.g. mortgage lenders) are more likely to be strongly affected by NIRP. Also country characteristics such as the degree of banking sector competition, the prevalence of fixed/floating lending rate as well as a country's current account surplus may play an important role. For instance, fierce bank competition and floating lending rate can amply the contraction of net interest margins, and banks operating in countries with sufficient surplus are likely to hold larger excess reserves subject to NIRP. The aforementioned factors are essential for the evaluation of NIRP by policy-makers.

The second paper (chapter 3) is strongly linked to the first. If the low and/or the negative interest rate environment compresses margins and profits, this may motivate banks to switch from interest to non-interest income in order to maintain profitability. Indeed, lower interest rates could generate gains on fixed-income securities. However, this depends on whether securities are held-for-trading, held-to-maturity or available for sale. For trading book securities, gains feed directly to the income statement whereas available-for-sale securities are classified as equity, and the effect of interest rate changes is zero if securities are held-to-maturity. In low interest and/ or negative rate environments, banks may decide, on the one hand, to increase securities to exploit interest rate cuts and realise gains on their trading

portfolios. However, protracted periods of low interest rates exhaust the possibility to cut rates further, and this, concomitantly with compressed margins and profits, may motivate banks to re-shuffle their securities portfolio from held-for-trading towards available-for-sale and/or held-to-maturity.

In a low interest rate environment, banks might also try to expand fee and commission income. Since fees and commissions are earned from a diversified array of services – such as, non-interest income derived transaction and credit services to brokerage and portfolio management, identifying the link between interest rates and these items can be challenging. There are two possible channels through which the interest rate environment influences fee and commission income. First, low yields can cause bank customers to demand more professional services for the purpose of portfolio management. Second, low interest rates boost asset prices and volumes, which positively impacts fees directly linked to servicing such business. Furthermore, in a low interest rate environment banks' incentive to search for yield is stronger. This influences banks to sell more services to customers to boost fee and commission income. In chapter 3, I investigate whether Italian banks have switched toward non-interest income as a reaction to the low interest rate environment. Again and as for the second chapter of the thesis, this research question has important policy implications in terms of both financial stability and monetary policy transmission. An excessive reliance on non-interest income could render bank revenues less stable as services are generally standardised products; hence customers can change provider without incurring in high transaction costs. Moreover, regulators do not require banks to hold regulatory capital against most fee and commission-related products, hence in a tougher regulatory regime and faced with a low interest rate environment, this could motivate a switch to non-interest income-related business, which potentially exacerbates stability concerns. In addition, if banks try to maintain profits in low interest rate environments by shifting to non-interest income activities, this will not increase lending to the real economy. As such, the latter limits the effectiveness of monetary policy.

To examine the effect of the low interest rate environments on non-interest income and securities, I use a granular dataset of 440 Italian banks between 2007 and 2016 that has been provided by the Italian Banking Association (ABI) and a dynamic panel fixed effects methodology. The granularity enables me to investigate bank income structures by examining specific balance sheet and income statement items alongside detailed notes to the account. Specifically, I differentiate fee and commission income by three activities: first, portfolio

management, brokerage and consultancy services: second, collection and payment services; third, current account services. In addition, I examine changes in the composition of bank securities holdings and differentiate between securities held-for-trading, available-for-sale and held-to-maturity.

Finally, in the third paper (chapter 4), I investigate whether the compression on margins – that motivates a switch from interest income to non-interest income – has an impact on bank lending behaviour and risk-taking. If NIRP decreases banks profitability eroding capital bases, banks may be reluctant to lend limiting monetary policy transmission and expected outcome. The downward stickiness of deposits (deposit rate channel) compresses net interest margins and pressurises profitability, which creates incentive for banks to maintain profitability by investing in higher-yield, hence riskier, securities. Moreover, when the yield curve is compressed, banks may be pushed out of low-yielding, short-term liquid assets into higher-yield, long-term illiquid assets, which alter portfolio risk. The third research question addresses these points. It tries to capture whether or not – after the implementation of NIRP – banks increased or decreased lending and risk-taking in comparison with a control group who has not been affected by negative rates. I make use of the 'reversal' interest rate hypothesis (Brunnermeier and Koby (2016)) to figure out what banks may be more prone to reduce lending under NIRP. Specifically, I investigate heterogenous effects of NIRP on bank lending for those banks that have different level of capitalisation, funding structure, business model and that operate in markets with different degree of competition. For instance, binding capital requirements may limit the pass-through of monetary policy on bank lending. This effect should be stronger for less capitalised banks. Banks that rely on deposits as a primary source of funding should be more affected by NIRP as deposits are more sticky downward. Hence, they can curtail lending to the real economy more than banks that are wholesale based. For the same reason, banks that have a business model interest-dependent should be more affected by NIRP and, consequently, may curtail lending more than banks that have a different business model. Banks that operate in less competitive environments make slower adjustments to interest rate (thus to net interest margins) which slows the transmission of monetary policy changes to bank lending. Contrarily, banks that operate in competitive markets make faster adjustment of interest rates and face greater margin compressions which may result in weaker lending.

Regarding bank risk-taking, I also investigate whether the effect of NIRP on bank risk-taking depends on bank-specific characteristics such as capitalisation, funding structure, and

diversification and on the characteristics of national banking sector such as the degree of competition. While NIRP could exert stronger impact on small banks via a deposit channel effect that motivates search for yield, risk-taking could be lower at large banks that could realise gains benefits from diversification. NIRP could also engineer increased investment in riskier assets at more prudent banks holding capital buffers to support greater taking of risk. Similarly, risk-taking could increase at less prudent banks with less skin-in-the-game that may gamble for resurrection. Finally, competition could amplify banks' exposure to negative interest rates. While banks may prefer safer investments if relatively competitive markets exert downward pressure on net interest margins, the association between market power and less competitive markets predicts that banks could raise mark-ups on loans to boost profits, which enhances banks' ability to make riskier loans.

To examine this issue, I employ a bank-level dataset comprising 6558 banks from 33 OECD countries over the period 2012-2016 and a propensity score matching (PSM hereafter) DiD. This approach provides a sound basis for drawing conclusions as to whether NIRP resulted in a change in bank lending and risk-taking in pre-and post-NIRP periods.

I contribute to the extant literature in several ways. First, earlier literature that investigates the effect of NIRP on bank margins, profits, lending and risk-taking is still limited. The literature generally comprises discussions on the possible effects of NIRP on bank performance and overviews of developments in key banking and other financial aggregates in the immediate pre- and post-NIRP period. Moreover, based on the Euro Area Bank Lending Survey of April of 2016, NIRP hurts bank profitability. Indeed, eighty percent of banks in the survey stated that they expected NIRP to have a negative influence on margins, profits and consequently lending. Finally, the second paper is the first to investigate the effect of the low interest rate environment on non-interest income and security holdings as the established literature employs aggregate non-interest income and securities information. My paper provides a greater level of granularity and detail into the relationship between low interest rates, non-interest income and securities holdings. Indeed, I consider specific fees and commissions reported in notes to the accounts and securities holdings divided by accounting classifications.

1.1 NIRP Transmission Channels

NIRP operates essentially in the same way as a positive interest rate cut. It works through six main channels: the interest rate channel, the lending channel, the asset valuation/balance sheet channel, the portfolio rebalancing/risk-taking channel, the exchange rate channel and the reflation channel.[1]

1.1.1 The Interest Rate Channel

The interest rate channel of monetary policy suggests that accommodative monetary policies reduce interest rates. This reduction lowers borrowers funding costs, raising investments and aggregate demand (as illustrated below). [2]

$$M \uparrow \rightrightarrows i_r \downarrow \rightrightarrows I \uparrow \rightrightarrows AD \uparrow$$

Where M indicates the money supply. M$\uparrow$ indicates an increase in the money supply; i.e. accommodative monetary policy, i_r is the real interest rate, I represents investments and AD is the aggregate demand. An important feature of the interest rate channel is its emphasis on the real (i_r) rather than nominal interest rate (sticky prices hypothesis). Specifically, the long-term real interest rate has major impact on investors' decisions. Focusing on real interest rates, central banks can provide stimulus even when monetary policy is constrained by the zero lower bound (ZBL). Accommodative monetary policies raise future inflation expectations (π^e), thereby lowering real interest rates (as shown in the Fisher equation below):

$$r = i - \pi^e$$

By targeting inflation expectations, central banks can use the interest rate channel to support investment and economic growth.

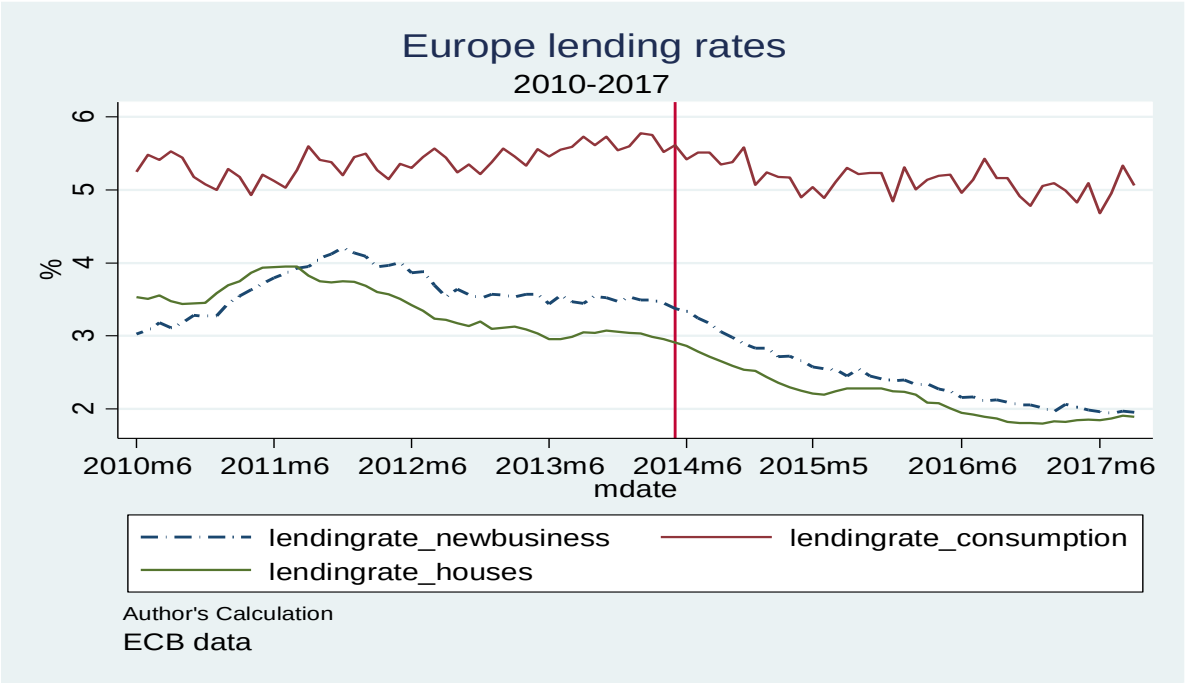
$$\text{M}\uparrow \rightrightarrows \pi^e \uparrow \rightrightarrows i_r \downarrow \rightrightarrows \text{I}\uparrow \rightrightarrows \text{AD}\uparrow$$

NIRP is assumed to lower short-term money market and bond rates (Hannoun, 2015; Jackson, 2015; Ball et al. 2016; Jobst and Lin, 2016; Arteta et al. 2016). Similarly to positive interest rates, negative rates can also lower long-term rates by acting on both investors' arbitrage differences in risk-adjusted expected returns and maturities of debt securities. As a result, deposit and lending rates decline improving bank funding costs and the budget constraint of households and firms. This effect should encourage economic agents to increase investment and consumption. As shown by figure 1.1 and 1.2, the introduction of negative rates in June

[1] Mishkin (1995) provides an overview of the transmission channels of monetary policy.
[2] Business and consumer investment decisions are included in this category.

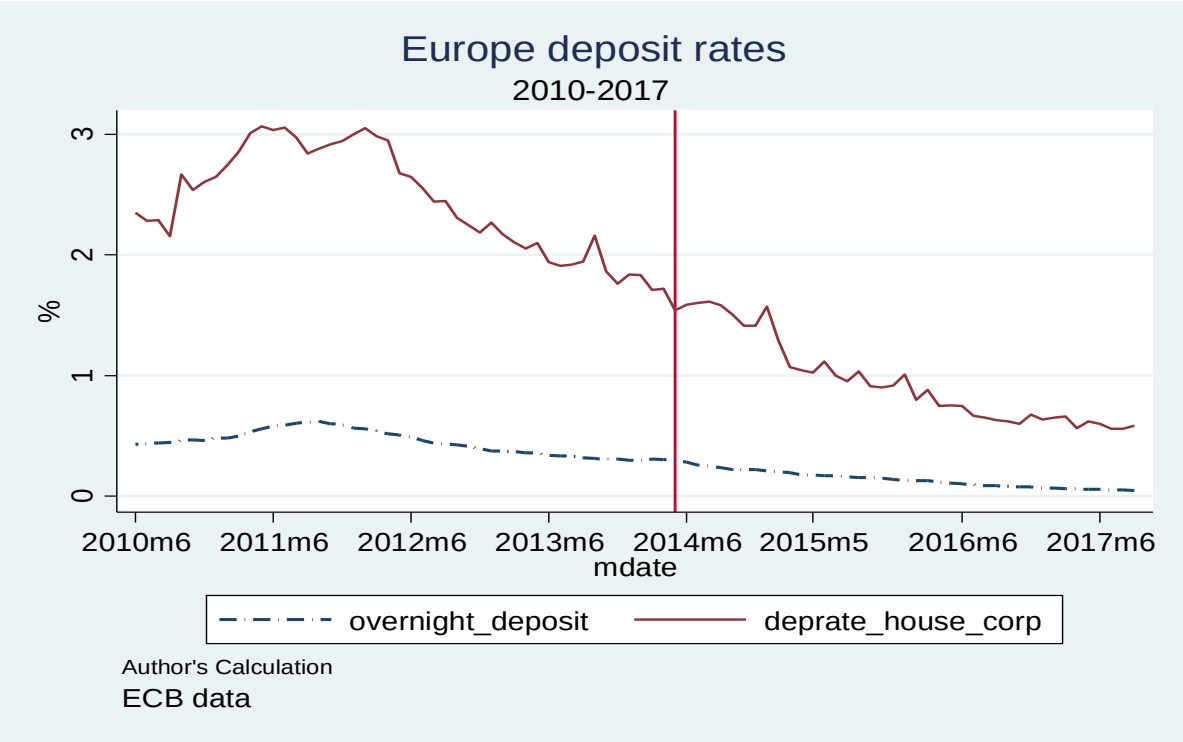
2016 (red vertical line in the graphs) contributed to a further reduction in lending as well as deposit rates, although sluggish.

Figure 1.1 European Lending Rates: 2010-2017



Notes: Figure 1.1 shows lending rates in the euro area over June 2010 – June 2017. The dashed blue line represents lending rates to new businesses. The green line indicates lending rates for house purchases whilst the red line displays lending rates for consumption.

Figure 1.2. European Deposit Rates: 2010-2017



Notes: Figure 1.2 shows deposit rates in the euro area over June 2016 – June 2017. The blue dashed line indicates the overnight deposit rate, while the red line the deposit rate to households and corporations.

Indeed, the interest rate channel can be distorted when rates are cut into negative territory and the transmission to loan and deposit rates limited. Commercial banks, in fact, might be reluctant to impose negative rates to customers fearing to lose deposit base. Deposits are an important source of funding for banks in normal times. By charging negative interest rates banks may lose market share as depositors will 'shop around' trying to find banks with positive deposit rates. Moreover, banks charging negative interest rates would likely receive adverse attention from media and the public, furtherly aggravating bank profitability. For these reasons, only in a few countries (mostly Denmark and Switzerland) some banks started to charge negative interest rates to customers. However, customers subjected to NIRP are mostly corporate or institutional depositors.[3] Bank may prefer to charge negative rates on institutional or corporate deposits as these customers are less likely to switch to cash. Hence, deposit rates (funding cost for banks) can be less affected by the policy (downward stickiness). This tendency, combined

[3] There is only one bank that charge negative interest rates on customers deposits. Alternative Bank, a small Swiss bank, started charging negative interest rates on depositors. Specifically, -0.125% for deposits up to 100,000 Swiss Francs and -0.75% for deposits above 100,000. The decision to apply negative interest rates on depositors rather than increase fees and commissions was driven by:"…a more transparent and fairer solution for our clientele". Apparently, Alternative banks did not lose many customers after NIRP but rather:" with all the media attention, we have seen new clients arrive who did not know us before and who wants to sign up since they share our values" (Rohner, 2015).

with efforts to maintain net interest margins, could potentially reduce the pass-through to lending rates.

1.1.2 The Credit Channel

The credit channel of monetary policy (see Bernanke and Gertler, 1995) is based on two different specific channels: the lending channel and the balance sheet channel.

1.1.2.1 The Lending Channel

Bernanke and Blinder (1988) and Bernanke and Gertler (1995) point out the existence of a lending channel of monetary policy transmission. The latter is based on the assumption that banks play a well-suited role in solving asymmetric information issues in the credit market. Expansionary monetary policies lead to an increase in bank reserves and deposits, which ultimately can lead to an increase in lending and aggregate demand.

$$M \uparrow \rightrightarrows \textit{bank deposits} \uparrow \rightrightarrows \textit{bank loans} \uparrow \rightrightarrows I \uparrow \rightrightarrows AD \uparrow$$

NIRP effectively acts as a tax on excess reserves (Hannoun, 2015; Arteta el al. 2016). Banks face an opportunity-cost of holding excess reserves on account at the central bank. Therefore, NIRP encourages banks to use them to increase lending. Under NIRP, the bank lending channel should be greater than the standard interest rate channel. Whilst NIRP may weaken the interest rate channel by limiting banks' ability to transfer negative interest rates to retail deposits, NIRP should amplify the bank lending channel by raising the cost of holding excess reserves. However, this depends also on macroeconomic and regulatory factors. If banks operate in environments with weaker investment opportunities, facing post-crises deteriorated balance sheets and tighter capital regulatory requirements, this may limit credit growth under NIRP. Consequently, profits will likely fall leading to an erosion of bank capital bases which can further limit credit growth, thus stifling the monetary transmission of NIRP to the real economy.

1.1.2.2 Balance Sheet Channel

Monetary policy can affect the balance sheet channel in several ways. A first channel is through firms' cash flow. Expansionary monetary policies reduce nominal interest rates, which in turn improve firm cash flows (less interest expenses). [4]

[4] In this situation, the nominal level of the interest rate is more important. Nominal interest rates play a crucial role as short-term rather than long-term interest rates have stronger impact on firms' cash flows (Mishkin, 1995).

$$M\uparrow \rightrightarrows i\downarrow \rightrightarrows cash\ flow\uparrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

This situation is particularly suitable for banks as both moral hazard and adverse selection may be reduced. Low firm net worth requires higher screening and monitoring costs for banks (adverse selection). Furthermore, borrowers with lower net worth have smaller equity stake in the company. Hence, they might engage in riskier projects (moral hazard). Riskier projects raise the likelihood that lenders will not be repaid. This can lead to high non-performing loans in banks' portfolio that can ultimately limit banks' willingness and ability to lend reducing investment and aggregate demand.

$$M\downarrow \rightrightarrows i\uparrow \rightrightarrows cash\ flow\downarrow \rightrightarrows Moral\ Hazard\uparrow \rightrightarrows Adverse\ Selection\uparrow \rightrightarrows NPLs\uparrow \rightrightarrows Lending\downarrow \rightrightarrows I\downarrow \rightrightarrows AD\downarrow$$

The aforementioned effect links to the mechanism described by Stiglitz and Weiss (1981) regarding credit rationing. Riskier borrowers are the ones that are willing to pay high interest rates because the benefits they receive if the investment pays off are much higher than the losses if the project is unsuccessful. Therefore, banks deny loans to investors when interest rates are high suspecting moral hazard behaviour. Accommodative monetary policy reduces this moral hazard problem as less risky borrowers should be the highest fraction of borrowers, hence leading banks to increase loans.

Finally, unexpected monetary policy easing has positive effects on prices. This lowers the value of firms' liabilities in real terms (reduced debt burden) as debt contracts are usually fixed in nominal terms. For the aforementioned described mechanisms, higher prices increase net worth, which can reduce asymmetric information raising investments and aggregate demand.

$$M\uparrow \rightrightarrows unanticipated\ P\uparrow \rightrightarrows Adverse\ Selection\downarrow \rightrightarrows Moral\ Hazard\downarrow \rightrightarrows Lending\uparrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

NIRP is assumed to improve borrowers' creditworthiness by reducing interest expenses as well as boosting asset prices. This should be beneficial for banks in terms of reducing moral hazard and adverse selection leading to a decline in the stock of non-performing loans.

1.1.2.3 Asset Valuation Channel

The asset valuation channel operates through a price and a wealth effect.

Price. Low interest rates boost assets prices by reducing the discount rate on cash flows from assets (Hannoun, 2015). Tobin's Q theory (see Tobin, 1969) presents a mechanism through which monetary policy affects equity prices. According to monetarists, accommodative

monetary policies leave economic agents with excess money holdings. Among the other alternatives, individuals can allocate excess liquidity increasing the demand for stocks and consequently their prices (search for yield). For Keynesians, this mechanism operates in a similar fashion. Loosening monetary policies make bonds less attractive relative to equities. High equity prices (e_p) have an effect on the ratio between the market value of a company and the replacement cost of capital (Tobin's Q ratio). When the market value of a company is high (q is high) in comparison to the cost of capital, the company can then issue equity at higher prices relative to the cost of new plant and equipment they invest.

$$M\uparrow \rightrightarrows e_p\uparrow \rightrightarrows q\uparrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

Wealth. The price effect complements the wealth effect. As suggested by Modigliani (1971) through the life-cycle model, equity prices have an effect on peoples' wealth and consequently on consumption. The consumption budget constrains is determined by individuals' long-run resources, namely human capital, real capital and financial wealth. When equity prices increase financial wealth increases and so consumption.

$$M\uparrow \rightrightarrows e_p\uparrow \rightrightarrows Wealth\uparrow \rightrightarrows Consumption\uparrow \rightrightarrows AD\uparrow$$

Both the price and wealth effect are at work under NIRP. However, they could potentially lead to distorted asset valuation and increase the risk of assets bubbles.

1.1.3 Portfolio Rebalancing Channel or Risk-Taking Channel

The portfolio rebalancing channel operates similarly to the asset valuation channel. In a low or negative interest rate environment, financial intermediaries are motivated to "search for yield" (Rajan, 2005). Search for yield promotes balance sheet re-composition from safe to risky assets and from short-term to long-term asset maturity.[5] The balance sheet re-composition in turn can have beneficial effects for enterprises as well as States. Banks provide major lending to firms and households to keep up profitability (usually low when interest rates are low). They can also buy long-term government bonds in an attempt to increase yields on security holdings. Major loans and long-term securities lead to a further interest rate reduction that can stimulate aggregate demand through different monetary transmission channels (mostly the interest rate channel)

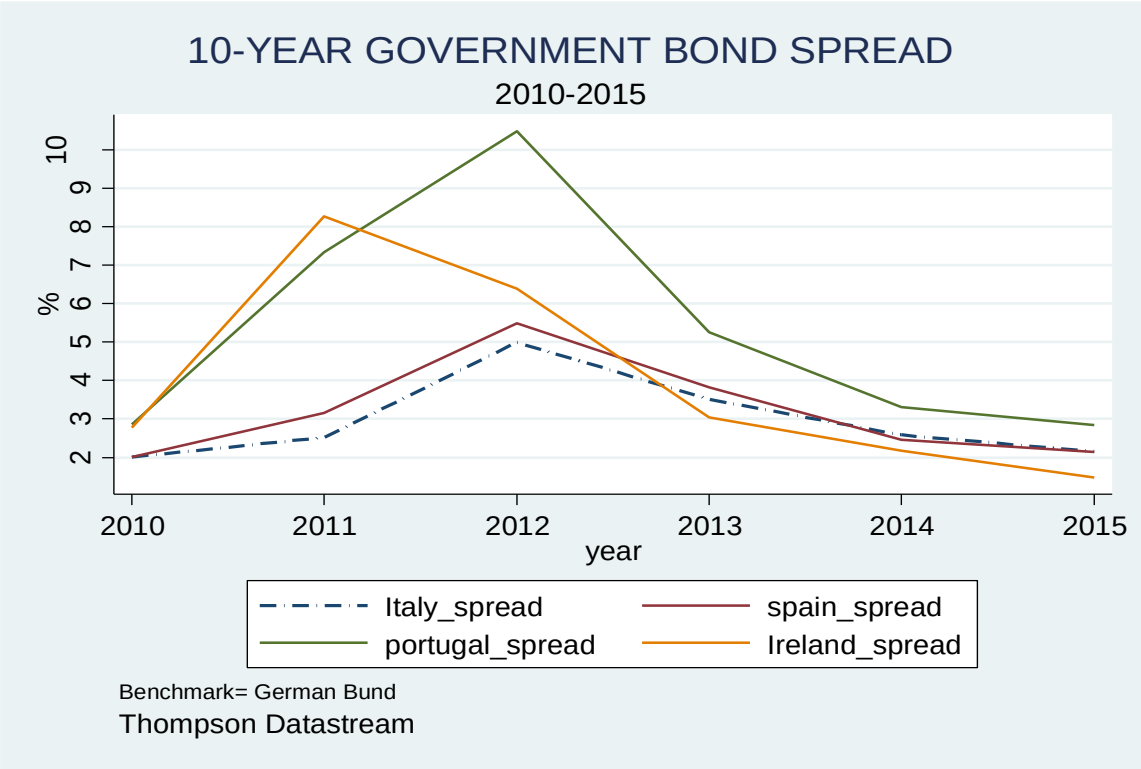
$$M\uparrow \rightrightarrows i\downarrow \rightrightarrows search\ for\ yield\uparrow \rightrightarrows lending\uparrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

[5] Borio and Zhu (2021) offer an explanation of the risk-taking channel.

$$M\uparrow \rightrightarrows i\downarrow \rightrightarrows \textit{long-term securities maturity}\uparrow \rightrightarrows i\downarrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

Indeed, according to Hannoun (2015), NIRP seems to have fuelled more risk-taking. The convergence between the returns of risky and low-risk assets as currently shown by the sovereign spread in the Euro Area is a clear sign in this direction (Figure 1.3). Moreover, according to Heider et al. (2016) and Nucera et al. (2017), banks affected by NIRP (deposit-based) started both to lend more to riskier borrower in comparison to wholesale-based banks and, at the same time, to perceive the latter as riskier. However, NIRP may have also acted in the opposite direction; i.e. pushing banks to reduce risk-taking. There are two reasons that may explain this possibility. First, the use of unconventional monetary policies (UMPs), such as quantitative easing (QE), in response to worsening macroeconomic conditions and deteriorating bank balance sheets, provided banks with excess liquidity; in turn, this allowed banks to deleverage their post-crisis balance sheets which limited potential supply-side benefits arising from exceptionally favourable financing conditions. Second, and given the monetary policy objective to increase bank lending, an unintended consequence of UMP is that banks simply used the excess liquidity to buy liquid assets such as government bonds. Arguably, this choice was rational in a period of slow economic recovery and high firm default rates. This could have been helped by the Basel capital requirements framework which treats sovereign exposure within the EU as risk-free and assigns zero risk weight to government bonds, which creates incentive for banks to acquire such assets to boost their capital positions.

Figure 1.3. Ten year government bonds spread (German Bund= benchmark)



Notes: Figure 1.3 shows the ten year government bond spread with German government bond employed as benchmark. The blue dashed line indicates the spread between Italian and German sovereign bonds. The green line represents the spread between the Portuguese and German government bonds. The red line displays the spread between Spanish and German government bonds, while the yellow line between the Irish and the German.

1.1.4 Exchange Rate Channel

Since the advent of flexible exchange rates and the internationalisation of economies around the world, the exchange rate channel has been playing a crucial role for monetary policy decisions. Accommodative monetary policies, reducing the level of interest rates, make domestic deposits and interest-denominated assets less attractive for investors in comparison with foreign currencies. Demand for foreign currencies increases generating an outflow of currencies from the country experiencing a reduction in rates to foreign countries. This leads to domestic currency depreciation (E↓). When domestic currency depreciates, domestic goods become cheaper than foreign goods, thereby causing a rise in net exports (NX↑) and supposedly in aggregate output (Y↑).

$$M\uparrow \rightrightarrows i_r\downarrow \rightrightarrows E\downarrow \rightrightarrows NX\uparrow \rightrightarrows Y\uparrow$$

NIRP is expected to operate in the same way as lower (higher) domestic interest rates should reduce (increase) financial inflows and lessen exchange rate appreciation (depreciation).

1.1.5 The Reflation Channel

As suggested by Hannoun (2015), central banks attempt to lift inflation towards the target level (generally set at 2%). By using different tools (among which negative rates), policy makers ward off the risk of a deflationary spiral which could lead to an increase in debt burden.

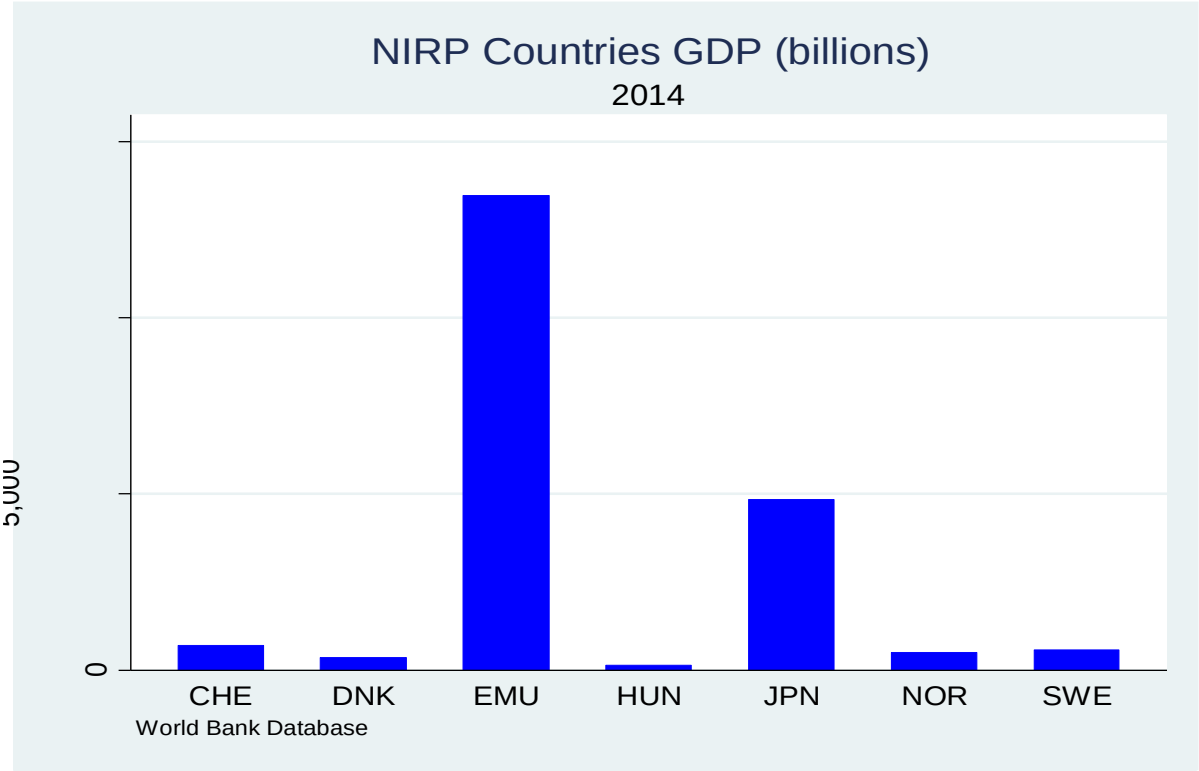
$$\text{M}\uparrow \rightrightarrows \pi^{e}\uparrow \rightrightarrows i_{r}\downarrow \rightrightarrows \text{I}\uparrow \rightrightarrows \text{AD}\uparrow$$

1.2 Theoretical Framework: The Implementation of Negative Interest Rates

1.2.1 Euro Area

I start the analysis focusing on the Euro-Area as it is the largest economic region in my sample (Figure 1.4).

Figure 1.4. GDP in countries that introduce NIRP in 2014

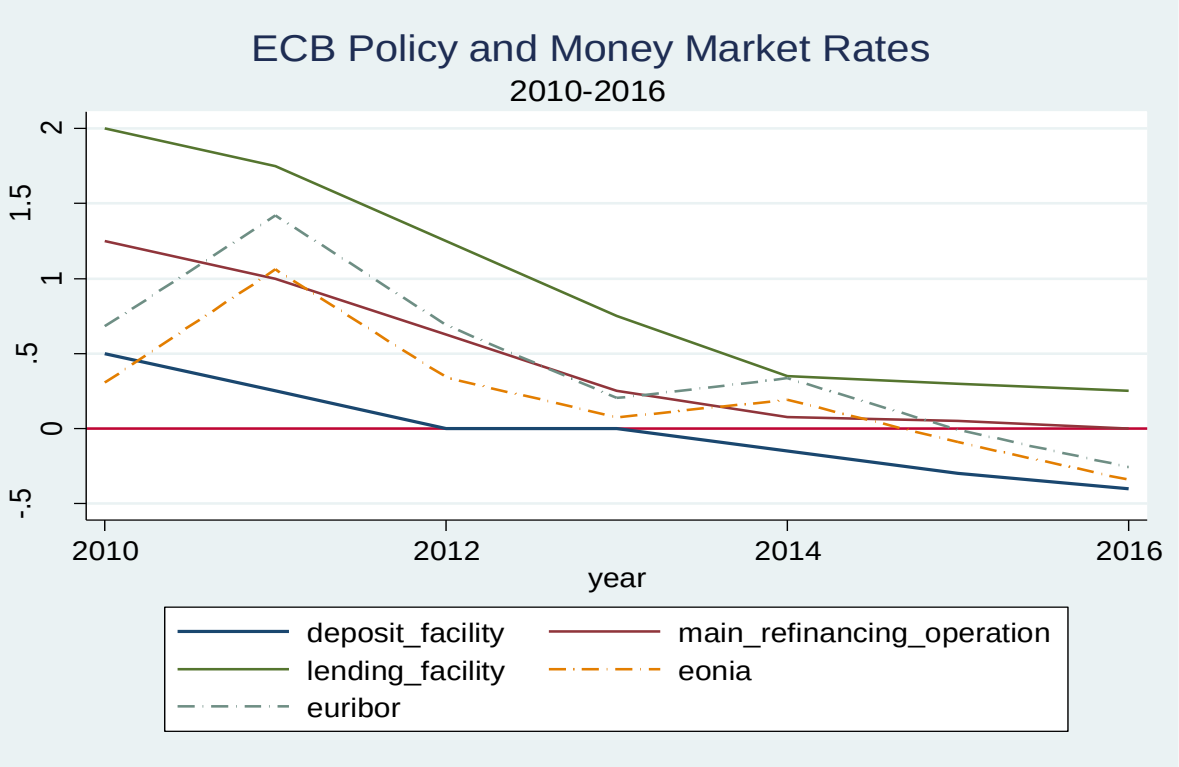


Notes: Figure 1.4 shows the Gross Domestic Product (GDP) for those countries affected by NIRP. As shown, the Euro area is by far the largest economy in the sample followed by Japan (JPN), Switzerland (CHE), Sweden (SWE), Norway (NOR), Denmark (DNK) and Hungary (HUN).

In June 2014, the European Central Bank (ECB) became one of the first central banks to move the deposit facility rate into negative territory – or the interest rate paid on excess reserves (IOER). The ECB reduced the deposit facility rate by -0.10 basis points in response to subdued inflation figures and weak economic prospects. The ECB operated further reductions in September 2014 cutting the deposit rate facility by -0.20 basis points, in December 2015 (-0.30 basis points) and in March 2016 (-0.40 basis points).

The ECB uses an interest rate corridor framework to implement its monetary policy strategy. The Governing Council of the ECB sets three official interest rates during the eight yearly meetings that are planned to determine the monetary policy stance. These three official interest rates are: the main refinancing operation (MRO) rate, the deposit facility rate and the marginal lending rate. The main refinancing operation as well as the lending facility follow the reduction of the deposit facility. As shown by Figure 1.5, money market rates (Eonia and Euribor) are always very close to the MRO rate and entered into negative territory after the introduction of NIRP.

Figure 1.5. European Central Bank Policy Rate and Money Market Rates: 2010-2016

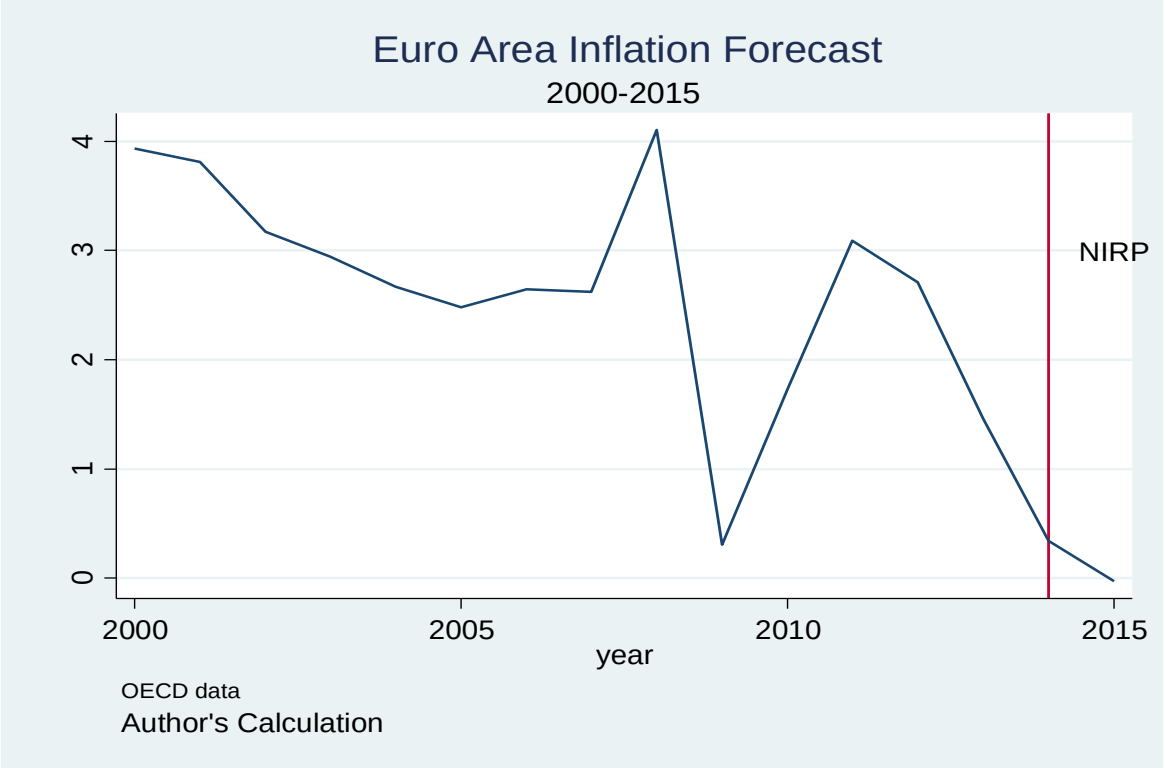


Notes: Figure 1.5 shows policy rates and money markets rate in the euro area over 2010 – 2016. The blue line represents the deposit facility rate that it is the lower limit of the corridor set by the ECB and turn negative in June 2014. The red line indicates the main refining operations rate of the ECB. The green line shows the trend of the lending facility rate that is the upper limit of the corridor set by the ECB. The two dashed lines display the Euribor (dashed line in light blue) and the Eonia (dashed line in orange). The red horizontal line separates positive from negative interest rates.

Arguably, inflation expectations and constantly weak aggregate demand and divergent output gap are the main reasons underlining the introduction of NIRP. After the GFC, the ECB has struggled to keep the inflation rate in-line with the target of 2% (figure 1.6). Moreover, the European Debt Crisis led to further aggregate demand contraction and the prospect of deflation.

These problems pushed the ECB to introduce, in addition to other unconventional monetary tools such as quantitative easing (QE) and targeted long-term refinancing operations (TLTROs), negative interest rates to provide additional monetary accommodation. Contrarily to other central banks that implemented negative interest rates, the ECB did not adopt a tiered-rate system for central bank deposits.[6] Instead, it charges a premium equal to 0.4% of bank excess reserves when depositing overnight at central banks in the Eurosystem.

Figure 1.6. Euro Area Inflation Forecast over 2000 - 2015



Notes: Figure 1.6 shows inflation forecasts for the euro area over 2000 – 2015. The vertical red line indicates the NIRP introduction.

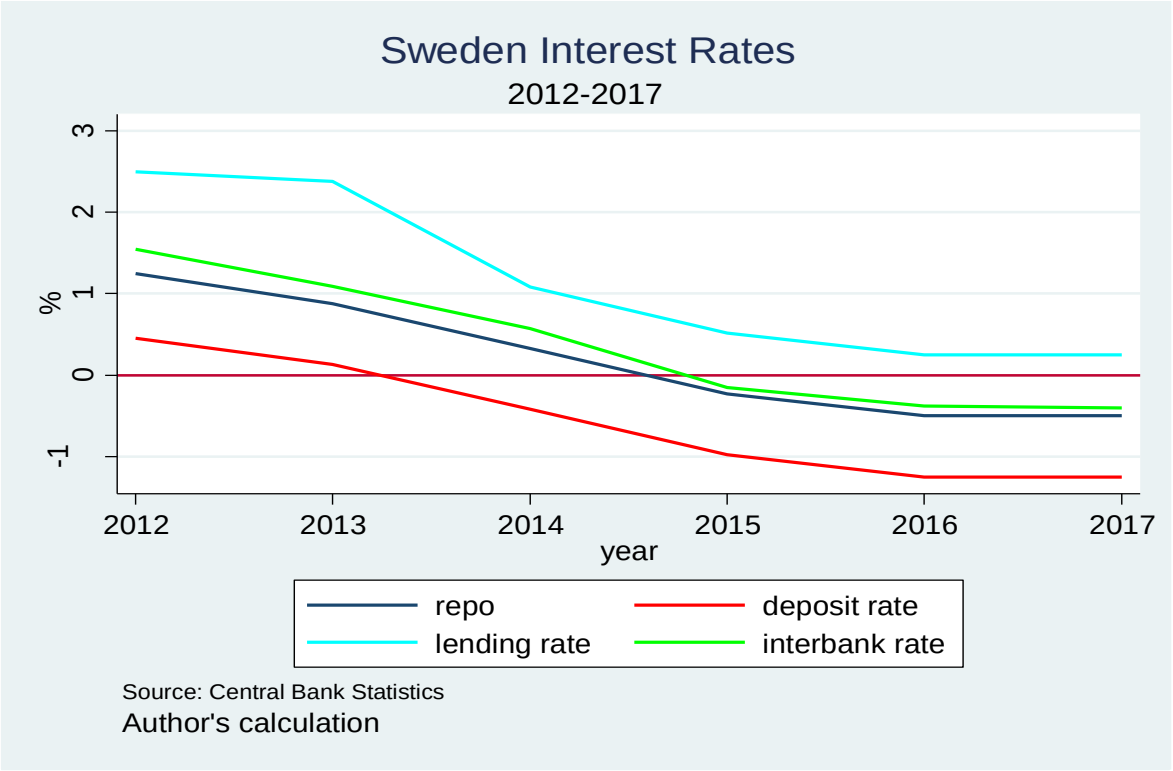
1.2.3 Sweden

The Swedish central bank (Sveriges Riksbank) implemented negative interest rates well before other central banks. The deposit rate was negative for an extended period of time from July 2009 to August 2010. The Sveriges Riksbank reintroduced negative interest rates in July 2014 to fight against deflationary pressure. Despite the NIRP introduction, the interbank market rate remained positive as in Sweden money market rates track the repo rate. Hence, in October 2014, Sveriges Risksbank cut the repo rate to zero as uncertainty about the global economy

[6] The tiered reserve system was introduced only in 2019.

heightened and inflation was far from target. Weak economic conditions led Sveriges Riksbank to cut the repo rate further in February 2015 and was also accompanied by different UMP measures such as a large-scale government debt purchase program. As shown in Figure 1.7 the interbank market rate closely tracked the repo rates entering in negative territory.

Figure 1.7. Swedish interest and money market rates over 2012 - 2017



Notes: Figure 1.7 shows policy and market rates in Sweden. The light blue line indicates the lending rate of the Riksbank which represents the upper limit of the corridor used to set the interest rate level. The red line is the deposit rates which indicates the lower limit of the corridor. The interbank rate and the repo rate are represented by the green and blue line, respectively. The red horizontal line separates positive from negative interest rates.

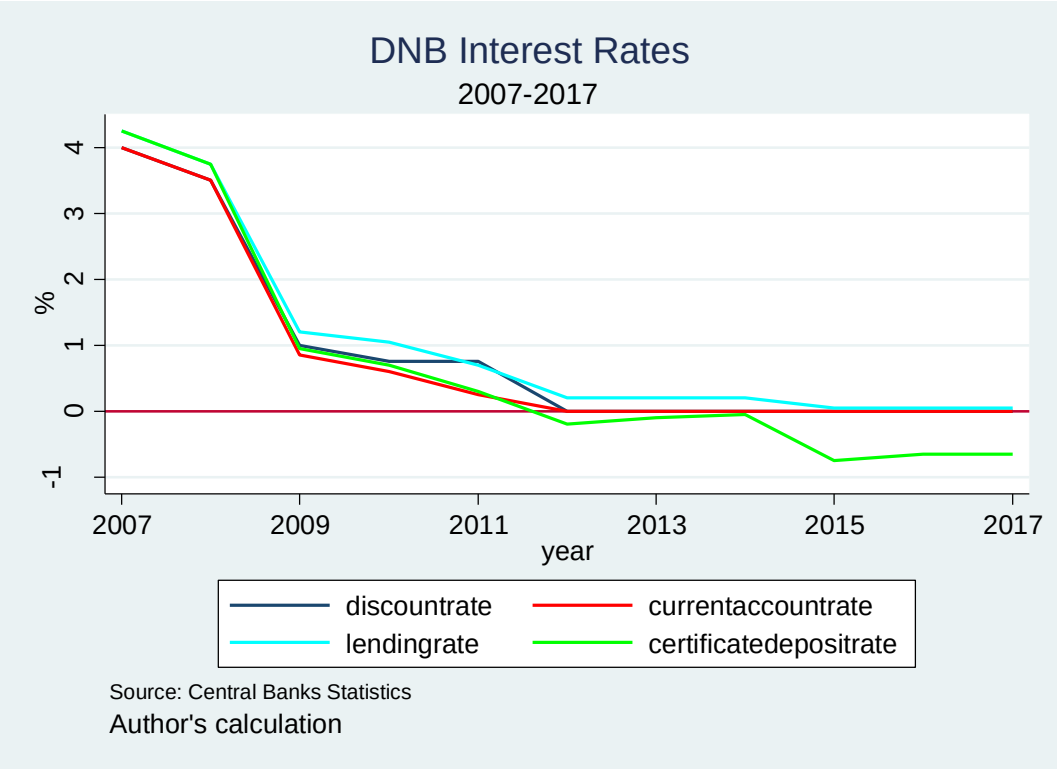
The Swedish central bank does not split commercial bank excess reserves into different tiers in order to manage the average interest rate on reserves but rather it conducts daily open market operations to drain excess reserves and replaces them with debt securities and other liabilities that have a higher yield.

1.2.3 Denmark

As in Sweden, Denmark had already adopted negative interest rates on certificate of deposits from July 2012 to March 2014 (Figure 1.8). For Denmark, the introduction of NIRP was motivated by exchange rate appreciation pressures rather than low inflation expectations as the

Danish krone was pegged to the Euro. The introduction of negative interest rates by the ECB led to an outflow of capital from the euro area and a consequent inflow of capital to Denmark. Thus, currency appreciated and the Danish central bank cut its certificate of deposits into negative territory on 5 September 2014. After the introduction of negative interest rates on certificate of deposits, the interbank rate turned negative together with the 1-month Copenhagen Interbank Offered Rate (CIBOR). Although the Danish central bank cut the certificate of deposit rate into negative territory in 2012, it was only in 2015 that the interbank rate turned negative. This is due to the fact that the interbank market is thin and complicates the monetary policy transmission mechanism (Andersen et al., 2015).

Figure 1.8. Denmark National Bank Interest Rates 2007-2017



Notes: Figure 1.8 shows money market and policy interest rates in Denmark over 2007 – 2017. The green line indicates the certificate of deposits rate which indicates the lower limit of the corridor set by the Danish central bank. The red line is the current account rate, whilst the blue line the discounted rate. In light blue it is displayed the lending rate which set the upper limit of the corridor. The red horizontal line separates positive from negative interest rates.

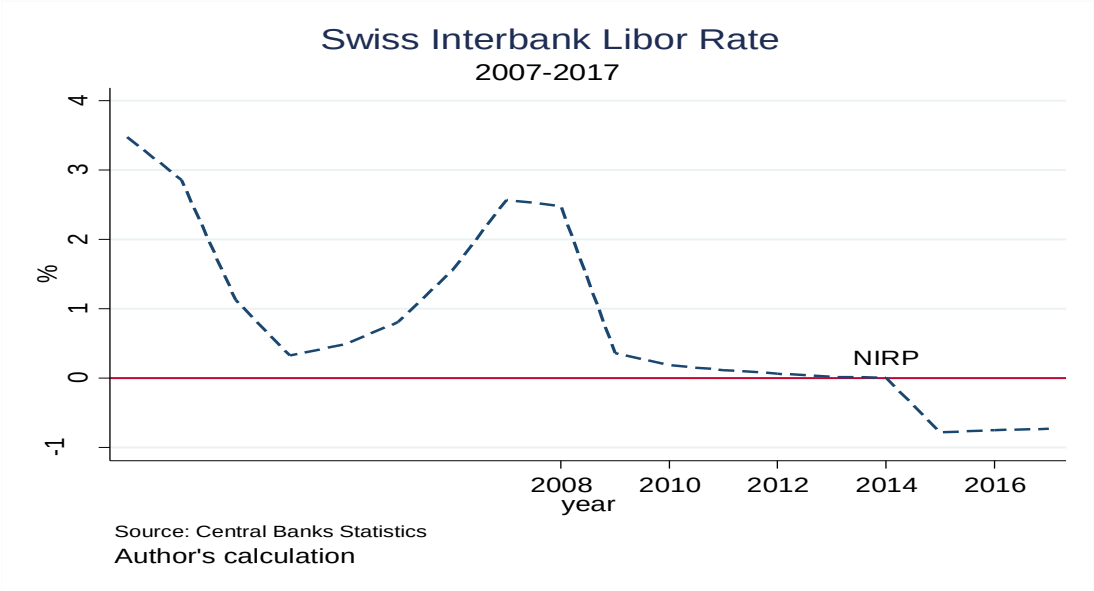
The amount of reserves that commercial banks can hold in this current accounts at the central bank is limited. When commercial banks exceed this limit, the excess is automatically converted in certificate of deposits at a negative interest rate. This particular system, in which

commercial banks can hold a limited amount of deposits at the central bank, was in place before the introduction of NIRP.

1.2.4 Switzerland

As in Denmark, the Swiss National Bank (SNB) implemented negative interest rates on 18th December 2014 to relieve pressure to the exchange rate and to maintain the peg with the Euro. The SNB lowered all of its available policy rates below zero in an effort to avoid excessive capital inflows. Contrarily to the other central banks who look at the interbank market rate, the SNB manages monetary policy by focusing on the Swiss Franc London Interbank Offered Rate (LIBOR). It establishes an upper and lower limit for the Swiss franc 3-month LIBOR and adjusts its operations (open market operations, standing facilities, repurchase agreements, SNB bills and foreign exchange transaction/swaps) to make sure that the market rate lies between these limits. This system appears to make monetary policy very effective as the LIBOR market rate becomes soon turned negative after the implementation of NIRP (figure 1.9).

Figure 1.9. Swiss National Bank Interbank Libor Rate: 2007-2017



Notes: Figure 1.9 shows the Interbank Libor Rate in Switzerland over 2007 – 2017. The blue dashed line indicates the Libor rate. The red horizontal line separates positive from negative interest rates.

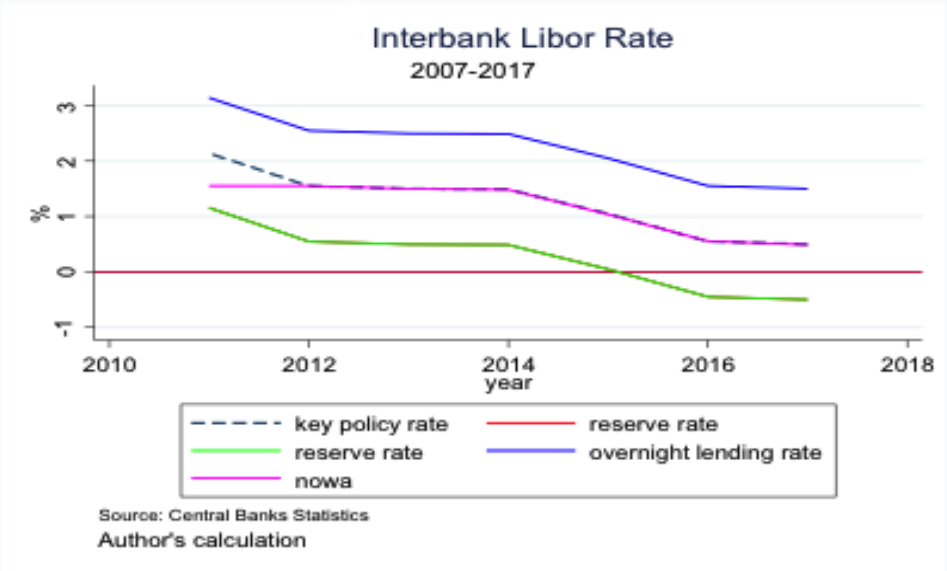
Given the concern over bank behaviour and the possible negative effect of negative interest rates on profitability, the SNB adopted a tiered reserve system where NIRP applies just for

those banks that hold excess reserves above a specific threshold. With this system, some banks were able to get wholesale funds at negative rates and place it with the SNB at zero. Although the negative interest rate applied by the SNB is markedly low (-75 basis points), the average rate is relatively high when compared to other NIRP-users. This is mostly related to the particular tiered reserves system put in place by the SNB that excludes 75% of excess reserves.

1.2.5 Norway

Contrarily to the majority of NIRP countries, that introduced NIRP in 2014, Norway adopted NIRP in September 2015 in response to concerns related to price stability (Jobst and Lin., 2016). The Norges Bank (NB) applied NIRP on its reserve rate that is the rate paid by the NB on excess reserves held by banks in Norway and it represents the lower limit of the corridor set by the NB (the D-loan rate or lending rate represents the upper limit of the corridor). Despite the introduction of NIRP, the NOWA (Norway's interbank overnight rate) did not go negative. This can be explained mostly by two factors. First, in Norway the interbank rate closely tracks the NB's policy rate at the centre of the interest rate corridor (Figure 1.10). Second and similar to other countries that adopted negative rates, the NB uses a tiered reserves system. The NB does pay a positive interest rate if commercial banks do not exceed a specific amount of excess reserves. It charges excess reserves only if excess reserves exceed a determined quota threshold. This has led the interbank overnight rate to remain close to the non-negative policy rate.

Figure 1.10. Norway Interbank Libor Rate: 2007-2017



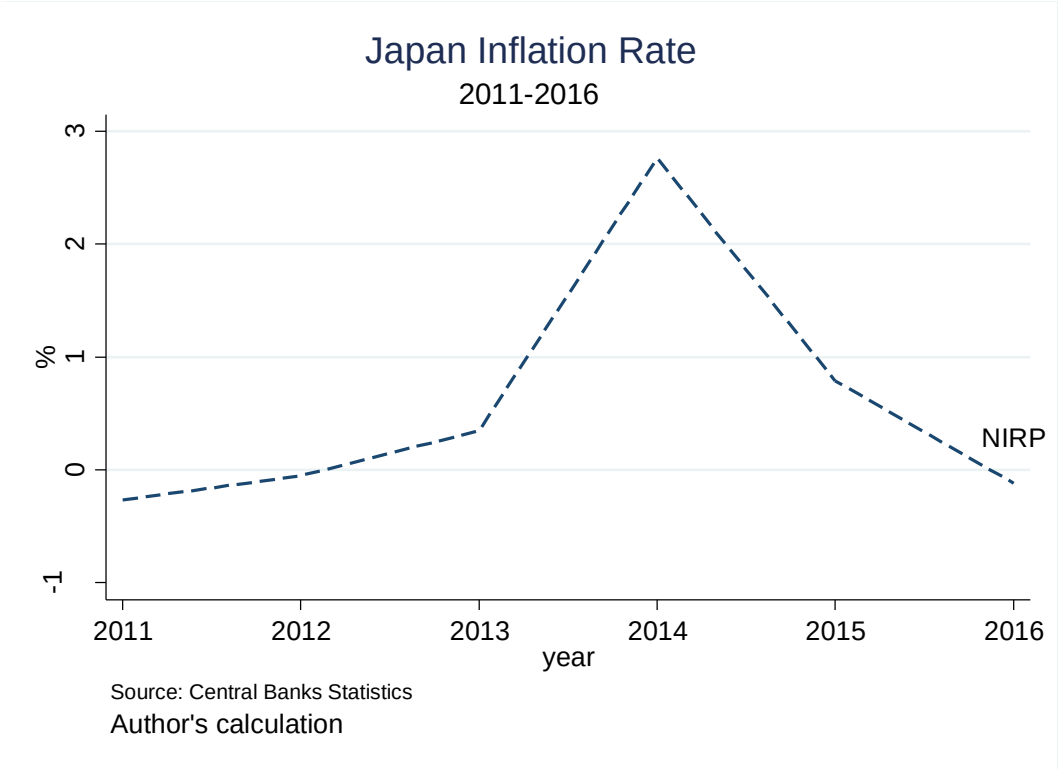
Notes: Figure 1.10 shows the Interbank Libor Rate in Norway over 2007 – 2017. The blue line indicates the overnight lending rate. The blue dashed line refers to the key policy rate. The purple line represents Norway's interbank overnight rate. The green line is the reserve rate. The red horizontal line separates positive from negative interest rates.

1.2.6 Japan[7]

The Bank of Japan (BoJ) adopted NIRP on 29th of January 2016. Its main aims were providing additional monetary policy stimulus and to fight against deflationary spirals (Figure 1.11).

Figure 1.11. Japan Inflation Rate: 2011-2016

[7] Although I do not include Japan in the empirical studies since it introduced NIRP only at the end of 2016. This provides too short of a period (lack of data) for the analysis. I include the historical explanation of NIRP adoption for information and completeness.



Notes: Figure 1.11 shows the Japan Inflation Rate over 2011-2016. The dashed blue line represents the inflation rate.

The BoJ set negative interest rates on its complementary deposit facility. After one month (February 2016), Japan's interbank overnight rate (also called uncollateralised overnight call rate) entered into negative territory. The complementary deposit rate sets the lower bound of the policy rate corridor, whereas the complementary lending rate the upper bound.

As for most of the central banks described, BoJ implemented a tiered reserve system divided in three tiers, each subjected to a different rate of interest. The first is remunerated at a positive rate of 0.1%. The second tier applies a 0% interest rate. Finally, the tier 3 is subjected to a negative interest rate of -0.1. The impact of NIRP on profitability has been the major concern of BoJ. Net interest margins experienced a severe compression as lending rates strongly declined after the NIRP introduction.

CHAPTER 2: Bank Margins and Profits in a World of Negative Rates[8]

Introduction

In this chapter, I will focus on the impact of the negative interest rate policy (NIRP) on bank profitability and margins. Specifically, by investigating the influence of negative interest rate policy (NIRP) on bank margins and profitability, this chapter identifies country- and bank-specific characteristics that amplify or weaken the effect of NIRP on bank performance. Using a dataset comprising 7,359 banks from 33 OECD member countries over 2012-2016 and a difference-in-differences methodology, I find that bank margins and profits fell in NIRP-adopter countries compared to countries that did not adopt the policy. Moreover, this adverse NIRP effect depends on bank-specific characteristics such as size, funding structure, business model, assets repricing and product-line specialization. The effectiveness of the pass-through mechanism of NIRP can also be affected by the characteristics of a country's banking system, namely, the level of competition and the prevalence of fixed/floating lending rates. The chapter proceeds as follow. Section 2.1 presents an overview of bank margins and profits in a world of negative rates. Section 2.2 reviews the relevant academic literature. Section 2.3 introduces my data and methodology. Section 2.4 presents the results along with several robustness checks and Section 2.5 concludes.

JEL: E43, E44, E52, G21, F34

Keywords: Negative interest rates, bank profitability, NIMs, difference-in-differences estimation, Propensity-Score-Matching

[8] This chapter, co-authored with Philip Molyneux and Ru Xie, has been published as journal article. Reference: "Bank Margins and Profits in a World of Negative Rates", *Journal of Banking and Finance*, 107, 105613.

2.1 Overview

Since the GFC, policy-makers have been facing a challenging economic situation dominated by economic stagnation, high unemployment and deflation. As an immediate monetary policy response, central banks cut interest rates aggressively through conventional accommodative monetary policies. However, when interest rates approached the zero lower bound (ZLB) without producing the hoped-for effects on nominal spending and inflation, many central banks implemented a range of unconventional monetary policies (UMPs) including large scale asset purchase (LSAPs) in the form of quantitative easing, as well as policy rate forward guidance. UMP took a step further from 2012 onwards when several countries/regions (Denmark, the Euro Area, Hungary, Norway, Sweden, Switzerland and Japan) implemented negative interest rate policy (NIRP) in order to provide further economic stimulus to constantly weak economies (the time of introduction of NIRP is noted in Table 2.1).

The aim of NIRP is to increase the cost to banks of holding excess reserves at the central bank encouraging banks to take reserves back on the balance sheet (Coeuré, 2016). This should lead to beneficial outcomes for the real economy coming mostly from a greater supply and/or demand for loans due to the decline in funding costs for both banks and borrowers. Nevertheless, going beyond the barrier determined by the ZLB and pushing rates into "uncharted" negative territory deserves serious consideration and analyses. In this regard, the "how low for how long" question has raised concerns about the long-term effect of this policy on financial intermediaries' performance and on the economy as a whole (McAndrews, 2015).

Since interest rates affect both the asset and the liability sides of banks' balance sheet, the effect of NIRP on bank performance is ambiguous (Riksbank, 2016). A cut in interest rates into negative territory may increase bank profitability if: a) there is significant loan growth and margins are not reduced, b) banks boost fee and commission income, c) they hold a sizeable amount of fixed-income securities, d) banks also reduce non-interest expenses, or/and e) negative interest rates improve borrowers' creditworthiness reducing loan-loss provisions. On the other hand, if banks are unable to reduce deposit rates to the same extent as loan rates then margins will be compressed, and if there are limited opportunities to boost non-interest income then profits will likely fall. This will depend also on bank-specific characteristics (size, funding structure, business model, asset repricing and product-line specialisation) as well as the

characteristics of a country's banking sector (degree of competition, prevalence of fixed /floating lending rates)). Banks that rely on wholesale funding may benefit from NIRP in terms of cheaper funding costs compared to those that depend mainly on retail deposits where rates are 'sticky' downward. Similarly, banks with a business model focused on non-interest income (so-called more services oriented) may be less affected by NIRP than banks focusing mostly on traditional intermediation activities. Large banks that have greater international reach, potential to increase lending abroad and more diversified portfolios are better equipped to hedge against interest rate risk and to switch to non-interest focused business models when margins are squeezed. Finally, banks with specific product-line specialisation (such as mortgage lenders) are more likely to be strongly affected by NIRP. Country features such as the degree of banking sector competition, the prevalence of fixed/floating lending rates, as well as a country's current account surplus may also play an important role. Higher bank competition level and fixed lending rates can amplify the contraction of NIMs, and banks operating in countries with sufficient surpluses are likely to hold larger excess reserves subject to NIRP.

The aforementioned factors are essential for the evaluation of NIRP by policy-makers as the pass-through effect of NIRP on bank performance can have profound policy implications in terms of both monetary transmission and financial stability. If NIRP results in a decline in profits, this can erode bank capital bases through a reduction in retained earnings. In turn, this can further limit credit growth stifling NIRP monetary transmission. Low profitability may also raise financial instability concerns especially as many European banks have been struggling to maintain (respectable) levels of profitability because of the slow economic recovery, historically high levels of non-performing loans, and a post GFC and European sovereign debt crisis deleveraging phase. Banks and depositors 'move-into-cash' behaviour could also affect monetary policy transmission and financial stability. If banks hoard cash, this would undermine the effect of NIRP and, consequently, weaken the transmission mechanism. On the other hand, the risk of deposit flight will endanger financial stability by boosting liquidity risk in the banking sector.

I contribute to the existing literature, which typically focuses on low and/or more 'normal' interest rate environments, by investigating, firstly, the impact of NIRP on net interest margins (NIM; i.e. the difference between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets) and bank profitability (measured by return on assets, ROA) and, secondly, how bank- and country-specific characteristics can amplify or weaken the pass-through effect of NIRP on banks performance. Based on the Euro Area Bank Lending Survey of April of 2016, NIRP hurts bank profitability. Eighty percent of banks in the survey stated that they expected NIRP to have a negative influence on margins and profits. The result provides further motivation for this investigation into the effects of NIRP on bank performance.

To investigate the impact of NIRP on bank margins and profits I employ a bank-level database comprising 7,352 banks in 33 OECD countries over the period 2012-2016 and a difference-in-differences (DiD) methodology. The DiD methodology enables us to draw conclusions on whether NIRP has squeezed banks' NIMs and profitability in NIRP adopter countries after the implementation of negative rates. Moreover, it permits to analyse the effectiveness of the pass-through mechanism of NIRP under different macroeconomic and bank-specific environments. My results show that NIM and ROA demonstrate a strong contraction after NIRP implementation in the treated group, with, on average, a reduction of 12.64% for NIM and 6.29% for ROA. This finding holds well even when DiD is combined with propensity score matching (PSM). The results also highlight that NIM contraction reduces bank profitability, despite the case that lower rates can boost bank profit through valuation gains on fixed-income securities (direct) and a reduced cost of non-performing loans (indirect). Finally, the negative effect on profits and margins appears to have been stronger for banks that: are small; have 'interest-oriented' business models; are real estate and mortgage specialists; are well capitalised; lend within national borders; weakly hedge against interest rate risk and operate in competitive systems and where floating loan rates predominate.

2.2 Literature Review and Hypotheses Tests

This study is based on the literature that analyses the effects of interest rates on bank performance. While there is an extensive literature on the determinants of bank margins and profits that follow the pioneering work of Ho and Saunders (1981), the literature evaluating interest rates, monetary policy and bank performance is still somewhat limited. In this section, I divide the literature review in: (a) studies that focus on conventional monetary policy and 'normal' interest rate environments; (b) studies that investigate the low interest rate

environment and its impact on bank performance; (c) papers focusing on the effect of unconventional monetary policy on bank margins and profits and; (d) papers investigating the effect of NIRP on bank performance. In each sub-section, the papers follow a chronological order.

2.2.1 Conventional monetary policy and 'normal' interest rate environment

One of the first empirical paper dates back to the early 1980s, in which the switch from low to high interest rates determined by the "Volcker doctrine" raised concerns about the soundness and stability of commercial banks and saving and loans associations ("thrift" institutions) that "borrow short and lend long". In this context, Flannery (1981) suggests that policy interest rates are a concern for policy makers since they can affect commercial bank revenues, costs and profitability. However, he states that evaluating the impact of interest rates changes on bank profitability is a difficult subject as it requires a very detailed assets and liabilities duration analysis that, for the lack of data and ambiguity of asset and liability maturity, is difficult or almost impossible to implement. For instance, savings accounts and demand deposits have short-term maturities, however, it is very well established that they are "sticky" to interest rate fluctuations and usually they have "effective" longer maturities. Similarly, explicit or implicit commitments to renew existing loans may increase the average loan maturity. Another point mentioned by Flannery (1981) is that the effect of changes in interest rates is stronger for retail banks. While large banks have a large portion of assets and liabilities that are similar to market securities and fluctuate closely with other market rates, retail banks face stricter maturity mismatch. To investigate the effect of interest rates on bank profitability Flannery (1981) employs a small sample of fifteen US banks over the period 1959-78, a panel regression methodology and data taken from *Compustat*. The results indicate that, among the fifteen banks, six bank revenues are very sensitive to interest rate changes. For four banks wide interest rate modifications can affect net NIMs. However, he finds also that large U.S. banks mitigate interest rate risk via hedging, modifying assets and liabilities in order to have similar average maturities. Thirteen banks display (after hedging) no statistically significant long run impact of interest rates on net current operating earnings. Moreover, two well-hedged banks experience higher NIMs when market rates rise.

Hancock (1985) criticises Flannery's (1981) decision to estimate the effect of interest rate changes on bank profits using only the Treasury bill as market rate. In this regard, Hancock (1985) notes that bank profits depend on the pool of interest rates for assets and liabilities items

and not just on one market rate. A second criticism considers bank expenses. To evaluate a profit function, bank expenses cannot be linked only to interest rates; i.e. when interest rates rise banks liabilities become more expensive. They need to be linked also to service charges, reserve requirements, and deposit insurance premiums. To evaluate the nexus between monetary policy and bank profitability Hancock (1985) relies on a sample of eighteen New York – New Jersey member banks of the Federal Reserve District #2 over the period 1973-78. The data are from *Functional Cost Analysis* collected by the FED of New York. The econometric specification estimates a profit translog function; necessary to the computation of the marginal and average rates of return. The main results indicate that the spread between interest rates charged on loans and interest rates paid on deposits is the most important variable in the analysis. Banks whose interest rates on loans (or assets in general) are more sensitive than interest rates on deposits (or liabilities in general) gain from an increase in the level of interest rates. Again maturity analysis as well as assets interest rates fixation appear to be the key factors for the evaluation of the impact of interest rate on bank profits.

Bank-specific characteristics appear also to be key factors that enable banks to hedge against interest rate risk avoiding excessive NIMs and profits volatility in 'normal' operating environments. In this regard, Angbazo (1997) investigates the determinants of net interest margins in the U.S. over 1989-1993. He argues that NIM is a function of asset quality, capitalisation, liquidity risk, interest rate risk, management quality and other factors. To investigate this relationship Angbazo (1997) regresses several measure of margins on bank-specific factors. Specifically, as dependent variables he employs: net interest margins-to-average earning assets, (both before and after loan loss provisions) and spread to average earning assets. As measures of asset quality, he includes: net charge-off-to-average loans, loan loss provisions-to-average loans, allowances for loan losses-to-average loans and non-performing assets-to-total assets. As a measure of capitalisation: core capital-to-total assets, risk adjusted capital ratio, core capital-to-risk weighted assets. Liquidity includes liquid assets-to-total liabilities, liquid assets minus liquid liabilities-to-total assets and purchased funds (repos and federal funds) -to-total assets. Management quality is captured by earning assets-to-total assets while interest rate risk is net short-term assets-to-book value of equity.[9] Finally,

[9] The interest rate risk measure is computed in line with Flannery and James (1984). Specifically, it is computed as: [net federal funds sold + trading account securities + securities maturing in less than one year + loans and leases maturing in less than one year + customers liabilities to the bank for outstanding acceptance] – [domestic and foreign deposits less than $100,000 and certificate of deposits in excess of $100,000 maturing in less than one year + other borrowed money + the banks' liabilities on customers' acceptance outstanding].

among the other factors he considers: total assets, total equity capital, non-interest bearing assets-to-total assets and implicit interest payments-to-total assets. Angbazo (1997) argues that: (a) banks with deteriorated asset quality require higher margins to compensate for the higher probability of default; (b) the higher is the level of short-term assets the lower is the interest rate risk; (c) the higher is a bank's liquidity position the lower is the liquidity premium and consequently the lower will be net interest NIM; (d) a higher cost of capital may require banks to charge higher margins to customers as banks capital is more expensive than debt; (e) implicit interest payments are associated with higher margins; (f) a higher opportunity cost of excess reserves is reflected into higher NIMs as reserves could be employed for profitable investment opportunities and; (g) high quality management translates into higher NIM. Angbazo (1997) also investigates the determinants of NIMs splitting the sample according to bank size and dividing banks into: super-regional banks (>$25 billion in assets), regional banks ($10-$25 billion in assets) and local banks ($1-$10 billion in assets). Angbazo (1997) shows that the aforementioned determinants have a stronger effect on NIMs for local/small banks rather than for regional and super-regional/large banks. He concludes that size is another important determinant of NIM and that large U.S. banks with assets size greater than $1 billion have net interest income that is not sensitive to interest risk volatility, while the opposite is found for small regional banks.

Demirgüç-Kunt and Huizinga (1999) employ a large sample of countries (80 countries) over the period 1988-95 that leads to about 7,900 individual commercial bank observations. Arguably, the availability of this large amount of data was made possible by new and sophisticated databases such as BankScope (used in this thesis). Demirgüç-Kunt and Huizinga (1999) were among the first to investigate the effect of real interest rates on bank margins and profitability. Contrarily to the previous two studies mentioned, they motivate in detail the decision to include *ex-post* spread (or *ex-post* interest income) and bank before-tax assets (BTP) divided by total assets as dependent variables. Regarding the *ex-post* spread measure, the authors suggest that there are two ways to calculate NIM, i.e. by using *ex-ante* or *ex-post* spread. Ex-ante spread is given by the difference between the contractual rates charged on loans and rates paid on deposits. Ex-post spread is instead given by the difference between interest income and interest expenses. The decision to use the latter rather than the former relies upon: a) by including the amount of loan defaults, the ex-post measure controls for the fact that banks with high-yield, risky credits can have higher margins due to high credit risk in the loans portfolio; b) ex-ante spread data are inconsistent as they are generally available at the aggregate

industry level and are put together from a variety of sources. Regarding the BTP measure, the authors prefer to include BTP to total assets ratio rather than BTP to total equity ratio to make fair comparison between developing and developed countries. In fact, in developing countries banks operate with extremely low equity capital, hence they tend to have inflated return on equity. To estimate the determinants of NIMs and BTP-to-total assets ratio, Demirgüç-Kunt and Huizinga (1999) employ a weighted least squares estimation technique that corrects the large volatility in the number of banks across countries. They also include country and year fixed effects in order to control for time-invariant and time-variant factors. Contrarily to the aforementioned studies, they include a large variety of determinants such as bank characteristics, macroeconomic conditions, institutional and market variables. As bank characteristics they include size, equity-to-total assets ratio, non-interest earning assets-to-total assets, loans divided-to-total asset, customer and short-term funding-to-total assets, overhead-to-total assets and foreign or domestic ownership.[10] As macroeconomic indicator they employ: GDP per capita, the growth rate of real per capita GDP, the percentage change in the GDP deflator (inflation) and real interest rate.[11] The authors also include two sets of financial structure variables. The first set considers a measure of market concentration, the number of banks, total assets as indicators of both market structure and scale economies. The second set comprises bank assets-to-GDP ratio to take into account banks market power, stock market capitalisation-to-GDP ratio and bank credit-to-GDP. Other explanatory variables that are included in the regression model are taxation, deposit insurance. Taxation is divided into: direct taxes (income taxes) and indirect taxes (reserve requirements). The deposit insurance variable is a dummy that takes value 1 if a country has a deposit insurance regime, 0 otherwise The results show: a) a positive relationship between equity-to-total assets and bank profitability; b) a negative (positive) relationship between loans-to-total assets and profitability (NIM); c) overhead cost-to-total assets is positively related to NIM suggesting that banks pass overhead expenditure to depositors and borrowers. In the profitability regression, overhead costs-to-total assets exhibits negative sign indicating that higher overheads lead to lower bank profit. d) The dummy variable foreign has a positive coefficient. It shows that foreign banks realise higher profits and apply higher margins. Among the macroeconomic variables inflation is positively related to both NIM and profitability and the real interest rate enters in the regression positively for both NIM and BTP-to-total assets. Reserve requirement results are important in two

[10] They consider a bank to be foreign-owned if 50% or more of its shares are owned by foreign residents.
[11] The real interest rate is constructed by using mainly short-term government debt yield.

respects. First, it displays a negative coefficient demonstrating that under-remunerated reserves lower NIM and profits.[12] Second, it shows that banks cannot fully pass the cost of reserves onto bank customers. On the contrary, the positive coefficient of income taxes suggest that banks are able to pass income taxes to bank customers. The deposit insurance variable affects NIM negatively as banks may decide to lend money cheaply. This can compress margins. Among the financial structure variables, bank concentration is positively related to bank profits while bank size has a positive impact on NIM. These results suggest the importance of market power as a determinant of NIM and profitability. The ratio of bank assets-to-GDP negatively affects margins and profits indicating that intense competition among banks cause profits and margins to shrink.

English (2002) analyses the impact of interest rate on NIM from a different perspective. While Demirgüç-Kunt and Huizinga (1999) focus on the main determinants of bank margins, English (2002) dedicates more attention to risks faced by banks when changes in the level of interest rates lead to drastic changes in NIM. The secondary banking crisis in the United Kingdom during the 1970s as well as the well-known Saving and Loan crisis (S&L crisis) in the U.S. during the 1980s are good examples of how rapid interest rate changes can threaten the stability of the banking sector. For instance, during the S&L crisis, bank net interest was negative for two consecutive years for the majority of thrift institutions. Interest rate changes can affect bank interest rate risk in two ways. First, they change the value of bank assets, liabilities and off-balance sheet positions. This in turn affects the economic value of the bank. Secondly, they modify bank future cash flows that can lead to liquidity problems. Consistent with Flannery (1981), English (2002) points out the difficulties to evaluate properly bank interest rate risk. The lack of granular data constrains a perfect identification of bank interest rate risk and researchers have to rely on approximations to estimate the casual impact of interest rate levels on bank risk. Moreover, interest rate risk can come from different sources such as, repricing risk, yield curve risk and basis risk. Repricing risk arises when average yield of bank assets and average yield of liabilities have different sensitivities to changes in market interest rates. For instance, banks can have fixed rate assets and liabilities with different maturities or/and floating rate assets and liabilities with different repricing periods that are linked to diverse market rates (assets linked to long-term market rates and liabilities linked to short-term interest

[12] Reserves are defined as under-remunerated because they pay low or zero interests, hence banks face an opportunity cost that is represented by the other opportunities they lose in order to comply with reserve requirements.

rates). Moreover, the speed of re-pricing of assets and liabilities depends also on country- and banking-sector specific characteristics. In some countries banks can adjust loan and deposit rates at will. In others, banking competition slows price adjustments as banks fear to lose their customers base. Yield curve risk arises when the curvature of the yield curve affects bank assets and liabilities. For instance, a flat yield curve negatively affects those banks that lend long-term fixed rate loans financed by short-term liabilities. Basis risk involves the possibility that two base rates will diverge unexpectedly due to different credit risk or liquidity characteristics. Another important point mentioned by English (2002) that has, so far, not received due attention regards the impact of interest rate changes on bank non-interest income, specifically fees and commissions. For instance, lower interest rates can lead to mortgage prepayments that deplete the pool of services sold by the bank, thereby reducing its fee income. Despite these problems, English (2002) uses a rather simplistic approach. English (2002) studies the link between interest rate risk exposure and bank margins using aggregate data of ten OECD countries over the period 1979-1999 and an error correction model. The results provide mixed conclusions. First, in countries like Australia and the United Kingdom there is no evidence of a relationship between the slope of the yield curve or changes in short-term interest rates and NIMs. Second, the expected positive relationship between yield curve and NIM is confirmed only for U.S. Third, the slope of the yield curve is negatively related to NIMs in Germany, Sweden, Norway and Switzerland indicating that those countries do not benefit from a steeper yield curve in terms of higher margin. English (2002) explains these unexpected results by suggesting that during the 1990s the yield curve was relatively steep but bank margins narrowed as a result of increasing competition, changes in technology and regulations.

Specialness, asset composition and size are found to be important by Hanweck and Ryu (2005) who investigate U.S. commercial banks sector with quarterly data over 1986-2003. Contrarily to Angbazo (1997) which as aforementioned identifies a positive relationship between credit risk and NIM, Henweck and Ryu (2005) indicate a possible negative relationship. This depends primarily on two reasons. First, when bank credit risk rises, risk-adverse managers could shift their funds to less risky borrowers charging them lower rates in an attempt to recover previous credit losses. Second, supervisors require banks with high deteriorated asset quality to decrease their credit risk exposure. This pushes banks to shift to lower yielding assets contracting NIM. To investigate whether interest rate changes have a diverse effect on NIMs depending upon bank-specific characteristics, Hanweck and Ryu (2005) divide the sample by bank specialisation into twelve groups (international banks, large non-international banks with assets

over $10 billion, agricultural banks, credit card banks, commercial and industrial loan specialists, commercial real estate specialists, commercial loan specialists, mortgage specialists, consumer loans specialists, other small specialists with assets of $1 billion or less, non-specialist banks with assets of $1 billion or less and non-specialist banks with assets of $1 billion or less). They find that international banks and credit card specialists have balance sheets that are less sensitive to interest rate risk. Contrarily, agricultural banks, mortgage specialists, small commercial loan specialists and small banks are sensitive to interest rate and term structure changes.

Similarly to English (2002), Albertazzi and Gambacorta (2009) use data of ten OECD countries (Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, United Kingdom and United States) over 1981-2003 and aggregate income statement and balance sheet data taken from the OECD database. Differently from English (2002), Albertazzi and Gambacorta (2009) investigate the effect of changes in profitability, measured as net interest income, non-interest income, operating expenses, provision, profits before taxes and return on equity following business cycle fluctuations. Moreover, they employ a Generalised Method of Moment (GMM) in the form of Arellano and Bond (1991) that is more efficient, consistent and allows to control for endogeneity problems due to the simultaneity of balance sheet and income statement data. Albertazzi and Gambacorta (2009) specify the econometric equation by regressing the aforementioned dependent variables on a wide set of country explanatory variables to evaluate their impact on bank profitability. Specifically, they include the lag of the dependent variable (possible inclusion in dynamic panels), the level of real gross domestic product, the rate of inflation, money market rate, long-term government bond interest rate, stock market capitalisation-to-GDP, total amount of loans-to-GDP, stock market volatility and the overall amount of banking sector total assets. The results suggest that the main drivers of net interest income are GDP, long-run interest rate, credit-to-GDP ratio, stock market capitalisation and market volatility. Specifically, a 1% increase in GDP leads to a 0.6% increase in net interest income, a 1% increase in long-run interest rate increases net interest income by more than 1% in the first year and 4% in the long-term and an increase in credit-to-GDP ratio leads to an increase of net interest income of about 0.1% and 0.4% in short-run and long-run, respectively. The main macroeconomic drivers of non-interest income differ substantially from those of net interest income (as expected). GDP and short-term interest rate are, in fact, not statistically significant. Inflation is positively related to fee and commission income. Higher inflation rate increases the nominal value of assets under management. Moreover, higher

inflation rates penalise lenders, hence banks might reorient their activities from intermediation to services. Important is the coefficient of long-term interest rate who enters in the regression with negative sign indicating an inverse relationship between interest rates and bank fees and commissions. During low interest rates the search for yield is stronger, hence individuals demand more professional services from banks for portfolio management purposes. Volatility is positively related to non-interest income. Periods of high uncertainty coincide with large transaction volumes and consequently more fees for banks.

Despite the wide set of macroeconomic variables employed by Albertazzi and Gambacorta (2009), their effect on bank operating expenses appears to be weak. Only one explanatory variable, namely credit-to-GDP, displays a positive and statistically significant relationship. This suggests that banks operating in more developed financial markets sustain higher operating (personnel) costs in order to guarantee constant and complex services to their customers. Contrarily to the results of operating expenses, provisions are strongly dependent on business cycle fluctuation. GDP is negatively related to bank provisioning. This indicates that during periods of economic upturn banks put aside less reserves as they expect borrowers to be able to repay their debts. However, this effect is consistent only when high GDP coincides with low level of interest rates as demonstrated by the positive relationship between provisioning and money market rate. Arguably, higher interest rates negatively affect borrower's creditworthiness and default probability constraining banks to build up loan loss provisions. Nevertheless, the coefficient of long-term rate is negatively related to bank loan loss provisions. This effect is likely due to the fact that protracted periods of relatively high interest rates signal positive expectations about future company productivity that offsets rising firm interest expenses. As expected, also stock market volatility and uncertainty motivate banks to increase provisioning to cover potential losses in case of recessions. The results on net interest income, non-interest income, operating expenses and provisioning are summarised by the relationship between PBT and the macroeconomic variables. PTB is positively related to GDP since higher GDP has a positive impact on net interest income and provisioning. Money market interest rates have a negative on PBT; banks put aside more loan loss provisions when short-term interest rates are higher. On the contrary, high long-term interest rates are positively associated to bank PBT as they positively impact net interest income and provisions. Finally, stock market volatility is negatively related to PBT because of the negative effect of volatility on provisions and non-interest income. Finally, in order to avoid excessive reliance on income statement variables, Albertazzi and Gambacorta (2009) extend the analysis by including profits

per unit of capital invested as dependent variable (ROE). As expected the results are in-line with PBT. On a related note, one pitfall of Albertazzi and Gambacorta (2009) is that they rely on aggregate country data, hence their study lacks the heterogeneity needed to evaluate bank performance when bank-specific variables such as, capitalisation, size, business model, liquidity etc, are considered.

2.2.2 Bank Profit and Margin in Low Interest Rate Environments

Genay and Podjasek (2014) investigate the effect of the low interest rate environment on the U.S. banks' margins and profitability over 2003Q3-2013Q2. They underline the difficulties to isolate the effect of interest rate changes on bank profits as after the GFC exogenous factors may have affected bank performance. However, they suggest NIMs and profits to be a function of short-term interest rate (T-bill) and the yield curve (spread between the ten-year Treasury note and three-month T-bill yields). Since, the macroeconomic environment plays a crucial role in shaping bank profitability they control for the growth rate of real gross domestic product (GDP), unemployment rate, house and commercial real estate prices and the Volatility Index (VIX). Moreover, since bank-specific characteristics can ease or amplify the effect of low interest rate on NIMs and profits, they divide the sample into four asset-size categories and control for banks' asset composition, funding structure and capitalisation. Their findings show that NIM is positively related to both short-term interest rates and the yield curve. Moreover, the effect is stronger for smaller rather than larger banks. Specifically, a 1 percentage point increase in short-term interest rate is associated with a 1.5 basis point increase in average NIM for smaller banks but only with a 0.3 basis points increase for larger banks. Similarly to Claessens et al. (2018), Genay and Podjasek (2014) estimate the effect of higher interest rates on banks' ROA to be small. Again, as Claessens et al. (2018), they suggest that banks have been able to insulate their profits in a low interest rate environment by altering their business model switching to higher fee income, adjusting their loan loss provisions or increasing their securities portfolio. Economic conditions appear to be more important for bank profitability. For instance, unemployment rate and house prices have three times greater effect on bank's profits and margins than interest rates.

On the other hand, Covas et al. (2015) show that, during a period of low interest rates (2010-2015), NIMs decline more markedly for large U.S banks (70 basis points against 20 for small

banks) because of two main reasons.[13] First, the decline in funding cost is more pronounced for smaller banks rather than large banks. Smaller banks experienced a greater decline in the cost of deposits which fell by about 60 basis points whilst it declines only 20 basis points for larger banks. Second, larger banks experienced a decline on the assets side and specifically on interest income earned on securities holdings. During the period of low interest rates, interest income declined to about 45 basis points for large banks and 40 for small banks.

Busch and Memmel (2015) study the German market during 'normal' and low interest rate environments over 1968-2013. The length of the time span allows them to distinguish between short- and long-term effects of the level of interest rates on NIM. They find that, during normal times and in the short-run, the level of interest rates has a strongly and statistically significant positive effect for both interest income and interest expenses which they identify to be about 0.52 and 0.55, respectively. They also note that the overall effect on NIM is negative as the magnitude of the coefficients is larger for interest expenses (0.55) than for interest income (0.52). However, in the long-run, the effect of interest rates on NIM is positive. Moreover, when they distinguish between small and large banks, they find small banks to be more sensitive to changes in interest rate than large banks. They also empirically showed that, during periods of low interest rates, the ZLB constraint on deposit products puts additional stress on bank margins.

Claessens et al. (2018), investigate the effect of the low interest rate environment on bank margins and profitability by employing a large sample of 3385 banks from 47 countries over 2005-2013. While they suggest that low interest rate can help: (a) economic recovery; and (b) enhancing bank balance sheets via capital gains and reduction of non-performing loans, persistently low interest rates may have a negative effect on bank profitability as banks are reluctant to lower deposit rates (stickiness of deposit). This in turn compresses bank NIM. If bank profitability is affected, the monetary transmission mechanism may be hampered as banks struggle to build up retained earnings and consequently capital that can be employed for lending. In such a situation, monetary transmission as well as financial stability concerns may arise. To investigate the effect of the low interest rate environment on bank margins and profits, Claessens et al. (2018) collect unconsolidated bank-level data from BankScope database and

[13] Covas et al. (2015) identify as large those banks with an assets size greater than $50 billion, vice versa for small banks.

monetary policy information from Bloomberg. Their sample includes: bank holding companies, commercial banks, saving banks and cooperative banks. As a measure capturing the low interest rate environment they employ the 3-month sovereign yield and the spread between the 10-year and the 3-month sovereign yield (a measure indicating the slope of the yield curve). To distinguish between low and high interest rate environments they include a binary variable that is equal one if the sovereign yield is equal or lower than 1.25 percent (low interest rate environment). As a dependent variable in their dynamic panel fixed effect specifications they employ: NIM, ROA, interest income margin and interest expenses margin. To control for bank-specific characteristics they use a measure of bank funding structure (deposits-to-total liabilities), capitalisation (equity-to-total assets) and liquidity (securities-to-total assets). Finally, to control for the macroeconomic environment they include the growth of gross domestic product. Bank-specific unobservable factors as well as time variant shocks over the sample period (e.g. financial crisis) are controlled with the inclusion of bank fixed and time effects, respectively. Claessens et al. (2018) find that NIMs are positively correlated to short-term interest rates. Specifically, a one percentage point increase in the short-term rate leads to 9 basis points increase in NIM. Furthermore, they find that lower interest rates have a significative higher impact on NIM than higher rates. A one percentage point decreases in short-term rates is associated with an 8 basis points reduction in NIMs if the banks operate in an high interest rate environment, whilst 20 basis point contraction if banks operate in a low interest rate environment. This compositional effect is also significant when considering the level of the yield curve. To check the validity of their results, Claessens et al. (2018) consider also two dependent variables (interest income-to-earning assets ratio and interest expenses-to-interest-bearing liabilities ratio) which are intended to capture sensitivity differences to interest rate changes between assets and liabilities. They find that the effect of interest rate is stronger for interest income rather than interest expenses. Hence, in a low interest rate environment interest income declines more markedly than interest expenses leading to a decline in NIM. They suggest that this effect is mostly due to the lower pass-through of policy and market rates to deposit rates which are sticky downward. Finally, Claessens et al. (2018) investigate whether the contraction of NIM in a low interest rate environment has a negative effect on bank profitability (measured using ROA). They show that the effect is not sizeable and, in some cases, not statistically significant. In this regard, they note that banks can in several ways offset the negative effects of low interest rates on bank profitability. For instance, in the short-run, banks can realize valuation gains from securities in the trading book. Banks can also reduce loan loss provisions as low interest rates improve borrowers' ability to repay their debts.

Moreover, low interest rates may help economies to recover improving consumption and investments. Hence, banks could improve their profitability from new lending and other financial services. Banks can also offset the negative effect on NIM by cutting costs, improving performance or by switching business model from interest to non-interest income activities via fees and commissions.

2.2.3 Unconventional Monetary Policy and Bank Performance

Empirical analysis of the influence of NIRP on bank margins and profits links to the unconventional monetary policy (UMP) literature. UMP includes Quantitative Easing (QE) (large-scale asset purchases) as well as policy guidance (aimed at managing down long-term interest rate expectations). These policies not only reduce market interest rates but expand and modify the size and composition of both central bank and commercial bank's balance sheets with likely impacts on bank margins and profits. In this regard, Lambert and Ueda (2014), using a sample of U.S banks over 2007-2012 investigate the relationship between UMPs and bank margins and profits. They employ several measures as proxies of monetary policy stance: the Taylor gap, the ratio of central bank assets-to-GDP, the length of time under which the policy rate stayed below the Taylor rule, the federal funds rate and the slope of the yield curve (computed as the difference between 10-years Treasury note and 3-months T-bill). To control for the macroeconomic environment they include: the inflation rate, the output gap, the real growth rate of GDP, the ratio of government balance-to-GDP (cyclical adjusted) and the VIX. Again and as previous studies, controlling for bank-specific characteristics is fundamental when investigating banks' profitability and margins. As such, they employ as bank controls: capitalisation (equity-to-total assets), size (the logarithm of bank total assets). Since monetary policy is not random but dictated by monetary authorities endogeneity issues may arise. To address this issue, Lambert and Ueda (2015) employ the System Generalised Method of Moments (S-GMM). They suggest that UMPs can have both positive and negative effects on bank profits. Bank can benefits from UMPs in term of lower funding costs and valuation gains that can boost profits. However, low interest rate environments (if protracted for long time) flatten the yield curve reducing revenues from floating loans, new loans and newly fixed income securities ultimately leading to a compression of NIMs. Their findings indicate that UMPs has a negative effect on NIM and ROA which is robust to different econometric specifications.

The relation between the slope of the yield curve and bank profitability has been evidenced also by Alessandri and Nelson (2015). However, while the previous studies focus on conventional monetary policies, they capture the effect of both conventional and unconventional monetary policies (UMPs). Specifically, they investigate whether the protracted period of low interest rates caused by central bank UMPs in response to the GFC has led to a reduction of bank margins and profitability. For this purpose, they employ quarterly data provided by the Bank of England for 44 active groups over the period 1992Q1 – 2009Q3. As in Albertazzi and Gambacorta (2009), Alessandri and Nelson (2015) use a GMM panel data econometric framework to avoid biases given by the inclusion of the lag of the dependent variable in an OLS or within-group estimation. Again, GMM is strongly suitable in unbalanced panel that presents data that are highly persistent and display autoregressive behaviour. However, one of the problems related to the choice of the GMM is given by length of the time series the use. These estimators have been developed for "large N and small T", meaning for large cross-section but small time series. For instance, when employed for long T, they produce unreliable coefficients, standard errors and specification tests. In order to avoid this problem, Alessandri and Nelson (2015), collapse the number of instruments as suggested by Roodman (2009). Moreover, they also employ a panel fixed effect regression as further robustness. As regressors in the econometric specification they include bank- country- and monetary policy-specific control variables. Considering the bank-specific controls they use leverage, defined as debt-to-total assets, and balance sheet growth. On the macro side, they employ 3-month government bond rate, 10-year government rate as a proxy for the yield curve, FTSE volatility, FTSE volume growth and the Herfindahl index for market concentration. Their findings suggest that over the long-run higher interest rates have an unambiguous positive effect on bank profitability and margins. Specifically, both short- and long-term interest rates are positively related to bank margins. Alessandri and Nelson (2015) argue that when interest rates fall, interest rates on loans fall quicker and banks increase provisions. This puts downward pressure on net interest margins. Since they detect an effect of monetary policy on bank margins, as a second step, they try to figure out whether or not interest rates have an effect also on bank profitability. The effect on bank profits is less clear as banks can use different strategies to face a reduction of margins. According to Alessandri and Nelson (2015), one possible strategy is to reduce interest rate risk exposure via hedging through the trading book. They find the coefficient between trading portfolio and interest rate to be statistically significant and negatively related suggesting that banks actively hedge again interest rate risk. Finally, they assess the overall effect of interest rate on bank operating profits. Consistently with the results

found for net interest margins and trading income, they show that a steeper yield curve and higher interest rates positively affect bank profitability.

2.2.4 The Effect of NIRP on Bank Margins and Profits

The effect of NIRP is expected to be transmitted via lower money market and bank lending rates to households and corporates. As explained in Chapter 1, these lower rates impact both sides of a bank's balance sheet. When lower policy rates are transmitted to bank loan rates, they reduce the value of bank assets. Conversely, lower policy rates also reduce the cost of bank liabilities, namely, lower funding expenses. The extant empirical literature that investigates the effect of NIRP on bank margins and profitability is still limited. It generally comprises discussions on the possible effects of NIRP on bank performance and overviews of developments in key banking and other financial aggregates in the immediate pre- and post-NIRP periods. Jobst and Lin (2016) suggest that the impact of NIRP is largely determined by the effect on bank intermediation. If NIRP is transmitted to lending rates, banks experience a decline in bank profitability unless banks charge customers negative rate on deposits or increase fee and commission income on current account. However, they argue that for banks is difficult to charge negative interest rates on deposits as depositors do not face the same costs as banks to store cash. Hence, this 'move into cash' can lead to bank liquidity problems. If lending rates decline more than deposits rates and existing loans (floating-rate) re-price while deposit rates remain sticky downward, NIMs are compressed. Consequently, NIM compression leads profits to decline impairing the monetary transmission to greater lending. They find that, despite of the fact that NIRP has been effective to lower lending rates, there is limited evidence that NIRP has affected bank profitability. They suggest that the positive effect of NIRP has outweighed the cost on margins. Banks operating in countries affected by NIRP have been able to offset the negative effect of NIRP on bank margins and profits by increasing lending volumes, lowering interest expenses, reducing loan loss provisions, increasing non-interest income and improving efficiency.

Arteta et al. (2016) express concerns about the risk of NIRP in terms of financial stability for the banking sector. If interest rates are far too negative or protracted for an extended period of time, this could erode bank profitability leading to instability and excessive risk-taking. Again and as for Jobst and Lin (2016) the main concern is that banks may be unwilling to pass the cost of negative rates to depositors fearing deposit imbalances. This ultimately leads to NIM compression. Following Bernanke (2016a), they argue that modestly negative interest rates

should have no effects on those banks that rely mainly on wholesale funding, large depositors and foreign depositors. However, banks that rely primarily on retail deposits as a source of funding may suffer a compression of NIM. However, they indicate that so far NIRP had a small impact as NIRP helped banks to reduce loan loss provision and increase other sources of income (e.g. fees and commissions).

Gross (2016) shares the same concerns as the previous two studies, namely that – by compressing margins – NIRP has a negative effect on the stability of the banking sector. However, by showing lending and deposit rate trends, Gross (2016) concludes that NIRP has no effect on bank profitability as deposit rates declined as much as lending rates supporting NIM. Moreover, he also suggests that NIM is higher today than what it was during the last financial crisis as negative interest rates helped banks to reduce loan loss provisions which support NIM and profits.

Blot and Hubert (2016) support the view that NIRP has modest effect on bank profitability. Their main argument is that excess reserves are so small compared to bank balance sheets in the Euro area that the impact of NIRP should be limited. For instance, they show that the annual gross direct cost of negative rates is €4.2 billion. Moreover, they highlight a mechanism through which banks offset the negative cost of NIRP on profits. By exploit other UMPs banks sell securities to the ECB. Since UMPs increase the demand and thus the price of bonds, banks sell securities when the capital gain realised is higher than the actual cost of keeping excess reserves. The authors acknowledge that NIRP could affect bank profitability if NIRP excessively flatten the yield curve and or deposit rates do not fall as much as lending rates. However, they point that UMPs such as Targeted Longer Term Refinancing Operations (TLTROs) could have eased the negative effect of NIRP on banks' profitability.

Brunnermeier and Koby (2016) present a "reversal interest rate" hypothesis according to which there is a rate of interest at which accommodative monetary policy "reverses" its effect and becomes contractionary. This happens because of two reasons. On the one hand, when central banks cut interest rates, banks realize capital gains on fixed income securities. On the other hand, rate cut contracts bank net interest margins. Hence, the threshold of the 'reversal rate' is determined by: (a) whether banks hold long-term fixed-income assets; (b) bank capitalization, i.e. whether or not banks face capital constraints; (c) the deposit supply elasticity. If banks hold a substantial amount of fixed income securities, this will result in capital gains that can push

lower the reversal interest rate. If the banking sector is not well capitalized the reversal rate will have less room for maneuvers as capital constrained banks will soon curtail lending following a decline in their profitability. Finally, when competition is fierce, banks profitability declines faster and the reversal interest rate will be higher. Low for long interest rate will likely depress lending as they flatten the yield curve and consequently banks margins and profits.

In this chapter, I aim to provide further evidence about the relationship between NIRP and bank margins and profitability. Moreover, I investigate whether the relationship between NIRP and bank profitability is determined by various bank- and country-specific features.

2.2.5 Hypotheses Testing

As aforementioned, earlier literature did not manage to provide a clear conclusion on the relationship between NIRP and bank profitability. There are two main reasons why a negative interest rate environment differs from that characterised by low interest rates (Arseneau, 2017; Eggertsson et al. 2017; Lopez et al. 2018). First, in contrast to a positive interest rate environment, NIRP is subject to the imperfect pass-through of deposit rates as banks are reluctant to impose negative rates on depositors in fear of losing their deposit base (Jobst and Lin, 2016; Demiralp et al. 2017). Second, negative interest rates excessively flatten the yield curve lowering expectations of future economic growth. Both of these effects can amplify NIM contraction in comparison to a positive rate environment because banks cannot reduce deposit rates to the same extent as loan rates and the flattening of the yield curve compresses interest income on long-term maturity assets. In this context, I want to investigate whether negative rates significantly squeezes bank NIM and profit in NIRP countries. If negative interest rates only have limited pass-through to bank deposits rates (Eggertsson et al. 2017; Lopez et al. 2018) and lending rates closely track policy rates, then the compression of long-term maturity assets combined with downward rigidities on deposit rates will narrow margins under NIRP (Heider et al. 2019). I investigate this point in Section 2.4.1 and 2.4.2 of the paper. My first hypothesis test is as follows:

H1: NIRP has a negative impact on bank margins and profits.

The impact of NIRP on bank profitability can vary according to bank and country-specific characteristics. Given the heterogeneity of banks and countries in my sample, I test the differing effects of NIRP on net interest margins and bank profitability by conducting several sub-sample

analyses. As suggested by Bernanke (2016), the effect of NIRP on bank profitability will depend on the source of bank funding. Banks that depend on retail deposits are more vulnerable as they will find it more difficult to pass negative rates onto depositors. Large banks have more diversified portfolios, greater international reach and hedging expertise; therefore, they can mitigate the effect of NIRP on bank margins and profits by hedging against interest rate risk via derivatives and increasing non-interest income activities (Altavilla et al. 2017; Chaudron, 2018). From a business model perspective, banks with different product-line specialisation tend to exhibit varying degree of sensitivity to interest rate risk. Hence, banks such as real estate mortgage specialists, that have a higher portion of long-term assets in their portfolio and face stronger maturity mismatch risk, could suffer a more considerable contraction in profitability induced by NIRP. This will depend also on the contractual details of existing loans and, in particular, their degree of interest rate indexation. Banks that hold mostly floating interest rate loans face stronger compression of NIM (IMF, 2017). When banks are under-capitalised, the positive effect of NIRP on bank funding cost is limited as banks face difficulties in raising capital. This may have a negative effect on bank profitability if the decrease in loan rates dominates the reduction of bank funding cost. However, banks that hold capital in excess of that required by regulation face an opportunity cost and profitability pressure as excessive capital could be employed for profitable investment opportunities. Finally, competitive behaviour among banks amplifies their exposure to negative interest rates. If competition between banks is fierce, lending rates should drop, and if deposits are already low, then margins will be compressed (Brunnermeier and Koby, 2016). I test the effectiveness of the pass-through mechanism of NIRP under different bank and country-specific features in Section 2.4.3 of the paper. The second hypothesis is accordingly as follows:

H2: The effect of NIRP on bank margins and profits depends on bank- and country- specific characteristics.

2.3 Methodology and Data

2.3.1 Methodology

To capture the effect of NIRP on ROA and NIM I use a DiD methodology. This methodology has been widely used in the policy evaluation literature and more recently to banking and financial sector issues (Beck et al., 2010; Calderon and Schaeck., 2013; Berger et al., 2014; Fiordelisi et al., 2017). The advantage of this approach is that it allows for a panel data set-up, which compares a treated group of banks (those impacted by the policy change) with those that

are unaffected (the control group or untreated banks). The approach also helps to control for 'omitted variable bias'. For instance, regulatory changes (such as Basel III or the launch of the ECBs Single Supervisory Mechanism) may affect treated and untreated bank performance alike, regardless of the NIRP introduction. However, as these changes may affect banks similarly, the DiD approach avoids this bias by differencing away common trends affecting both groups. My regression model takes the following form:

$$Y_{ijt} = \alpha + \beta_1\left(Treated_{ij} * Post_{jt}\right) + \beta_2 X_{ijt} + \varphi_t + \gamma_j + \varepsilon_{ijt} \quad (2.1)$$

where Y_{ijt} is the NIM (or ROA) of bank *i* in country *j* at time *t*. $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise. $Post_{jt}$ is a dummy variable that takes the value 1 after the period that country j at time t decided to implement NIRP and 0 before that period, and β_1 represents the average difference in NIM and ROA between countries that switched to NIRP and countries that did not.[14] X_{ijt} is a vector of bank- and country-specific characteristics to capture cross-bank and cross-country heterogeneity over time that can affect NIM and ROA. Bank-specific variables are a combination of balance sheet and performance measures (see next section for a detailed explanation). I also include country specific dummies (γ_j) to control for time-invariant, unobservable characteristics that can shape NIM and ROA. I include year fixed effects (φ_t) to control for time-variant shocks over the sample period on bank NIM and ROA limiting the potential bias in estimates of β_1. All regressions are estimated with bank-level clustering, namely allowing for correlation in the error terms. I use robust standard errors to control for heteroscedasticity and dependence (see Bertrand et al, 2004; Donald and Lang, 2007; Petersen, 2009).

The inclusion of covariates in a DiD framework presents advantages but also disadvantages (Lechner, 2010). On the one hand, introducing explanatory covariates can have the positive advantage of detecting cross-bank and cross-country heterogeneity that can potentially affect bank NIM and ROA independently by the introduction of NIRP. On the other hand, the introduction of covariates can cause two main problems. First, when banks are relatively

[14] The majority of NIRP countries in my sample introduced NIRP in 2014, hence $Post_{jt}$ takes the value 1 from 2014. However, since Sweden, Norway and Switzerland introduced NIRP in 2015 for these the $Post_{jt}$ dummy is set at 2015.

homogeneous in both the treatment and control group, additional covariates can weaken, instead of strengthen, the likelihood that both groups maintain the parallel trend, hence violating my assumption. Second, time varying covariates can change or be influenced by the post-treatment period, leading to endogeneity problems. I assess this problem in three ways. First, I provide statistical tests of mean differences for bank and country covariates between the treated and the control group (Table 2.1 and Table 2.2). As displayed, the control variables are, on average, in most cases statistically different between the two groups. Second, I test the control variables for multicollinearity using the *Variance Inflation Factor* (VIF). A mean VIF of 1.07 suggests that my controls are not highly correlated (a correlation matrix is provided in Table A2 in the appendix). Second, to avoid the possibility that time varying control variables can be influenced by the intervention (the NIRP introduction), I test the control variables as dependent variables in the difference-in-differences specification. The test suggests that the control variables are not affected by the intervention.

Table 2.1. Macroeconomic and institutional variables descriptive statistics divided into the treatment and control groups (percentage values)

Country	NIRP adoption	Number of banks	GDP growth	Inflation	Unemployment	Yield curve	Credit-to-GDP	CB_GR	M0_GR	Lerner index	Loans rate	Deposits rate	Reserve	Taxation	Depth credit info	Legal rights
Treatment Group																
			0.21	2.04	4.73	1.65	128.63	0.05	5.95	0.23	3.64	1.27	2.80	4.87	5.50	4.00
Austria	Jun-14	357	(0.09)	(0.50)	(0.30)	(0.60)	(4.59)	(23.17)	(10.87)	(0.03)	(1.25)	(1.11)	(0.08)	(0.43)	(0.86)	(0.00)
			0.20	1.21	8.13	2.00	131.93	0.05	5.06	0.19	5.33	1.93	2.20	5.59	4.25	4.00
Belgium	Jun-14	72	(0.16)	(0.97)	(0.45)	(0.82)	(19.45)	(23.17)	(1.99)	(0.01)	(0.87)	(1.34)	(0.14)	(0.44)	(0.43)	(0.00)
			0.34	-0.50	4.36	0.55	175.96	14.05	23.57	0.12	3.18	0.08	4.16	4.90	5.25	6.00
Switzerland	Jan-15	422	(0.17)	(0.47)	(0.12)	(0.37)	(3.74)	(17.60)	(20.10)	(0.09)	(0.93)	(0.07)	(0.25)	(0.12)	(0.43)	(0.00)
			0.28	1.16	5.23	1.24	141.97	0.05	6.64	0.12	4.21	1.41	1.82	7.88	6.50	6.00
Germany	Jun-14	1914	(0.14)	(0.66)	(0.16)	(0.37)	(8.84)	(23.17)	(12.94)	(0.01)	(0.74)	(0.09)	(0.09)	(0.10)	(0.86)	(0.00)
	Jul-12															
	Apr-14		0.10	1.05	7.03	1.29	219.43	-8.52	3.05	0.31	5.33	1.37	4.66	4.23	4.50	8.00
Denmark	Sep-14	95	(0.15)	(0.80)	(0.36)	(0.38)	(6.54)	(14.17)	(1.16)	(0.02)	(1.40)	(1.05)	(0.43)	(0.20)	(0.86)	(0.00)
			0.56	1.46	8.80		73.61	0.05		0.18	4.21	1.24	7.12	2.07	5.50	7.00
Estonia	Jun-14	10	(0.39)	(1.86)	(1.00)		(2.60)	(23.17)		(0.00)	(1.27)	(1.22)	(0.24)	(1.43)	(0.87)	(0.00)
			0.13	0.80	25.4	3.72	218.56	0.05	-1.99	0.29	3.46	1.66	1.27	4.46	5.50	5.00
Spain	Jun-14	162	(0.63)	(1.19)	(0.66)	(1.58)	(18.85)	(23.17)	(5.81)	(0.02)	(0.92)	(1.14)	(0.18)	(0.49)	(0.86)	(0.00)
			-0.14	1.27	8.13	1.46	157.19	0.05	4.85	0.07	2.87	1.40	3.02	5.08	4.50	7.00
Finland	Jun-14	64	(0.31)	(1.08)	(0.41)	(0.43)	(9.35)	(23.17)	(1.68)	(0.00)	(0.07)	(1.25)	(0.29)	(0.41)	(0.86)	(0.00)
			0.18	0.84	10.06	1.96	146.59	0.05	2.76	0.19	3.78	2.81	1.98	8.07	4.50	4.00
France	Jun-14	410	(0.11)	(0.70)	(0.23)	(0.72)	(1.56)	(23.17)	(6.43)	(0.10)	(1.08)	(1.47)	(0.12)	(0.19)	(0.86)	(0.00)
			-0.39	-0.61	25.9	12.66	137.29	0.05	6.39	0.21	5.41	3.12	3.22	3.41	5.50	3.00
Greece	Jun-14	14	(0.50)	(1.26)	()1.27)	(6.87)	(1.41)	(23.17)	(2.66)	(0.01)	(0.78)	0.08)	(0.47)	(0.60)	(0.87)	(0.00)
			0.43	1.77	9.63	5.51	63.05	-6.46	8.99	0.13	5.46	2.72	4.53	3.86	4.25	8.66
Hungary	Mar-14	46	(0.60)	(2.37)	(1.33)	(1.63)	(3.85)	(11.87)	(5.02)	(0.00)	(1.16)	(1.22)	(0.58)	(0.35)	(0.43)	(1.89)
			2.43	0.52	13.13	3.51	166.18	0.05	5.53	0.28	3.55	2.84	2.78	5.04	5.50	7.00
Ireland	Jun-14	59	(2.68)	(0.73)	(1.26)	(2.13)	(37.69)	(23.17)	(14.13)	(0.00)	(1.07)	(1.47)	(0.23)	(1.15)	(0.86)	(0.00)
			-0.16	1.13	11.8	3.55	172.97	0.05	0.74	0.07	3.92	2.27	0.74	4.05	5.50	2.00
Italy	Jun-14	608	(0.34)	(1.19)	(0.78)	(1.36)	(2.79)	(23.17)	(5.12)	(0.01)	(1.26)	(1.02)	(0.03)	(0.68)	(0.86)	(0.00)
			0.93	1.37	5.70	1.34	194.19	0.05	8.68	0.31	3.40	1.58	3.47	6.45		3.00
Luxembourg	Jun-14	106	(0.69)	(0.88)	(0.43)	(0.59)	(6.25)	(23.17)	(5.91)	(0.01)	(1.25)	(1.40)	(0.57)	(0.16)		(0.00)
The			0.19	1.63	6.30	1.57	283.85	0.05	5.24	0.16	4.29	2.66	4.22	6.40	4.50	2.00
Netherlands	Jun-14	79	(0.29)	(0.85)	(0.71)	(0.47)	(4.52)	(23.17)	(1.82)	(0.01)	(1.33)	(1.38)	(0.04)	(0.23)	(0.86)	(0.00)
			0.39	1.75	3.36	2.23	132.93	10.00	-5.41	0.40	4.39	2.95	2.56	10.26	4.50	5.00
Norway	Sep-15	168	(0.21)	0.60)	(0.12)	(0.40)	(7.98)	(10.78)	(19.40)	(0.01)	(0.71)	(0.05)	(0.02)	(0.17)	(0.86)	(0.00)
			-0.41	0.81	15.43	5.70	182.54	0.05	4.68	0.28	4.51	2.61	1.37	5.80	5.50	2.00
Portugal	Jun-14	136	(0.64)	(1.16)	(0.94)	(3.26)	(13.39)	(23.17)	(1.49)	(0.01)	(1.27)	(0.07)	(0.07)	(0.29)	(0.86)	(0.00)

Sweden	Feb-15	111	0.65 (0.35)	0.15 (0.42)	8.06 (0.47)	1.53 (0.51)	153.33 (3.33)	11.05 (12.41)	-5.05 (2.06)	0.40 (0.01)	3.72 (1.11)	1.38 (1.14)	1.01 (0.04)	7.37 (0.36)	4.25 (0.43)	6.00 (0.00)
Slovenia	Jun-14	19	0.17 (0.59)	1.01 (1.23)	9.50 (0.57)	4.15 (1.75)	78.61 (9.84)	0.05 (23.17)	6.15 (3.16)	0.10 (0.02)	4.60 (1.09)	2.32 (1.04)	4.04 (0.51)	3.78 (1.34)	3.00 (0.71)	3.00 (0.00)
Slovakia	Jun-14	18	0.58 (0.29)	1.15 (1.57)	13.80 (0.37)	2.41 (1.10)	65.96 (4.62)	0.05 (23.17)	6.93 (5.88)	0.11 (0.01)	4.97 (0.08)	1.71 (0.09)	2.84 (0.46)	6.53 (0.74)	4.50 (0.87)	7.00 (0.00)
Total treatment		4870														
Mean treatment			0.34 (0.10)	0.96 (0.15)	10.58 (0.80)	3.10 (0.40)	152.20 (6.55)	0.57 (2.22)	5.45 (1.04)	0.20 (0.01)	4.20 (0.01)	2.04 (0.00)	3.01 (0.17)	5.26 (0.18)	4.65 (0.17)	4.98 (0.28)
Control Group																
Australia		145	0.62 (0.69)	2.05 (0.42)	5.63 (0.33)	3.51 (0.47)	162.15 (9.78)	9.96 (20.31)	-1.96 (7.00)	0.15 (0.02)	5.33 (0.79)	3.15 (0.04)	3.33 (0.06)	6.92 (0.13)	5.50 (0.86)	11.00 (0.00)
Canada		124	0.40 (0.29)	1.35 (0.40)	7.06 (0.12)	1.97 (0.30)	193.92 (8.57)	3.74 (14.63)	5.10 (0.74)	0.40 (0.02)	4.17 (0.08)	1.80 (0.09)	2.24 (0.10)	6.57 (0.23)	6.50 (0.86)	9.00 (0.00)
Chile		57	0.70 (0.32)	3.42 (1.00)	6.26 (0.18)	4.98 (0.39)	117.08 (3.43)	-4.41 (3.70)	8.73 (3.22)	0.31 (0.00)	6.39 (1.22)	3.22 (0.06)	5.02 (4.57)	3.99 (0.66)	5.00 (0.70)	4.00 (0.00)
Czech Republic		40	0.42 (0.50)	1.34 (1.20)	6.73 (0.37)	1.76 (0.80)	69.77 (1.64)	11.30 (10.93)	5.07 (1.76)	0.32 (0.00)	5.18 (1.42)	1.86 (1.06)	6.00 (1.21)	6.03 (0.18)	5.50 (0.86)	6.33 (0.94)
Great Britain		505	0.54 (0.20)	1.72 (1.10)	7.26 (0.71)	2.19 (0.29)	175.03 (12.02)	2.78 (13.54)	4.73 (0.63)	0.21 (0.00)	4.53 (1.22)	1.82 (1.11)	7.38 (0.24)	5.28 (0.60)	6.50 (0.86)	7.00 (0.00)
Iceland		36	0.74 (0.18)	0.77 (0.94)	6.43 (0.34)	6.40 (0.23)	128.95 (19.58)	3.71 (23.17)		0.21 (0.00)	4.23 (0.55)	1.26 (0.07)	13.28 (0.92)	7.97 (1.07)	5.50 (0.87)	5.00 (0.00)
Israel		16	0.71 (0.72)	3.18 (1.44)	5.53 (0.41)	3.28 (0.88)	84.35 (1.31)	-14.97 (20.96)	9.20 (2.87)	0.25 (0.01)	6.88 (0.52)	3.33 (0.01)	9.89 (0.35)	5.63 (0.59)	5.50 (0.86)	6.00 (0.00)
Korea		102	0.70 (0.12)	1.36 (0.53)	3.26 (0.17)	3.05 (0.44)	159.97 (4.35)	1.27 (4.92)	15.08 (2.23)	0.32 (0.00)	5.17 (1.38)	2.70 (0.09)	2.02 (0.28)	4.68 (0.25)	6.50 (0.86)	5.00 (0.00)
Mexico		186	0.58 (0.20)	3.66 (0.55)	4.85 (0.17)	5.80 (0.17)	49.54 (2.56)	8.05 (5.08)	11.67 (4.42)		6.68 (0.98)	3.25 (0.04)	4.64 (0.30)	5.76 (0.28)	6.50 (0.86)	8.33 (0.00)
New Zealand		36	0.63 (0.25)	0.93 (0.36)	6.23 (0.53)	3.87 (0.34)	176.10 (1.85)	-6.47 (11.48)	5.64 (1.60)	0.23 (0.00)	5.73 (1.07)	3.27 (0.03)	3.11 (0.49)	10.07 (0.44)	5.75 (1.30)	12.00 (0.00)
Poland		172	0.61 (0.43)	1.04 (1.72)	9.90 (0.51)	3.81 (0.83)	68.87 (3.50)	-0.81 (7.61)		0.34 (0.02)	5.40 (1.29)	2.72 (0.07)	2.82 (0.21)	4.40 (0.35)	6.50 (0.86)	7.00 (0.00)
Turkey		149	0.91 (0.36)	8.23 (1.31)	9.03 (0.23)		73.22 (3.87)	7.40 (11.12)	4.67 (10.26)	0.42 (0.01)	6.66 (1.02)	3.26 (0.05)	4.46 (0.08)	5.40 (0.06)	5.50 (0.86)	2.00 (0.00)
USA		921	0.51 (0.13)	1.31 (0.72)	7.26 (0.82)	2.20 (0.27)	241.88 (7.28)	14.41 (16.36)	10.46 (8.82)	0.33 (0.00)	5.40 (0.09)	1.25 (1.57)	3.95 (0.13)	8.14 (0.67)	7.00 (1.00)	11.00 (0.00)
Total control		2489														
Mean control			0.60 (0.04)	2.30 (0.28)	6.30 (0.28)	3.47 (0.21)	130.98 (7.46)	3.07 (1.80)	6.08 (1.22)	0.30 (0.01)	5.55 (0.01)	2.57 (0.01)	5.05 (0.42)	6.51 (0.26)	5.87 (0.15)	7.04 (0.44)
T-test			0.26**	1.33***	-4.27***	0.36	-21.21**	2.49	0.62	0.10***	1.31***	0.05***	2.03***	1.25***	1.21***	2.06***

NIRP-affected floating rate countries: Germany, Austria, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal, Sweden and Slovenia.

NIRP-affected fixed rate countries: Denmark, France, Hungary, Norway, the Netherlands and Slovakia,

Note: The Table displays mean and standard deviation (in parentheses) for the sample of countries divided into the treatment (Treatment group) and control groups (Control group). NIRP adoption displays the time of adoption of NIRP. Number of banks is the number of banks used in the sample by country. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the yearly level of unemployment in percentage. Yield curve is the 10-year government bond return. Credit-to-GDP is the ratio of aggregate gross loans to real GDP. CB_GR is the logarithmic yearly growth rate of central bank total assets. M0_GR is the logarithmic yearly growth rate of the money supply M0. Lerner index is the Lerner index. Loans rate is the ratio of interest on loans to total gross loans. Deposits rate is the ratio of interest expenses to total deposits. Reserve is the ratio of cash and balances at the central bank to total assets. Taxation is the ratio of taxes to operating income. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Floating-Fixed Rate is the share of variable loans in total loans to household and non-financial corporation. Floating rate countries are those that have a share of variable rate loans to total loans greater than 63% (median), and vice versa for fixed-rate countries. T-test difference in means between Mean treatment and Mean control is also reported in the Table. ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

Sources: Orbis Bank Focus; SNL financials.

Furthermore, the DiD approach requires that several assumptions hold. First, the control group must constitute a valid counterfactual for the treatment. In order to address this concern, I estimate Pearson correlation coefficients (Table A2 in the Appendix) for three macroeconomic variables (GDP growth, Inflation and Unemployment) in the treatment and control groups. The significance of coefficients suggests that the countries in the two groups experienced a similar macroeconomic environment confirming the fact that the control group constitutes a valid counterfactual scenario for the treatment.

Table 2.2 Descriptive statistics of control and treatment group prior and after NIRP

TREATMENT

	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel A: Bank Profitability and Margins										
NIM	8916	2.06%***	0.95%	0.49%	4.12%	8040	1.92%***	0.78%	0.49%	4.12%
ROA	9025	0.47%***	0.59%	0.00%	2.29%	8108	0.40%***	0.97%	0.00%	2.29%
Panel B: Bank Balance Sheet										
Size	9048	13.79***	1.59	11.51	16.58	8138	13.76***	1.58	11.51	16.58
Lending diversification	250	0.81%	0.20%	0.02%	0.69%	330	0.80%	0.20%	0.01%	0.69%
E/TA	9046	10.06%***	5.28%	4.07%	21.76%	8136	10.22%***	5.01%	4.07%	21.76%
Tier1 ratio	5158	14.70%***	4.46%	9.88	23.99	5306	16.16%***	4.54%	10.70	25.00
Liquidity	8549	21.00%***	14.00%	1.00%	46.00%	7895	21.73%	15.09%	0.07%	46.68%
Credit risk	8111	0.29%***	0.41%	0.00%	1.17%	7401	0.25%	0.42%	0.00%	1.17%
Cost-to-income	5042	71.35%***	15.11%	47.09%	95.28%	7664	72.70%***	15.00%	47.09%	95.28%
Loan growth	8131	3.58%***	6.66%	-7.27%	15.36%	7630	3.32%***	6.45%	-7.27%	15.36%
Off-balance sheet	4505	7.88%***	6.16%	1.65%	21.46%	6549	7.67%***	6.12%	1.65%	21.46%
Non-interest income	8842	35.72%***	23.45%	12.50%	87.67%	8019	37.48%	22.90%	12.50%	87.67%
Fees & Commissions	8662	0.77%***	0.60%	0.00%	2.16%	7855	0.80%***	0.59%	0.00%	2.16%
Interest income	4658	3.02%***	1.13%	1.06%	3.67%	7145	2.55%***	0.79%	1.06%	3.67%
Interest expenses	4609	1.17%***	0.64%	0.25%	1.65%	7066	0.82%***	0.43%	0.25%	1.65%

CONTROL

	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel C: Bank Profitability and Margin										
NIM	4686	2.92%***	1.71%	0.39%	6.15%	4331	2.93%***	1.65%	0.39%	6.15%
ROA	4811	1.03%***	1.00%	-0.10%	3.26%	4457	1.03%***	0.97%	-0.10%	3.26%
Panel D: Bank Balance Sheet										
Size	5008	14.33***	1.98	11.21	17.63	4650	14.36***	2.07	11.21	17.63
E/TA	5006	16.46%***	13.93%	5.47%	51.27%	4648	16.66%***	13.89%	5.47%	51.27%
Tier1 ratio	2287	15.62%***	4.28	9.88	23.99	2101	15.63%***	4.45%	9.88	23.99
Liquidity	4374	22.00%***	19.00%	1.00%	64.00%	4341	22.04%	20.13%	0.09%	64.85%
Credit risk	3760	0.33%***	0.39%	0.00%	1.21%	3504	0.26%	0.38%	0.00%	1.21%
Cost-to-income	3319	63.87%***	16.08%	37.68%	90.89%	4135	65.46%***	16.60%	37.68%	90.89%
Loan growth	3735	6.35%***	12.92%	-11.50%	31.12%	3759	8.63%***	11.99%	-11.5%	31.12%
Off-balance sheet	2040	21.98%***	22.17%	0.70%	72.46%	2472	22.16%***	22.55%	0.71%	72.46%

Non-interest income	4534	38.10%***	29.94%	5.02%	96.61%	4349	37.33%	29.63%	5.02%	96.61%
Fees & Commissions	4236	0.58%***	0.68%	0.00%	2.10%	3948	0.59%***	0.67%	0.00%	2.10%
Interest income	2456	3.45%***	1.52%	0.83%	5.79%	3137	3.25%***	1.62%	0.83%	5.79%
Interest expenses	2380	1.27%***	0.97%	0.20%	2.81%	3034	1.19%***	0.96%	0.20%	2.81%

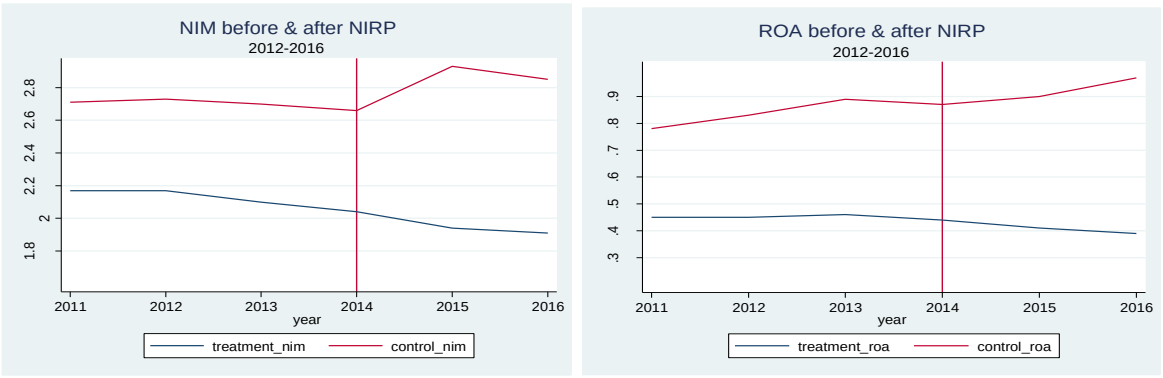
Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. Size is the natural logarithm of bank total assets. Lending diversification is the ratio of loans inside the Euro area on total loans taken for a sample of SSM supervised banks (treatment group). E/TA is the ratio of bank equity-to-total assets. Tier 1 ratio is the Tier1 ratio as reported for regulatory purposes. Liquidity is the ratio of bank liquid securities-to total assets. Credit risk is the ratio of loan loss provision to total assets. Cost-to-income is the ratio of operating expenses to operating income. Loan growth is the logarithm growth rate of gross loans. Off-balance sheet is the ratio of off-balance sheet items to total assets. Non-interest income is the ratio of non-interest income to gross revenues. Fees & commissions is the ratio of net fees and commissions to total assets. Interest income is the ratio of interest income to total assets. Interest expenses is the ratio of interest expenses on total assets. All variables have been winsorized at 1% level. T-test difference in means between Mean treatment and Mean control prior and after NIRP is also reported. ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

Furthermore, as a robustness check, I combine the difference-in-differences methodology with propensity score matching (PSM) which, by pairing each bank with a control unit, allows us to control for banks having similar characteristics.

Finally, assignment of the treatment has to be exogenous with respect to bank performance. In other words, the policy action ('intervention') should affect bank performance and not vice versa. As pointed out by Couere' (2016), Riksbank (2016) and IMF (2017) the aim of NIRP is "pushing up below-target inflation" or "responding to weak aggregate demand". Increased cost of holding excess reserves at the central bank encourages banks to take reserves back on the balance sheet to improve loan supply. Hence, influencing bank performance (profits and margins) is not the policy-makers main target but rather a side effect. Moreover, Figure 2.1 shows that, prior to the introduction of NIRP, NIM and ROA moved in a similar direction but the relationship changed thereafter. This is confirmed when I examine the requirement of a 'parallel trend assumption'. According to Bertrand et al. (2004) and Imbens and Wooldridge (2009) the DiD approach is valid only under the restrictive assumption that changes in the outcome variable over time would have been exactly the same in both treatment (countries that experienced NIRP) and control groups (without NIRP) in the absence of the intervention (the introduction of NIRP). Figures 1 depicts the level of NIM and ROA from 2011 to 2016 for both NIRP adopter and non-adopter countries. Both NIM and ROA move in the same direction in the pre-treatment period (correlation among the treatment and control group is 0.94 and 0.58 for NIM and ROA in the pre-NIRP period, respectively), indicating that the parallel trend

assumption holds. Since June 2014, when policy rates in most of the NIRP adopter countries turned negative, NIRP affected banks register lower performance with NIM falling below 2% in 2014-2015 and below 0.40% for ROA in 2015 (correlation among the treatment and control group is -0.87 and -0.94 for NIM and ROA in the post-NIRP period, respectively).

Figure 2.1. Average NIM and ROA among treated banks (blue line) and non-treated banks (red line) from 2011 – 2016. Correlation of NIM and ROA among the treatment and control group prior to NIRP-introduction is 0.94 for NIM and 0.58 for ROA, respectively. Correlation of NIM and ROA among the treatment and control group after NIRP-introduction is -0.87 for NIM and -0.94 for ROA, respectively.



Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio.

2.3.2 Data

I rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information from several sources. The macroeconomic series are from Thomson DataStream, World Bank Databases (World Bank Financial Development Database and World Bank Doing Business Database), Bank for International Settlements Database and ECB Statistical Warehouse Database. Bank balance sheet and performance data are from Orbis Bank Focus and SNL Financial with the aim of maximising the sample size. This also makes it possible to check the consistency of the information provided and to minimise misreporting and outliers. Since Orbis comprises cross-country banks that operate in more than one country, balance sheet data can be either consolidated or unconsolidated. To avoid concerns regarding banks that operate in more than one country in both treated and non-treated groups, I use bank account data that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but not with an unconsolidated subsidiary. To avoid differences in reporting and accounting conventions, both Orbis Bank Focus and SNL Financial provide standardised bank accounting information. Orbis Bank Focus gives information on whether a company is active or inactive. This allows us to check bank entry and exit status. Accordingly, I drop banks that are or have

become inactive over the sample period. I remove also those banks with an annual asset growth higher than 50% to deal with those in substantial mergers and acquisitions activity. My sample covers 7,352 financial institutions (commercial banks, savings banks, cooperative banks, bank holding companies, finance companies and real estate mortgage specialists) from 33 OECD countries over 2012 - 2016. The sample period is intentionally short. According to Bertrand et al. (2004) and Roberts and Whited (2013), the change in the treatment group should be concentrated around the onset of the treatment. Moving away leads to unobservable and other factors that affect the treatment outcome leading to omitted variables bias and consequently threatening the validity of my model. The treated countries include those of the Euro Area, Hungary, Sweden and Switzerland. Bank balance sheet variables are winsorized at the 1% and 99% level to avoid the influence of outliers.

Descriptive statistics for bank ROAs and NIMs, other bank balance sheet variables, the macroeconomic and institutional variables in the treatment and control groups prior to and after the introduction of NIRP are shown in Tables 2.1 and 2.2 (a more detailed explanation of the variables and expected signs is provided in Table A3 in the appendix). Panels A and C of Table 2 display summary statistics of my dependent variables. Following Borio et al. (2015) and Claessens et al. (2018), I define net interest margin (NIM) as the difference between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets. Return on assets (ROA) is calculated by dividing bank's net income by total assets. As shown in Table 2, the mean values of ROA and NIM for the control group remain constant in the pre and post – NIRP periods. However, for the treatment group the mean values of ROA and NIM experienced a contraction in the post-NIRP period from 0.47% to 0.40% and from 2.06% to 1.92%, respectively.

Bank balance sheet data. Panels B and D of Table 2.2 present summary statistics of bank balance sheet data. Bank size (Size) is measured as the logarithm of bank total assets. According to Goddard et al. (2004) and Mirzaei et al. (2013) banks size affects profits positively through the realisation of economies of scale. However, as suggested by Demirgüç-Kunt and Huizinga (1999) and Demirgüç-Kunt et al. (2004) large efficient banks apply lower margins to customers through increasing returns to scale. Therefore, I use Size to control for the impact of economies of scale on bank NIMs and profits. Large banks, with greater international reach, have more potential to increase lending abroad in comparison to small banks that lend mostly within national borders. To investigate this point, I hand collect data on

lending outside the Euro area for 116 (*Lending diversification*) significantly supervised entities (SIs) by the ECBs Single Supervisory Mechanism (SSM). I expect large banks with international reach to offset the negative impact of NIRP on net interest margins and profitability. I test this prediction in section 2.4.3 of the chapter.

I employ several variables to control for bank risk aversion, liquidity, credit risk and bank operating efficiency. Several studies (McShane and Sharpe, 1985; Saunders and Schumacher, 2000; Maudos and Fernandez de Guevara, 2004) use the ratio of equity-to-total assets (*E/TA*) and Tier1 ratio (*Tier1 ratio*) as a proxy for bank risk aversion. A positive relation is expected between this variable and NIM as risk averse banks will require higher margins to cover the greater cost of equity (Berger, 1995). I also use liquidity (Carbo and Fernandez, 2007) and a credit risk measure (Carbo and Fernandez, 2007; Poghosyan, 2013; Almarzoqi and Naceur, 2015) to control for bank liquidity and credit risk. In this context, I use the ratio of liquid securities-to-total assets (Liquidity) and loan-loss provisions-to-total assets (Credit risk), respectively. I expect that banks with higher liquidity and credit risk to apply a premium to margins. As suggested by Maudos and Fernandez de Guevara (2004) and Maudos and Solis (2009) I measure bank management efficiency by using the cost-to-income ratio (Cost-to-income), defined as the operating cost that is necessary to generate one unit of income. High quality management should be reflected in a more profitable assets composition and lower liabilities costs. An increase in this ratio means a decrease in the quality/efficiency of management that will translate into lower margins and profits.

Following Angbazo (1997) and Mirzaei et al. (2013), I use the ratio of off-balance sheet activities-to-total assets (Off-balance sheet) to take into account the possibility of hedging against interest rate risk. Earlier studies demonstrate a positive relation between bank off-balance sheet size and margins and profits. On the one hand, off-balance sheet instruments lead to higher NIM as banks are compensated for increased contingent risk. On the other hand, off-balance sheet items allow banks to expand their assets base thus generating more profits. In section 2.4.3 of the paper, I conduct a sub-sample analysis where I split the sample to compare the effect of NIRP among banks that strongly hedge against interest rate risk and banks that do not.

In order to control for the impact of bank business models, I employ variables of bank loan growth (Loan growth), non-interest income-to-gross revenues (Non-interest income), net fees

and commissions-to-total assets (Fees & commissions), interest income-to-total assets (Interest income) and interest expenses-to-total assets (Interest expenses). In section 2.4.3 of the chapter, I use non-interest income and fees & commissions to test whether NIRP motivates banks to switch from a business model that is 'interest oriented' to one that is more 'service oriented' (Altavilla et al. 2017). As shown in Table 2.2, the mean value of Loan growth improved in the post-NIRP period for the control group from 6.35% to 8.63%. At the same time, the ratios on Non-interest income, Fees & commissions, Interest income and Interest expenses remain constant in the post-NIRP period for the control group. However, for the treatment group, the mean value of Loan growth fell from 3.58% to 3.32% in the post-NIRP period. Alongside, the mean value on Interest income declined from 3.02% to 2.55% for the treatment group in the post-NIRP period. The mean values on Non-interest income and Fees & commissions improved from 35.72% to 37.48% and from 0.77% to 0.80%, respectively, indicating that banks in the treatment group moved to a more service- oriented business model in the post-NIRP period. In a robustness check in section 2.4.4 of the paper, I check for the different effects that NIRP may have on interest income and interest expenses by including them as dependent variables in the regression model.

Country level controls. Table 1 displays the country-specific variables including: macroeconomic performance indicators; measures of banking sector competition; proxies for other UMP instruments; and a variable that shows whether floating or fixed interest rates are more prevalent in respective countries. I first employ GDP growth (GDP growth), consumer price inflation (Inflation), the sovereign bond yield (Yield curve) and the size of credit in the economy (Credit-to-GDP) as measures of macroeconomic conditions. Athanasouglu et al. (2008) recognise a twofold GDP growth effect on bank performance. On the one hand, GDP growth has a positive effect on bank profits coming from a greater demand for loans. In contrast, there may be a negative relationship if the supply of funds (deposits) declines due to a rise in consumption in-line with GDP growth. The extended literature (Molyneux and Thornton, 1992; Boyd et al, 2001; Demirgüç-Kunt et al, 2004; Gelos, 2006; Almarzoqi and Naceur, 2015) has also demonstrated a positive relationship between nominal inflation and bank margins and profits. Since several studies underline the positive relation between the expectation of interest rates and NIM and profitability, I also control for the slope of the yield curve by using the 10-year government bond return. Finally, to capture the importance of bank credit in the economy I include the loan volume to GDP ratio.

As other UMPs, including central bank asset purchase programs (Di Maggio et. al, 2016; Kandrac and Schulsche, 2016; Rodnyanski and Darmouni, 2017; Chakraborty et. al, 2017), were conducted at the same time as NIRP, I include variables to account for these effects. In-line with Gambacorta et al. (2014), Lambert and Ueda (2014), and Alessandri and Nelson (2015) I employ the logarithm growth rate of a country's central bank balance sheet *(CB_GR)*. I also use the logarithm growth rate of the monetary base *(M0_GR)* as a further control to isolate the impact of other UMP's on bank NIM and ROA.

Bank profitability and margins may also be driven by banking sector competition. Following Maudos and Fernandez de Guevara (2004), Carbo and Fernandez (2007), Hawtrey and Liang (2008), Lepetit et al. (2008), Maudos and Solis (2009), Almarzoqi and Naceur (2015) and Entrop et al. (2015), I use the Lerner index (Lerner index) to control for competition in the banking sector. The Lerner index is the difference between the price and the total marginal cost as a proportion of the price of banking services and is taken from the World Bank Global Financial Development Database. It ranges between 0 (perfect competition) and 1 (monopoly). NIRP is expected to have a stronger impact in more competitive banking markets as changes in policy rates are likely to be passed on more effectively.

I also try to disentangle the impact of NIRP on bank margins and profitability in those countries that for historical or cultural reasons have a preference for lending at a floating or fixed rate basis. I define floating rate countries as those that have a share of variable rate loans to total loans greater than 63% (median), and vice versa for fixed-rate countries. One would expect the impact of NIRP to be greater in countries where floating rates are more prevalent. Following Albertazzi and Gambacorta (2009) I address this issue by using the share of variable rate loans in total loans-to-households and non-financial corporations (floating-fixed rate) taken from the ECB Statistical Warehouse.

Finally, in section 4.4.4 of the paper, I test the different elasticity of deposit rates and loan rates to NIRP. Following Carbo and Fernandez (2007), I define the price of loans as the ratio of gross interest income-to-loans (Loans rate) and the price of deposits as the ratio of interest expenses-to-deposits (Deposits rate).

Further institutional controls. Table 1 presents also further institutional controls relating to: total bank reserves (Reserves); taxation (Taxation); depth of credit information (Depth credit

info); and legal and investors' rights (Legal rights). Extensive is the literature that takes the ratio of cash and balances at the central bank-to-total assets to capture both the regulatory requirement and the opportunity cost of banks to hold less-than-market remunerated reserves at the central bank (Demirgüç-Kunt and Huizinga, 1999; Angbazo, 1997, Maudos and Fernandez de Guevara, 2004; Gelos, 2006; Maudos and Solis, 2009; Almarzoqi and Naceur, 2015). The effect of bank reserves on profitability and margins could be either positive or negative. The relation may be negative as under-remunerated reserves lower net interest income and profitability. Alternatively, if banks pass the cost of reserves onto bank customers, I should expect a positive relationship.

I also include the ratio of taxes-to-operating income (Demirgüç-Kunt and Huizinga, 1999; Gelos., 2006) to take into account the direct effect of corporate income taxes on bank margins and profits, as banks may try to pass through increases in corporate income taxes to bank customers. In-line with Gelos (2006) and Almarzoqi and Naceur (2015), I also use a depth of credit information index that measures rules affecting the scope, accessibility and quality of credit information available through public or private credit registries. The index ranges from 0 to 8, with higher values indicating the availability of more credit information (from either a public registry or a private bureau) to facilitate lending decisions. Banks are likely to require higher margins if credit information is poor. Finally, I control for the strength of legal rights (Demirgüç-Kunt and Huizinga, 1999; Gelos., 2006; Poghosyan, 2013; Almarzoqi and Naceur, 2015). The legal rights index ranges from 0 to 12 and measures the degree to which collateral and bankruptcy law protect the rights of lenders. The higher the score the stronger the legal protection in a certain country. I expect that weak contract enforcement and inefficient collateral reconciliation may prompt banks and investors to require higher margins and profits to compensate for the additional risk.

2.4. Empirical results

2.4.1. Baseline results

The baseline results from estimating equation (2.1) are presented in Table 2.3. my main interest is the size, sign and statistical significance of the coefficient of β_1 that represents the average difference in the change of NIM and ROA between countries that adopted NIRP and those that did not, denoted in the table as the *NIRP-effect*. In the regression results denoted as Table 3, the coefficients of *NIRP-effect* are sizeable, negative and statistically significant at the 1% and 5% level for NIM and ROA, respectively. Countries where central banks implemented NIRP

experienced a decline in NIM and ROA of 16.41% and 3.06%, respectively, compared to countries that did not adopt NIRP. In-line with expectations, the size of the coefficient on NIMs is larger than that of ROA. Overall, this result is consistent with the hypothesis that NIRP has a negative impact on bank margins and profits. It also indicates that the contraction in NIM (as a key component of bank profitability) indirectly drags down bank ROA but to a lesser extent – a fall in margins reduces profits but not to the same extent as the overall effect is likely mitigated by higher non-interest income (via increased fees and commissions, security valuations, trading income and such like).[15]

Table 2.3. The effect of NIRP on NIM and ROA

	NIM	**ROA**
NIRP-Effect	-0.1641***	-0.0306**
	(0.0183)	(0.0139)
Size	-0.1239***	0.0038
	(0.0080)	(0.0036)
E/TA	0.0234***	0.0322***
	(0.0026)	(0.0018)
Liquidity	-0.5165***	-0.1135***
	(0.0708)	(0.0411)
Loan growth	0.0031***	0.0030***
	(0.0006)	(0.0005)
Cost-to-income	-0.0041***	-0.0140***
	(0.0006)	(0.0005)
Credit risk	24.5769***	-27.2195***
	(2.1916)	(1.6302)
GDP growth	-0.0229	0.0292*
	(0.0190)	(0.0150)
Inflation	0.0610***	0.0242***
	(0.0066)	(0.0049)
Depth credit info	-0.0379***	-0.0048
	(0.0079)	(0.0083)
Legal rights	0.1904***	0.0670**
	(0.0450)	(0.0323)
Credit-to-GDP	-0.0039***	0.0005
	(0.0005)	(0.0004)
Yield curve	0.0199***	-0.0053
	(0.0059)	(0.0046)
Taxation	1.5347***	0.4216**
	(0.1688)	(0.1675)
Reserves	0.2768	0.7155***
	(0.2669)	(0.1947)
Observations	17,271	17,286
R-squared	0.513	0.566
Number of banks	4,612	4,612

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. E/TA is the ratio of bank

[15] I test this hypothesis in the following section of the chapter.

equity-to-total assets. Liquidity is the ratio of bank liquid securities-to-total assets. Cost-to-income is the ratio of operating expenses-to-operating income. Credit risk is the ratio of loan loss reserves-to-total assets. Loan growth is the logarithm growth rate of gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Credit-to-GDP is the ratio of aggregate gross loans-to-real GDP. Yield curve is the 10-year government bond return. Taxation is the ratio of taxes-to-operating income. Reserve is the ratio of cash and balances at the central bank-to-total assets. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

The covariates are mostly significant at conventional levels with signs in-line with the literature on the determinants of NIM and ROA. Size is mostly negative and statistically significant for NIM suggesting that small banks have lower margins than their larger counterparts. The E/TA variable is positively correlated to both NIM and ROA implying that less leveraged banks register higher margins and profits. In contrast, Liquidity is negatively related to both NIM and ROA revealing that banks that are less liquid apply higher margins to compensate for greater risks. The control variable of Loan growth is positively related to both NIM and ROA showing that lending volume is a strong determinant of bank margins and profits. In contrast, the Cost-to-Income ratio displays a negative relationship to both the dependent variables. Efficient management translates into higher margins and profits. As expected, Credit risk is positively correlated with NIM and negatively with ROA. On one hand, banks with large non-performing assets apply higher margins to compensate for the excessive risk. On the other hand, banks with deteriorating loan quality in their balance sheets face lower profitability. Among the macroeconomic variables, Inflation displays a strong positive coefficient for both NIM and ROA suggesting that the low inflation decade since the GFC is another factor affecting banking sector performance. Depth of credit also illustrates a significant negative relation with NIMs. Poor credit information results in higher margins required by banks. Credit-to-GDP is negatively related with NIM indicating that banks operating in countries with less developed financial sectors apply higher margins. As expected, the Yield curve is positively related with NIM. This result is in-line with the literature examined in section 2.2. Finally, Taxation is positive for both NIM and ROA suggesting that banks that pay higher taxes pass through corporate income taxes to bank customers.

2.4.2 Propensity Score Matching – Difference-in-Differences

As previously described, one of the difference-in-differences assumptions requires that the control group must constitute a valid counterfactual for the treatment. Although I provide evidence (section 3.1) that both the treatment and the control group experience a similar

macroeconomic environment in the years following the financial crisis, I further test this assumption by constructing a control sample using propensity score matching (PSM) as proposed by Rosenbaum and Rubin (1983). The predicted probability (propensity score) of NIRP to be undertaken by a country is obtained from the estimation of a Probit model. I use macroeconomic variables (GDP and the inflation rate) to match banks operating in NIRP adopter and non-adopter countries. Furthermore, to make sure that the propensity score predicted from the Probit model is successful in controlling for bank-specific differences between treated and the comparison group in the pre-NIRP period, I include bank size, equity strength, and lending growth in the propensity score estimation. The propensity score matching model can be represented as follow:

$$p_i = \Pr(D_i = 1 | X_{ijt}) = \delta(X_{ijt}^{'}\beta + \varepsilon_i) \quad (2.2)$$

where D_i is a dummy variable describing the treatment status. D=1 if the bank has been affected by the policy, and D=0 otherwise. X_{ijt} is a vector of observable macroeconomic variables and bank characteristics in the two years prior to NIRP and δ is a standard normal cumulative distribution function. Specifically, I implement kernel matching (Heckman et al. 1998) with weighted averages of all the banks in the control group to construct the counterfactual outcome. The advantage of using Kernel matching is the relatively smaller variances resulting from the fact that more information is used in the estimation. The results from the Probit model, used to generate propensity scores of being affected by NIRP, are presented in Table 2.4. As displayed, the majority of the covariates are significant at the 1% level suggesting that banks operating in countries with weaker economic prospects (represented by lower GDP growth (GDP growth) and low inflation (Inflation)) have a greater probability of being affected by the negative interest rate policy. Moreover, countries with banks that are small (Size), with lower loan growth (Loan growth) and that are less capitalised (E/TA) tend to have a higher probability to be the target of NIRP.

Table 2.4. Propensity score estimation: Probit model

	NIM	**ROA**
GDP growth	-4.6537***	-4.6595***

	(0.0870)	(0.0870)
Inflation	-1.1712***	-1.1742***
	(0.0279)	(0.0279)
Size	-0.1934***	-0.1924***
	(0.0107)	(0.0106)
E/TA	-0.0468***	-0.0465***
	(0.0033)	(0.0033)
Loan growth	-0.0097***	-0.0098***
	(0.0019)	(0.0018)
Observations	11677	11730
Pseudo R square	0.5460	0.5468
Log Likelihood	-3291.54	-3300.36
LR test (chi square)	7918.52	7964.23

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Size is the natural logarithm of bank total assets. E/TA is the ratio of bank equity-to-total assets. Loan growth is the logarithm growth rate of gross loans. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

The results from the PSM matching difference-in-differences estimations are presented in Table 2.5. As shown, matched banks NIMs and ROAs display a sizeable and statistically significant contraction after NIRP providing further evidence on the reliability of the baseline estimates.

Table 2.5. Difference-in-differences - PSM results

	NIM	**ROA**
NIRP-effect	-0.1220***	-0.1010***
	(0.0180)	(0.0140)
Country FE	Y	Y
Year FE	Y	Y
Observations	22331	22520

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

2.4.3 NIRP Results Based on Bank and Country Sub-Sample Analyses

As suggested by Bech and Malkhozov (2015), Jobst and Lin (2016), Arteta et al. (2016), Brunnermeier and Koby (2016) and IMF (2017), the contraction in NIM and erosion of profitability should be more marked for small banks operating in competitive markets. I also expect the influence of NIRP to vary for banks with specific product-line specialisations and that operate in countries where floating rate assets are more prevalent. If competition from other banks is sufficient, lending rates should decrease, and if deposit rates are already low, then margins will be compressed. This effect should be stronger for small retail banks relying on deposits as a source of funding. Banks that hold mostly floating interest rate loans face stronger compression of NIM as lending rates for new loans decline and existing (variable-rate) loans re-price while deposit rates remain sticky-downward. Also banks with a specific product line specialisation (such as real estate mortgages) that have a higher portion of long-term assets in their portfolio (facing stronger maturity mismatch risk), should also be more highly affected by NIRP. In contrast, large banks with a more diversified business model, greater potential to increase lending in NIRP non-affected countries and stronger interest rate risk hedging behaviour will be able to anticipate the reduction of net interest margins by: increasing non-interest income via fees and commissions; increasing net interest income by lending in monetary regimes not affected by NIRP; and using derivatives to hedge against interest rate risk. In the following sub-sections, I focus on the role of bank size, bank business model, market competition, asset interest rate composition, capitalisation and bank specialisation.

2.4.4 NIRP and Bank Size

First, I examine the impact of NIRP on NIMs and ROAs by running percentile regressions based on size.[16] The results reported in Table 2.6 can be summarised as follows. First, the largest banks show a statistically insignificant contraction in margins (panel A in Column 1) in comparison to the smallest banks that display a compression in margins of 17.83% (Panel A in Column 7). Second, NIRP positively affects large bank profitability as demonstrated by the statistical significance of the coefficient (Panel B in Column 2). Following dell'Ariccia et al. (2010), this result suggests that NIRP enables large wholesale funded banks to take greater advantage of declining funding costs partially offsetting pressure on margins and profitability. Second, the coefficients get larger in magnitude as bank size shrinks. This is consistent with

[16] I define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion.

the literature mentioned in Section 2.1 indicating that large banks, through hedging and lending and income diversification, are better able to protect themselves against interest rate risk.

To gain further insights into large bank behaviour, I investigate whether diversification opportunities allows the largest banks to anticipate the reduction in net interest margins by shifting towards a more service orientated business model Table 2.7 (Panel A and B) shows the estimates based on bank size for the impact on non-interest income (NII) and fees and commissions income (FEE). The results confirm the hypothesis that the large banks adapt their business model according to the monetary policy environment and increase non-interest income and fees and commission income.

Table 2.6. The influence of NIRP on NIM and ROA by splitting the sample in four percentiles based on bank size

	Bank Size>75th percentile		Bank Size>50th & <75th percentile		Bank Size>25th & <50th percentile		Bank Size<25th percentile	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)	NIM(5)	ROA(6)	NIM(7)	ROA(8)
Panel A.								
NIRP-effect	-0.0032		-0.1321***		-0.1695***		-0.1783***	
	(0.0203)		(0.0239)		(0.0281)		(0.0466)	
Panel B.								
NIRP-effect		0.0358**		-0.0670***		-0.0695***		-0.1409***
		(0.0183)		(0.0214)		(0.0254)		(0.0320)
R2	0.3552	0.2780	0.3102	0.2942	0.3711	0.2562	0.2956	0.1532
N.banks	1843	1855	2084	2115	2177	2195	2074	2159
N.Obs	6468	6514	6563	6637	6581	6629	6361	6621
T-test Bank size>25th & <50th = Bank size <25th						1.93***		
T-test Bank size >25th & <50th = Bank size>50th & <75th					1.27***			
T-test Bank size >75th = Bank size>50th & <75th			0.69***					

Note: Panel A displays difference-in-differences regression results of NIRP on NIM split by bank size percentiles. Panel B shows difference-in-differences regression results of NIRP on ROA split by bank size percentiles. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. I define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion. All the percentile regressions include fixed country and time effects. T-test for difference in means among percentiles is reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

2.4.5 NIRP and Bank Business Model

Furthermore, I test whether banks that strongly hedge against interest rate risk are less affected by NIRP. I use the ratio of off-balance sheet items (OBS) on total assets and split the sample according to the median level of OBS, defining as the sub-sample of strongly hedged banks with more than 6% of off-balance sheet to total assets ratio, vice versa for the group of weakly-hedged. The assumption is that the larger the amount of OBS items the more likely that interest rate risk will be hedged. The results are displayed in Table 2.8 (Panel A). As expected and in-line with recent papers investigating the low interest rate environment on interest rate risk (Chaudron, 2018), I find that large banks with substantial off-balance sheet activities are likely to hedge against interest rate risk more effectively – they display lower net interest margin contraction as well as higher ROA (although not statistically significant).

In Panel B of Table 2.8, I test whether large banks with greater international reach and potential to increase lending abroad offset the negative impact of NIRP on bank margins and profitability by diversifying lending in monetary regimes unaffected by negative interest rates. For this test, I hand collect data on lending inside and outside the Euro area for 116 significantly supervised entities (SIs) regulated by the ECBs Single Supervisory Mechanism (SSM). I reckon SIs represent a suitable sample as these banks operate globally and therefore have substantial lending diversification opportunities. To match the SIs with suitable banks belonging to the control group, I apply the nearest neighbour PSM approach. Specifically, I match control group banks that have size and lending similar to the SIs treatment group. Once again, the results suggest that large banks did not face a reduction of net interest margins and return on assets after NIRP when compared with a control group of banks with similar characteristics. This is also in-line with Altavilla et al. (2017) who employ a sample of 288 large European banks and did not find any effect of the low interest rate environment on bank profitability. This result has also important policy implications in terms of financial stability. Since the effect on SI banks is small and not statistically significant, it is therefore less critical for financial stability purposes.

Table 2.7. The influence of NIRP on non-interest income and fees and commissions by splitting the sample in four percentiles based on bank size

	Bank Size>75th percentile		Bank Size>50th & <75th percentile		Bank Size>25th & <50th percentile		Bank Size<25th percentile	
	NII(1)	FEE(2)	NII(3)	FEE(4)	NII(5)	FEE(6)	NII(7)	FEE(8)
Panel A.								
NIRP-effect	2.5876***		3.476***		3.0223***		0.770	
	(0.443)		(0.489)		(0.602)		(0.835)	
Panel B								
NIRP-effect		0.0004***		0.0003***		0.0002		-0.00004
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
R2	0.0999	0.1090	0.1340	0.1000	0.1562	0.1440	0.1528	0.0947
N.banks	1950	1765	2079	1970	2165	2076	2091	1945
N.Obs	6499	6197	6476	6234	6493	6309	6276	5961
T-test Bank size>25th & <50th = Bank size <25th						1.93***		
T-test Bank size >25th & <50th = Bank size>50th & <75th				1.27***				
T-test Bank size >75th = Bank size>50th & <75th			0.69***					

Note: Panel A displays difference-in-differences regression results of NIRP on NII split by bank size percentiles. Panel B shows difference-in-differences regression results of NIRP on FEE split by bank size percentiles Non-interest income (NII) is the ratio of non-interest income-to-gross revenues. Fees & commissions (FEE) is the ratio of fees and commissions income-to-total assets. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. I define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion. All the percentile regressions include fixed country and time effects. T-test for difference in means among percentiles is reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 2.8. The effect of NIRP on banks that: strongly (weakly) hedge against interest rate risk; have diversified lending; operate in more (less) competitive markets; in countries where floating (fixed) rates predominate; and for levels of bank capital

	NIM(1)	ROA(2)	NIM(3)	ROA(4)	T-test
Panel A.					
Weak-hedging			**Strong hedging**		65.94%***
NIRP-Effect	-0.2048***	-0.0623**	-0.0887***	0.0164	
	(0.0299)	(0.0243)	(0.0211)	(0.0171)	
R-squared	0.295	0.246	0.352	0.291	
N.Banks	3,152	3,168	2,793	2,806	
N.Obs	10,394	10,448	8,914	8,951	
Panel B.					
Lending Diversification					
NIRP-Effect	0.0768	-0.0292			
	-0.0614	-0.0309			
R2	0.0107	0.0309			
N.Banks	224	225			
N.Obs	896	900			
Panel C.					
More Competitive			**Less Competitive**		0.20***
NIRP-effect	-0.0903**	-0.0632***	-0.0301	0.0851***	
	(0.0372)	(0.0247)	(0.0205)	(0.0193)	
R2	0.1643	0.0247	0.2788	0.1632	
N.Banks	4559	4640	3361	3443	
N.Obs	15096	15259	10877	11142	
Panel D.					
Fixed rate countries			**Floating rate countries**		26.20%***
NIRP-effect	0.0222	0.0286*	-0.0368**	0.0031	
	(0.0155)	(0.0141)	(0.0141)	(0.0107)	
R2	0.0058	0.0017	0.0244	0.0008	
N.Banks	3689	3773	6436	6543	
N.Obs	13095	13411	23066	23454	
Panel E.					
Less Capitalised			**More Capitalised**		6.40%***
NIRP-Effect	-0.0267	-0.0102	-0.1502***	-0.0937***	
	(0.0186)	(0.0151)	(0.0191)	(0.0154)	
R2	0.43	0.348	0.272	0.191	
N.Banks	2726	2726	6036	6153	
N.Obs	7428	7428	18545	18973	

Note: Panel A displays difference-in-differences regression results obtained by splitting the sample according to the median level of Off-balance sheet items-to-total assets. Weak-hedging is defined as those banks with less than 6% off-balance sheet assets-to-total assets ratio, and vice versa for Strong-hedging banks. Panel B presents difference-in-differences regression results for a sample of significantly supervised entities (SIs) belonging to the treatment group. The control group used has been created by applying nearest neighbour propensity score matching. Panel C displays difference-in-differences regression results obtained by splitting the sample between more competitive and less competitive banking sectors as measured by the Lerner index. More competitive systems are those banking sectors with a Lerner index below 0.24, and vice versa for less competitive markets. Panel D shows difference-in-differences results obtained by splitting the sample dividing the treatment group into floating and fixed rate countries. Fixed rate are those countries having a share of variable loans-to-total loans lower than 63% and vice versa for fixed-rate loans. Panel E presents difference-in-differences regression results obtained by splitting the sample between less and well capitalised banks. Banks are considered as less capitalised if they have Tier 1 ratio below the median value (14.37%) and vice versa for well capitalised banks. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning

assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Weak-hedging is the below median off-balance sheet-to-total assets ratio. Strong-hedging is the above median off-balance sheet-to-total assets ratio. Lending diversification is the ratio of loans inside the Europe-to-total loans. More competitive is the below median of the Lerner index. Less competitive is the above median level of Lerner index. Floating rate countries is the above median share of variable rate loans in total loans-to-households and non-financial corporations. Fixed rate countries is the below median share of variable rate loans in total loans-to-households and non-financial corporations. Less capitalised is the below median of tier1 ratio. More capitalised is the above median of tier1 ratio. T-test for difference in means among the median level of the variables is also reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

2.4.6 NIRP and Banking Sector Competition

In Panel C of Table 2.8, I assess the impact of NIRP in the context of competitive conditions in banking markets. In this case, I use the Lerner index as a proxy for competitive conditions.[17] Sørensen and Werner (2006) argue that banks operating in a less competitive environment make slower adjustments to interest rates (and therefore to NIM), which slows the transmission of monetary policy. Brunnermeier and Koby (2016) present a "reversal interest rate" hypothesis according to which there is a rate of interest at which accommodative monetary policy "reverses" its effect and becomes contractionary. They show that low interest policy is likely to have a more limiting effect on bank lending in competitive markets because of the associated pressure on NIM. As the Lerner index varies between 0 and 1, I split the sample according to the median of the Lerner index, defining as more-competitive those banking sectors with a Lerner index below 0.24, and vice versa for less-competitive. The results, reported in Panel C of Table 2.8 confirm my hypothesis and support the aforementioned studies: namely that the impact of NIRP on bank profits and margins in competitive markets is negative and statistically significant. In less competitive markets in contrast, the impact of NIRP is negative but statistically insignificant for NIM while positive and statistically significant for ROA suggesting that banks here are better able to maintain profitability as they face less competition and downward lending rates pressure.

2.4.7 NIRP and Fixed/Floating Lending Rate Countries

In Panel D of Table 2.8, I try to disentangle the effect of NIRP for floating-rate and fixed-rate countries. According to Albertazzi and Gambacorta (2009), Jobst and Lin (2016) and Brunnermeier and Koby (2016), the impact of NIRP should have a greater effect on variable-rate loans and on new loans. Hence, banks having a higher proportion of outstanding floating

[17] For this exercise, similar tests were also undertaken using the Boone index and the Herfindahl-Hirschman Index (HHI). The results are similar to those using the Lerner index.

rate loans/assets should be strongly adversely affected by the new monetary regime compared to those that rely more on fixed rate assets. The ECB's Statistical Warehouse provides data on the share of variable rate loans in total loans-to-households and non-financial corporations. Again, I split the sample dividing the treatment group into floating and fixed rate countries according to the median (see Table 2.2 for a list of floating and fixed rate countries). For this exercise, I consider a floating rate country as having a share of variable rate loans to total loans greater than 63%, and vice versa for fixed-rate countries. The results confirm a negative and significant relationship between NIRP and NIM in countries where floating loan rates prevail. In countries with a high percentage of fixed loan rates, NIRP boosted ROA by cutting bank funding cost without diminishing the lending rate.

2.4.8 NIRP and Bank Capitalisation

As a further test, I investigate whether negative interest rates have a diverse effect depending on the level of bank capitalisation. When banks have little capital, the increase in the cost of funding can dominate increases in loan rates as banks face difficulties in raising capital. In such a scenario, NIRP should have a greater effect on banks that are less capitalised. However, it is also true that banks that hold capital in excess of that required by regulations face an opportunity cost and profitability pressure as excessive capital could be employed for profitable investment opportunities. In my sample banks are, on average, well-capitalised (the median level is 14.37%). When I split the sample according to the median level of capital (using the Tier1 ratio), I discover that banks with lower capital ratios keep-up profitability to mitigate the negative impact of negative rates on net interest margins and profits. Banks that are well capitalised suffered more from NIRP. This result is shown in Panel E of Table 2.8. This result adds also to the ongoing debate on the benefits and costs of bank capital under tight macro prudential policies.

2.4.9 NIRP and countries in surplus/deficit

As mentioned in the Section 2.1, the cost of negative deposit rates is likely to be greater for banks in surplus countries where banks hold large excess reserves. To test this hypothesis, I split the sample according to country surpluses. The results shown in Table 2.9 do not support this view as I find similar for surplus/deficit countries.

Table 2.9. NIRP, NIM and ROA for surplus/deficit countries

	Surplus Countries		Deficit Countries	
	NIM	ROA	NIM	ROA
NIRP-Effect	-0.1304***	-0.0649***	-0.1259***	-0.0563***
	(0.0146)	(0.0119)	(0.0222)	(0.0184)
Observations	23,524	23,910	11,884	12,179
R-squared	0.288	0.228	0.268	0.113
Number of banks	6,556	6,663	3,362	3,438

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after 2014, 0 otherwise. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively. Surplus countries are those countries that have surplus current account on average over the sample period.

2.4.10 NIRP and regulatory features of the banking environment

Regulatory features such as reserve requirements and activity restriction may affect the effect of NIRP. For instance, non-interest income is typically low in countries with heavy restrictions on non-traditional banking activities. This can limit bank ability to switch to other sources of income like services strengthening possible negative effects of NIRP. To asses this peculiar question, I download data from the World Bank – Bank Regulation and Supervision Survey – that provides information on bank regulation and supervision for 143 jurisdictions (it covers 31 out of 33 countries in my sample). By using this survey, I create an index of activity restrictions. In the bank activity restriction section of the survey (Section 4), policy-makers are asked to answer the following questions: (1) What are the conditions under which banks can engage in securities activities?; (2) What are the conditions under which banks can engage in insurance activity?; (3) What are the conditions under which banks can engage in real estate activities?; (4) What are the conditions under which banks can engage in non-financial businesses except those businesses that are auxiliary to banking business? The answers to each question are multiple choice and identify different degree of activity restrictions and are classified as: (a) a full range of activities can be conducted directly in banks; (b) A full range of activities are offered by all or some of these activities must be conducted in subsidiaries or in other part of a common holding company or parent; (c) Less than a full range of activities can be conducted in banks, or subsidiaries, or in another part of a common holding company or parent and; (d) None of these activities can be done in either banks or subsidiaries, or in another part of a common holding company or parent.

By using this information, I create an index where: letter *a* is equal to weak activity restrictions and takes the value 1; letter *b* is equal to weak-mid activity restrictions and takes the value 2; letter *c* is equal to mid-strong activity restrictions and takes the value 3 and; letter *d* is equal to strong activity restrictions and takes the value 4. I sum the answers for each question and obtain an index of activity restrictions ranging from 0 (weak activity restrictions) to 14 (strong activity restrictions). The results of the index are summarised by Table 2.10 below:

Table 2.10. Bank activity restrictions index

Country	Activity Restrictions Index
Austria	5
Australia	8
Belgium	6
Canada	9
Switzerland	4
Chile	12
Germany	0
Denmark	10
Estonia	10
Spain	7
Finland	7
France	9
Great Britain	5
Greece	9
Hungary	6
Ireland	7
Iceland	7
Israel	14
Italy	10
Korea	13
Luxembourg	10
Mexico	9
Netherlands	6
Norway	9
New Zealand	8
Poland	14
Portugal	8
Slovenia	8
Slovakia	13
Turkey	11
USA	13

To investigate the impact of activity restrictions I split the activity restrictions index according to the median level. The regression results are shown in Table 2.11. By looking at the magnitude of the coefficient NIRP-effect there seems to be a difference in the level of net interest margin between banks operating in countries with weak/strong activity restrictions. The coefficient of strong activity restriction is almost doubled that of banks operating in countries with weak activity restrictions. However, the results do not hold well for ROA that shows opposite effect.

Table 2.11. NIRP, NIM and ROA for banks subjected to weak/strong activity restrictions

	Weak Activity Restrictions		Strong Activity Restrictions	
	NIM	ROA	NIM	ROA
NIRP-Effect	-0.0890***	-0.0701***	-0.2110***	-0.0467***
	(0.0153)	(0.0126)	(0.0188)	(0.0147)
Observations	20,211	20,607	14,565	14,850
R-squared	0.298	0.228	0.267	0.168
Number of Banks	5,665	5,775	4,085	4,158

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after 2014, 0 otherwise. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

2.4.11 NIRP and Bank Product-line Specialisation

As a final test, I try to capture differences in bank specialisation. As suggested by Hanweck and Ryu (2005) banks with different product-line specialisations tend to have distinctive business models and consequently they exhibit varying degrees of sensitivity to interest rate risk. The magnitude of this effect depends on the composition and repricing of existing assets and liabilities. Banks that have a higher proportion of net long-term assets in their portfolios should experience a greater contraction in their NIM as interest rates decline. Accordingly, I divide the sample into different bank types (bank holding companies, commercial banks, cooperative banks, finance companies, real estate mortgage specialists and savings banks) relying on the classification provided by Orbis Bank Focus. The results are displayed in Table 2.12 (Panels A and B). As expected, real estate mortgage specialists and finance companies face strong NIM and ROA compression after the introduction of negative rates in comparison with the control group. The results demonstrate a similar negative and significant effect of NIRP on the performance of commercial banks, cooperative banks and saving banks. This

negative and significant effect disappears in the group of bank holding companies, which is in-line with my previous results on bank size, income and lending diversification.

2.5 Further Robustness Checks

2.5.1 Lending Rates, Deposit Rates, Interest Income and Interest Expense

NIRP induces reductions in interest rates to motivate banks to run down their excess reserve balances. However, since deposits (may) have a "price floor" set at zero, a decline in lending rates can lead to a contraction in NIMs.[18] I control for this effect by including in my analysis both lending rate and deposit rates. The results are reported in Panel A of Table 2.13 (columns 1-2). As expected, Loans rate displays a strong positive relation to NIMs (column 1) suggesting that higher interest rates on lending are associated with high net interest margins. In contrast, Deposits rate has negative sign (column 1) indicating that lower deposit rates allow banks to benefit from reduced funding costs. The coefficients between NIM and NIRP retain their significance level with magnitudes in-line with the baseline regressions. The significance of the coefficients between ROA and NIRP drops-off due to the fact that a narrowed NIM will motivate banks to compensate the loss by focusing on fee and commission income. In order to identify the individual effect of lending and deposit rates on bank performance I employ Interest income and Interest expenses as dependent variables in my econometric specifications.

[18] However, as already explained, in countries like Sweden and Denmark, where banks operate in a highly concentrated banking system they may find it easier to lower retail deposit rates below zero.

Table 2.12. NIRP and bank specialisation.

	Bank Holdings Companies		Commercial Banks		Cooperative Banks		Finance Companies		Real Estate and Mortgage Banks		Savings Banks	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)	NIM(5)	ROA(6)	NIM(7)	ROA(8)	NIM(9)	ROA(10)	NIM(11)	ROA(12)
Panel A.												
NIRP-effect	-0.0876		-0.1329***		-0.0793***		-0.2630***		-0.3012***		-0.0986***	
	(0.0680)		(0.0321		(0.0229)		(0.0742)		(0.0635)		(0.0282)	
Panel B.												
NIRP-effect		0.0232		-0.0504**		-0.0122		-0.1841***		-0.1274***		-0.0078
		(0.0466)		(0.0247)		(0.0296)		(0.0568)		(0.0494)		(0.0256)
R2	0.3921	0.1545	0.387	0.1741	0.3302	0.2517	0.2939	0.2302	0.3541	0.2491	0.6477	0.5123
N.Banks	527	531	1425	1446	1663	1664	581	603	226	226	1299	1299
N.Obs	1960	1980	5222	5287	6157	6162	1949	2026	857	859	4940	4940

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Classification for bank holding companies, commercial banks, cooperative banks, finance companies, real estate and mortgage banks and saving banks it taken from Orbis Bank Focus. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

The results reported in Panel A of Table 2.13 (columns 3-4) confirm a negative and significant effect of NIRP on both interest expense and interest income. However, the larger magnitude of the interest income coefficient supports the hypothesis that NIRP has a bigger effect on interest income as deposit rates are sticky downward. Most banks have not passed on the negative interest rates to their customers. Banks that rely on deposits are reluctant to reduce rates, fearing the loss of their funding base. It appears that the mismatch between sticky deposit rates and competitive loan rates diminishes bank interest income more than the beneficial effect of NIRP on interest expenses in terms of reduced wholesale funding costs.

2.5.2 Other Unconventional Monetary Policy

NIRP was brought into the UMP mix by central banks several years after the adoption of other UMPs, and in particular, the extensive use of outright asset purchases via QE. It is important to disentangle the effects of NIRP on profitability and margins from the effects of these policies. Outright asset purchases were aimed at expanding the central bank's balance sheet to increase the level of the monetary base, encouraging banks to lend – in order (ultimately) to boost nominal spending (Bernanke and Reinhart, 2004). Accordingly, I proxy for the use of other UMPs by including, alternatively, variables that take into account the central bank balance sheet size and (alternatively) the size of the monetary base. The results reported in Panel B of Table 2.13 (columns 1-4) are in-line with the studies of Lambert and Ueda (2014) and Alessandri and Nelson (2015) underlining the possible negative effect of UMP on margins. However, unlike NIRP, other UMP improved bank profitability measured by ROA by facilitating higher credit supply and better funding conditions. In contrast, the results of NIRP confirm that negative rates have squeezed both bank margins and profitability.

Table 2.13. Robustness checks

Panel A. Lending rate, deposit rate, interest income and interest expense				
	NIM(1)	ROA(2)	Interest Income(3)	Interest Expense(4)
NIRP-effect	-0.1193***	-0.008	-0.0026***	-0.0016***
	(0.6900)	(0.0126)	(0.0001)	(0.0001)
Loans rate	7.0750***	3.0984***		
	(0.8746)	(0.3707)		
Deposits rate	-7.3207***	-2.8912***		
	(0.9049)	(0.5787)		
R2	0.4084	0.2929	0.3328	0.4203
N.Banks	5092	5098	5888	5776
N.Obs	15209	15223	17396	17091

Panel B. Unconventional Monetary Policy (UMP)

	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.1520***	-0.0584***	-0.1620***	-0.0842***
	(0.0144)	(0.0108)	(0.0142)	(0.0105)
CB_GR	-0.0393*	0.0733***		
	-0.0209	-0.0196		
M0_GR			-0.0012***	0.0005*
			-0.0003	-0.0003
R2	0.295	0.2124	0.2791	0.2004
N.Banks	7238	7354	5335	5422
N.Obs	25212	25627	19486	19809
	Panel C. NIRP and the EU		**Panel D. NIRP, no Switzerland, Norway and Sweden**	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.1601***	-0.0584***	-0.1284***	-0.0589***
	(0.0286)	(0.0198)	(0.0154)	(0.0124)
R2	0.2189	0.128	0.261	0.212
N.Banks	5527	5623	6543	6658
N.Obs	19897	20244	23363	23784
	Panel E. Fake NIRP		**Panel F. NIRP at aggregate level**	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.017	-0.0079	-0.0014	0.0033
	(0.0176)	(0.0169)	(0.0064)	(0.0153)
R2	0.124	0.0789	0.735	0.273
N.Banks/Countries	7183	7307	33	33
N.Obs	20123	20472	132	132

Note: Panel A (Columns 1 and 2) displays difference-in-differences regression results when both Loans rate and Deposits rate have been controlled for, while Columns 3 and 4 present results where the dependent variables are interest income (Column 3) and interest expenses (Column 4). Panel B shows the difference-in-differences regression results when proxies of unconventional monetary policies are included. Panel C reports difference-in-differences regression results when the treatment group includes only European NIRP adopters and the control group includes only European non-NIRP adopters. Panel D displays difference-in-differences regression results when late NIRP adopter countries (Switzerland, Norway and Sweden) have been removed from the sample. Panel E shows difference-in-differences regression results where the NIRP intervention has been set in 2013. Panel F displays difference-in-differences regressions results of the NIRP effect at the aggregate country level. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income-to-total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Interest income is the ratio of interest income-to-total assets. Interest expenses is the ratio of interest expenses-to-total assets. Loans rate is the ratio of interest on loans-to-total gross loans. Deposits rate is the ratio of interest expenses-to-total deposits. . M0_GR is the logarithmic yearly growth rate of the money supply M0. CB_GR is the logarithmic yearly growth rate of central bank total assets.

2.5.3 Splitting the Sample at the European Level and Removing Countries that introduced NIRP in 2015.

As further robustness checks, I alter the country sample in two ways. Firstly, I focus only on European countries where the treatment group includes only European NIRP adopters and the control group includes only European non-NIRP adopters. Second, I remove late NIRP – adopter countries, namely Switzerland (adoption in January 2015), Norway (September 2015)

and Sweden (February 2015) to see whether the results hold. Splitting the sample in multiple control and treatment groups helps also to reduce biases and unobservable variables associated with just one comparison. These results are reported in Panels C and D of Table 2.13 (columns 1 to 4). The coefficients of NIRP in both cases remain negative and statistically significant.

2.5.4 Placebo Tests

I report two final robustness checks. First, I try to eliminate the possibility that bank margins and profitability in the treatment group may have altered prior to the introduction of NIRP—for example, in anticipation of the adverse effects of NIRP, or for some bank-specific reasons—thereby invalidating my choice of DiD estimation. If the estimated coefficients on the 'false' NIRP are not statistically significant, I can be more confident that the baseline coefficient is capturing a genuine monetary policy shock. Moreover, it allows us to control for the difference between low and negative interest rate environments. In Panel E of Table 2.13 I report results from estimates in which I extend my sample to the period from 2011 – 2014 setting the introduction of a "fake" NIRP in 2013. The coefficient on the NIRP variable is still negative but smaller and not statistically significant adding further support to the validity of my baseline estimation. Second, my research question is to investigate whether bank- and country-specific characteristics amplify or ease the effect of NIRP on bank performance. However, banks in each country are heterogeneous and they can be affected differently by NIRP. Hence, at an aggregate level, there can be a neutral overall effect as banks that suffer from the introduction of NIRP counterbalance those that benefit from the policy. If I do not find any significant relationship between NIRP and margins and profits at the aggregate level, I can be more confident that my results are driven by bank-specific characteristics. The results in Panel F of Table 2.13 strengthen my findings. The NIRP-effect is not significant when I conduct cross-country comparisons by averaging banks in each country to document aggregate effects. This provides further evidence that the effect of NIRP depends on the aforementioned bank-specific features.

2.6 Conclusions and Policy Implications

Since 2012, several central banks have adopted NIRP aimed at boosting real spending by facilitating an increase in the supply of bank loans. The policy has generated controversy with skeptics pointing to several factors that might affect the soundness of financial institutions and complicate the transmission from negative policy rates to higher bank lending. One factor that has been mentioned is that NIRP could compress NIMs and, therefore, bank profits, which may

erode bank capital bases via a reduction in retained earnings posing financial instability concerns. Reduced retained earnings and the subsequent erosion of bank capital may also limit the transmission of NIRP to bank lending as retained earnings are the most important source of bank's own funds (Shin., 2016). This creates a vicious circle where squeezed margins and low profits limit bank's ability to retain earnings and build capital buffers ultimately increasing risks as well as stifling NIRP monetary transmission.

In this chapter, I provide new evidence that bank margins and profitability fared worse in NIRP-adopter countries than in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in NIMs and ROAs of 16.41% and 3.06%, respectively, compared to those countries in which central banks did not follow this policy. Furthermore, the evidence points also to a dichotomy between non-binding monetary policy goals and binding capital requirements. This suggests a policy coordination dilemma where NIRP tries to boost lending growth at a time when prudential requirements force banks to hold greater amount of higher quality capital and liquidity.

My findings also show that the effect of NIRP on margins and profitability depends upon bank- and country-specific factors. For instance, large banks are able to mitigate the negative effect of NIRP on NIMs and ROAs through hedging, lending diversification and by switching from interest to non-interest oriented business models. Consequently, small banks appear to be more affected by the policy. Among country-specific factors I find NIRP to have a stronger adverse effect on bank profitability in competitive banking sectors and in countries where floating interest rates predominate. These results hold and are robust to the inclusion of a wide range of bank-specific, institutional and macroeconomic control variables. They also stand-up in the face of a broad range of robustness checks, including controlling for the effects of lending and deposits rates, other forms of unconventional monetary policy, sub-sample analysis, aggregate effects, and to (possible) changes prior to the introduction of NIRP. Overall, the adverse impact of NIRP on margins and profits appears to have been stronger for banks that: are small; have 'interest-oriented' business models; are real estate and mortgage specialists; are well capitalised; lend within national borders; weakly hedge against interest rate risk; operate in competitive banking systems; and where floating loan rates predominate. These empirical results revealed from the paper calls for greater policy emphasis on the appropriate supervision and monitoring of banks profitability in countries that are more affected by the policy.

Appendix A

Table A1 Correlation Matrix. This table represents the correlation matrix among the variables used in the baseline regression. Correlations that are significant at least at 5% level are reported using bold italics. The number on the horizontal axis indicates the variables in the vertical axis. Each horizontal number matches with the variable's position in the vertical.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Size		**-0.27**	**0.07**	0.01	**-0.26**	**0.03**	**0.05**	**-0.03**	0.00	**0.15**	**0.22**	-0.00	**0.12**	**0.09**
E/TA	**-0.27**		**0.11**	**0.11**	**-0.08**	-0.01	**0.13**	**0.23**	**0.06**	**0.09**	**-0.2**	**0.12**	**-0.07**	**0.21**
Liquidity	**0.07**	**0.11**		**-0.06**	**0.06**	**-0.04**	**-0.02**	**0.03**	**0.13**	**0.07**	**0.06**	0.00	**0.02**	**-0.03**
Credit risk	0.01	**0.11**	**-0.06**		**-0.27**	**-0.06**	**-0.14**	**0.15**	**-0.12**	**-0.25**	**-0.04**	**0.33**	**-0.32**	0.00
Cost-to-income	**-0.26**	**-0.08**	**0.06**	**-0.27**		**-0.07**	**-0.03**	**-0.05**	**0.10**	**-0.02**	**-0.12**	**-0.13**	**-0.37**	**0.02**
Loan growth	**0.03**	-0.01	**-0.04**	**-0.06**	**-0.07**		**0.07**	**0.15**	**0.07**	**0.09**	**-0.07**	0.01	**0.08**	**0.05**
GDP growth	**0.05**	**0.13**	**-0.02**	**-0.14**	**-0.03**	**0.07**		**-0.07**	**0.18**	**0.31**	**0.10**	**-0.16**	**0.05**	**0.15**
Inflation	**-0.03**	**0.23**	**0.03**	**0.15**	**-0.05**	**0.15**	**-0.07**		**-0.26**	**-0.06**	**-0.16**	**0.37**	**-0.02**	**0.09**
Depth credit info	0.00	**0.06**	**0.13**	**-0.12**	**0.10**	**0.07**	**0.18**	**-0.26**		**0.52**	**0.36**	**-0.08**	**0.07**	**0.03**
Legal rights	**0.15**	**0.09**	**0.07**	**-0.25**	**-0.02**	**0.09**	**0.31**	**-0.06**	**0.52**		**0.73**	**-0.05**	**0.16**	**0.19**
Credit-to-GDP	**0.22**	**-0.20**	**0.06**	**-0.04**	**-0.12**	**-0.07**	**0.10**	**-0.16**	**0.36**	**0.73**		**-0.07**	**0.04**	**0.04**
Yield curve	-0.00	**0.12**	0.00	**0.33**	**-0.13**	0.01	**-0.16**	**0.37**	**-0.08**	**-0.05**	**-0.07**		**-0.10**	0.00
Taxation	**0.12**	**-0.07**	**0.02**	**-0.32**	**-0.37**	**0.08**	**0.05**	**-0.02**	**0.07**	**0.16**	**0.04**	**0.10**		**-0.09**
Reserve	**0.09**	**0.21**	**-0.03**	0.00	**0.02**	**0.05**	**0.15**	**0.09**	**0.03**	**0.19**	**0.04**	0.00	**-0.09**	

Note: Size is the natural logarithm of bank total assets. E/TA is the ratio of bank equity-to-total assets. Liquidity is the ratio of bank liquid securities-to-total assets. Credit risk is the ratio of loan loss reserves-to-total assets. Cost-to-income is the ratio of operating expenses-to-operating income. Loan growth is the logarithm growth rate of gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Credit-to-GDP is the ratio of aggregate gross loans-to-real GDP. Yield curve is the 10-year government bond return. Taxation is the ratio of taxes-to-operating income. Reserve is the ratio of cash and balances at the central bank-to-total assets.

Table A2. This table shows macroeconomic indicators and Pearson correlation test for the control and treatment group during the period 2007-2015. I arbitrarily chose a longer time period (in comparison with the sample period) to highlight that these macroeconomic indicators move together for several years after the GFC. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Variable	Mean Control	Mean Treatment	Std.Dev. Control	Std.Dev. Treatment	Pearson Corr.
Unemployment	7.38	7.54	1.86	3.70	0.6978*
GDP growth	0.35	0.19	0.47	0.64	0.9021***
Inflation	2.04	1.47	1.53	1.22	0.8659***

Note: Unemployment is the yearly level of unemployment in percentage. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage.

Table A3. This table displays variables, units, description and source of the variables used in the sample.

Variable	Units	Description	Source	Expected Sign NIM	Expected Sign ROA
Bank Profitability and Margin					
NIM	ratio	Net interest margin computed as the difference between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets.	Orbis Bank Focus	n.a	n.a
ROA	ratio	Return on assets is calculated by dividing bank's net income by total assets.	Orbis Bank Focus	n.a	n.a
Dummy					
Treated	dummy	Treated is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise.		-	-
Post	dummy	Post is a dummy variable that takes the value 1 after a period that country j at time t decided to implement NIRP and 0 before that period.		-	-
Treatment	dummy	Treatment is the interaction between the dummy treated and the dummy post		-	-
Bank balance sheet					
Size	logarithm	Size is the natural logarithm of bank total assets.	Orbis Bank Focus	-	+
E/TA	ratio	E/TA is calculated as the ratio of bank equity on total assets.	Orbis Bank Focus	+	-/+
Liquidity	ratio	Liquidity is computed as the ratio of bank liquid securities on total assets.	Orbis Bank Focus	+	-/+
Credit risk	ratio	Credit risk is computed as the ratio of loan loss provisions on total assets.	Orbis Bank Focus & SNL financial	+	-/+
Cost-to-income	ratio	Cost-to-income ratio is calculated as the ratio of operating expenses on net operating income.	Orbis Bank Focus & SNL financial	-	-
Loan growth	percentage	Loan growth is the logarithmic growth rate of gross loans.	Orbis Bank Focus & SNL financial	+	+
Off-balance sheet	ratio	Off-balance sheet is computed as the ratio of off-balance sheet on total assets	Orbis Bank Focus	+	+
Non-interest income	ratio	Non-interest income is calculated as the ratio of non-interest income on gross revenues	Orbis Bank Focus	-	+
Fees & commissions	ratio	Fees & commissions is calculated as the ratio of fees and commissions income to total assets	Orbis Bank Focus	-	+
Interest income	ratio	Interest income is calculated as the ratio of interest income on total assets	Orbis Bank Focus	+	+
Interest expenses	ratio	Interest expenses is calculated as the ratio of interest expenses on total assets	Orbis Bank Focus	-	-

Macroeconomic Conditions and Monetary Policy					
GDP growth	percentage	GDP growth is calculated the yearly growth rate of real GDP.	Thompson Datastream	-/+	-/+
Inflation	percentage	Inflation is the yearly Consumer Price Index.	Thompson Datastream	+	+
Unemployment	percentage	Unemployment is the yearly level of unemployment.	World Bank Database	-	-
Yield curve	percentage points	Yield curve is measured as the 10-year government bond return.	Thompson Datastream	+	+
Credit-to-GDP	ratio	Credit-to-GDP is measured as the ratio of gross loans to real GDP.	Bank for International Settlement Database	+	+
CB_GR	percentage	CB_GR is the logarithm growth rate of central bank balance sheet size.	Orbis Bank Focus	-	+
M0_GR	percentage	M0_GR is the logarithm growth rate of of the money supply M0.	Thompson Datastream	-	+
Loans rate	ratio	Loans rate is the ratio of interest on loans to total gross loans.	Orbis Bank Focus	+	+
Deposits rate	ratio	Deposits rate is the ratio of interest expenses to total cost of deposits.	Orbis Bank Focus	-	-
Lerner index	positive number	The Lerner index is the difference between the price and the total marginal cost as a proportion of the price of banking services. It ranges between 0 (perfect competition) and 1 (monopoly).	World Bank Global Financial Development Database	-	-
Floating-fixed rate countries	ratio	Floating-fixed rate countries is computed as the share of variable rate loans in total loans to households and non-financial corporations.	European Central Bank Statistical Warehouse Database	-	-
Institutional Variables					
Depth of credit info	positive number	Depth of credit information index measures rules affecting the scope, accessibility, and high quality of credit information available through public or private credit register. The index ranges from 0 to 8 with higher value indicating the availability of more credit information.	World Bank Doing Business Database	-	-
Legal right	positive number	Legal right is an index that measures the strengths of minority shareholder protections against misuse of corporate assets by directors for their personal gain as well as shareholders rights, governance safeguards and corporate transparency requirements that reduce the risk of abuse. It ranges from 0 (weak legal rights protection) to 12 (strong legal rights protection).	World Bank Doing Business Database	+	+
Reserve	ratio	Reserve is calculated as the ratio of cash and balances at the central bank on total assets.	Orbis Bank Focus & SNL financial	-/+	-/+
Taxation	ratio	Taxation is computed as the ratio of taxes on operating income	Orbis Bank Focus & SNL financial	-/+	-/+

Chapter 3: Banks' Non-Interest Income and Securities Holdings in a Low Interest Rate Environment: The Case of Italy[19]

Introduction

In this chapter and using a sample of 440 Italian banks between 2007 and 2016, I investigate whether low interest rate affect banks' non-interest income and securities holdings. I find that low interest rates motivate banks to expand their fee and commission income and to restructure their securities portfolios. A granular breakdown of bank income statements suggests banks grow non-interest income in various ways including portfolio management as well as brokerage and consultancy services and increase fee income from current account and payment services. In addition, banks re-balance securities portfolios away from those 'held-for-trading' to securities 'available-for-sale' and 'held-to-maturity' where the latter feed through to improve equity positions. My findings allude to different behaviour between large and small banks: while larger banks increase revenue from brokerage, consultancy and portfolio management services, smaller banks generate fee income from customer current accounts. Interestingly, I uncover evidence that lower capitalised banks grow securities holdings relatively more than well capitalised banks. The chapter is organised as follows. Section 3.1 presents the research question and the mechanisms through which low interest rates can affect bank non-interest income and securities holdings. Section 3.2 shows the literature review. Secton 3.3 introduces data and methodology. Section 3.4 discusses empirical results. Section 3.5 presents several robustness checks and Section 3.6 concludes.

[19] This chapter, co-authored with Philip Molyneux, Chiara Torriero and Jonathan Williams, has been published as journal article. Reference: "Banks' non-interest income and securities holdings in a low interest rate environment: The case of Italy", European Financial Management, Early View, doi: 10.1111/eufm.12268.
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3.1 Background

Since the peak of the GFC in 2008 and the ensuing economic downturn, the European Central Bank (ECB) (and other central banks) has implemented a range of unconventional monetary policy (UMPs) measures to boost national economies. The measures include non-standard monetary policies including large-scale asset purchases (LSAP); quantitative easing (QE); forward guidance (FG) and the negative interest rates policy (NIRP)[20] and the outcome has been historically low policy and/or official interest rates. This has led policymakers to express concern at the negative impact on bank margins and profitability (Alessandri and Nelson; 2015; Bush and Memmel; 2017; Molyneux et al. 2019).[21]

The impact of low interest rates on bank profitability is ambiguous because low rates realise opposite effects on various income statement items (Riksbank, 2016). *Ceteris paribus* low policy rates increase the demand and supply of credit to positively affect bank interest revenues. Other expansionary monetary policies boost bank reserves, therefore, increasing the quantity of available funds (Bernanke and Gertler, 1995). The reduced cost of capital can improve creditors' ability to repay loans and, in turn, lessen loan losses (Altavilla et al., 2017). Lower interest rates could generate gains on fixed-income securities[22] but it depends whether securities are held-for-trading, held-to-maturity or available-for-sale. For trading book securities, gains feed directly to the income statement whereas available-for-sale securities are classified as equity, and the effect of interest rate changes is zero if securities are held-to-maturity. In low interest rate environments, banks may decide, on the one hand, to increase securities held-for-trading to exploit interest rate cuts and realise gains on their trading portfolios. However, protracted periods of low interest rates exhaust the possibility to cut rates further, and this, concomitantly with compressed margins and profits,

[20] See Gertler et al. 2011; Bowdler & Radia, 2012; Cour-Thimann & Winkler, 2013; Gambacorta et al. 2014; Chen et al. 2016; Eser et al. 2016 and Heider et al. 2019 for an overview of the unconventional monetary policy literature.

[21] Official rates in Italy are set by the ECB. The two main official rates are the marginal lending rate (the rate at which banks can borrow from the ECB overnight) and the rate on the deposit facility (this is the interest banks receive – or have to pay in times of negative interest rates – for depositing money with the ECB overnight). The marginal lending rate has fallen from 5.25% in July 2008 to 0.4% by June 2014 and has gradually continued to fall to 0.25% by September 2019. The deposit facility rate has reduced from 3.25% in July 2008, first went negative at -0.1% in June 2014 and has remained negative since then standing at -0.5% by September 2019. The Euro interbank rate Eonia (Euro OverNight Index Average) is the average interest rate for interbank 1-day lending in euros. This has fallen from 3.72% in January in 2008 to -0.079 % in January 2015 and has stayed negative (-0.451%) up to September 2019.

[22] This effect is just temporary. It reflects interest rate changes and disappears when the change is over.

may motivate banks to re-shuffle their securities portfolio from held-for-trading towards available-for-sale and/or held-to-maturity.

In low interest rate environments, banks might also try to expand fee and commission income. Since fees and commissions are earned from a diversified array of services – such as, non-interest income derived from transaction and credit services to brokerage and portfolio management, identifying the link between interest rates and these items can be challenging. There are two possible channels through which the interest rate environment influences fee and commission income. Low yields can cause bank customers to demand more professional services for the purpose of portfolio management (Albertazzi and Gambacorta, 2009). On the supply side, low interest rates boost asset prices and volumes, which positively impacts fees directly linked to servicing such business. Furthermore, in a low interest rate environment banks' incentive to search for yield is stronger (Rajan, 2006), which influences banks to sell more services to customers to boost fee and commission income.

Low interest rates, however, can negatively affect net interest margins (Altavilla et al., 2017; Borio et al., 2017; Claessens et al., 2018). Low rates compress margins due to an imperfect passthrough to deposit rates. Banks are reluctant to impose negative rates on depositors because of fears of creating adverse effects on deposit balances (Jobst and Lin, 2016; Borio et al., 2017). This downward stickiness in deposit markets means that any reduction in lending rates exceeds deposit rates, which ultimately compresses margins. A contraction in net interest margin, absent a compensating increase in other sources of revenue can cause reductions in earnings, capital and credit growth. In such an environment, banks may be encouraged to adapt their business model by switching from interest to non-interest income in order to maintain profitability.

In this paper, I investigate the effect of low interest rates on banks' non-interest income and securities holdings. Whereas the impact of low interest rates on bank net interest margins is well documented, its effect on non-interest income has, so far, received less attention. The link between interest rates and bank business models has important policy implications in terms of both financial stability and monetary policy transmission. An excessive reliance on non-interest income could render bank revenues less stable (DeYoung and Roland, 2001). Moreover, regulators do not

require banks to hold regulatory capital against most fee and commission-related products, so in a tougher regulatory regime and faced with a low interest rate environment, this could motivate a switch to non-interest income-related business, which potentially exacerbates stability concerns.[23] In addition, if banks try to maintain profits in low interest rate environments by shifting to non-interest income activities, this will not increase bank lending to the real economy. As such, the latter limits the effectiveness of monetary policy.

To examine the effect of low interest rate environments on non-interest income and securities, I use a granular dataset comprising 440 Italian banks between 2007 and 2016 that has been provided by the Italian Banking Association (ABI). The granularity enables us to investigate bank income structures by examining specific balance sheet and income statement items alongside detailed notes to the accounts. Indeed, while recent studies consider aggregate non-interest income (Altavilla et al., 2017; Borio et al., 2017), I can disentangle effects into various sub-categories. Specifically, I differentiate fee and commission income by three activities: first, portfolio management, brokerage and consultancy services; second, collection and payment services; third, current account services. In addition, I examine changes in the composition of bank securities holdings and differentiate between securities held-for-trading, available-for-sale and held-to-maturity. Overall, I find a negative relationship between the level of interest rates and fee and commission income and total securities. A granular breakdown of bank income statements suggests that banks grow non-interest services in various ways, namely, by enhancing fee income from: portfolio management, brokerage and consultancy; collection and payment services; and current account charges. My analysis shows banks re-balance their securities portfolios away from held-for-trading to available-for-sale and held-to-maturity securities. My findings identify different behaviour between large and small banks. While larger banks boost income from increased brokerage, consultancy and portfolio management services, smaller banks focus more on increasing customer current account fees. I find also that lower capitalised banks hold more securities (as a % of total assets) compared to well capitalised banks.

[23] The regulation on prudential requirements (as part of the Capital Requirements Regulation, CRR) requires – even if indirectly through operational risk – own funds for fee and commission-related services. Indeed, as these services may originate operational risks, the Basic Indicator Approach (BIA) requires banks to set aside capital for operational risk that is equal to 15% of the average of the total revenues over three years. This includes also fees and commissions income.

3.2 Literature Review

Recently, a growing body of research has examined how monetary policy affects bank performance in low interest rate environments. This chapter builds on this literature by investigating the effect of a protracted period of low interest rates on the detailed components of bank non-interest income. While much of the literature evaluates the effect of monetary policy on net interest margins and bank profitability (return on assets),[24] there is scant literature to link monetary policy and non-interest income.

Albertazzi and Gambacorta (2009) study the relationship between bank profitability and the business cycle by using data from 10 industrialised economies. Albertazzi and Gambacorta is one of the first papers to link macroeconomic and monetary policy conditions to banks' non-interest income. To investigate the aforementioned relationship, they use a GMM dynamic panel and include several macroeconomic variables such as the real gross domestic product, the inflation rate, the money market rate, the long-term government bond rate, the stock market capitalisation divided by GDP, the total amount of loans divided by GDP, the stock market volatility and the overall total assets of the banking sector. They uncover a negative relationship between fee and commission income and long-term interest rates, which they interpret as implying: (a) when interest rates are low, savers demand more professional services from banks to manage their portfolios; and (b) a fall in rates squeezes interest margins and orientates bank attention towards fee-earning activities.

Borio et al. (2017) investigate the link between the level of interest rates and the slope of the yield curve on non-interest income by employing a sample of 267 banks from 14 countries over 1995 – 2012. As in Albertazzi and Gambacorta (2009), they use a GMM dynamic panel to investigate the relationship between interest rates and non-interest income. As a dependent variable, they employ non-interest income as a ratio of total assets. As monetary policy indicators, the three-month interbank rate, the slope of the yield curve computed as the difference between the ten-year government bond yield and the three-month interbank rate. Macroeconomic variable includes: the growth rate of nominal GDP, stock market indices, housing prices and the standard deviation of

[24] See, for instance, Flannery (1981); Hancock (1985); Angbazo (1997); Demirgüç-Kunt and Huizinga (1999); English (2002) and Alessandri and Nelson (2015).

the three-month interbank rate. To take into account bank-specific characteristics they include: bank-fixed effects, time effects, the natural logarithm of bank total assets (size), the ratio of equity-to-total assets (leverage and/or capitalisation), the liquidity-to-total assets ratio (liquidity), the share of short-term liabilities (funding structure), the cost-to-income ratio (management quality) and the standard deviation of the annual percentage change in market value of the assets (asset volatility). They identify a negative relationship that they attribute to two possible effects. First, that lower interest rates generate gains on bank securities portfolios. However, the effect on income statements depends on the conventions under which banks book securities (as available-for-sale, held-for-trading or held-to-maturity). Second, at low rates asset prices and volumes are higher, hence, the search for yield is stronger, which motivates banks to sell more securities service-related products (for instance, portfolio management services) to customers.

In contrast to previous studies and based on a sample of 288 large euro area banks from 2000 to 2016, Altavilla et al. (2017) fail to find any relationship between the level of interest rates or the slope of the yield curve and non-interest income. Indeed, they suggest that banks hold relatively small amounts of mark-to-market securities to realise substantial capital gains.The employ and dynamic panel with fixed effects and several financial variables to capture the effect of the monetary policy environment. Specifically, the yield curve, the VIX, the Expected Default Frequency, real GDP and Inflation. Moreover, they take from the consensus estimated the expected GDP and Inflation. These two variables are the main focus of the analysis as the authors suggest that when expected values of GDP and inflation are accounted for the effect of monetary policy on bank profitability is insignificant. As bank-specific variables they include: return on assets, net interest income, non-interest income, provisions, NPL ratios, Tier 1 capital ratio and cost-to-income. Kok et al. (2019) use a panel econometric model to stress-test fees and commissions over a three-year horizon conditional on adverse macroeconomic scenarios. They suggest that, while loan loss provisions, trading income and net interest income receive strong attentions by supervisory authorities, fee and commission income lacks attention. Since, fees and commissions constitute on average between 25% and 30% of euro are bank total income, it is important to estimate the volatility of such an income stream when macroeconomic conditional are (or are expected to) deteriorated. They also find a negative relationship between short-term interest rates and fee and commission income. They suggest that lower short-term rates are usually associated

with higher business volumes, and in a low interest rate environment banks refocus their strategies from activities generating net interest income towards higher fee and commission income.[25]

I contribute to the extant literature by providing a greater level of granularity and detail into the relationship between low interest rates, non-interest income and securities holdings. While the established literature employs aggregate non-interest income and securities information, this paper is the first to disentangle the effect of low interest rates by considering specific fees and commissions reported in notes to the accounts and securities holdings divided by accounting classifications.

3.3 Data and Methodology

3.3.1 Methodology

The empirical strategy seeks to identify the effect of low interest rates on bank non-interest income and securities holdings. For this purpose, I follow Altavilla et al. (2017), Claessens et al. (2018) and Lucas et al. (2019) and apply a dynamic panel fixed effects methodology. Equation [1] shows the specification of the baseline empirical framework:

$$Y_{it} = \alpha_i + \beta_1 Y_{it-1} + \beta_2 STrate_{t-1} + \beta_3 GR\_CB_{t-1} + \varphi Z_{it-1} + \varphi_i + \sigma_t + \varepsilon_{it} \qquad [3.1]$$

Where *Y* represents my main dependent variables; non-interest income (fee and commission income-to-operating income (FEE)), and securities-to-total assets (SEC)). I use two indicators to proxy the low interest rate environment, the three-month EONIA (*STrate*) rate, and the growth in assets of central bank balance sheets (GR_CB)[26] to account for the effect of unconventional

[25] Other studies do not specifically investigate non-interest income but they find an indirect effect. For instance, using a cross-section of 47 countries, Claessens et al. (2018) investigate the impact of low interest rate environments on bank margins and profits between 2005 and 2013. Their results show the impact of low interest rates on NIMs is greater than on RoA since banks realise valuation gains on fixed-income securities, which mitigates the overall adverse impact of reduced margins on overall profitability. Heider et al. (2019) study the effect of negative interest rates on bank credit and risk-taking for a sample of euro area banks from 2013 to 2015 finding that high-deposit banks offset the negative shock on their net worth by charging higher fees.

[26] The Euro interbank rate Eonia (Euro OverNight Index Average) is the average interest rate for interbank 1-day lending in euros. This has fallen from 3.72% in January in 2008 to -0.079 % in January 2015 and has stayed negative (-0.451%) up to September 2019. Lambert and Ueda (2014), Peydro et al. (2017) and Molyneux et al. (2019), among

monetary policies.[27] A vector Z specifies various lagged bank-specific variables: bank size (Size); liquidity (Liquidity); capitalisation (E/TA); asset quality (NPLs); and cost-to-income ratio (Cost-to-income).[28] Equation [3.1] includes time effects (σ_t) to control for the effect of crises and regulatory changes that have affected bank performance. I also include bank fixed effects (φ_i) to control for time-invariant bank-specific factors that shape bank performance. I estimate all regressions using bank-level clustering to allow for correlation in the error term and use robust standard errors to address heteroscedasticity issues (Petersen, 2009). In addition, I use the variance inflation factor (VIF) to check for multicollinearity amongst covariates in the baseline regression. A mean VIF of 1.13 suggests that my covariates are not highly correlated (Table A in Appendix 3 shows a correlation matrix).

I develop the econometric specification by using the granular data to further investigate the effect of low interest rates on bank non-interest income. Specifically, I split fee and commission income into: revenue derived from portfolio management, brokerage and consultancy services (FEEMAN); collection and payment services (FEEPAY); and fees from current accounts (FEEACCOUNT). I construct each measure as a ratio of operating income. I decompose securities into: available-for-sale (AFS); held-for-trading (HFT); and held-to-maturity (HTM) and express each measure as a ratio of total assets. This granular division should permit a better understanding of non-interest income in an environment characterised by low interest rates.

To control for potential problems arising from endogeneity and simultaneity, I specify one-period lags of the covariates, and in a further check for robustness, employ the dynamic System Generalised Method of Moments (S-GMM) panel methodology. This methodology should reduce endogeneity biases and take into account bank heterogeneity, thereby reducing the omitted variable bias. Moreover, the latter has a well-documented advantage when the data are highly persistent.

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others, use central bank balance sheet size to proxy unconventional monetary policy because quantitative easing and major asset purchases rapidly increase the size of central bank balance sheets.

[27] Although some studies, such as, Borio et al. 2017 and Altavilla et al. 2017, use the slope of the yield curve computed as the difference between the ten- and two-year government bond yield (or the short-term rate), I find short-term rates and the yield curve are subject to multicollinearity. In my case, the correlation coefficient between short-term rates and the slope of the yield curve is 0.98.

[28] The next section (3.3.2) will explain and justify my choice of variables.

Instruments are used following Blundell and Bond (1998) where exogenous variables are transformed in first differences and instrumented by themselves whilst endogenous variable by their lags in levels. The system GMM consistency is given by the validity of the instruments used, which are tested with the Hansen test. Since these estimators were developed for "large N and small T" panels, large T reduces the asymptotic properties of the S-GMM making coefficients and standard errors less reliant as well as invalidating the Hansen's test. For this reason, I also control for this issue by collapsing the set of instruments as suggested by Roodman (2009). We use the two steps estimator methodology, i.e. using the inverse of the covariance matrix of the moment vector from the first-step estimation as the weighting matrix in the second step and standard errors who are computed using the Windmeijer bias-corrected estimator (Windmeijer, 2005).

3.3.2 Data

I construct a dataset from various sources. I source bank balance sheet and income statement data from the Italian Banking Association (ABI Banking Data). This novel dataset covers the population of Italian banks. It has a high degree of granularity that allows me to fully investigate bank income structures through detailed analysis of specific balance sheet items, income statement and information in notes to the accounts (typically unavailable in commercial databases). Furthermore, the time series data contains no missing values. I source monetary policy series from Thomson Datastream and the European Central Bank Statistical Data Warehouse. The initial sample includes 734 financial institutions between 2007 and 2016. Whilst several banks exited the market following the global financial crisis and European sovereign crisis, I keep those banks that report data across the sample period.[29] To deal with mergers and acquisitions, I drop observations that display an excessive annual asset growth rate (exceeding 50%). I winsorize variables at 1% to mitigate the influence of outliers. My final sample contains 440 banks and 3,960 bank-level observations. Table 3.1 summarises the variables.

[29] I prefer a balanced rather than an unbalanced panel as the latter can amplify the omitted variable bias (Baltagi and Song., 2006). However, survivorship bias could affect a sample comprising only active banks. Therefore, I use the original unbalanced sample as a further robustness check to verify the validity of my baseline results.

Table 3.2 shows descriptive statistics for bank fee and commission income, securities, other balance sheet variables, and monetary policy indicators. Panel A displays summary statistics of the dependent variables. Following Busch and Kick (2009), the ratio of fee and commission income-to-operating income (FEE) indicates bank income diversification toward service-based activities. The evolution of the ratio of securities-to-total (SEC) shows if the protracted period of low interest rates motivated banks to enlarge or shrink their securities portfolios. As noted above, I decompose the dependent variables, FEE and SEC. Specifically, I split FEE into income derived from: portfolio management, brokerage and consultancy fees (FEEMAN); collection and payment services fees (FEEPAY); and current accounts fees (FEEACCOUNT), each as a ratio to operating income.[30] I divide securities into those available-for-sale (AFS), held-for-trading (HFT), and held-to-maturity (HTM) each as a ratio of total assets.

[30] I have more than 20 fee and commission variables in the dataset but apart from FEEMAN, FEEPAY and FEEACCOUNT all other components represent less than 5% of total fee and commission income. As such, the aggregate variable FEE includes all components, but for different types of fee income I focus on the aforementioned major three components.

Table 3.1. Variable name, units of measurement, definition and source

Variable	Units	Definition	Source
Non-interest income items			
FEE	ratio	FEE is the ratio of fee and commission income-to-total revenue	ABIFast
FEEMAN	ratio	FEEMAN is the ratio of management, brokerage and consultancy fees-to-total revenue	ABIFast
FEEPAY	ratio	FEEPAY is the ratio of payment services fees-to-total revenue.	ABIFast
FEEACCOUNT	ratio	FEEACCOUNTS is the ratio of current account fees-to-total revenue.	ABIFast
Bank balance sheet & Income statement items			
SEC	ratio	Securities is the ratio of all types of financial assets-to-total assets.	ABIFast
AFS	ratio	AFS is the ratio of available-for-sale securities-to-total assets.	ABIFast
HFT	ratio	HFT is the ratio of held-for-trading securities-to-total assets.	ABIFast
HTM	ratio	HTM is the ratio of held-to-maturity securities-to-total assets.	ABIFast
Size	logarithm	Size is the natural logarithm of bank total assets.	ABIFast
Liquidity	ratio	Liquidity is the ratio of short-term liquid assets-to-total assets.	ABIFast
NPL ratio	ratio	NPL is the ratio of non-performing loans-to-total gross loans.	ABIFast
Cost-to-income ratio	ratio	Cost-to-income ratio is the ratio of operating expenses-to-total revenue.	ABIFast
E/TA	ratio	E/TA is the ratio of bank equity-to-total assets.	ABIFast
Macroeconomic Conditions and Monetary Policy			
STrate	Percentage	STrate is the three-month EONIA.	Thomson Datastream
CB_GR	percentage	CB_GR is the logarithm yearly growth rate of the European Central Bank balance sheet size	European Central Bank Statistical Data Warehouse

Table 3.2. Descriptive Statistics

	Obs	Mean	St.Dev	p1	p99
Panel A. Dependent Variables					
FEE	4400	0.2201	0.0811	0.1127	0.3780
SEC	4400	0.2241	0.1193	0.0160	0.4061
FEEMAN	4400	0.0592	0.0502	0.0065	0.1713
FEEPAY	4400	0.0552	0.0284	0.0090	0.0980
FEEACCOUNTS	4400	0.0836	0.0388	0.0128	0.1408
AFS	4400	0.2007	0.1401	0	0.5843
HFT	4400	0.0115	0.0216	0	0.0670
HTM	4400	0.0076	0.0275	0	0.1060
Panel B. Monetary Policy & Balance Sheet Variables					
STrate	4400	0.9802	1.417	-0.3420	3.730
GR_CB	4400	0.1421	0.2023	-0.2327	.3762
Size	4400	13.3318	1.6901	10.4953	18.6153
E/TA	4400	0.1074	0.0344	0.0598	0.1717
Npls	4400	0.0180	0.0255	0	0.0726
Liquidity	4400	0.2351	0.1419	0.0001	0.6407
Cost-to-income	4400	0.6705	0.3727	0.3517	1.1741

Note: FEE is the ratio of net fees and commissions-to-total revenue. SEC is the ratio of total securities-to-total assets. FEEMAN is the ratio of management, brokerage and consultancy fees-to-total revenue. FEEPAY is the ratio of payment services fees-to-total revenue. FEEACCOUNTS is the ratio of account fees-to-total revenue. AFS is the ratio of available-for-sale securities-to-total assets. HFT is the ratio of held-for-trading securities-to-total assets. HTM is the ratio of held-to -maturity securities-to-total assets. STrate is the three-month EONIA. GR_CB is the yearly growth rate of central bank total assets. Size is the logarithm of bank total assets. E/TA in the ratio of equity-to-total assets. Liquidity is the ratio of liquid securities-to-total assets. NPL is the ratio of non-performing loans-to-total gross loans. Cost-to-income is the ratio of operating expenses-to-total revenue.

Panel B shows summary statistics of my variables of interest and bank-specific controls. STrate is the three-month EONIA interest rate. The effect of short-term interest rates on fee and commission income is not clear cut. From the perspective of savers, low interest rates should be *ceteris paribus* associated with higher bank business activities as low interest rates exert a positive effect on asset prices and volumes (Kok et al. 2019). Moreover, at low rates, bank customers may demand more professional services to manage portfolios and search for yield (Albertazzi and Gambacorta, 2009). From the bank side, there may be a rebalancing effect from low interest rate generating activities, such as, loans towards more service-based sources of income. This scenario makes possible a negative relationship between STrate and FEE. Other things equal, lower interest rates should generate capital gains on bank security holdings (Borio et al. 2017). However, this depends on how banks book their securities. If securities are in the trading book, gains feed directly into the income statement; if available-for-sale they go into equity, and there is no effect if banks hold

securities to maturity. Hence, the expected sign of STrate on the overall holdings of securities (SEC) is uncertain.

In accord with Lambert and Ueda (2014) and Peydro et al. (2017), I employ the growth rate of the ECB bank balance sheet (GR_CB) to proxy unconventional monetary policy (UMP). On the one hand, banks benefit from UMP in terms of lower funding costs and positive valuation effects via increased asset prices. On the other hand, UMPs can flatten the yield curve, which reduces revenues from floating rate and new loans and narrows net interest margins (Alessandri and Nelson, 2015). Hence, a flat yield curve may motivate banks to switch toward a more services-oriented business model. Based on this discussion, I envisage a positive relationship between FEE and central bank asset growth. In contrast to the relationship between STrate and bank securities, the relationship between GR_CB and securities is not clear-cut. On the one hand, by flattening the yield curve, UMPs affect bank securities reinvestment risk, namely, the expected level of earnings of any reinvestment of cash flow during the period. If yields decrease securities values improve, but the rate of return for future investment declines and motivates banks to hold fewer securities as, in general, a flattening yield curve implies that interest rates will stay low for long. On the other hand, a portfolio rebalancing channel toward securities is possible as: a) the current regulatory framework allows banks to hold European sovereign debt without capital charges (zero-risk weights) and exposure limits and;[31] b) deteriorating macroeconomic conditions, higher levels of non-performing loans and tighter prudential regulation may motivate banks to substitute lending for securities for stronger capital positions as well as to "reach-for-yield" (Altavilla et al. 2017).

I measure bank size (Size) as the logarithm of total assets. DeYoung and Rice (2004) suggest size relates positively to fee and commission income and securities holdings because larger banks rely more heavily on non-interest income than small banks. I employ several variables to control for bank risk aversion, asset quality, liquidity and operating efficiency. I use the ratio of equity-to-total assets (E/TA) to proxy bank risk aversion. A negative relationship is expected between this variable and service-based activities and securities as less capitalised banks may prefer to expand services and hold more securities due to low (or zero) capital requirements. Furthermore, capital

[31] Although here I am not able to disentangle between government bonds and other securities holdings, in Italy 81% of securities held by the banking sector are government bonds, and the majority are domestic (Peydro et al. 2017).

constrained banks may curtail lending and invest more in securities to raise fee and commission income to maintain profits. I employ liquidity and a measure of credit risk to control for bank liquidity and asset quality. I expect illiquid banks and banks with poorer quality loans to charge higher fees and commissions for services. I expect a positive relationship between NPLs and securities because deterioration in the quality of credit worsens both capital ratios and profitability, which motivate banks to cut lending and invest in securities. Finally, I measure the efficiency of bank management through the cost-to-income ratio (Cost-to-income) or the operating cost necessary to generate one unit of income (Altavilla et al. 2017). Since the main input needed to produce more fee-based products is typically fixed or quasi-fixed (labour expenses), I expect a positive relationship between the cost-to-income ratio and fee and commission income (DeYoung and Roland, 1999).

3.4 Empirical Findings

3.4.1 Baseline Results

I present baseline results from estimates of equation [3.1] in Table 3.3. Columns 1 to 3 report estimates when FEE is the dependent variable while SEC is the dependent variable for columns 4 to 6. Columns 1 and 4 show estimates from models with bank fixed effects but excluding bank-specific controls and time effects. Columns 2 and 5 show variations in the baseline estimates by adding bank controls while Columns 3 and 6 include both bank controls and time effects. My main interest is the size, sign and statistical significance of the coefficients of β_2 (STrate) and β_3 (GR_CB). These coefficients signal the effects of low interest rate environments on bank non-interest income and securities holdings.

I find low interest rates realise a negative, statistically significant (at the 1% level across specifications) effect on fee and commission income (Column 1). A one percentage point decrease in the short-term interest rate increases fee and commission income by around 2.5% relative to the mean. Greater demand for and supply of services in low interest rate environments (see section 3.1 and 3.2.2) allow banks to redistribute part of their income from traditional intermediation to fee-based activities. FEE is positively and significantly associated to GR_CB (at the 1% level). A 100-basis point increase in central bank asset growth increases fee and commission income by 5.27% relative to the mean. The effect is economically more important than the STrate. In the short-term,

banks benefit from a funding cost reduction and security gains, which serve to limit incentives for banks to expand service-related activities. However, in the long-run UMPs flatten the yield curve to compress newly issued and floating long-term maturity assets like loans, which offsets lower funding costs and motivates banks to switch into other sources of income.

I discover a negative, statistically significant relationship between STrate and SEC, which infers that banks prefer to hold more securities in low interest rate environments when monetary policy is accommodative (Column 4). A one percentage point decrease in STrate increases bank securities holdings by around 6% relative to the mean. Again, as for fee and commission income, I find a positive relationship between SEC and the proxy for unconventional monetary policy (GR_CB). A one percentage point increase in the ECB balance sheet increases bank security holdings by 18%. This result suggests a portfolio-rebalancing channel toward securities motivate by either banks' risk shifting or liquidity hoarding behaviour. In an economic environment characterised by slow economic recovery and high levels of non-performing loans as in Italy (Accornero et al. 2017), holding liquid securities could be the consequence of a credit demand problem, with few opportunities to lend (Summers, 2014) or a pool of risky borrowers (Rogoff, 2015). Hence, banks could hoard liquid securities rather than issue relatively illiquid loans to small and medium enterprises (SMEs).

Columns 2 and 5 report results from the regressions I augment with bank controls. I continue to observe a statistically significant effect of STrate and GR_CB on the key dependent variables. The bank-level controls are also statistically significant. Size is positively related to securities suggesting that large banks hold relatively more securities than their smaller counterparts (Column 5). Smaller banks appear to have expanded income more into service-related activities compared to larger banks (Column 2). Credit risk is positively associated to both FEE and SEC which I interpret as indicating that banks with weaker asset quality pass these costs to customers through higher fees, rationing lending, and investing more in securities (Columns 2 and 5). Liquidity is negatively related to FEE (Column 2) as lower bank liquidity encourages a switch towards service-related products.[32] Finally, the cost-to-income ratio displays a positive association to FEE (Column

[32] I remove liquidity from the Security regressions (columns 7 to 9) because it is highly correlated with the lag of the dependent variable. The correlation coefficient is 81.83%.

2). Since fee-related services are both labour and fixed cost intensive, I contend this explains the positive relation between FEE and cost-to-income. Columns 3 and 6 show the results are robust to the inclusion of time effects.

Table 3.3. NIMs, FEEs and Securities holdings in a low interest rate environment

	(1) **FEE**	(2) **FEE**	(3) **FEE**	(4) **SEC**	(5) **SEC**	(6) **SEC**
L.FEE	0.4091***	0.4049***	0.4422***			
	(0.0321)	(0.0354)	(0.0340)			
L.SEC				0.6882***	0.6216***	0.5925***
				(0.0155)	(0.0175)	(0.0198)
L.STrate	-0.0054***	-0.0060***	-0.0140***	-0.0132***	-0.0086***	-0.0139***
	(0.0008)	(0.0010)	(0.0011)	(0.0007)	(0.0010)	(0.0035)
L.GR_CB	0.0116***	0.0115***	0.0554***	0.0410***	0.0328***	0.0306***
	(0.0031)	(0.0032)	(0.0059)	(0.0044)	(0.0045)	(0.0044)
L.Size		-0.0064*	-0.0073*		0.0142**	0.0063
		(0.0038)	(0.0041)		(0.0065)	(0.0060)
L.E/TA		-0.0285	-0.1222		-0.1836***	-0.2151***
		(0.0868)	(0.0830)		(0.0688)	(0.0681)
L.NPLs		0.1000*	0.1593***		0.5912***	0.4501***
		(0.0519)	(0.0508)		(0.0876)	(0.0912)
L.Liquidity		-0.0242**	-0.0331***			
		(0.0115)	(0.0113)			
L.Cost-to-income		0.0090**	0.0105***		-0.0033	-0.0027
		(0.0042)	(0.0039)		(0.0030)	(0.0026)
Observations	3,960	3,960	3,960	3,960	3,960	3,960
R-squared	0.2646	0.2728	0.4213	0.6012	0.6162	0.6413
Number of banks	440	440	440	440	440	440
Bank-FE	YES	YES	YES	YES	YES	YES
Year-FE	NO	NO	YES	NO	NO	YES

Note: L.FEE is the lag of the ratio of net fees and commissions-to-total revenues. L.SEC is the lag of the ratio of total securities-to-total assets. L.STrate is lag of the three-month EONIA. L.GR_CB is the lag of yearly growth rate of central bank total assets. L.Size is lag of the logarithm of bank total assets. L.E/TA is the lag of the ratio of equity-to-total assets. L.Liquidity is the lag of the amount of liquid securities-to-total assets. L.NPLs is the lag of the ratio of non-performing loans-to-total gross loans. Cost-to-income is the lag of the ratio of operating expenses-to-total revenues. Regressions include fixed bank and time effects as specified. Robust standard errors clustered by bank in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

3.4.2 Breakdown in Fee and Commission Income

Table 3.4 presents results from when I breakdown fee and commission income into three constituents: portfolio management, brokerage and consultancy fees (FEEMAN); collection and payment services fees (FEEPAY); and current accounts fees (FEEACCOUNT). As previously,

columns 1, 4 and 7 show estimates when I specify bank fixed effects only. Results in columns 2, 5 and 8 include bank controls and columns 3, 6 and 9 include bank controls and time effects.

As expected, I find each fee sub-category displays negative and positive significant relationships to STrate and GR_CB, respectively (mostly at the 1% level). In low interest rate environments, enterprises are more likely to prefer security issuance and related services because of lower capital costs. Also, investors, both retail and wholesale, are likely to increase demand for professional services to manage portfolios and search for yield (Albertazzi and Gambacorta, 2009). Consequently, banks grow their revenues by placing securities, or underwriting for firms, and managing portfolios for investors. Banks (of course) may simply charge more for non-interest income activities to offset the negative effect of low rates on bank profitability (Altavilla et al. 2018 and Lucas et al. 2018).

3.4.3 Securities Activity Breakdown

Table 3.5 shows results when I classify securities as available-for-sale (AFS), held-for-trading (HFT), and held-to-maturity (HTM). As above, columns 1, 4 and 7 show estimates when I specify bank fixed effects only. Results in columns 2, 5 and 8 include bank controls and columns 3, 6 and 9 include bank controls and time effects.

Table 3.5 reveals bank behaviour in terms of securities holdings during episodes of low interest rates. While coefficients for AFS (columns 1 to 3) and HTM securities (columns 7 to 9) are negatively related to STrate, I observe a positive relationship to GR_CB. This suggests that in an environment characterised by accommodative monetary policy, banks hold more securities to purse liquidity needs and/or requirements (in the case of HTM) or risk-shifting (for AFS).

Table 3.4. Management, brokerage and consultancy fees; cash receipts and payments fees; and current account fees in a low interest rate environment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	FEEMAN	**FEEMAN**	**FEEMAN**	**FEEPAY**	**FEEPAY**	**FEEPAY**	**FEEACCOUNTS**	**FEEACCOUNTS**	**FEEACCOUNTS**
L.FEEMAN	0.4655***	0.4358***	0.4152***						
	(0.0502)	(0.0467)	(0.0462)						
L.FEEPAY				0.4490***	0.4590***	0.4672***			
				(0.0231)	(0.0226)	(0.0231)			
L.FEEACCOUNTS							0.3094***	0.3102***	0.3518***
							(0.0291)	(0.0291)	(0.0279)
L.STrate	-0.0017***	-0.0012***	-0.0043***	-0.0009***	-0.0009***	-0.0021***	-0.0041***	-0.0045***	-0.0023***
	(0.0002)	(0.0004)	(0.0006)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0004)	(0.0004)
L.GR_CB	0.0022*	0.0020*	0.0094***	0.0043***	0.0044***	0.0109***	0.0101***	0.0101***	0.0238***
	(0.0014)	(0.0014)	(0.0027)	(0.0008)	(0.0008)	(0.0019)	(0.0015)	(0.0015)	(0.0027)
L.Size		-0.0086***	-0.0113***		-0.0004	-0.0005		-0.0038***	-0.0010
		(0.0028)	(0.0030)		(0.0007)	(0.0007)		(0.0013)	(0.0013)
L.E/TA		0.0077	-0.0454		0.0286*	0.0020		-0.0701**	-0.0847***
		(0.0467)	(0.0461)		(0.0168)	(0.0162)		(0.0291)	(0.0273)
L. NPLs		0.1734***	0.1157***		0.0205	0.0277**		-0.0171	0.0273
		(0.0369)	(0.0383)		(0.0132)	(0.0137)		(0.0314)	(0.0336)
L.Liquidity		0.0195***	0.0013		0.0013	-0.0042*		-0.0081*	-0.0126***
		(0.0047)	(0.0043)		(0.0023)	(0.0024)		(0.0045)	(0.0047)
L.Cost-to-income		0.0005	0.0005		-0.0006	-0.0006*		-0.0010	-0.0001
		(0.0022)	(0.0022)		(0.0004)	(0.0003)		(0.0006)	(0.0005)
Observations	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960
R-squared	0.2110	0.2448	0.3032	0.2421	0.2448	0.3317	0.1476	0.1517	0.2261
Number of banks	440	440	440	440	440	440	440	440	440
Bank-FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year-FE	NO	NO	YES	NO	NO	YES	NO	NO	YES

Note: L.FEEMAN is the lag of ratio of management, brokerage and consultancy fees-to-total revenues. L.FEEPAY is the lag of ratio of payment fees-to-total revenues. L.FEEACCOUNTS is the lag of the ratio of current account fees-to-total revenues. L.STrate is the lag of three-month EONIA. L.GR_CB is the lag of yearly growth rate of central bank total assets. L.Size is lag of the logarithm of bank total assets. L.E/TA is the lag of the ratio of equity-to-total assets. L.Liquidity is the lag of the amount of liquid securities-to-total assets. L.NPLs is the lag of the ratio of non-performing loans-to-total gross loans. Cost-to-income is the lag of the ratio of operating expenses-to-total revenues. Regressions include fixed bank and time effects as specified. Robust standard errors clustered by bank in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Indeed, in low interest rate environments, banks seem to prefer holding AFS and HTM securities over HFT for trading. I confirm this interpretation since the coefficient on HFT securities (columns 4 to 6) shows a positive (negative) relationship with STrate (GR_CB). Indeed, if banks treat securities as HFT, the unrealised changes in fair value (losses or gains realised due to changes in price) feeds directly into the profit and loss statement. Treating securities as AFS means unrealised changes are reported in other comprehensive income (available-for-sale portfolio) and are booked directly to equity. At first sight, one may expect banks to expand HFT securities to exploit interest rate cuts and realise trading portfolio gains. However, protracted periods of low interest rates exhaust the ability of further cuts and, at the same time, raise concerns about the possibility of tighter monetary policies in the future. This, concomitantly with damper margins and profits, motivates banks to re-shuffle their securities portfolio from HFT to AFS and HTM. As such, these findings indicate risk-shifting behaviour. The magnitude of the effect is economically meaningful. For instance, a one percentage point decrease in STrate decreases HFT securities by 14.78% relative to the mean, while it increases AFS and HTM by 6.87% and 11.84%, respectively.

3.5 Robustness checks

I present robustness checks and further variations of the baseline model. As suggested in Section 3.4, banks grow fee and commission income in low interest rate environments in various ways that I describe above: portfolio management, brokerage and consultancy fees; collection and payment services fees; and current account fees. Arguably, FEEMAN (portfolio management, brokerage and consultancy fees), which are investment-banking-related services, require a higher level of expertise and are more likely provided by larger rather than smaller banks. Panel A of Table 3.6 (columns 1 to 3) shows coefficients on the interaction of bank size and STrate. As expected, the results infer that larger banks focus more on portfolio management, brokerage and consultancy services, while smaller banks focus more on increasing fee income from customer current accounts. This result is consistent with Bottero et al. (2019) who find small retail banks respond to low interest rates by raising fees on deposit account services. I do not find any relationship between bank size and fees from payment services.

Table 3.5. Available for sale, held for trading and held to maturity securities in a low interest rate environment.

	(1) **AFS**	(2) **AFS**	(3) **AFS**	(4) **HFT**	(5) **HFT**	(6) **HFT**	(7) **HTM**	(8) **HTM**	(9) **HTM**
L.AFS	0.7173***	0.6655***	0.6324***						
	(0.0163)	(0.0161)	(0.0196)						
L.HFT				0.5363***	0.5327***	0.5290***			
				(0.0227)	(0.0234)	(0.0236)			
L.HTM							0.5509***	0.5500***	0.5517***
							(0.0450)	(0.0459)	(0.0460)
L.STrate	-0.0138***	-0.0100***	-0.0180***	0.0017***	0.0016***	0.0016***	-0.0009***	-0.0006**	-0.0007**
	(0.0008)	(0.0011)	(0.0042)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0003)
L.GR_CB	0.0325***	0.0267***	0.0276***	-0.0040***	-0.0038***	-0.0026***	0.0067***	0.0062***	0.0156***
	(0.0050)	(0.0051)	(0.0051)	(0.0008)	(0.0008)	(0.0007)	(0.0017)	(0.0016)	(0.0038)
L.Size		0.0161**	0.0091		-0.0004	-0.0002		-0.0008	0.0004
		(0.0074)	(0.0071)		(0.0007)	(0.0008)		(0.0014)	(0.0015)
L.E/TA		-0.1490*	-0.2015**		0.0372**	0.0379**		-0.0440*	-0.0359
		(0.0830)	(0.0864)		(0.0154)	(0.0157)		(0.0243)	(0.0236)
L. NPLs		0.5274***	0.3568***		0.0141	0.0255		0.0291	0.0591*
		(0.0869)	(0.0992)		(0.0154)	(0.0175)		(0.0302)	(0.0348)
L.Cost-to-income		-0.0041	-0.0033		-0.0007**	-0.0008*		-0.0001	-0.0003
		(0.0032)	(0.0027)		(0.0004)	(0.0004)		(0.0004)	(0.0005)
Observations	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960
R-squared	0.6746	0.6830	0.6971	0.4883	0.4903	0.4919	0.3015	0.3026	0.3062
Number of banks	440	440	440	440	440	440	440	440	440
Bank-FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year-FE	NO	NO	YES	NO	NO	YES	NO	NO	YES

Note: L.AFS is the lag of available for sale securities to total assets ratio. L.HFT is the lag of held for trading securities to total assets ratio. L.HTM is the lag of held to maturity securities to total assets ratio. L.STrate is the lag of three-month EONIA. L.GR_CB is the lag of yearly growth rate of central bank total assets. L.Size is lag of the logarithm of bank total assets. L.E/TA is the lag of the ratio of equity to total assets. L.Liquidity is the lag of the amount of liquid securities to total assets. L.NPLs is the lag of the ratio of non-performing loans to total gross loans. Cost-to-income is the lag of the ratio of operating expenses to total revenues. Regressions include fixed bank and time effects as specified. Robust standard errors clustered by bank in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Panel B of Table 3.6 reports results of tests of the regulatory capital arbitrage hypothesis and the risk-bearing capacity hypothesis. The regulatory capital arbitrage hypothesis (Allen and Gale, 2007) suggests that less capitalised banks face difficulties to grow lending, which motivates acquisition of securities (mostly government bonds) given their favourable regulatory capital treatment. The risk-bearing capacity hypothesis (Adrian and Shin, 2011) proposes that lowly capitalised banks assume different risks depending whether their securities are held-to-maturity, held-for-trading or available-for-sale. In contrast, better capitalised banks can assume greater risks. To test these hypotheses, I interact STrate and capitalisation. The results in Panel B show that banks with lower levels of capital hold more securities, which support the capital arbitrage hypothesis. However, I cannot support the risk-bearing capacity hypothesis as interactions are statistically insignificant.

As a third robustness check, I test for the reliability of my measures of conventional (STrate) and unconventional monetary policy (GR_CB) by employing the "shadow rate" as in Wu and Xia (2016).[33] The shadow rate measures the overall stance of monetary policy when conventional monetary policy tools such as short-term rates hit the zero lower bound (ZLB). Since short-term rates become ineffective at the ZLB and central banks resort to UMPs, the shadow rate takes into account the effect of UMPs by allowing short-term rates to fall below zero. The results displayed in Panel C of Table 3.6 (Columns 1 and 2) are in-line with the baseline results. Specifically, the shadow rate shows a statistically significant (at the 1% level) and negative relationship to both FEE and SEC indicating that when the shadow rate decreases banks grow fees and commissions income and securities. This result further validate my choice of the monetary policy variables employed in the baseline regression. As a fourth robustness check, I keep the original unbalanced sample – that includes the overall population of Italian banks (734 financial institutions) – to investigate whether the results are affected by survivorship biases. The results are reported in Panel D of Table 3.6 (Columns 1 to 4). The coefficients of STrate and GR_CB have sign and statistical significance in-line with the baseline regressions.

[33] Data on European Central Bank shadow rate are available at:
https://sites.google.com/site/jingcynthiawu/shadowrate_ECB.xls?attredirects=0

Table 3.6. Robustness checks

	(1)	(2)	(3)	(4)
	FEEMAN	**FEEPAY**	**FEEACCOUNT**	
Panel A. Bank size and fees and commissions				
L.STrate	0.0050***	-0.0013	-0.0082***	
	(0.0018)	(0.0009)	(0.0017)	
L.STrate*L.Size	-0.0007***	-0.0001	0.0004***	
	(0.0001)	(0.0001)	(0.0001)	
Observations	3,960	3,960	3,960	
R-squared	0.4247	0.3134	0.3319	
Number of banks	440	440	440	
Bank-FE	YES	YES	YES	
Year-FE	YES	YES	YES	
Panel B. Bank capitalization and securities	**SEC**	**AFS**	**HFT**	**HTM**
L.STrate	-0.0125***	-0.0093***	0.0016***	-0.0009
	(0.0024)	(0.0026)	(0.0005)	(0.0007)
L.STrate*L.E/TA	0.0327*	-0.0066	-0.0002	0.0022
	(0.0187)	(0.0210)	(0.0046)	(0.0048)
Observations	3,960	3,960	3,960	3,960
R-squared	0.6177	0.6831	0.4905	0.3030
Number of banks	440	440	440	440
Bank-FE	YES	YES	YES	YES
Year-FE	YES	YES	YES	YES
Panel C. Shadow rate	**FEE**	**SEC**		
L.Shadowrate	-0.0079***	-0.0067***		
	(0.0006)	(0.0007)		
Observations	3,960	3,960		
R-squared	0.4213	0.6364		
Number of banks	440	440		
Bank-FE	YES	YES		
Year-FE	YES	YES		
Panel D. Unbalanced Panel	**FEE**	**FEE**	**SEC**	**SEC**
L.STrate	-0.0144***		-0.0091***	
	(0.0010)		(0.0032)	
GR_CB		0.0264***		0.0245***
		(0.0031)		(0.0040)
Observations	5,325	5,325	5,325	5,325
R-Squared	0.3975	0.3450	0.5917	0.5939
Number of banks	731	731	731	731
Bank-FE	YES	YES	YES	YES
Year-FE	YES	YES	YES	YES

Note: FEEMAN is the ratio of management, brokerage and consultancy fees-to-total revenues. FEEPAY is the ratio of payment fees-to-total revenues. FEEACCOUNTS is the ratio of account fees-to-total revenue. SEC is the ratio of total securities-to-total assets. AFS is the available for sale securities-to-total assets ratio. HFT is the held for trading securities-to-total assets ratio. HTM is the held to maturity securities-to-total assets ratio. L.STrate is the lag of three-month EONIA. L.GR_CB is the lag of yearly growth rate of central bank total assets. L.Size is lag of the logarithm of bank total assets. L.E/TA is the lag of the ratio of equity-to-total assets. L.Shadowrate is the lag of the shadow rate as defined in Wu and Xia (2016). Regressions include fixed bank and time effects as specified. Robust standard errors clustered by bank in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Finally, I employ S-GMM estimation to test the validity of my econometric specification. If the estimated coefficients of the dynamic panel fixed effects are of the same sign and significance as the S-GMM results, I can be more confident about the reliability of the baseline results. Table 3.7 reports results from models estimated using the S-GMM. I confirm the coefficients are consistent, which endorses the reliability of my baseline findings.

3.6 Conclusion

Since August 2007, the ECB has adopted several conventional and unconventional monetary policies aimed at easing tension in the financial sector and to boost credit to the economy. These measures have reduced interest rates to historically low levels raising concerns among policy makers about the effects on bank behaviour. I investigate the effect of low interest rates on bank non-interest income and securities holdings using a granular dataset of the population of Italian banks from 2007 to 2016. While there is a recent literature that analyses the effects of low interest rates on margins and profits (Alessandri and Nelson, 2015; Bush and Memmel, 2017; Claessens et al., 2018), the effect of the low interest rate environment on bank non-interest activities has received less attention. This paper fills this gap by investigating the effect of low interest rates on bank non-interest income and securities holdings. Moreover, it adds to the extant literature (Borio et al, 2017; Altavilla et al., 2019) by considering detailed fees and commissions reported in notes to the accounts as well as securities holdings according to specific accounting classifications. Overall, I find a negative relationship between the level of interest rates and fee and commission income and securities holdings. A granular breakdown of income statements suggests banks grow non-interest services in various ways, namely, by boosting fees from: portfolio management, brokerage and consultancy services; collection and payment services; and current accounts. Banks re-balance securities portfolios away from held-for-trading towards securities available-for-sale and held-to-maturity. Greater demand for and supply of services in a low interest rate environment allows banks to redistribute part of their income from traditional intermediation to fee-based services. Banks also grow their securities portfolio re-balancing them away from held-for-trading towards securities available-for-sale and held-to-maturity. In an economic environment characterised by slow economic recovery and high levels of non-performing loans, as in Italy,

banks prefer to hold liquid securities owing to poor credit demand or a pool or risky borrowers (for instance SMEs). My findings suggest different behaviour between large and small banks. While larger banks increase income from greater brokerage, consultancy and portfolio management revenue, smaller banks focus more on increasing current account fees. I also find lower capitalised banks increase securities holdings compared to well capitalised banks.

This result is important for policy makers because of its implications for financial stability and monetary policy transmission. On the one hand, revenues from traditional lending activities may be more stable than non-interest income, and greater reliance on non-interest income could render bank revenues and overall performance less stable. Moreover, regulators have provided a generous regulatory treatment for most government securities, that incents banks to hold less capital against these assets, which may have negative repercussions for the stability of the banking sector. Also, and from a monetary policy transmission perspective, if low interest rates and other accommodative monetary policies encourage banks to grow non-interest income activities, it implies that bank lending is not responding as expected to such policy actions.

Table 3.7. Robustness checks

	(1) **FEE**	(2) **SEC**	(3) **FEEMAN**	(4) **FEEPAY**	(5) **FEEACCOUNTS**	(6) **AFS**	(7) **HFT**	(8) **HTM**
L.STrate	-0.0047***	-0.0093***	-0.0034***	-0.0037***	-0.0033***	-0.0098***	0.0014***	-0.0004***
	(0.0011)	(0.0010)	(0.0009)	(0.0012)	(0.0004)	(0.0012)	(0.0002)	(0.0000)
L.GR_CB	0.0091**	0.0402***	-0.0051*	0.0096***	0.0052***	0.0306***	-0.0031***	0.0067***
	(0.0039)	(0.0062)	(0.0028)	(0.0030)	(0.0017)	(0.0058)	(0.0008)	(0.0001)
Observations	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960
Number of banks	440	440	440	440	440	440	440	440
Estimation method	System GMM	System GMM	System GMM	System GMM	System GMM	System GMM	System GMM	System GMM
N. Instruments	52	50	52	47	44	52	52	52
Bank controls	YES	YES	YES	YES	YES	YES	YES	YES

Notes: FEE is the ratio of net fees and commissions-to-total revenues. SEC is the ratio of total securities-to-total assets. FEEMAN is the ratio of management, brokerage and consultancy fees-to-total revenues. FEEPAY is the ratio of payment fees-to-total revenues. FEEACCOUNTS is the ratio of account fees-to-total revenue. AFS is the available for sale securities-to-total assets ratio. HFT is the held for trading securities-to-total assets ratio. HTM is the held to maturity securities-to-total assets ratio. Windmeijer bias-corrected robust standard errors clustered by bank in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively

Appendix B

Table B1. Correlation matrix among the variables used in the baseline regression. Correlations that are significant at least at the 5% level are reported using bold italics. The number on the horizontal axis indicates the variables in the vertical axis.

	1	2	3	4	5	6	7
STrate (1)		**0.4753**	**-0.0856**	**-0.2344**	**-0.2208**	**0.0114**	**0.1371**
GR_CB (2)	**0.4753**		**-0.0277**	**-0.0719**	**-0.0487**	**0.0116**	**0.0271**
Size (3)	**-0.0856**	**-0.0277**		**-0.2382**	**0.1112**	**0.032**	**-0.4712**
Liquidity (4)	**-0.2344**	**-0.0719**	**-0.2382**		**-0.0821**	**0.0332**	**-0.1161**
NPLs (5)	**-0.2208**	**-0.0487**	**0.1112**	**-0.0821**		-0.0016	**0.0923**
Cost-to-income (6)	**0.0114**	**0.0116**	**0.032**	**0.0332**	-0.0016		**0.0148**
E/TA (7)	**0.1371**	**0.0271**	**-0.4712**	**-0.1161**	**0.0923**	**0.0148**	

Note: STrate is the three-month EONIA. GR_CB is the yearly growth rate of central bank total assets. Size is the logarithm of bank total assets. Liquidity is the amount of liquid securities-to-total assets. NPLs is the ratio of non-performing loans-to-total gross loans. Cost-to-income is the ratio of operating expenses-to-total revenues. E/TA is the ratio of equity-to-total assets.

Chapter 4: Did Negative Interest Rates Improve Bank Lending or Fuel Bank Risk-Taking?[34]

Introduction

Since 2012 several central banks have introduced a negative interest rate policy (NIRP) aimed at boosting real spending by facilitating an increase in the supply and demand for bank loans. I employ a bank-level dataset comprising 6558 banks from 33 OECD member countries over 2012-2016 and a matched difference-in differences estimator to analyze whether NIRP resulted in a change in bank lending and bank risk-taking in NIRP-adopter countries compared to those that did not adopt the policy. My results suggest that following the introduction of negative interest rates, bank lending was weaker in NIRP-adopter countries. This adverse NIRP effect appears to have been stronger for banks that were smaller, more dependent on retail deposit funding, less well capitalized, has business model reliant on interest income and operated in more competitive markets. Moreover, I uncover evidence that NIRP-affected banks reduce their holdings of risky assets compared to NIRP non-affected banks. I infer that banks deleverage post-crises deteriorated balance sheets and invest in liquid assets such as government bonds exploiting favourable sovereign regulations. I find also that risk-taking behavior is sensitive to capitalization and banks with stronger capital ratio take more risk. Risk-taking is greater in less competitive markets because stronger market power insulates net interest margins and profitability.

The paper proceeds as follows. Section 4.1 presents and overview of the chapter. Section 4.2 reviews the related academic literature on NIRP. Section 4.3 introduces the data and methodology. Section 4.4 presents the results between NIRP and lending along with several robustness checks to address threats to validity. Section 4.5 presents the results of the relationship between NIRP and bank-risk taking and some robustness checks. Section 4.6 concludes.

[34] Part of this chapter, co-authored with Philip Molyneux, John Thornton and Ru Xie, has been published as journal article. Reference: "Did negative interest rates improve bank lending?", Journal of Financial Services Research, 57, 51-68.

4.1 Motivation

The GFC of 2008-09 resulted in the worst economic recession in advanced economies since the 1930s. Central banks initially responded by reducing policy interest rates sharply. When these rates approached zero without there being the hoped-for recovery in nominal spending, many central banks experimented with a range of unconventional monetary policies (UMP) to provide further stimulus, including large-scale asset purchases (LSAPs) to raise asset prices and increase the supply of bank reserves, targeted asset purchases to alter the relative prices of different assets, and forward guidance to communicate about future policy rate paths. The effectiveness of these policies in raising nominal spending has been at the center of a vigorous policy and academic debate with no clear consensus emerging. Nonetheless, since 2012 six European economies (Denmark, the Euro area, Hungary, Norway, Sweden and Switzerland) and Japan have taken unconventional monetary policy a step further by introducing a negative interest rate policy (NIRP) aimed at additional monetary accommodation.[35]

The primary objective of NIRP in adopter countries is to stabilize inflation expectations and support economic growth, and in Denmark and Switzerland the policy was also aimed at discouraging capital inflows to reduce exchange rate appreciation pressures (see Jobst and Lin, 2016). Support for the real economy was expected to come from a greater supply and demand for loans, with loan supply increasing as banks ran down their (large) excess reserve balances, and loan demand increasing in response to a further fall in lending rates. As for UMP more generally, NIRP fueled debate on the likelihood that it would be successful (see, for example, Arteta et al. 2016; Ball et al. 2016; Jobst and Lin, 2016). The key issues relate to NIRP's efficacy and limitation in stimulating economic growth and inflation, as well as how the policy influences bank profitability, financial stability, and exchange rates. Skeptics of NIRP (for example, McAndrews, 2015) point to several possible complications, including a limited pass-through to lending rates as banks may hold deposit rates steady to maintain their deposit funding base. Such behaviour has an adverse influence on bank profitability, which can limit credit growth if banks charge higher

[35] See Bech and Malkhozov (2016) for a discussion of the implementation mechanisms of NIRP in adopting countries.

lending rates or fees to cover losses, or if a diminished capital base makes banks more reluctant to lend. Other associated distortions in asset valuations can create asset price bubbles threatening financial stability. Moreover – since negative interest rates implicitly raise the opportunity cost for banks holding large amounts of negative yielding reserves – banks may opt to hold riskier and higher yielding assets fueling risk-taking.

The empirical literature on NIRP and its effects is small and generally comprises overviews of developments in key banking and other financial aggregates in the immediate pre- and post-NIRP periods rather than rigorous econometric analysis. My paper contribution is twofold. First, it contributes to the literature by examining how NIRP has performed with respect to a key policy objective – achieving an increase in bank lending to support economic growth. To examine this issue, I employ a bank-level dataset comprising 6558 banks from 33 OECD member countries over the period 2012-2016 and a matched difference-in-differences approach. This approach provides a sound basis for drawing conclusions as to whether NIRP resulted in a change in bank lending in pre-and post-NIRP periods and whether NIRP-adopter countries improved bank lending compared to countries that did not adopt the policy. It also allows us to examine factors that might have been influential in the effectiveness of NIRP compared to other monetary policy approaches.

Second, it testes whether NIRP leads to increases in bank risk-taking. Since one of the objectives of NIRP is to increase the cost to banks of holding excess reserves at the central bank, this should motivate the latter to invest in risker assets to boost subdue inflation and economic growth. This effect should materialized through two channels. First, downward stickiness of deposit rates (deposit rate channel) compresses net interest margins and pressurizes profitability, which creates incentives for banks to maintain profitability by investing in higher-yield, hence riskier, assets. Second, the yield curve compression channel suggests NIRP motivates banks out of low-yielding, short-term liquid assets into higher-yield, long-term illiquid assets, which alters portfolio risk (Arsenau, 2017). The effect of NIRP will also depend on bank-specific characteristics (capitalisation, funding structure, and diversification) and characteristics of national banking sectors, such as, the degree of competition.

In contrast to the conclusions of most of the recent research in the area, I find that banks in NIRP-adopter countries reduce lending significantly compared to those in countries that do not adopt the

policy. This adverse NIRP effect is stronger for banks that were smaller, more dependent on retail deposits, less well capitalized, had business models reliant on net interest margins, and operated in more competitive market environments. Moreover, I show NIRP-affected banks reduce their holding of risky assets compared to NIRP-non-affected banks. It infers that banks deleverage post-crises deteriorated balance sheets and invest in liquid assets such as government bonds exploiting favourable sovereign regulations. However, additional results show risk-taking increases when banks are sufficiently capitalised or can benefit from market power in less competitive markets.

4.2 Literature review

4.2.1 Literature bank lending channel

Until the GFC, the benchmark monetary theory for many macroeconomists drew upon Wallace (1981) and Eggertsson and Woodford (2003) who viewed liquidity as having no further role once nominal policy rates reached their lower bound. Bernanke and Blinder (1988) and Bernanke and Gertler (1995) theorise the existence of a bank lending channel of monetary policy. Their theory suggests that open market sales by central bank drain bank reserves and consequently deposits, which, in turn, reduce bank loanable funds. The authors assume that there is an imperfect substitution between bank liabilities; hence banks cannot raise other forms of deposits because of regulatory restrictions and/or higher costs. This assumption has been long criticised as it depicts a reality that existed in the 1970s in the U.S. when regulatory restrictions on deposits were in place (deposit ceiling). However, they contend that the bank lending channel can be at work even if there are no restrictions across the spectrum of bank liabilities. Indeed, the bank lending channel may work if there are bank-specific reasons that alter the effects of monetary policy changes. For instance, banks that are poorly capitalised face difficulties in issuing certificates of deposits (CDs) or banks that are illiquid may be forced to curtail lending following monetary policy tightening.

Kashyap and Stein (2000) investigate the bank lending channel of monetary policy following the pioneering work of Bernanke and Blinder (1988). The bank lending channel suggests that central bank open market operations can contract or expand the supply of loans. Specifically, when the central bank tighten monetary policy by dragging reserves from the banking sector, this compromises bank's ability to raise deposits (transaction deposits). If banks are able to raise other form of deposits such as CDs, the problem does not persist. However, there is an imperfect substitutability between transaction deposits and CDs as the latter are not protected by deposit

insurance. If banks cannot substitute freely different forms of deposits, contractionary monetary policy can limit lending. However, Kashyap and Stein (2000) highlight many confounding factors that can affect the bank lending channel. For instance, reduction in credit supply could be simply driven by the demand for credit. Moreover, lending contraction may happen as tighter monetary policy raises interest rates and consequently borrower willingness to borrow money. They try to overcome these identification problems by using bank-level data and, specifically, differences in bank characteristics. Thus, if two small banks face limitations in raising CDs but one bank is less liquid than the other, the former will have to shrink its balance sheet following a negative shock as it cannot rely on a liquidity buffer as the latter. The results they find indicate that when monetary policy is contractionary, small illiquid banks curtail lending.

Similarly to Kashyap and Stein (2000), Kishan and Opiela (2000) consider banks by assets size and capital leverage ratios to investigate the bank lending channel of monetary policy. Indeed, they suggest that small and undercapitalized banks may not be able to offset a drain in deposits as they may struggle to sell CDs. As for Kashyap and Stein (2000), they find a negative relationship between monetary policy and lending for banks that are small and undercapitalised. More specifically, they underline a mechanism through which tighter monetary policy reduces bank lending. This mechanism presupposes a combination of the bank lending channel and balance sheet channel. First, a contraction of monetary policy weakens borrower balance sheet. This in turn may raise bank credit risk decreasing the value of bank loans portfolios which, ultimately, reduces capital. Banks with poor capital positions curtail lending to meet capital requirement regulations.

4.2.2 Unconventional monetary policy and bank lending

After the GFC, various studies highlight mechanisms through which UMP (policy guidance, LSAPs and NIRP) can have an impact on lending. Curdia and Woodford (2011) provide a model with heterogeneous agents and imperfections in private financial intermediation to demonstrate that UMP will affect the economy providing either an increase in bank reserves to boost lending to the private sector, or that UMP changes expectations about future interest-rate policy. The authors argue that, after the GFC, central banks drastically changed their composition of the balance sheets as well as the monetary policy tools. For instance, Federal Reserve (FED) liabilities

such as reserves grew by more than 100 times. On the asset side, other assets than Treasury securities became prominent as new liquidity facilities to other sectors of the economy.

Brunnermeier and Sannikov (2016) develop a model that show that UMP can work against adverse feedback loops that precipitate crises by affecting the prices of assets held by constrained agents. An adverse shock leads financial intermediaries to suffer losses. As a reaction, they shrink the balance sheet reducing investments. However, this behavior can lead to what Brunnermeier and Sannikov (2016) describes as the "paradox of prudence", where households shift from real investment to cash further reducing bank ability to lend and raising financial instability issues. In this situation monetary policy can limit the negative effects of shocks in the economy by boosting asset prices such as government bonds, which are held by constrained sectors of the economy such as financial intermediaries. As this sector recovers and recapitalises they are again able to lend and to support the real economy. The authors also suggest that accommodative monetary policy may affect moral hazard. However, they note, that this problem is less severe than the bailouts of failing financial institutions.

Del Negro et al. (2017) investigate the effects of interventions in which government provides liquidity in exchange for illiquid private paper once nominal interest rates reach the zero bound. During the GFC, the Federal Reserve tremendously expanded the balance sheet exchanging government securities for private financial assets either through direct purchases or in the form of collateralised short-term loans. These interventions have been named as Term Auction Facility, Primary Dealer Credit Facility and Term Security Lending Facility and can be defined as nonstandard open market operations. Del Negro et al. (2017) show that, in the absence of UMPs, output and inflation would have dropped by an additional 30% and 40%, respectively. They also argue that this result depends on the duration of the crisis. If agents had expected a longer crisis, the contraction in output and inflation would have been even greater. The reasons why UMP is so effective relies on the fact that conventional monetary policies are constrained by the zero lower bound.

Brunnermeier and Koby (2016) present a "reversal interest rate" hypothesis according to which there is a rate of interest at which accommodative monetary policy "reverses" its effect and

becomes contractionary. The reversal interest rate depends on such factors as the composition of banks' asset holdings, the degree of interest rate pass-through to loan and deposit rates, and banks funding structures - they argue that quantitative easing increase the reversal rate and should only be employed after interest rates cuts have been exhausted.[36]

UMP relates to policies that guide longer-term interest rate expectations and expand and change the composition of central bank balance sheets (Bernanke and Reinhart, 2004). It is aimed at facilitating credit expansion in order to boost economic growth. However, little is known about the effectiveness and pass-through of unconventional policy to bank lending. In this regard, Berger et al. (2017) study the Term Auction Facility (TAF) and the Term Discount Window Program (TDWP) implemented by the FED as a reaction to the GFC. The FED created the TAF in December 2007 which involved a series of auctions for funds at fixed maturities made available to depositary institutions. The TDWP was a temporary program that provided financial institutions discount window funds with a maturity up to 30 and 90 days. These two programs have been extraordinary in magnitude reaching an average of $221 billion per day over the period August 2009 to December 2009. The aim of both programs was to improve banking sector lending to the real economy. Berger et al. (2017) discover that bank lending was stronger following FED initiatives. Moreover, the effect is similar for both small and large banks.

Focusing on the effect of UMP on bank lending in the U.S. Rodnyansky and Darmouni (2017) investigate whether quantitative easing and mortgage backed securities purchases facilitated an increase in mortgage lending. The authors argue that assessing the impact of UMP such as QE is made difficult by the absence of a control group. However, they suggest that QE should restore confidence leading to greater borrowing and consumption. On the other hand, they warn policy-makers indicating that asset bubbles and excessive risk-taking may be possible. They find that QE has been successful in improving bank lending to the real economy. Specifically, banks with a relatively high share of Mortgage Backed Securities (MBS) increase lending of about 3% (after the first round of QE) in comparison to banks with little MBS exposure.

[36] My later empirical analysis tests dimensions of the Brunnermeier and Koby (2016) hypothesis.

In contrast to Rodnyansky and Darmouni (2017), Chakraborty et al. (2017) find that increased mortgage lending may crowd-out commercial lending at the same time. They show that banks that benefitted from FED MBS purchases increased mortgage origination at the expense of commercial lending. As Rodnyansky and Darmouni (2017), the authors suggest that identifying a casual link between UMPs and bank lending is difficult as there are other factors that may affect bank lending after the crisis. To overcome this problem they try to exploit as much as bank heterogeneity as possible arguing that some banks are expected to be more affected by the policy than others. Specifically, through QE the FED lower yields and increases assets prices of different assets. This should improve bank balance sheets and increase lending. However, there is a heterogeneous effect as banks holding more assets such as MBS of Treasury securities should benefit more from QE. Chakraborty et al. (2017) find that firms that have relationships with banks holding large amount of MBS reduce investment by 12 points as these banks crowded out commercial lending for mortgage lending.

Bowman et al. (2015) examine the effectiveness of the Bank of Japan (BoJ)'s injections of liquidity into the interbank market via QE in order to promote bank lending (using bank-level data from 2000 to 2009). The first experience of Japan with QE in 2001 consisted mostly of three key elements. First, the BoJ changed its target policy rate from uncollateralized overnight rate to the current account balance. Second, it boosted the purchase of government bonds and other assets and, third, it committed to keep QE until inflation was on target. By doing so, the BoJ injected unprecedented amounts of liquidity into the economy. However, it produced scarce results as inflation kept being negative and bank loans declined in the years following QE. Bowman et al. (2015) indicate the difficulties of assessing the impact of monetary policy in Japan owing to the absence of a proper counterfactual. Without a counterfactual it is difficult to identify what would have happened to bank lending without QE. To overcome this problem the authors employ liquidity constrained banks. *Ceteris paribus*, banks with stronger liquidity positions should have lent more than banks that were liquidity-constrained. Bowman et al. (2015) report a robust, positive, and statistically significant effect of bank liquidity positions on lending suggesting that the expansion of reserves associated with UMP likely boosted the flow of credit (although the overall increase was modest).

Butt et al. (2014) examine the effect of QE to bank lending in the UK. QE should increase bank reserves and deposits motivating banks lend via the bank lending channel of monetary policy. The authors report no evidence of a traditional bank lending channel associated with LSAPs in the UK and suggest that this was because it gave rise to deposits that were likely to quickly leave banks.[37] Evidence suggests that QE boosted GDP and inflation through a portfolio rebalancing channel but not through a bank lending channel.

4.2.3 NIRP and bank lending

The effect of NIRP is expected to be transmitted via lower money market and bank lending rates to households and corporates (Jobst and Lin, 2016). These lower rates impact both sides of bank balance sheets. When lower policy rates are transmitted to bank loan rates, they reduce the value of bank assets. Conversely, lower policy rates also reduce the cost of bank liabilities, namely, lower funding expenses. Heider et al. (2019) investigate the effect of NIRP on bank lending and risk-taking in the Euro area. They suggest that, when interest rates are negative, banks that strongly rely on deposits see their net worth dropping. As a result, they cut lending and increase risk-taking to regain profitability. Negative interest rates reduce bank net worth due to the imperfect pass-through of monetary policy to lending rates. Indeed banks can be reluctant to charge negative interest rates on depositors are limited by regulation to do so. Heider et al. (2019) employ a difference-in-differences econometric set up to investigate the effect of NIRP on bank lending behaviour. To address the identification issues they investigate differences in the behaviour of deposit-dependent banks to those banks that do not strongly depend on deposits as main source of financing (measured by the deposit ratio). They find that when policy rates remain positive, deposit rates closely track policy rates. However, when policy rates turn negative, banks that rely on deposit funding are reluctant to reduce deposit rates fearing a loss of their funding base. In cases where sticky deposit rates compress lending margins, banks tend to shift activities toward fee-based services.

[37] A related literature focuses on the broader macroeconomic effects of LSAPs (e.g., Lenza et al. 2010; Baumeister and Benati, 2013; Fujiwara, 2004; Berkmen, 2012; Schenkelberg and Watzka, 2013; Kapetanios et al., 2012) and generally finds a positive—albeit often small—impact of LSAPs on output and inflation.

Ball et al. (2016) survey developments in the monetary policy transmission mechanism in NIRP-adopter countries. They argue that policy rate cuts below zero are generally transmitted to bank lending rates, although sluggishly as banks do not always pass negative rates onto depositors. In some countries, such as Denmark, the average deposit rates for non-financial firms is slightly negative while in Switzerland large time deposits have turned negative. However, they also point that banks did not charge customers deposits with negative rates. The authors fear that negative interest rates on transaction deposits may create a sort of 'shop around' effect where customers literally move deposits from banks charging negative interest rates to those that do not. They also conclude that there is no clear relationship between NIRP and bank credit expansion. Their results are also in-line with Arteta et al. (2016) which suggest that lending rates generally decline under NIRP, particularly in countries with greater bank competition, but the pass-through is only partial due to downward rigidities in retail deposit rates (reflecting the importance of retail deposits as a source of bank funding).

Bräuning and Wu (2017) also focus on the effect of NIRP on bank lending. Since negative interest rates reduce bank profitability due to the imperfect pass-through of deposit rates, banks have to restore their profitability by searching for yield; by increasing lending or purchase of alternative assets. They find that during the NIRP period a surprise decrease in the target rate strongly increases lending to both households and firms. They also find that, during the NIRP period, surprise decreases in the target rate lowers loan rates, above all for loans with longer maturity. They indicate that this effect is in-line with bank 'search for yield' behaviour. After NIRP, banks switched to longer maturity and riskier assets.

Finally, Demiralp et al. (2019) investigate the effect of NIRP on bank lending. They highlight the importance of bank business models. Indeed, their results suggest that banks react to NIRP. However, the reaction depends on bank's business model. Specifically, banks that mainly rely on deposit funding adjust their balance sheet by reducing their excess liquidity and providing more funds. Investment banks mainly employ their excessive reserves in substitution to wholesale funding. Finally, wholesale banks react to NIRP by purchasing government securities.

4.2.4 Low interest rates, NIRP and bank risk taking

This chapter links also to the literature that investigates the link between low interest rate and bank risk-taking. Borio and Zhu (2012) theorize the existence of a "risk-taking channel" in the monetary transmission mechanism, which stipulates a relationship between expansionary monetary policy and greater bank risk-taking. The risk-taking channel of monetary policy is defined as the impact of monetary policy changes on risk-tolerance or risk perceptions. This channel operates in (at least) three ways. First, low interest rates boost asset prices, collateral values and profits reducing the perception of risk as well as augmenting its tolerance. Moreover, low interest rates tend to increase borrowers' net worth which motivates them to take on more debt and expand investment. This creates a sort of 'multiplier' where new investments raise asset prices, further increasing net worth and, consequently, other investments. Second, low and negative rates on securities motivate banks to switch to riskier assets to meet the nominal return of their liabilities.[38] Third, since cuts in policy rates can boost bank profit via valuation gains on securities and rising asset prices, cuts could alter bank risk-tolerance, risk-perception and risk-appetite. Yet, there is not an academic consensus on the net effect of low interest rates on bank behaviour and risk-tolerance.

Recent literature strongly supports the view that accommodative monetary policy leads to increased risk-taking. Angeloni et al. (2015) show that persistently low interest rates, together with a lack of supervision, induces banks to increase the amount of risky assets as they exploit cheap short-term borrowing funding. By using quarterly U.S. data over the period 1980Q1 – 2008Q4 and VAR models, Angeloni et al. (2015) demonstrate that when interest rates rise, liabilities become more expensive and banks have incentive to de-lever and reduce holdings of risky assets. This implies that rate increases could facilitate lower risk-taking.

Delis and Kouretas (2011) examine a large dataset of Euro area banks between 2001 and 2008. They argue that low interest rates compress net interest margins and pressurise profitability, this pushes banks to search for yield increasing risk-taking. As a risk taking measure they employ the ratio of risk assets-to-total assets. They compute this measure as bank assets minus cash, government securities (at market value) and balances due from other banks. Risk assets are assets that are subject to changes in values due to changes in market conditions or changes in credit

[38] Economic theory highlights the difficulty for banks to apply negative rates on customer deposits. For instance, some countries link deposits to a legal guaranteed minimum nominal return (see Gambacorta, 2009).

quality at various re-pricing opportunities. As an additional variable of bank risk-taking, they employ the non-performing loans ratio, which reflects the quality of bank assets. Delis and Kouretas (2011) report a strong negative relationship between risk-taking and interest rates. Moreover, banks with higher level of capital display lower risk-taking suggesting a sort of skin-in-the-game effect. On the contrary, banks with greater off-balance sheet activities show higher risk-taking indicating that banks engaging in non-traditional intermediation activities have more riskier assets in the balance sheet. Using a database of 23 million loans in Spain (from 2008 to 2012), Jimenez et al. (2014) investigate the effect of low interest rates and bank risk-taking. They report a similar impact on loan credit ratings granted before and after a cut in ECB overnight rates. While all banks increase lending supply when rates are low, less capitalised banks grant more and riskier loans, presumably because they hold less skin-in-the-game and may gamble for resurrection.

De Nicolò et al. (2010) suggest that a high franchise value could discourage banks from gambling for resurrection even if interest rates fall. The negative and wide-ranging consequences of the GFC were incentive for policy-makers to intervene in market conditions and structures to restore confidence and create conditions for prompt and sustained economic recovery. The regulatory response in Basel 3 strengthens the financial architecture by increasing bank capital requirements and introducing new liquidity requirements to improve the soundness of banks and the banking system. At the same time, policy-makers employed new tools or unconventional monetary policies (UMPs), such as, quantitative easing (QE), forward guidance (FG) and NIRP to stimulate further continually weak economies.[39]

Through NIRP, central banks sought to improve the effect of other (current or past) expansionary policies, such as, charging banks for holding excess reserves. The aim of such unconventional tools is to lower long-term interest rate expectations. However, when interest rates tend to zero or below, they can affect bank profitability and riskiness (Arteta et al. 2018; Jobst and Lin, 2016). Clayes and Darvas (2015) analyse experiences of QE in the US, UK and Japan. Their results show that banks did not significantly loosen credit standards, leading the authors to suggest that correct and balanced regulation effectively limits banks' propensity to increase leverage. On the contrary,

[39] See Joyce et al. (2012) for a review of UMPs.

and based on the syndicated loans market in the U.S., Aramonte et al. (2019) find financial institutions increase lending to riskier borrowers when long rates are exceptionally low and expected to remain so. Similarly, Kandrac and Schlusche (2017) show that liquidity injections via QE by the U.S. Federal Reserve did facilitate an increase in the supply of loans; however, the growth of riskier loans outpaced less risky loans. Contrarily, in Europe, APP actions by the European Central Bank simply fed into higher holdings of liquid assets by banks (Ryan and Whelan, 2019; Baldo et al. 2017). Arguably, banks opted to hold low yielding reserves rather than interbank loans because counterparty exposures are subject to capital charges at various risk weights.[40]

Whilst some contend that monetary policy is not neutral from a stability prospective, a limited literature examines the riskiness of banks under negative interest rates, without reaching a clear-cut consensus. The ECB's use of NIRP in 2014 is associated with a decrease in volume of syndicated loans, along with an increase in their riskiness, especially for banks with large volumes of deposits (Heider et al. 2019). Similarly, Eggertsson et al. (2019) point out a lower lending growth associated with the adoption of negative interest rates in the Swedish banking system for banks with high retail deposit shares. The limited pass-through of negative rates to their funding structure leads banks to increase, rather than decrease, loan rates, with an ultimate contractionary effect on the aggregate output. In the same vein, Amzallag et al. (2019) find a significant increase in loan interest rates on residential fixed rate mortgages after the NIRP introduction by Italian banks more reliant on retail overnight deposits. An investigation of the impact of deposit facility interest rate cuts by the ECB on bank risk shows that whereas risk declines for large banks, it increases for smaller banks, especially those funded mostly with customer deposits (Nucera et al. 2017).[41] All the aforementioned studies provide clear evidence that firm-level characteristics are important factors in determining the relation between bank behaviour and NIRP transmission. Further evidence comes from a cross-country study of changes in bank risk following announcements of NIRP by central banks. Using rates on credit default swaps of listed banks to

[40] Following this rationale, capital requirements might also be a reason for the concentration of excess liquidity at country level as low interest rates make the expected return from some kinds of investments (e.g. unsecured overnight lending) not worth the capital cost attached.

[41] Nucera et al. (2017) measure bank risk using the SRisk indicator, which captures the propensity for a bank to become undercapitalised in a financial crisis (Brownlees and Engle, 2017).

proxy risk, Arteta et al. (2018) find that NIRP does not affect financial stability through increases in the risk-taking although, in the long run, it can be threatened by the lower profitability.

In this regard, studies on bank profitability show, however, mixed results. While the squeeze in interest margins and returns on assets after the NIRP suggesting higher bank instability, Lopez et al. (2018) show, however, that bank profitability is unaffected by the adoption of negative nominal interest rates. Thanks to both the pass-through to liabilities rates and gains in non-interest income, such as capital gains and gains on securities, the transmission mechanism of monetary policy should work even in a negative interest rate environment. The relatively inelastic deposit demand associated with periods of slow economic activities, low investment opportunities and higher preference of safer assets, may allow the pass-through of interest rate cuts into negative territory to depositors, reducing the pressure on net interest margins and stimulating both credit supply and the corresponding firm investment (Altavilla et al., 2019). In line with this view, exploiting data from the Italian administrative credit register and firm-bank relationship, Bottero et al. (2019) find that a portfolio rebalancing channel has been at work after NIRP adoption, leading banks to increase their credit supply and lower loan rates to constrained, but viable, firms. On the contrary, some recent studies provide evidence of the contradictory effect of negative interest rates on bank lending, supporting the reversal interest rate hypothesis. Inoue et al. (2019), using as quasi-natural experiment the unexpected NIRP adopted by the Bank of Japan and a bank-firm matched dataset, find a stronger contraction in lending supply for banks more exposed to the policy, with a meaningful negative effect on fixed investments for firms that rely more on loans from more affected banks.

4.3 Methodology and data

4.3.1 Methodology

The empirical strategy aims to identify the causal effect of NIRP on stimulating bank lending. For this purpose, I combine propensity score matching (PSM) with difference-in-differences to investigate the impact of NIRP on bank lending in NIRP affected countries compared with non-affected countries. Since the decision to undertake NIRP is not random but dictated by monetary authorities based on inflation targets and macroeconomic conditions, it may suffer from endogeneity and selection bias, as there can be unobservable factors correlated with both the

treatment and with bank lending. I attempt to mitigate this counterfactual issue by constructing a control sample using propensity score matching, proposed by Rosenbaum and Rubin (1983). The predicted probability (propensity score) of NIRP to be undertaken by a country is obtained from the estimation of a Probit model. Monetary authorities typically make policy decisions based on their forecast of the performance of the economy. Thus, I use forecasted macroeconomic variables (output gap and inflation rate) to match banks operating in NIRP-adopter and non-adopter countries. Furthermore, to make sure that the propensity score predicted from the Probit model is successful in controlling for bank-specific differences between treated and the comparison group in the pre-NIRP period, I include bank size, bank equity strength, and profitability in the propensity score estimation. The propensity score matching model can be represented as follow:

$$p_i = \Pr(D_i = 1 | X_i) = \delta(X_i'\beta + \varepsilon_i) \quad (4.1)$$

where D_i is a dummy variable describing the treatment status. D=1 if the bank has been affected by the policy, and D=0 otherwise. X_i is a vector of observable forecasted macroeconomic variables and bank characteristics in the two years prior to NIRP and δ is a standard normal cumulative distribution function. Specifically, I implement Kernel Matching (Heckman et al. 1998) with weighted averages of all the banks in the control group to construct the counterfactual outcome. The advantage of using Kernel matching is the relatively smaller variances resulting from the fact that more information is used in the estimation.

The major concern of the matching approach is that the NIRP decision is likely to be driven by unobservable characteristics. In this case, the Conditional Independence Assumption linked with the propensity score matching approach is unlikely to hold. Since these unobservable country level characteristics are time-invariant, I implement the matched difference-in-differences estimator, which compares the conditional pre- and post- treatment bank lending with those of the untreated countries (Heckman et al. 1998 and Blundell and Costa Dias, 2002). The combination of PSM with a difference-in-differences approach extends the propensity scores matching method by ruling out the unobservable heterogeneity and relaxing Conditional Independence Assumption.

In the next step, I estimate the average treatment effect with a matched difference-in-differences approach. This matched difference-in-differences estimator can be obtained by applying weighted least squares to the matched data set. Using a difference-in-differences estimator to compare matched bank lending between NIRP and non-NIRP affected banks prior to and after NIRP introduction, the baseline specification takes the following form:

$$\Delta Y_{ijt} = \alpha + \beta_1 \left(Treated_{ij} * Post_{jt} \right) + \varphi_t + \gamma_j + \varepsilon_{ijt} \quad (4.2)$$

where ΔY_{ijt} is the growth rate of lending (measured by gross, mortgage and commercial & industrial loans) and the growth rate of risky assets (computed as total assets less cash, government securities and due to banks) of bank i in country j at time t, $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, and $Post_{jt}$ is a dummy variable that takes the value 1 after the period that country j at time t decided to implement NIRP and 0 before that period, and β_1 represents the average difference in the change in bank lending or bank risk-taking between countries that switched to NIRP and countries that didn't lower interest rates to break the zero lower bound. The majority of NIRP countries in the sample introduced NIRP in 2014, hence $Post_{jt}$ takes the value 1 from 2014 year-end. However, since Sweden, Norway and Switzerland introduced NIRP in 2015 for these the $Post_{jt}$ dummy is equal 1 from 2015 year-end.[42] I also include φ_t, and γ_j, to capture, respectively, year and country fixed effects to limit the potential for bias in estimates of β_1. I include country-specific dummies to control for time-invariant, unobservable country characteristics that can shape bank lending. I include year fixed effects to control for possible shocks over the sample period that can affect bank lending such as other monetary policies and changes in regulation. All regressions are estimated with bank-level clustering, namely allowing for correlation in the error terms. I use robust standard

[42] To be more specific regarding the dummy variable timings I look at the accounting reporting date of all banks in my sample as there are banks that report in different periods of the year and others just at the end. If a bank reports in a period that is before or in the same month of the date of introduction I set the dummy post at 0. Orbis Bank Focus allows you to distinguish between these banks as it gives the reporting accounting date for all the banks in my sample. For Europe NIRP was introduced in June 2014, so I set the dummy variable post equal 1 from the end of 2014, and also for Denmark and Hungary. The six months gap between date of introduction and the dummy post are essential to investigate the effect on lending. For countries like Sweden and Switzerland that introduced NIRP at the beginning of 2015 (January for Switzerland and February for Sweden) the dummy post is set equal 1 for banks that report accounting data either in the middle of the year or at the end.

errors to control for heteroscedasticity and dependence (see Bertrand et al. (2004); Petersen (2007) and Donald and Lang (2007).

4.3.2 Data

I rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information from two main sources. As in chapter 1, the macroeconomic series are from Thompson DataStream and the OECD database. The bank balance and performance data are from Orbis Bank Focus. Since Orbis comprises cross-country banks that operate in more than one country, balance sheet data can be either consolidated or unconsolidated. To avoid concerns regarding banks that operate in more than one country in both treated and non-treated groups, I use bank account data that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but not with an unconsolidated subsidiary. The sample covers commercial banks, savings banks, cooperative banks and bank holding companies from 33 OECD countries over 2012 - 2016, giving us a total of 23,247 observations.[43] There are 20 countries in the treated group and 13 countries in the control group.[44] Descriptive statistics for the bank lending series, other bank balance sheet variables, and the macroeconomic series in the treatment and control groups of countries are shown in Table 4.1. I winsorize at the 1% level for treatment and control to reflect different group distributions.[45]

4.3.3 Dependent variable NIRP and bank lending

Panel A of Table 4.1 presents summary statistics for bank lending. In a recent study on monetary stimulus and bank lending, Chakraborty et al. (2017) find that in response to the Federal Reserve's asset purchases, banks shift resources away from C&I lending into mortgage origination. To take this potential crowding-out effect between bank lending activities into consideration, I group bank lending behaviour into three types: gross loans, mortgage loans and C&I loans. I use the logarithm growth rate of gross loans, mortgage loans and commercial and industrial (C&I) loans as my measures of bank lending.

[43] As in chapter 2, the sample period is intentionally short. According to Roberts and Whited (2013) and Bertrand et al. (2004) the change in the treatment group should be concentrated around the onset of the treatment. Moving away leads to unobservable and other factors that affect the treatment outcome threatening the validity of the model.
[44] As in chapter 2, I exclude Japan in my sample as the country only adopted NIRP in early 2016, which provides too short of period to examine the impact of NIRP on bank lending.
[45] In the Appendix, I discuss winsorizing by distinguishing between different group distributions.

4.3.4 Dependent Variable NIRP and bank risk-taking

Panel A of Table 4.1 presents also summary statistics for bank risk-taking. Following Delis and Kouretas (2011), I construct the main bank-level variable of interest, *GRisky*, as total assets less cash, government securities and due to banks. This indicator captures changes in bank portfolios and any rebalancing towards riskier assets due to changes in market conditions and/or credit quality that affect asset values. Positive values indicate the growth in risky assets exceeds growth in safer assets (cash, government securities, and due to banks), and vice-versa for negative values. Further motivation for my preferred indicator highlights concerns that banks could engage in regulatory arbitrage to lower risk-weighted assets and improve capital adequacy, especially if using internal-rating based models to assess credit risk (Mariathasan and Merrouche, 2014). Variation in adoption rates of internal-rating based models across countries could introduce bias if risk-weighted assets was to proxy risk (Bruno et al. 2015). Since my main variable (Grisky), which is intended to capture variation in risky assets, excludes sovereign bonds, I may not be able to fully capture the purchase of riskier government securities that may drive risk-taking behaviour. Hence, as a robustness check, I re-estimate regressions using the Z-scores (and its components) as dependent variable, which is a widely employed measure of risk (Mohsni and Otchere, 2014; Beck et al. 2013).[46]

4.3.5 Selected control variable NIRP and bank lending

Panel B of Table 4.1 presents summary statistics on other bank balance sheet data, including bank size (log(TA)), equity ratio (E/TA), profitability (ROE), liquidity ratio (Liquidity), total capital ratio (Capital), funding structure (Funding_Structure), and income structure (Income_Structure). In a recent theoretical study, Brunnermeier and Koby (2016) suggest that monetary policy may have unintended contractionary effects on lending due to bank capital constraints, bank business models and market competition. To empirically test the hypothesis of Brunnermeier and Koby (2016), I also include variables that account for bank funding and income structures and the Hirshman-Herfindahl market structure index (HHI) to proxy the impact of bank competition.

[46] $Z_{i,t} = \frac{ROA_{i,t}+EA_{i,t}}{\sigma(ROA)_{j,t}}$; where ROA is return on assets for bank *i* at time *t*, EA is the ratio of equity-to-total assets, and σ(ROA) is the standard deviation of ROA in country *j* at time *t*.

Earlier literature also highlights the major transmission channels of other UMP policies including central bank asset purchase programs (Di Maggio et. al, 2016; Rodnyanski and Darmouni, 2017; Kandrac and Schulsche, 2017; Chakraborty et. al, 2017). In-line with Gambacorta et al. (2014), I employ the logarithm growth rate of a country's central bank balance sheet as a further control to isolate the impact of other UMP on bank lending behavior.

Another issue is that bank lending may be driven by loan demand from households and corporates. To address this concern, I construct loan demand indices based on data from the ECB and FED bank lending surveys. Both of these surveys identify loan demand as the need of enterprises and households for bank loan financing, irrespective of whether a loan is granted or not.[47] Based on data from these two surveys, I construct loan demand indices for the Euro area and US, focusing on increases or decreases in loan demand. Panel C of Table 4.1 presents summary statistics of macroeconomic conditions, monetary policy and loan demand indices.

4.3.6 Selected control variable NIRP and bank risk-taking

Panel B of Table 4.1 shows descriptive statistics of the selected control variables for bank risk-taking. As for bank lending I measure bank size by the natural logarithm of total assets (log(TA)). The too-big-to-fail hypothesis suggests a positive relation between bank size and risk-taking. However, prospective portfolio diversification gains, better managerial skills and easier funding conditions could work to produce an inverse relationship (Bertay et al., 2013). The ratio of equity-to-total assets measures bank capitalisation (*E/TA*). The capital channel of monetary policy suggests bank responses to monetary policy impulses vary significantly with capitalisation (Gambacorta and Mistrulli, 2004; Van den Heuvel, 2002). Whereas soundly capitalised banks can increase holdings of riskier assets, binding capital constraints at under capitalised banks mitigates risk-taking (Gambacorta and Shin, 2015; De Nicolò et al., 2010). Notwithstanding, the impact of capitalisation on risk-taking is ambiguous. I cannot exclude the possibility that a bank might gamble for resurrection, or that weakly capitalised banks assume greater risks to increase earnings, which, if retained, could bolster bank equity thereby improving soundness (Calem and Rob, 1999).

[47] The bank lending surveys from ECB and FED are available at:
1) https://www.federalreserve.gov/boarddocs/snloansurvey/
2) https://www.ecb.europa.eu/stats/money/surveys/lend/html/index.en.html

Again, I proxy bank funding structure using the ratio of customer deposits-to-total liabilities (Funding_Structure). Funding affects how sensitive banks are to changes in interest rates. Low and/or negative interest rates could lead to greater risk-taking to protect profitability if sticky deposit rates and heavy reliance on (stable) deposit funding exerts downward pressure on net interest margins. This scenario would expose deposit-funded banks to changes in monetary policy in comparison to wholesale banks, which manage the price of their liabilities more dynamically (Demirgüç-Kunt and Huizinga, 2010).

The ratio of non-interest income-to-total income is proxy for bank Income_Structure (Borio and Gambacorta, 2015; Beck et al. 2013; Delis et al. 2011). Low interest rates could coerce banks that rely heavily on intermediation business to acquire riskier assets to compensate for downward pressure on bank profitability (Altunbas et al., 2011). My models specify bank liquidity (*Liquidity*), which I measure as previously by using the ratio of liquid assets-to-customer deposits and short-term funding. Larger volumes of liquid assets could facilitate the transfer of resources to more profitable assets, which suggests the relation between liquidity and growth of risky assets is positive (Acharya and Naqvi, 2012). However, even adequate amounts of liquidity could signal risk-aversion under conditions of weak profitability and few investment opportunities, which may occur if adverse selection effects increase the pool of low quality borrowers, and tighter capital requirements. I use return on assets (*ROA* – net income-to-total assets) to proxy bank profitability. Whilst, less profitable banks face incentives to take risks in an attempt to boost profitability (Poghosyan and Čihak, 2011), profitable banks could use their resources to increase risky lending. I proxy credit risk using the ratio of nonperforming loans-to-gross loans (*NPLs*). Nonperforming loans reflect the quality of assets and signal possible losses. I expect higher credit risk will negate bank risk-taking causing an inverse relationship, conditional on the health of the bank (Delis and Kouretas, 2011).

Panels C reports bank industry, macroeconomic and monetary policy variables. I control for the effect of GDP growth on bank risk-taking (Altunbas et al. 2018). Upturns in the business cycle should enhance bank income and profit, thereby strengthening equity and lessening bank appetite for risk. Thus, I expect a negative relationship. I include inflation (Forssbaeck, 2011; Mannasoo and Mayes, 2009), and the VIX (Poligrova and Santos, 2017) to proxy market expectations of stock market volatility. Higher inflation and expected volatility are associated with less risk-taking,

indicating an inverse relationship. I account for how competitive national banking markets are because market structure exerts differential effects on bank risk-taking. Following Schaeck and Cihak (2014), the proxy for competition is the Boone indicator, which captures the sensitivity of bank profit to changes in marginal cost. The World Bank Global Financial Development Database is the source of this variable.[48] My final control is the log growth rate of a country's central bank balance sheet (*CB_GR*) (Lambert and Ueda, 2014; Molyneux et al. 2019). I specify this variable because other UMP policies, such as, asset purchase programs by central banks, were in operation at the same time as NIRP (Di Maggio et. al, 2016; Kandrac and Schulsche, 2016).

Table 4.1. Descriptive statistics: treatment and control groups

	I. Treatment group:					II. Control group				
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev**	**Min**	**Max**
Panel A: Bank Lending										
GL_GR	7543	-0.04	0.41	-9.73	8.54	15704	0.03	0.45	-10.17	7.31
MORT_GR	3795	-0.03	0.39	-7.00	7.90	5938	0.02	0.50	-9.13	7.71
CL_GR	3259	-0.11	0.54	-6.96	4.83	8018	0.02	0.61	-8.25	6.76
Panel B: Bank Balance Sheet Data										
Log(TA)	8138	13.77	2.12	3.94	21.72	18700	14.07	2.38	2.95	21.90
E/TA	8136	10.48%	5.71%	3.83%	24.93%	17703	11.74%	6.56%	3.83%	24.93%
ROE	8099	4.56%	4.40%	0.00%	16.83%	18261	6.27%	5.18%	0.00%	16.83%
Liquidity	7895	21.76%	15.12%	0.90%	46.94%	17264	20.67%	15.44%	0.90%	46.94%
Capital	5700	18.38%	4.57%	11.00%	26.30%	11302	17.40%	4.59%	11.00%	26.30%
Income_Structure	7881	6.67%	5.69%	0.00%	16.99%	18261	4.97%	5.05%	0.00%	16.99%
Funding_Structure	7465	64.61%	20.30%	20.40%	85.32%	14752	65.06%	20.98%	20.40%	85.32%
HHI	10092	855	536	453	3777	56608	446	397	249	4237
Panel C: Macroeconomic Conditions and Monetary Policy										
Output_gap	20456	-2.09%	2.64%	-15.09%	0.56%	45588	-2.36%	1.04%	-6.03%	2.70%
CPI_forecast	20456	1.00%	1.08%	-1.39%	5.65%	46244	1.50%	1.17%	-0.87%	8.89%
GDP growth	10092	0.41%	0.66%	-0.19%	6.62%	56604	0.44%	0.28%	-1.13%	1.89%

[48] Several authors examine the effect of competition on bank risk-taking (see Boyd and De Nicolò, 2005; Jiménez et al. 2013; Kick and Prieto, 2015). For robustness, and because the relationship between market concentration and competition is ambiguous (Claessens and Laeven, 2004), in unreported tests I replace the Boone indicator with alternative proxies for competition, namely, the Herfindahl–Hirschman index (HHI) and Lerner index. I obtain the Lerner index from the World Bank Global Financial Development Database, and calculate the HHI Index.

Inflation	10092	0.43%	0.77%	-1.73%	4.39%	56608	1.51%	1.14%	-1.73%	8.93%
Unemployment	4978	7.91%	4.71%	4.50%	26.30%	45047	7.34%	2.51%	3.1%	27.20%
CB_GR	5700	-0.02	0.15	-0.41	0.35	46991	0.09	0.16	-0.66	0.45
M0_GR	6588	8.07	10.17	-4.55	20.12	51648	9.51	9.22	-26.63	51.56
Deposit Rate	1962	0.50%	0.57%	-0.18%	1.41%	5512	3.38%	4.83%	0.03%	16.77%
Loan Demand	8360	15.74	13.85	-22.92	48.33	46772	10.40	16.00	-68.33	23.10

Notes: This table reports the summary statistics of the key variables used in my analysis for both the treatment and the control groups. Panel A, Panel B and Panel C show descriptive statistics for the dependent variables, bank balance sheet data and macroeconomic condition and monetary policy variables, respectively. GL_GR is the yearly logarithm growth rate of loans plus loan-loss reserves; MORT_GR is the yearly logarithm growth rate of mortgage loans; CL_GR is the yearly logarithm growth rate of commercial and industrial loans. Log(TA) is the natural logarithm of bank total assets. E/TA is the ratio of bank equity-to-total assets. ROE is the ratio of bank pre-tax profits-to-total equity. Liquidity is the ratio of bank liquid asset to total assets. Capital is bank total capital ratio. Income_Structure is the ratio of bank interest income-to-total income. Funding_Structure is the ratio of bank deposit funding-to-total liabilities. HHI is the Herfindahl-Hirschman index. Output_gap is the yearly forecasted Output Gap. CPI_forecast is the yearly forecasted Consumer Price Index. GDP_GR is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the rate of yearly unemployment in percentage. CB_GR is the monthly logarithm growth rate of central bank balance sheet size. M0_GR is the logarithm growth rate of the money supply M0. Deposit Rate is the country level aggregate deposit rate in percentage. Loan Demand is the monthly credit demand indices constructed from data from ECB and Federal Reserve loan demand surveys.

Despite the fact that I use PSM to match countries with similar forecasted macroeconomic variables, it can be argued that a reduction in bank lending is driven by weak economic prospects. To gain further insight, in Table 4.2, I provide country level average lending growth rates before and after NIRP. Panel A shows before and after NIRP average lending growth for NIRP-affected countries while Panel B is for counties that did not experience NIRP. Although the results suggest that both NIRP- affected and non-affected countries experienced a reduction in bank lending after the treatment period, the reduction in lending experienced by NIRP-adopter countries was larger and the difference between mean lending in the two periods for this group was statistically significant.

Table 4.2. Average bank lending measured by gross loans, mortgage loans and C&I loans before and after NIRP at country level.

Panel A: NIRP-affected Countries

	GL_GR			MORT_GR			CL_GR		
	Before	After	P-value	Before	After	P-value	Before	After	P-value
Austria	1.73%	-3.94%	0.000	1.27%	-7.83%	0.029	2.32%	-8.22%	0.000
Belgium	2.02%	1.41%	0.764	4.01%	-7.23%	0.458	-4.96%	-8.73%	0.631

Denmark	1.86%	-5.56%	0.000	2.88%	-9.36%	0.002	0.84%	-13.39%	0.061
Estonia	2.48%	3.81%	0.794	0.05%	-1.23%	0.843	1.93%	3.76%	0.891
Finland	1.71%	-0.82%	0.285	2.12%	-5.33%	0.077	-5.59%	-6.10%	0.943
France	2.56%	-3.58%	0.000	-2.09%	-3.09%	0.497	0.04%	-7.88%	0.001
Germany	3.45%	-2.49%	0.000	1.95%	-3.07%	0.000	1.51%	-8.36%	0.000
Greece	-0.24%	-0.29%	0.993	1.74%	-4.98%	0.515	-2.95%	-5.39%	0.793
Hungary	1.97%	-5.71%	0.003	1.20%	-7.66%	0.211	-3.18%	-16.20%	0.026
Ireland	1.73%	-8.09%	0.000	-1.32%	-14.10%	0.000	3.37%	-11.51%	0.144
Italy	2.11%	-6.19%	0.000				26.02%	-15.79%	0.207
Luxembourg	5.00%	0.52%	0.015				2.70%	-8.99%	0.043
Netherland	1.80%	-3.82%	0.006	1.80%	-7.76%	0.000	1.18%	-5.02%	0.233
Norway	6.75%	-10.46%	0.000	9.98%	-10.27%	0.039	8.45%	-10.43%	0.000
Portugal	0.07%	-6.81%	0.000	0.27%	-8.51%	0.000	1.16%	-15.27%	0.004
Slovakia	3.09%	1.20%	0.582	1.81%	3.61%	0.802	4.32%	-7.11%	0.036
Slovenia	2.43%	-8.84%	0.001	4.01%	-4.53%	0.216	-1.29%	-20.74%	0.019
Spain	1.51%	-5.72%	0.000	-1.36%	-7.40%	0.193	5.62%	-1.26%	0.197
Sweden	4.40%	-1.31%	0.000	1.00%	-0.32%	0.698	6.91%	-6.75%	0.005
Switzerland	3.83%	3.41%	0.497	12.52%	3.78%	0.150	4.28%	3.11%	0.923
Average	2.51%	-3.16%	0.000	1.79%	-5.29%	0.000	2.64%	-8.51%	0.000

Panel B: NIRP-non-affected Countries

	GL_GR			MORT_GR			CL_GR		
	Before	After	P-value	Before	After	P-value	Before	After	P-value
Australia	3.20%	-10.04%	0.000	3.63%	-9.65%	0.000	8.73%	-10.52%	0.000
Canada	4.22%	-0.85%	0.001	5.42%	1.50%	0.088	4.38%	-1.89%	0.047
Chile	8.75%	-4.89%	0.000	9.26%	-1.59%	0.009	8.83%	-3.66%	0.003
Czech R.	3.75%	-3.16%	0.040	-0.18%	7.65%	0.349	-5.59%	6.06%	0.218
Iceland	2.14%	4.60%	0.656				-5.37%	6.13%	0.143
Israel	3.74%	1.20%	0.486	1.03%	6.11%	0.395	-2.96%	-3.85%	0.871
Korea	2.61%	6.28%	0.101	-6.81%	-4.31%	0.834	3.39%	10.74%	0.085
Mexico	7.25%	6.86%	0.821	6.98%	-0.33%	0.008	7.90%	8.60%	0.783
N. Zealand	1.43%	6.11%	0.188	3.57%	4.70%	0.800	-1.27%	5.30%	0.381
Poland	5.41%	-1.18%	0.000	4.09%	7.61%	0.507	5.57%	4.05%	0.755
Turkey	6.90%	4.32%	0.231	7.94%	-2.02%	0.038	4.28%	8.91%	0.230
UK	3.35%	4.46%	0.340	1.73%	2.44%	0.667	2.91%	-6.70%	0.001
USA	2.22%	10.60%	0.000	4.10%	7.37%	0.011	1.12%	13.85%	0.000
Average	4.23%	1.87%	0.226	3.40%	1.62%	0.400	2.46%	2.85%	0.891

Notes:This table displays country level average lending growth rates before and after NIRP for NIRP-affected (Panel A) and NIRP-non-affected countries (Panel B). GL_GR is the yearly average growth rate of loans plus loan-loss reserves before and after NIRP introduction in NIRP-affected and NIRP non-affected countries. MORT_GR is the yearly average growth rate of mortgage loans before and after NIRP introduction in NIRP-affected and NIRP non-

affected countries. CL_GR is the yearly average growth rate of commercial and industrial loans in NIRP affected and NIRP non-affected countries.

4.4 Empirical results NIRP and bank lending

4.4.1 Propensity score matching

Propensity score matching is implemented to mitigate the issue of selection bias. To establish an adequate control group I match countries according to pre-treatment characteristics. The results from the Probit model, that are used to generate propensity scores of being affected by NIRP, are presented in Table 4.3. As displayed, the majority of the covariates are significant at the 1% level suggesting that banks operating in countries with weaker economic prospects represented by lower forecasted inflation (*CPI_forecast*) and wider forecasted output gap (*Output_gap*) have a higher probability of being affected by the negative interest rate policy. Moreover, countries with banks that are small (*Size*), with lower profitability (*ROE*), and that are less capitalised (*Capital*) tend to have a higher probability of being the target of NIRP.

Table 4.3. Propensity score estimation: Probit model

	GL_GR	**MORT_GR**	**CL_GR**
Output_gap	-0.0054	0.2152***	0.1918***
	(0.0060)	(0.0123)	(0.0094)
CPI_forecast	-0.2725***	-0.6013***	-0.2836***
	(0.0145)	(0.0347)	(0.0298)
Size	-0.1697***	-0.2725***	-0.1305***
	(0.0083)	(0.0174)	(0.0134)
Capital	-0.0430***	-0.0920***	-0.0954***
	(0.0024)	(0.0076)	(0.0049)
ROE	-0.0782***	-0.1095***	-0.1191***
	(0.0026)	(0.0062)	(0.0045)
Observations	11889	4921	5753
Pseudo R square	0.1512	0.4057	0.3097
Log Likelihood	-6182.20	-1341.10	-2648.64
LR test (chi square)	2203.35	1831.27	2376.69

This table displays the PSM probit estimation results. The dependent variables are GL_GR (annual logarithm growth rate of loans plus loan-loss reserves), MORT_GR (annual logarithm growth rate of mortgage loans), and CL_GR (annual logarithm growth rate of commercial and industrial loans). Output_gap is the yearly forecasted Output Gap. CPI_forecast is the yearly forecasted Consumer Price Index. Size is the natural logarithm of bank total assets. Capital

is bank total capital ratio. ROE is the ratio of bank pre-tax profits-to-total equity. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

4.4.2 Combined PSM Difference-in-Differences estimator

The PSM approach reduces but does not eliminate the selection bias caused by unobservable time invariant country-characteristics. Thus, I implement the combined PSM difference-in-differences estimator to remove unobserved heterogeneity. The results from the PSM matching difference-in-differences estimations are presented in Table 4.4. The dependent variables are the (natural logarithm) growth rate of gross loans (GL_GR), mortgage loans (MORT_GR) and commercial and industrial (CL_GR) loans. In column 1 of Table 4.4 with GL_GR as the dependent variable, the coefficient on NIRP is sizeable, negative and statistically significant at the 1% level, indicating that countries, in which central banks implemented NIRP experienced a decline in total bank lending of around 8.7% relative to those countries in which central banks did not follow this policy. The remaining columns with MORT_GR and CL_GR as dependent variables demonstrate similar results with negative and significant coefficients on NIRP. The sizeable, negative and statistically significant results on NIRP indicate that countries that implemented NIRP experienced a decline in bank lending relative to those in which central banks did not follow this policy. Negative rates break the zero lower bound of interest rates. However, banks rely on deposit funding and are reluctant to pass-on the negative rates to depositors. Due to this imperfect pass-through narrower margins add pressure on banks to reduce lending. My results are in-line with Heider et al. (2017).

Table 4.4. Baseline Regression

	GL_GR	**MORT_GR**	**CL_GR**
NIRP-effect	-0.0866*** (0.0054)	-0.0540** (0.0218)	-0.0641** (0.0226)
Year FE	Y	Y	Y
Country FE	Y	Y	Y
Observations	22015	9525	10869

This table displays the baseline regression results of the impact of NIRP on bank lending. The dependent variables are GL_GR (annual logarithm growth rate of loans plus loan-loss reserves), MORT_GR (annual logarithm growth rate of mortgage loans), and CL_GR (annual logarithm growth rate of commercial and industrial loans). NIRP-effect is the dummy variable that takes the value 1 if bank i in country j has been affected by NIRP after NIRP implementation, 0 otherwise. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

4.4.3 Robustness tests

In this section, I take an in-depth exploration of the transmission of negative rates on bank lending. The results also serve as robustness checks of my baseline model.

NIRP was brought into the UMP mix by central banks together with the adoption of other unconventional monetary policies, most particularly extensive outright asset purchases, and it is important to disentangle the effects of NIRP on lending from the effects of these policies. Outright asset purchases were aimed at expanding central bank balance sheets to increase the level of the monetary base in order to boost nominal spending (Bernanke and Reinhart, 2004). I proxy for the use of other UMPs by including the log of the growth rate of central bank total assets to take account of central bank balance sheet size. The results reported in panel A of Table 4.5 are for each of the three categories of bank lending and suggest that NIRP and central bank asset purchases had the opposite impact on bank lending. Other UMPs are positively associated with bank lending growth but the coefficients on NIRP remain negative and significant. Thus, the estimates suggest that NIRP did not manage to achieve the intended results of stimulating bank lending and economic growth. On the other hand, other UMPs appear to have been more effective in boosting bank lending.

The second robustness check aims to control for the effect of credit demand on bank lending behavior. To this end, I make use of indicators of loan demand from the U.S Federal Reserve Board's Senior Loan Officer Opinion Survey on Bank Lending Practices and the ECB's Euro Area Bank Lending Survey, both of which have elements focused on the need of firms and households for bank loan financing (irrespective of whether the loan is granted). I construct monthly credit demand indices from the aforementioned ECB and Federal Reserve surveys. These results are reported in columns 1, 2 and 3 of panel B (Table 4.5) where the coefficient on NIRP remains negative and statistically significant for gross and C&I loans. The results demonstrate that the negative relationship between NIRP and bank lending is not driven by loan demand. In column 4 of panel B (Table 5) I report the result with Loan demand as the dependent variable. The result reveals a positive relationship between loan demand and NIRP-effect, which indicates an increase in loan demand in treated countries. The result suggests a gap between loan supply and loan

demand in NIRP adopter countries and confirms that the reduction in bank lending is not driven by loan demand.

For a third robustness check, I alter the country sample where the treatment group includes only European countries so the control group includes only European non-NIRP adopters.[49] These results are reported in panel C of Table 5. The coefficients on NIRP-effect in the cases of gross loans and mortgage loans remain negative and statistically significant. However, in a sample within the EU, C&I loans and NIRP- effect demonstrates a positive and significant relationship.

The motivation for Denmark and Switzerland to adopt NIRP was focused on discouraging capital inflows to reduce exchange rate appreciation pressures; a policy fundamentally different from other treated countries. In the fourth robustness check, I remove Denmark and Switzerland from the sample. The results are reported in panel D of Table 4.5 and show the coefficient on the NIRP effect remains negative and significant, which confirms the baseline results.

As a final robustness test, I try to eliminate the possibility that bank behavior in the treatment group may have altered prior to the introduction of NIRP—for example, in anticipation of adverse effects of NIRP, or for some bank-specific reasons—thereby invalidating the choice of difference-in-differences estimation. I model false NIRP periods for 2012 and 2013. If the estimated coefficients on the 'false' NIRP are not statistically significant or negative, I can be more confident that my baseline coefficient is capturing a genuine monetary policy shock. The results are reported in panel E of Table 4.5. The coefficients on the NIRP dummy are positive and statistically significant in the cases of gross loans, and positive and insignificant in the case of mortgage loans and C&I loans adding further support to the validity of the baseline results. The results also reaffirm and strengthen the conclusion of the baseline results that differential bank lending behavior was driven by NIRP.

4.4.4 NIRP and the reverse interest rate hypothesis

[49] I follow Bertrand and Mullainathan (2003) and Jayaratne and Strahan (1996) that use different control groups as a further test to control for the omitted variables problem. Multiple control and treatment groups reduce biases and unobservable variables associated with just one comparison.

In this section, I report results from a test of aspects of the Brunnemeier and Koby (2016) 'reversal rate hypothesis' within a matched difference-in-differences framework by creating NIRP-adopter treatment groups and non-adopter control groups according to whether banks meet representations of bank-specific factors that these authors suggest might reduce bank lending in a low interest rate setting. Specifically, I focus on bank capitalization, funding structure, business model, interest rate exposure, and competitive conditions in the banking market. First, I examine the impact of bank capital on lending by grouping banks in the treatment and control groups according to whether they have total capital ratios above or below the median for banks in the sample, labelling banks with higher than median capital ratios as 'well-capitalized' and those below the median as 'under-capitalized'. The results for the different categories of loans are reported in panels A and B of Table 4.6. In panel A, the coefficients on NIRP-effect for all categories of bank lending are negative and statistically significant suggesting a substantially larger decline in lending by under-capitalized banks after the introduction of NIRP. Panel B exhibits different results in the group of well-capitalized banks. The coefficient on gross loans is smaller in magnitude and the coefficients on mortgage and business loans turn positive, indicating a mixed and unclear effect of NIRP on bank lending in the group of well-capitalized banks. This is consistent with the Brunnemeier and Koby's (2016) assertion that in situations of economic uncertainty and changing regulation, binding capital requirements can limit the pass-through of monetary policies to bank lending. These results are also in-line with Carlson et al. (2013) and Gambacorta and Mistrulli (2004). Both studies show the importance of capital as a buffer against monetary policy shocks on lending.

Table 4.5. Robustness Checks

This table displays the effect of NIRP on bank lending controlling for monetary policy and other factors. Panel A (Monetary Policy) controls for unconventional monetary policies; Panel B (Loan Demand) controls for credit demand shocks; Panel C (EU only) includes only European countries so the control group includes only European non-NIRP adopters; Panel D (Without Denmark and Switzerland) remove Denmark and Switzerland; Panel E (Placebo Test) estimates the effect of NIRP on bank lending by modelling a false NIRP intervention. NIRP-effect is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP after NIRP implementation, 0 otherwise. GL_GR is the yearly logarithm growth rate of loans plus loan-loss reserves; MORT_GR is the yearly logarithm growth rate of mortgage loans; CL_GR is the yearly logarithm growth rate of commercial and industrial loans. CB_GR is the monthly logarithm growth rate of central bank balance sheet size. Loan Demand is the monthly credit demand indices constructed from data from ECB and Federal Reserve loan demand surveys. All regressions include fixed country and time effects. Robust standard errors clustered by bank in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

A. Monetary Policy

	GL_GR	**MORT_GR**	**CL_CR**
NIRP-effect	-0.0843***	-0.0583**	-0.0521*
	(0.0059)	(0.0225)	(0.0217)
CB_GR	0.1750***	0.2040***	0.1440***
	(0.0079)	(0.0181)	(0.0245)
N. Obs	21763	9340	10288

B. Loan Demand

	GL_GR	**MORT_GR**	**CL_CR**	**Loan_Demand**
NIRP-effect	-0.1160***	-0.0658	-0.1830***	1.2310***
	(0.0139)	(0.0358)	(0.0299)	(0.0240)
Loan_Demand	-0.0336***	-0.0113	0.0036	
	(0.0048)	(0.0078)	(0.0080)	
N.Obs	11070	6821	8251	13121

C. EU Only

	GL_GR	**MORT_GR**	**CL_CR**
NIRP-effect	-0.0401***	-0.0755**	0.0481*
	(0.0084)	(0.0247)	(0.0209)
N.Obs	16499	7249	7497

D. Without Denmark and Switzerland

	GL_GR	**MORT_GR**	**CL_CR**
NIRP-effect	-0.0875***	-0.0620**	-0.0781***
	(0.0053)	(0.0192)	(0.0207)
N.Obs	20643	8415	10820

E. Placebo Test

	GL_GR	**MORT_GR**	**CL_CR**
NIRP-effect	0.0270***	0.0274	0.0165
	(0.0309)	(0.0524)	(0.0515)
N.Obs	9627	6710	8148

Second, I consider how NIRP interacts with bank funding structures. I distinguish between retail deposit-based and wholesale funding-based banks on the assumption that if interest rates on retail deposits are more downwards sticky then the introduction of NIRP would likely pose greater

limitations on retail deposit-based banks to increase lending (Sääskilahti, 2018). I consider as retail deposit banks those with retail deposits greater that 50% of total liabilities. This is confirmed by the results reported in panels C and D of Table 4.6, where the coefficients on NIRP are highly negative and significant in all the three categories of bank lending for deposit-based banks but indicate that NIRP resulted in a unclear relationship with bank lending for wholesale funding-based banks. The result is consistent with the argument of Dell'Ariccia et al. (2014) that NIRP enabled wholesale-funded banks to take greater advantage of the decline in funding costs and provide more loans.

I assess the impact of bank business models on lending in a NIRP context by distinguishing between traditional interest-dependent banks from those that have a more fee-dependent business model. For the purposes, a bank is defined as interest-dependent if the interest earnings share of total earnings is above the median for banks in my sample; banks are deemed to be fee-based if their interest earnings share is below the median. If interest rates on retail deposits are sticky downwards then the introduction of NIRP would likely pose more constraints for banks with interest-dependent than fee-dependent business models. The results from these estimates are reported in panels E and F of Table 4.6 and show that banks whose business model is mainly interest-based reduced their lending by more than banks whose business model was more fees orientated.

The final test of the Brunnemeier and Koby (2016) hypothesis is to assess the impact of NIRP on lending in the context of competitive conditions in banking markets. In this case, I proxy market competition by focusing on market concentration in each country as indicated by the Herfindahl-Hirschman Index (HHI). Sørensen and Werner (2006), for example, use the concentration ratio as a proxy for competition and conclude that banks operating in a less competitive environment make slower adjustments to interest rates (and therefore to net interest margins), which slows the transmission of monetary policy changes to bank lending.[50] I define markets as competitive with

[50]The US Department of Justice 'generally considers markets in which the HHI is between 1,500 and 2,500 points to be moderately concentrated, and consider markets in which the HHI is in excess of 2,500 points to be highly concentrated'. https://www.justice.gov/atr/herfindahl-hirschman-index. I recognize that there are shortcomings with using the HHI as a proxy for competitive conditions. There are different views about competition and concentration in the literature. Claessens and Laeven (2003), for example, point out that there are some countries, such as USA, that show levels of monopolistic competition in banking despite the large number of banks, while countries like Canada

a HHI value below 1000 (the median value in my sample) and split the sample for the treatment and control groups. According to Brunnemeier and Koby (2016) low interest policy is likely to have a more limiting effect on bank lending in competitive markets because of the associated pressure on net interest margins. The results reported in panels G and H of Table 4.6 support this view: the impact of NIRP on bank lending in competitive markets is highly negative and statistically significant for the categories of gross loans and C&I loans, suggesting that banks in these markets have little option but to generate alternative income from other sources to maintain profitability. In more concentrated markets, the impact of NIRP is weaker suggested by smaller and less significant coefficients on NIRP-effect.

Table 4.6. NIRP and bank lending, bank capitalization, funding structure and business model

	GL_GR	**MORT_GR**	**CL_GR**
A. Undercapitalized			
NIRP-effect	-0.1060***	-0.0808*	-0.1570***
	(0.0115)	(0.0398)	(0.0427)
No. of observations	7784	3697	4638
B. Well-capitalized			
NIRP-effect	-0.0521***	0.0207	0.0924*
	(0.0099)	(0.0340)	(0.0367)
No. of observations	7560	3689	4214
C. Retail Funding-Based			
NIRP-effect	-0.0834***	-0.137***	-0.0531*
	(0.0118)	(0.0387)	(0.0297)
No. of observations	10290	3686	4058
D. Wholesale Funding-Based			
NIRP-effect	-0.0665***	-0.0228	-0.0278
	(0.0092)	(0.0274)	(0.0439)
No. of observations	9839	5561	6088
E. Interest earnings-based			
NIRP-effect	-0.0732***	-0.1780***	-0.6400***
	(0.0117)	(0.0194)	(0.0283)
No. of observations	8383	5459	4989
F. Fee-based			
NIRP-effect	0.00991	-0.0725	-0.0517
	(0.0414)	(0.0727)	(0.0611)
No. of observations	8781	1921	3253
G. Competitive markets			

are highly competitive, although the number of banks is relatively small. For this reason I also cross-checked using Boone and Lerner indicators.

NIRP-effect	-0.1420***	-0.0826	-0.2110***
	(0.0309)	(0.0524)	(0.0515)
No. of observations	10872	5852	7652
H. Concentrated markets			
NIRP-effect	-0.0623*	0.0105	-0.0975**
	(0.0204)	(0.1220)	(0.0501)
No. of observations	11538	3659	3189

This table displays the results of NIRP on bank lending based on bank and country sub-sample analyses. Panel A (Undercapitalized) and Panel B (Well-capitalized) show the results of NIRP on bank lending for banks that have total capital ratios above or below the median, respectively. Panel C (Retail Funding Based) and Panel D (Wholesale Funding Based) represent the results of NIRP on bank lending for banks that have an amount of retail deposits greater (Retail Funding Based) or lower (Wholesale Funding Based) than 50% of total liabilities. Panel E (Interest earnings-based) and F (Fee-based) illustrate the results of NIRP on bank lending for bank that have interest earnings as share of total earnings above (Interest earning-based) or below (Fee-based) the median. Panel G (Competitive markets) and Panel H (Concentrated markets) show the results of NIRP on bank lending for banks that have a HHI value below (Competitive markets) or above (Concentrated markets) the median. NIRP-effect is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP after NIRP implementation, 0 otherwise. GL_GR is the yearly logarithm growth rate of loans plus loan-loss reserves; MORT_GR is the yearly logarithm growth rate of mortgage loans; CL_GR is the yearly logarithm growth rate of commercial and industrial loans. All regressions include fixed country and time effects. Robust standard errors clustered by bank in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

4.5 Empirical Results NIRP and bank risk-taking

4.5.1 Propensity Score Matching

Table 4.7 presents results from estimations of equation [1]. Table 4.7 include all the control variables to capture heterogeneity among banks and countries as well as both country- and year-fixed effects to take into account unobservable factors and to reduce the omitted variable bias. My interest turns to the magnitude, sign and significance of the coefficient of β_1, which measures the average difference in the change in bank risk-taking between countries that adopted NIRP and countries that did not (the NIRP-Effect in Table 4.3).

Table 4.7. Difference-in-differences- PSM

	GRisky
NIRP-Effect	-0.1900***
	(0.0460)
No. Observations	2560
Country-FE	Yes

Time-FE	Yes
Bank Controls	Yes

Note: GRisky is the yearly growth rate of risky assets, i.e. the difference between total assets and cash, government securities and advances to other banks. NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank i in country j has been affected by NIRP after the NIRP implementation, 0 otherwise. The regression includes fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

The NIRP-effect, β_1, is economically meaningful, negative and statistically important at the 1 per cent level of significance. It infers the amount of risky assets on bank balance sheets in banks operating in NIRP-adopter countries declined by around 19 percentage points (NIRP-Effect) after the introduction of NIRP in comparison to countries that did not adopt. In other words, this result means that NIRP leads to a decrease in bank risk-taking. There are two reasons that explain why NIRP did not increase bank risk-taking. First, the use of UMPs, such as QE (from 2015 in Europe), in response to worsening macroeconomic conditions and deteriorating bank balance sheets, provided banks with excess liquidity; in turn, this allowed banks to deleverage post-crisis balance sheets, which limited potential supply-side benefits arising from exceptionally favourable financing conditions. Second, and given the monetary policy objective to increase bank lending, an unintended consequence of UMP is that banks simply used the excess liquidity to buy liquid assets such as government bonds. Arguably, this choice was rational in a period of slow economic recovery and high firm default rates. As aforementioned, Basel capital requirements treat sovereign exposures within the EU as risk-free and assign zero risk weight to government bonds, which creates incentive for banks to acquire such assets to boost bank capital position. Hence, I contend that post-crises (GFC and European sovereign debt crisis) deteriorated balance sheets may have influenced the composition of bank risk-weighted adjusted assets in a way that counters the effect of NIRP on bank risk-taking, especially during period of economic uncertainty. Although cheaper central bank funds could alter bank risk-tolerance and risk-perception resulting in greater risk-taking, banks might have tempted to de-lever and cleanse their balance sheets by investing more heavily in assets with low or zero risk weighting. My de-leverage hypothesis suggests banks prefer to exploit the favourable regulatory treatment of sovereigns and invest in ‘safer’, liquid

assets, such as, government bonds that carry (in Europe) zero risk weight to boost capital positions, which I contend is an unintended consequence of NIRP.[51]

4.5.2 NIRP, deleveraging and sovereign bond holdings

Earlier (section 4.1), I suggested that bank may prefer to invest in liquid assets, such as, sovereign bonds rather than increase exposure to riskier assets to exploit the favourable regulatory treatment of sovereigns in Europe. I also suggested that this process might require banks to cleanse and deleverage deteriorated post-crisis balance sheets. To provide further insight into these possibilities, I examine whether banks in the treatment group reduced in size whilst concomitantly increasing exposure to sovereign debt in comparison to the control group following NIRP. For this exercise, I use the growth rate of total assets (*Asset growth*), and the ratio of government bonds-to-total assets (*Sov. Bond*) as two dependent variables in the difference-in-differences model.[52] Panel A (column 2) of Table 4.8 confirms the deleveraging hypothesis as asset growth at banks in NIRP adopter countries is significantly less than at banks in non-adopter countries. Column 3 confirms proposition that banks in NIRP adopter countries significantly increase exposure to zero risk-weighted sovereign debt. The result supports also the arguments in Altavilla et al. (2017) that a very high degree of substitutability exists between lending and sovereign debt in periods of distress and economic weakness.

Furthermore, I investigate whether the increase in sovereign bond holdings is driven by the favourable regulatory treatment of sovereigns in Europe. For this exercise, I consider the behaviour of NIRP-affected banks that operate in those countries for which zero risk weight regulation does not apply; namely Switzerland and Norway. If banks in Switzerland and Norway do not increase the purchase of sovereign securities, I can be more confident about the fact that NIRP-affected banks exploit the peculiar regulatory treatment of sovereign securities enlarging their portfolios of government bonds at the expenses of other asset classes. The results are reported in panel B of Table 4.8 (column 3) are negative (although not statistically significant) indicating that NIRP-affected banks operating in those countries where the favourable regulatory treatment of

[51] I test for the effects of unconventional monetary policies, deleveraging, and regulatory capital arbitrage on NIRP in the following sections.

[52] I remove Switzerland and Norway as the favourable regulatory treatment of sovereign bonds applies only to European countries.

government bonds is not applied reduce their sovereign exposure compared to NIRP non-affected banks. This further confirms the capital arbitrage motive of purchasing sovereign securities rather than increase risk-taking under negative interest rates.

4.5.3 Other Unconventional Monetary Policies

It is important to disentangle any confounding effects upon bank risk-taking arising from NIRP and other UMP actions. NIRP was a latecomer in terms of implementation and followed on the heels of extensive use of QE by central banks to acquire assets of distressed firms. The rationale of QE is to expand central bank balance sheets to increase the monetary base, which should stimulate bank lending and ultimately boost nominal spending (Bernanke and Reinhart, 2004). To disentangle potentially confounding effects from NIRP and UMP, I augment the baseline model with a proxy for the use of other UMPs, that is, the growth of central bank balance sheets (Lambert and Ueda, 2014; Molyneux et al. 2019). Thus, I re-estimate with variables accounting for the NIRP-effect and UMP-effect. Panel C of Table 4.8 (column 1), clearly shows a significant NIRP-effect that reduces bank risk-taking even after controlling for the effect of UMPs.

4.5.4 Removing countries that introduced NIRP in 2015 and placebo test

I apply further tests of robustness. First, I restrict the cohorts of treatment group by removing Denmark and late NIRP adopter countries to see whether the results hold. Denmark introduced NIRP from July 2012 to March 2014 and then again from September 2014. Switzerland introduced NIRP in January 2015, whilst Sweden and Norway in February and September 2015, respectively. Splitting the sample in multiple control and treatment groups helps also to reduce biases and unobservable variables associated with just one comparison (Bertrand et al. 2004). The result is reported in panel D of Table 4.8 (column 1). The coefficient remains negative and statistically significant corroborating the baseline findings. Second, I try to eliminate the possibility that risk-taking in the treatment group changed before central banks started to use NIRP. It might be the case that banks were anticipating adverse effects of impending NIRP and altered behaviour, or some bank-specific factors caused a change in risk-taking. A presence of pre-NIRP change in risk-taking would invalidate my choice of difference-in-differences estimation. To consider this possibility, I re-estimate the model from 2011 to 2014 and introduce a "fake" NIRP in 2013. If the estimated coefficient on "fake" NIRP-effect is not statistically significant or different in sign, I can

be more confident that the baseline coefficient is capturing a genuine monetary policy shock. Moreover, use of "fake" NIRP controls for differences between low and negative interest rate environments. Panel E in Table 4.8, column 1, shows the "fake" NIRP-effect is insignificant and of opposite sign, which adds further support to the validity of my baseline estimation.

Table 4.8. Robustness checks

	GRisky (1)	**Asset Growth (2)**	**Sov. Bond (3)**
Panel A. Deleveraging & Sovereign Bonds Holding			
NIRP-effect		-0.0868***	0.0062***
		(0.0079)	(0.0010)
No. Banks		7386	3368
No. Observations		25801	9303
Country fixed effects		Yes	Yes
Year effects		Yes	Yes
Panel B. Sovereign holdings in Switzerland and Norway			
NIRP-effect			-0.0060
			(0.0038)
No. Banks			1115
No. Observations			3547
Country fixed effects			Yes
Year effects			Yes
Panel C. Unconventional Monetary Policies (UMPs)			
NIRP-Effect	-0.0864***		
	(0.0158)		
CB_GR	0.0387		
	(0.0430)		
No. Banks	2729		
No. Observations	5835		
Country fixed effects	Yes		
Year effects	Yes		
Panel D. NIRP, no Denmark, Switzerland, Norway and Sweden			
NIRP-Effect	-0.0997***		
	(0.0161)		
No. Banks	2584		
No. Observations	6006		
Country fixed effects	Yes		
Year effects	Yes		
Panel E. "Fake" NIRP			
NIRP-Effect	0.0418		
	(0.0290)		

No. Banks	799
No. Observations	1437
Country fixed effects	Yes
Year effects	Yes

Note: Panel A reports the results for NIRP and deleveraging (column 2) and sovereign bond holdings (column 3). Panel B reports the results for NIRP and sovereign bond holding by focusing on Switzerland and Norway. Panel C reports the results for the effect of NIRP by controlling for unconventional monetary policy (column 1). Panel D reports the results for the effect of NIRP by removing Denmark, Switzerland, Norway and Sweden. Panel E reports the result of the placebo test. GRisky is the yearly growth rate of risky assets, i.e. the difference between total assets and cash, government securities and advances to other banks. Asset growth is the growth rate of bank total assets. Sov.Bond is the ratio of government securities-to-total assets. NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank i in country j has been affected by NIRP after the NIRP implementation, 0 otherwise. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

4.5.5 NIRP and Z-score

A large literature (Kacperczyk and Scnabl, 2013; Becker and Ivashina, 2014; Acharya and Steffen 2015) indicates that during the European sovereign debt crisis, banks increased holdings of riskier sovereign bonds. Since the main variable (Grisky), which is intended to capture variation in risky assets, excludes sovereign bonds, I may not be able to fully capture the purchase of riskier government securities that can drive risk-taking behaviour. To control for this issue, I employ the log of the Z-score as additional dependent variable. If the value of the Z-score is in-line with the baseline regression, I can be more confident about the reliability of the results. As shown in Table 4.9 (column 1), the NIRP-effect coefficient is positive and statistically significant in all the econometric specifications. This infers distance-to-default declines or bank stability improves following NIRP. Again, the implication is consistent with the baseline and further strengthens the reliability of my results.

I further decompose the Z-score into a profitability and leverage component (Barry et al. 2011) to investigate whether the increase in the Z-score in column 1 is driven by improved capitalisation or banks profitability.[53] The results in columns 2 and 3 suggest that the aforementioned improvement in the Z-score measure is determined by improved capital rather than profitability. Again, I contend that banks preferred to de-lever and cleanse their balance sheet investing in liquid assets carrying low or zero risk-weight to boost capital positions.

[53] I follow Barry et al. (2011) and decomposes the Z-score into two components. The profitability Z-score is computed as $Zscore_{i,t} = ROA_{i,t}/\sigma(ROA)_{i,t}$ where ROA is return on assets for bank i at time t, and σ(ROA) is the standard deviation of ROA in country j at time t. The leverage Z-score is calculated as $Zscore_{i,t} = E/TA_{i,t}/\sigma(ROA)_{i,t}$ where EA is the ratio of equity-to-total assets, and σ(ROA) is the standard deviation of ROA in country j at time t.

Table 4.9. NIRP and Z-score

	(1)	(2)	(3)
	Z-SCORE	**Profitability Z-SCORE**	**Leverage Z-SCORE**
NIRP-effect	0.0240***	-0.0038	0.0276***
	(0.0056)	(0.0173)	(0.0055)
Observations	26,247	23,178	26,357
R-squared	0.233	0.114	0.228
Number of banks	7,257	6,906	7,272
Country fixed effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Cluster	Bank	Bank	Bank

Note: Z-score equals return on assets and equity-to-total assets on the standard deviation of return on assets. Profitability Z-score equals return on assets on the standard deviation of return on assets. Leverage Z-score equals equity to total assets on the standard deviation of return on assets. NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank *i* in country *j* has been affected by NIRP after the NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total asset; E/TA equals bank equity-to-total assets; ROA is the net income-to-total asset ratio; Liquidity equals liquid assets-to-retail deposits and short-terms funding; Funding structure equals bank deposits funding-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

4.5.6 Capitalisation, size and competition

I run a set of additional tests to account for various bank- and country-specific features whose impact could be meaningful in assessing risk-taking incentives in a negative interest rate environment. First, I examine the capital channel view that bank responses to monetary policy impulses varies according to levels of capitalisation (Van den Heuvel, 2002). I test this proposition by restricting my sample into weak and strong capitalised banks, that is, banks in the lowest and highest deciles of the distribution of the total capital ratio (Borio and Gambacorta, 2016), and re-estimating the baseline model. Panels A and B in Table 8 show the effect of NIRP on risk-taking is non-linear. Consistent with the baseline result, panel A shows an inverse relationship for undercapitalised banks. However, the economic importance of the effect is much greater since the decrease in risky assets more than doubles the reduction documented for the whole sample. My

result highlights tension between objectives of monetary policy and prudential regulation. Undercapitalised banks find it difficult to invest in risky assets because they must comply with capital requirements, which acts to dampen the impact of monetary stimulus (De Nicolò et al., 2010). Furthermore, during crisis episodes, banks face difficulties to issue new equity or increase retained earnings. Undercapitalised banks might improve capital ratios by reducing risk-weighted exposures via a deleveraging process, but such action may amplify pro-cyclicality of bank loans (Jiménez et al., 2010). Panel B shows a positive relation for highly capitalised banks, which indicates strong growth in risky assets following adoption of NIRP presumably because this cohort possess large capital buffers (Gambacorta and Shin, 2015). It implies strong capitalised banks can reallocate resources toward riskier, profitable investments to compensate the negative impact of NIRP on profits.[54]

The evidence offers important policy implications because I highlight the key role played by bank capital in the transmission mechanism of monetary policy. Under difficult macroeconomic conditions and negative interest rates, which exacerbate pressures on bank profitability, only well-capitalized banks increase risk-taking. The impact of capital buffers above minimum requirements is twofold. First, undercapitalized banks experience a direct impact due to difficulties in issuing new equity, in terms of volume and cost. Second, undercapitalised banks face constraints in securing wholesale deposit funding during crisis periods in contrast to strong capitalised banks (Iyer et al. 2014).

I test for the effect of size by splitting the sample into banks holding total assets above and below the median. Whereas Icannot find a significant relation for smaller banks (Panel C), I observe a significant and inverse relation for larger banks (Panel D). In explanation, I allude to greater opportunities to support profitability at larger banks, for instance, changing loan intensity and using cross selling to increase fee and commission incomes (Altunbas et al., 2018; Nucera, 2017). Larger banks show greater tendency to realise economies of scale and scope and are relatively less

[54] The results are consistent with literature on the relation between capitalisation and risk-taking. Kim and Sohn (2017) and Gambacorta and Mistrulli (2004) find over-capitalised banks more willing to increase risk-taking because larger capital buffers allow them to bear losses whilst maintaining high levels of capital concomitantly.

reliant on retail deposits. This suggests larger banks can benefit from lower wholesale funding costs, which reduces incentive to invest in riskier assets under NIRP (Salas and Saurina, 2002).

Next, I consider if, and how, competition conditions affect the effect of NIRP on bank risk-taking. For this purpose, I split treatment and control groups by the Boone indicator, which is my proxy for competition, with values below (above) the median indicating more (less) competitive markets. My motivation follows evidence that identifies a meaningful effect of market structure on the speed of transmission of monetary policy (Sorensen and Werner, 2006) and on corresponding bank risk-taking (Boyd and De Nicolò, 2006). Panels E and F report results, which show that banks invest more in risky assets following NIRP but only in less competitive markets. This suggests higher levels of market power reported at banks operating in less competitive markets afford banks greater leeway to price over marginal cost (Turk Ariss, 2010), which dampens downward pressure on net interest margins and profitability post NIRP (Brunnermeier and Koby, 2017).

Table 4.10. Risky assets, capitalisation, size and competition before and after NIRP

	GRisky (1)
Panel A. Undercapitalised banks (<10th percentile)	
NIRP-Effect	-0.2180***
	(0.0632)
No. Banks	41
No. Observations	60
Panel B. Overcapitalised banks (>90th percentile)	
NIRP-Effect	0.5440***
	(0.1140)
No. Banks	67
No. Observations	104
Panel C. Small Banks (under median)	
NIRP-Effect	-0.1060
	(0.0967)
No. Banks	991
No. Observations	1710
Panel D. Large banks (over median)	
NIRP-Effect	-0.1150***
	(0.0180)
No. Banks	1770
No. Observations	3941
Panel E. Non-Competitive markets (under median)	
NIRP-Effect	0.0858**
	(0.0345)
No. Banks	1985
No. Observations	3734
Panel F. Competitive markets (above median)	
NIRP-Effect	-0.0312
	(0.0313)
No. Banks	729
No. Observations	1844

Note: Panel A and Panel B report the results of NIRP on the split sample of banks that are in the lowest (Undercapitalised banks) and the highest (Overcapitalised banks) deciles of the distribution of the total capital ratio. Panel C and Panel D report the results of NIRP on the split sample of banks that have under median (Small banks) and above median (Large banks) total assets. Panel E and F report the results of NIRP on the split sample of banks that operate in non-competitive markets (under median Boone index) and in competitive markets (above median Boone index). NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank *i* in country *j* has been affected by NIRP after the NIRP implementation, 0 otherwise. Tot. capital ratio equals Total Capital (Tier 1 + Tier 2)-to-risk-weighted assets. Size is the natural logarithm of bank total asset. Boone is the Boone indicator at country level. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

4.6 Conclusions

Beginning in 2012, several central banks adopted a negative interest rate policy aimed at boosting real spending by facilitating an increase in the supply and demand for loans. The policy generated controversy with skeptics pointing to several factors that might complicate the transmission from negative policy rates to higher bank lending. Empirical evidence on the impact of the policy is scant. In this paper, I provide new evidence that bank lending fared worse in NIRP-adopter countries than it did in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in total bank lending relative to those countries in which central banks did not follow this policy. This result holds for gross bank lending and separately for mortgage and C&I lending, the key categories of bank lending, and is robust to the inclusion of several bank-specific control variables. It also stands up in the face of a wide array of robustness checks, including controlling for the effects of other aspects of UMP, developments in loan demand across countries, for possible bank funding constraints, and to (possible) changes in bank behavior prior to the introduction of NIRP. My results are also relevant to the validity of the 'reverse interest rate hypothesis' developed recently by Brunnemeier and Koby (2016) in that bank-specific factors (capitalization, funding structure, business model, interest rate exposure, competitive conditions) appear to reduce banks' willingness to lend in a negative interest rate setting. Moreover, I provide evidence on the impact of negative interest rate policy upon bank risk-taking. My results suggest that NIRP has produced an unintended outcome, namely, a lower level of risk-taking that I can quantify as a reduction in risky assets held by banks in the NIRP affected countries of 19 per cent. Whilst implying monetary policy alone is insufficient to change bank behaviour, I contend that the NIRP-effect sees banks preferring to deleverage their balance sheets and invest in liquid assets such as government bond exploiting their favourable regulatory treatment. Bank risk-taking behaviour, however, is sensitive to the level of prudence since banks with stronger capital ratios increase their investment in risky assets. I find also that NIRP leads banks to assume more risks in less competitive markets where higher levels of market power act to insulate interest margins and profitability. My findings imply that regulatory capital arbitrage could inadvertently retard economic recovery if poorly capitalised banks reduce investment in assets that have higher risk weights to comply with risk-based capital requirements (the so-called 'good risk-taking').

Appendix: Mitigating misleading implications for policy: Treatment of outliers in a difference-in-differences framework

Introduction

Applications of the difference-in-differences estimator in banking and finance commonly treat outliers using the winsorize approach. Failure to winsorize outliers in both the treatment and control groups introduces volatility in estimated coefficients, significance levels, and standard errors. A faulty application of this process can lead to spurious findings that remain undetected. In demonstration, I randomly generate placebo interventions in bank-level data and discuss how to detect and limit the mis-application of the winsorizing approach. In what follows section 1 introduces the problem. Section 2 explains hot to detect it. Section 3 introduces data and methodology. Section 4 presents results and Section 5 concludes.

1. Background

The practice of 'winsorizing' (or 'winsorization') is a valid and popular tool for researchers needing to deal with outliers in a distribution of data.[55] Named after 20th century biostatistician Charles Winsor, winsorization replaces extreme value/s (or 'outliers') with the value of the highest data point not considered an outlier; winsorizing transforms data to limit the effects of outliers rather than removing observations.[56] An 80% winsorized mean averages data below 10% and above 90%; retention of data is a benefit for significance testing purposes as opposed to reducing sample size. Notwithstanding valid reasons to contain outliers, Leone et al (2014) caution against losing important information inherent in extreme observations.

The difference-in-differences (DD) framework creates additional considerations. Application of DD investigates difference in trends between two groups; a treatment (group affected) and control (group unaffected) following an intervention and/or exogenous shock. Outlying values may be different for treatment and control groups. This implies that one should winsorize data separately for each group; otherwise, we are applying values from one group to the other, which may cause serious estimation problems. Reading a random sample of 50 papers that apply DD suggests this problem is widespread. I examine values of maximum and minimum descriptive statistics to detect the anomaly; equal values of maximum and minimum in treatment and control groups before and after intervention suggests in various cases the incorrect application of winsor.[57] Avoidance of detailed summary statistics in DD papers applying winsor is also signal of potential problems.[58]

Using bank-level data, I construct DD placebo interventions to demonstrate how severe the problem is. The estimations uncover large variation in coefficients, significance, and standard

[55] Using a sample of top finance journal papers (JF, JFE, RFS, JFQA) over the period 2008-2012, Adams et al. (2017) show that winsorizing covers 49% of the outliers' mitigation methods.
[56] Trimming and dropping remove data completely from the sample.
[57] Section 2 will provide a detailed explanation of how to detect the problem.
[58] DD Winsor papers tend to display the first and last percentiles in descriptive statistics rather than minimum and maximum values. To gain further insight into this problem, I randomly select 50 DD Winsor and 50 Winsor-no-DD papers. 26 DD Winsor papers present just mean and standard deviation in comparison with 7 Winsor-no-DD. 11 DD-Winsor papers display first and last percentiles in comparison with 5 Winsor-no-DD. Finally, 13 DD-Winsor papers show minimum and maximum values in comparison with 37 Winsor-no-DD. These results concur with Adams et al. (2017) and Leone et al. (2015) who find papers avoid mentioning preferred methods to mitigate outliers and related information.

errors on applying different winsor techniques. My results speak to the DD literature; I identify ramifications arising from a technical issue in DD applications, which could lead to faulty policy recommendations if unchecked (Bertrand et al., 2004; Donald and Lang, 2007; Imbens and Wooldridge, 2009; Roberts and Whited, 2012). The problem I detect is little discussed in the wider academic literature. By using DD placebo regressions, I quantify the extent of mismeasurement due to improper treatment of outliers. Lastly, I offer suggestions on how to detect and tackle the problem.

2. Detecting the problem

I use a stylised normal density function to show the erroneous application of Winsor. Figure D1 shows two distributions of data divided by the control (0 on top of the figure) and the treatment (1 on top of the figure). In the treatment group, I arbitrarily introduce an outlier to skew the distribution to the left to justify winsorizing.[59] I apply two strategies: normal winsorization and winsorization by group. Figure D2 illustrates the outcome of applying winsor without distinguishing between two groups. Winsor replaces the outlier with the smallest value in the two groups (zero in this case). However, zero is a value belonging only to the control group; zero appears an outlier following winsorization.[60] Winsorizing by group and treating outliers separately mitigates this problem (see figure D3).

Figure D1. Normal density function (no-Winsor)

[59] Examining the most suitable technique (winsorizing, trimming or dropping, for example) in this circumstance is beyond the scope of this paper.
[60] Section 3 will discuss problems related to the estimation.

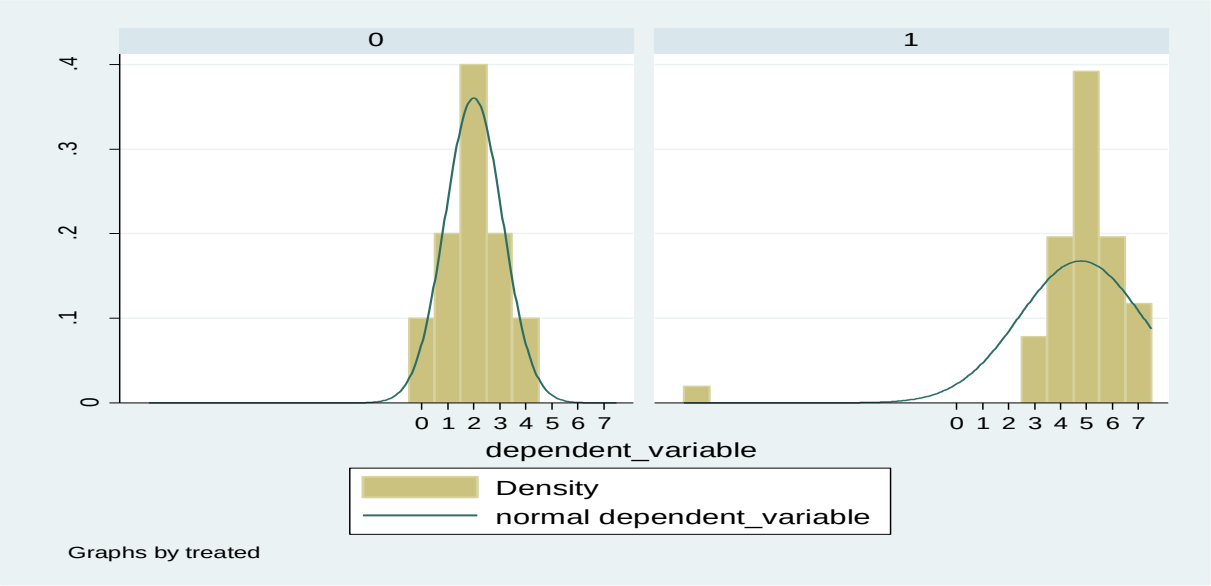

Figure D2. Normal Density Function (Winsor)

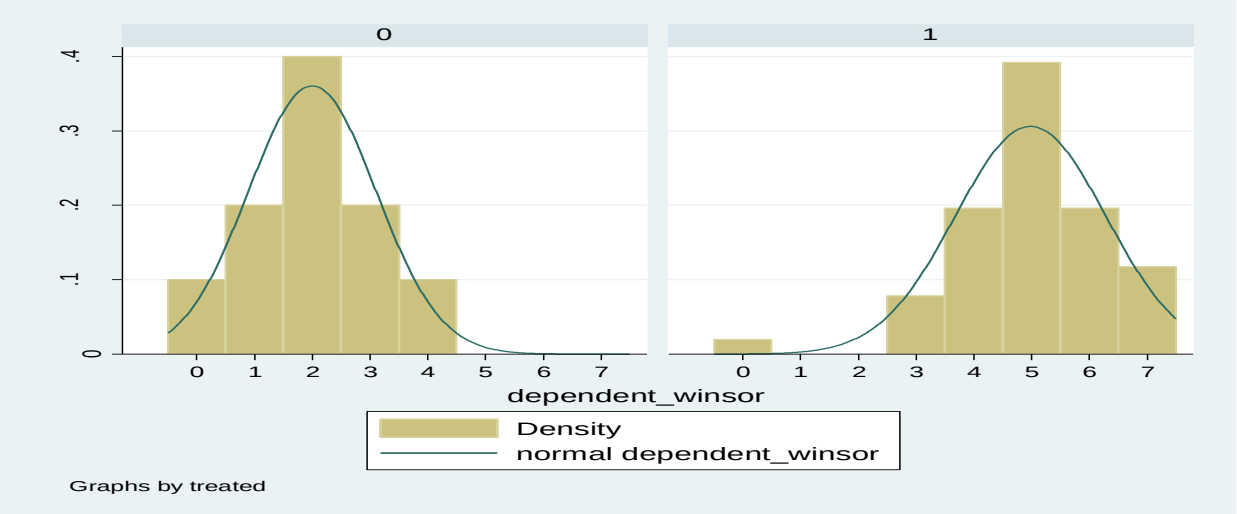

Figure D3. Normal Density Function (Winsor by group)

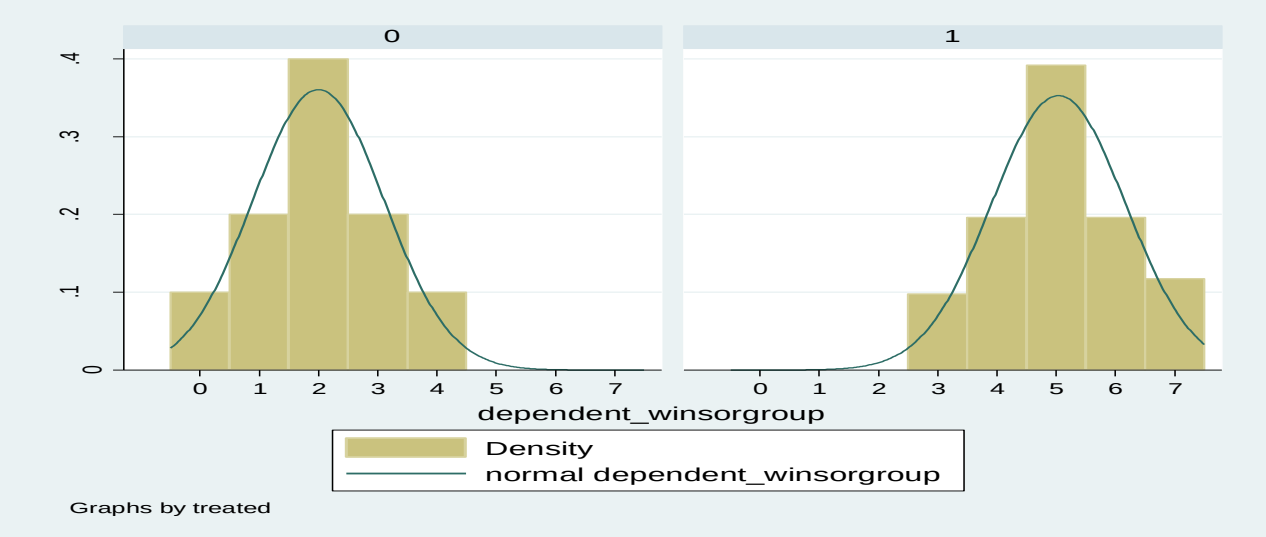

Table D1 shows how I can detect the winsor problem if authors provide descriptive statistics for treatment and control groups. The authors state that they winsorize the variable *Daily efficiency* at 2 standard deviations from the mean. The table shows *Min* and *Max* are equal for both treatment and control groups prior to and after the intervention, which signals application of winsorization without differentiating between the groups. Improper treatment of outlying values of *Daily efficiency* can lead to serious estimation problems.

Table D1. Winsor Problem Detection in Min and Max Descriptive Statistics

	Pre-award					Award period				
Variable	Obs	Mean	Sd	Min	Max	Obs	Mean	Sd	Min	Max
					Treatment					
Tardy	7,126	0.04	0.20	0.0	1.0	5,742	0.03	0.16	0.0	1.0
Minutes late	7,126	−1.73	5.37	−59.7	54.0	5,737	−2.19	5.10	−49.0	58.2
Total absences	7,846	0.04	0.19	0.0	1.0	6,318	0.05	0.21	0.0	1.0
Single absences	7,846	0.01	0.07	0.0	1.0	6,318	0.01	0.11	0.0	1.0
Daily efficiency	6,576	125.60	32.40	54.5	218.0	5,669	124.70	36.20	54.5	218.0
Late	7,126	0.15	0.35	0.0	1.0	5,742	0.10	0.29	0.0	1.0
Monthly absences	7,861	0.79	1.65	0.0	8.0	6,339	1.03	1.80	0.0	10.0
Total hrs worked	7,861	8.25	1.64	0.0	23.7	6,339	8.17	1.69	0.0	13.1
Tenure	7,861	3,373	2,681	176	9,262	6,339	3,186	2,708	176	9,262
Age	7,861	43.51	10.05	21.0	62.0	6,339	43.63	9.84	21.0	62.0
Male	7,861	0.43	0.50	0.0	1.0	6,339	0.43	0.49	0.0	1.0
Base salary	7,861	25,695	845	19,240	28,600	6,339	25,495	1,363	19,240	28,600
					Control					
Tardy	23,600	0.03	0.17	0.0	1.0	14,081	0.02	0.15	0.0	1.00
Minutes late	23,600	−2.12	4.73	−59.4	59.0	14,081	−1.88	5.07	−59.0	59.0
Total absences	27,449	0.05	0.22	0.0	1.0	16,300	0.05	0.22	0.0	1.00
Single absences	27,449	0.02	0.13	0.0	1.0	16,300	0.02	0.12	0.0	1.00
Daily efficiency	22,320	120.30	34.70	54.5	218.0	14,148	125.30	35.60	54.5	218.00
Late	23,600	0.17	0.38	0.0	1.0	14,081	0.14	0.34	0.0	1.00
Monthly absences	27,684	1.06	1.76	0.0	15.0	16,474	1.13	1.78	0.0	12.00
Total hrs worked	27,684	8.01	1.38	0.0	44.0	16,474	8.09	1.25	0.0	16.37
Tenure	27,684	1,720	1,920	4.0	8,566	16,474	1,754	1,992	60.0	8,566
Age	27,684	39.36	12.88	18.0	69.0	16,474	39.87	12.79	19.0	69.00
Male	27,684	0.34	0.47	0.0	1.0	16,474	0.32	0.47	0.0	1.00
Base salary	27,522	19,850	4,899	8,320	48,526	16,474	19,734	5,167	8,320	48,526

Source: Gubler, T., Larkin, I., Pierce, L., 2016. Motivational spillovers from awards: Crowding out in a multitasking environment. Organization Science 27(2): 286-303 (page 292). https://doi.org/10.1287/orsc.2016.1047

3. Methodology and Data

3.1 Methodology

I use random samples of bank-level data and randomly generate placebo interventions to capture the effect of applying different winsor techniques. Equation (1) shows a standard DD framework:

$$Y_{it} = \alpha + \beta_1 Treated_i + \beta_2 Post_t + \beta_3 (Treated_i * Post_t) + \varphi_t + \gamma_i + \varepsilon_{it} \quad (1)$$

Where Y_{it} is the dependent variable[61] of bank *i* at time *t*. $Treated_i$ is a dummy variable taking the value of 1 if bank i is affected by an intervention/shock and 0 otherwise[62]. $Post_t$ is a dummy variable equal to 1 following intervention/shock and 0 before[63]; β_3 represents the average difference in the dependent variable between banks in the treatment and control groups prior to and after the intervention/shock. In common with DD applications, γ_i and φ_t capture bank and year fixed effects, respectively, and limit potential for bias in estimates of β_3.[64]

My estimations of equation (1) apply three treatments to outliers. First, I exclude treatment of outliers. Next, I use winsor indiscriminately on both groups (the method I regard as technically incorrect). Lastly, I apply winsor to treated and untreated banks (the 'best alternative'). In all applications, I winsorize the dependent variable at 1% and 99%.[65]

3.2 Data

My sample includes 16,675 financial institutions from 2008 to 2015; Orbis Bank Focus is the source of my bank balance sheet data.

Table D2 presents descriptive statistics from the three treatments. The first and fourth rows show statistics without treatment of outliers, absent Winsor; the standard deviation of E/TA (equity-to-total assets) is significantly larger than treated data for both groups due to the number of outliers in the sample. The second and fifth rows show statistics for indiscriminate use of winsor, E/TA Winsor; group minimum and maximum are equal and standard deviation comparable across groups. The third and sixth rows show application of winsor by group. Now, minimum and

[61] Initially, I employ the ratio of equity-to-total assets as an illustration. This ratio is a measure of bank solvency, which is an important indicator of the financial resilience of banks and the wider financial sector. Hence, providing erroneous results due to improper mitigation of how to treat outliers can have strong repercussions for interpretation of policy relevant empirical studies. For robustness, and later in the paper, I select different bank performance indicators; the ratios of net interest income-to-average earnings, securities-to-total assets, non-interest income-to-gross revenue, liquid assets-to-deposits and short-term borrowing, and deposits-to-total liabilities. The decision to use these variables is not casual; I choose variables that exhibit a substantial number of outliers in the dataset. In addition, I also apply alternative intervention windows.

[62] The sample banks come from OECD countries. Treated banks (dummy equal to 1) are European, untreated (dummy equal to 0) are non-European.

[63] In this case, the dummy variable equals 1 after 2014 and 0 otherwise (intervention window 2012-2016). Iuse different estimation windows to confirm the validity of my results.

[64] Standard errors are robust and clustered at bank level.

[65] Researchers apply different Winsor levels, such as, 10% and 90% or 5% and 95%. Most common are 1% and 99%. Of the 50 papers I examine, 39 use 1% and 99% levels of Winsorization.

maximum values and standard deviations differ between groups. E/TA Winsor presents two problems. The first concerns the mean. E/TA Winsor replaces outliers with equal values in both treatment and control groups. For the treatment group, the mean of E/TA Winsor is larger in comparison to no treatment (absent Winsor) and winsorizing by group. In contrast, the mean of the control group of E/TA Winsor is lower than the other two means. Second, the standard deviations of E/TA Winsor show less variation, which renders more homogenous the two groups.

Table D2. Descriptive Statistics: Control and Treatment groups

	Obs.	Mean	Std. Dev.	Min	Max
Treatment					
E/TA absent Winsor	17182	12.94	18.45	-967.21	100
E/TA Winsor	17182	14.03	8.51	4.52	30.95
E/TA Winsor by group	17182	10.14	5.15	4.07	21.76
Control					
E/TA no Winsor	9654	18.55	29.66	-969.91	100
E/TA Winsor	9654	10.96	7.07	4.52	30.95
E/TA Winsor by group	9654	16.55	13.91	5.47	51.27

4. Results

Table D3 shows results from estimating equation (1) and applying each Winsor technique. All estimations specify bank and year fixed effects. Column 1 of table D3 shows the result without Winsor. The coefficient of interest, *Treatment (E/TA),* is statistically insignificant with large standard error. The coefficient is insignificant at conventional levels when I winsorize by group (see column 3). However, the coefficient's significance changes if I fail to differentiate between treatment and control groups; it is statistically significant at the one percent level and the magnitude of standard error smaller (see column 2). In a DD framework, the inference would be that the effect of the treatment on the treated group led to a significant difference in E/TA in the control group after intervention. In terms of my application, the effect of treatment realises

improvement in bank solvency, of interest to bank management, bank regulators and policymakers, but the implication is misleading because of improper use of winsorization.

Table D3. Winsorization Techniques and DD Methodology

	No-Winsor (1)	Winsor (2)	Winsor by group (3)
Treated	-5.670***	-3.085***	-6.626***
	(0.606)	(0.196)	(0.279)
Period	0.385	0.203***	0.252**
	(0.353)	(0.0620)	(0.0989)
Treatment (E/TA)	0.129	0.190***	0.147
	(0.365)	(0.0719)	(0.103)
No. of Banks	7467	7467	7467
No. of Observations	26836	26836	26836

To ensure sample selection does not affect the results, I re-estimate equation (1) on multiple random samples and different intervention windows. Table D4 shows the Treatment (E/TA) coefficient rejection rate of the three Winsor techniques for alternative intervention windows (2008-2012, 2012-2016)[66], 106 random samples and 6 variables. When winsorization is applied to both groups the rejection rate, namely rejecting the null hypothesis that β_3 is equal to zero in favour of the alternative that β_3 differs from zero, is the highest supporting the validity of my previous results.[67]

[66] Intervention is set in 2010 and 2014 for the two windows.
[67] I consider as rejected under a 10% p-value significant level.

Table D4. Rejection Rate Winsor Techniques

Placebo windows	No. of Samples	No. of Variables	No-Winsor Rejection Rate Treatment (E/TA) (1)	Winsor Rejection Rate Treatment (E/TA) (2)	Winsor by Groups Rejection Rate Treatment (E/TA) (3)
2012-2016	57	6	21%	75%	36%
2008-2012	49	6	18%	69%	37%
	53	6	20%	72%	37%

5. Conclusion

Much of the banking and finance literature that applies difference-in-differences use winsorized data to deal with outliers. However, the practice of winsorizing data, and replacing outliers with values equal in both treatment and control groups, can produce misleading results, and by extension, faulty inferences for policy. This paper demonstrates the effects of improper use of winsorization. My recommendation is to always apply winsorization separately for treatment and control groups in a DD framework.

Chapter 5: Conclusions and Limitations

Since 2012, several central banks have cut policy interest rates to extremely low levels aimed at boosting real spending by facilitating an increase in the supply of bank loans. The low and negative interest rate environment has generated controversy with skeptics pointing to several factors that might affect the soundness of financial institutions and complicate the transmission from low and negative policy rates to higher bank lending. One factor that has been mentioned is that low and negative interest rates could compress NIMs and, therefore, bank profits, which may erode bank capital bases via a reduction in retained earnings posing financial instability concerns. Reduced retained earnings and the subsequent erosion of bank capital may also limit the transmission of NIRP to bank lending as retained earnings are the most important source of bank's own funds. This creates a vicious circle where squeezed margins and low profits limit bank's ability to retain earnings and build capital buffers ultimately increasing risks as well as stifling NIRP monetary transmission. Additionally, compressed margins and lower profits may motivate banks to re-shuffle their portfolio switching from interest to non-interest income activities.

In this thesis, I provide, in chapter 2, new evidence that bank margins and profitability fared worse in NIRP-adopter countries than in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in NIMs and ROAs of 16.41% and 3.06%, respectively, compared to those countries in which central banks did not follow this policy. However, my findings also show that the effect of NIRP on margins and profitability depends upon bank- and country-specific factors. For instance, large banks are able to mitigate the negative effect of NIRP on NIMs and ROAs through hedging, lending diversification and by switching from interest to non-interest oriented business models. Consequently, small banks appear to be more affected by the policy. Among country-specific factors I find NIRP to have a stronger adverse effect on bank profitability in competitive banking sectors and in countries where floating interest rates predominate.

In the third chapter. I find a negative relationship between the level of interest rates and fee and commission income and securities holdings. A granular breakdown of income statements suggests banks grow non-interest services in various ways, namely, by boosting fees from: portfolio

management, brokerage and consultancy services; collection and payment services; and current accounts. Banks re-balance securities portfolios away from held-for-trading towards securities available-for-sale and held-to-maturity. Greater demand for and supply of services in a low interest rate environment allows banks to redistribute part of their income from traditional intermediation to fee-based services. Banks also grow their securities portfolio re-balancing them away from held-for-trading towards securities available-for-sale and held-to-maturity. In an economic environment characterised by slow economic recovery and high levels of non-performing loans, as in Italy, banks prefer to hold liquid securities owing to poor credit demand or a pool or risky borrowers (for instance SMEs). My findings suggest different behaviour between large and small banks. While larger banks increase income from greater brokerage, consultancy and portfolio management revenue, smaller banks focus more on increasing current account fees. I also find lower capitalised banks increase securities holdings compared to well capitalised banks.

Finally, in chapter 4, I provide new evidence that bank lending fared worse in NIRP-adopter countries than it did in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in total bank lending relative to those countries in which central banks did not follow this policy. This result holds for gross bank lending and separately for mortgage and C&I lending, the key categories of bank lending, and is robust to the inclusion of several bank-specific control variables. It also stands up in the face of a wide array of robustness checks, including controlling for the effects of other aspects of UMP, developments in loan demand across countries, for possible bank funding constraints, and to (possible) changes in bank behavior prior to the introduction of NIRP. My results are also relevant to the validity of the 'reverse interest rate hypothesis' developed recently by Brunnemeier and Koby (2016) in that bank-specific factors (capitalization, funding structure, business model, interest rate exposure, competitive conditions) appear to reduce banks' willingness to lend in a negative interest rate setting. Moreover, I provide evidence on the impact of negative interest rate policy upon bank risk-taking. My results suggest that NIRP has produced an unintended outcome, namely, a lower level of risk-taking that I can quantify as a reduction in risky assets held by banks in the NIRP affected countries of 19 per cent. Whilst implying monetary policy alone is insufficient to change bank behaviour, I contend that the NIRP-effect sees banks preferring to deleverage their balance sheets and invest in liquid assets such as government bond exploiting their favourable regulatory treatment. Bank risk-taking behaviour, however, is sensitive to the level of prudence since banks

with stronger capital ratios increase their investment in risky assets. I find also that NIRP leads banks to assume more risks in less competitive markets where higher levels of market power act to insulate interest margins and profitability. My findings imply that regulatory capital arbitrage could inadvertently retard economic recovery if poorly capitalised banks reduce investment in assets that have higher risk weights to comply with risk-based capital requirements (the so-called 'good risk-taking').

This thesis is not free of limitations. For instance, the methodology employed in chapter 2 and chapter 4 (i.e. the DiD) is prone to endogeneity biases. For instance, NIRP is not an exogenous shock as it has been decided by policy makers based on economic projection, so it can be argued that banks' profitability and lending growth was already weaker in NIRP affected countries. While this assumption is reasonable, I checked for this issue in the robustness check section of chapter 2 and 4. Specifically, the parallel trend assumption as well as placebo tests have shown that profitability and lending growth were similar in the pre-NIRP period.

The literature on NIRP is still scant and more researches are needed to assess the impact of negative interest rates on the banking sector and, more generally, on the real economic as a whole. However, one stream of research that has not deeply been taken into account is how bank market power affects NIRP transmission mechanism. For instance, NIRP can have a greater pass through to lending rates in those environment where banks compete for loans and deposits, whilst it may have null or opposite effect where banks can exercise their market power raising lending rate. In a fragmented European Union – at least concerning the banking sector competition – this research question would be of great help for policy makers' monetary policy decision.

Bibliography

Accornero, M., Alessandri, P., Carpinelli, L., Sorrentino, A. M. 2017. Non-performing loans and the supply of bank credit: evidence from Italy. *Questioni di Economia e Finanza. Bank of Italy Occasional Paper* N.347, Bank of Italy: Rome.

Acharya, V., Naqvi, H., 2012. The seeds of a crisis: A theory of bank liquidity and risk taking over the business cycle. *Journal of Financial Economics*, 106(2), 349–366.

Adams, J.C., Hayunga, D.K., Mansi, S., Reeb, D.M., 2017. Identifying outliers in finance. Available at SSRN: https://ssrn.com/abstract=2986928

Adrian, T., Shin, H. S., 2011. Financial intermediaries and monetary economics. *Handbook of Monetary Economics*, Elsevier: Amsterdam.

Agarwal, S., Chomsisengphet, S., Mahoney, N., Stroebel, J., 2018. Do banks pass through credit expansion to consumers who want to borrow? *Quarterly Journal of Economics*, 133, 129-190.

Albertazzi, U., Gambacorta, L., 2009. Bank profitability and the business cycle. *Journal of Financial Stability* 5, 393-409.

Alessandri, P., Nelson, B., 2015. Simple banking profitability and the yield curve. *Journal of Money, Credit and Banking* 47, 143-75.

Allen, F., Gale, D., 2007. Understanding Financial Crisis. *Oxford University Press*.

Almarzoqi, R., Naceur, S. B., 2015. Determinants of bank interest margin in the Caucasus and Central Asia. *International Monetary Fund Working Paper* 15/87, April. Washington DC: IMF.

Altavilla, C., Boucinha M., Peydro, J. L., 2017. Monetary policy and bank profitability in a low interest rate enviroment. ECB Working Paper Series No 2105, October. Frankfurt: European Central Bank.

Altunbas, Y., Gambacorta, L., Marqués-Ibáñez, D., 2014. Does monetary policy affect bank risk-taking? *The International Journal of Central Banking*, 95-136.

Altunbas, Y., Binici, M., Gambacorta, L., 2018. Macroprudential policy and bank risk. *Journal of International Money and Finance*, 81, 203-220.

Amzallag, A., Calza A., Georgarakos D., Sousa J.. 2018. Monetary Policy Transmission to mortgages in a negative interest rate environment, ECB Working Paper No. 2243 (2019).

Andersen, S., Campbell, J. Y., Nielsen, M. K., Ramadorai, T. 2015. Sources of inaction in household finance: Evidence from the Danish mortgage market. NBER Working Paper 21386, National Bureau of Economic Research.

Angbazo, L., 1997. Commercial bank net interest margin, default risk, interest rate risk, and off-balance sheet banking. *Journal of Banking & Finance* 21, 57-87.

Angeloni, I., Faia, E., Lo Duca, M. 2015. Monetary policy and risk taking. *Journal of Economics Dynamic and Control*, 52, 285-307.

Aramonte, S., Lee, L., Stebunovs, V., 2019. Risk Taking and Low Longer-term Interest Rates: Evidence from the U.S. Syndicated Loan Market. *Journal of Banking and Finance*, 105511.

Arseneau, D. M., 2017. How would US banks fare in a negative interest rate environment? *Finance and Economics Discussion Series* 2017-030, March. Washington DC: Board of Governors of the Federal Reserve System, doi: https://doi.org/10.17016/FEDS.2017.030.

Arteta, C., Kose, M.A., Stocker, M., Taskin, T., 2016. Negative interest rate policies: Sources and implications. World Bank Policy Research Paper 7791, August. Washington DC: World Bank.

Arteta, C., Kose, M.A., Stocker, M., Taskin, T., 2018. Implications of negative interest rate policies: An early assessment. Pacific Economic Review, 23(1), 8–26.

Athanasoglou, P. P., Brissimis, S. N., Delis, M. D., 2008. Bank-specific industry-specific and macroeconomic determinants of bank profitability. *Journal of International Financial Markets, Institutions and Money* 18, 121-136.

Baldo, L., Hallinger, B., Helmus, C., Herrala, N., Martins, D., Mohing, F., Wang, Y. (2017). The distribution of excess liquidity in the euro area. ECB Occasional Paper Series, (N° 200).

Ball, L., Gagnon, J., Honohan, P., Krogstrup, S., 2016. What else can central banks do? Geneva Reports on the World Economy 18, The International Center for Monetary and Banking Studies (ICMB) and the Centre for Economic Policy Research (CEPR). ICBM: Zurich and CEPR: London.

Barry, T.A., Lepetit, L., Tarazi, A., 2011. Ownership structure and risk in publicly held and privately owned banks. *Journal of Banking and Finance*, 35(5), 1327-1340

Baumeister, C., Benati, L., 2013. Unconventional monetary policy and the Great Recession – estimating the impact of a compression in the yield spread at the zero lower bound. *International Journal of Central Banking*, 165-212.

Bech, M., Malkhozov, A., 2015. How have central banks implemented negative policy rates? Bank for International Settlements, *(BIS) Quarterly Review*, March, 31-44. Basel: BIS.

Beck, T., Hess, H., 2009. Why are interest spreads so high in Uganda? *Journal of Development Economics* 88, 192-204.

Beck, T., Levine, R. Levkov, A., 2010. Big bad banks? The winner and the losers from the deregulation in the United States. *Journal of Finance* 65, 1367-1667.

Beck, T., De Jonghe, O., Schepens, G., 2013. Bank competition and stability: Cross-country heterogeneity. *Journal of Financial Intermediation*, 22, 218–244.

Berger, A. N., 1995. The profit-structure relationship in banking: Test of market-power and efficient-structure hypotheses. *Journal of Money, Credit and Banking* 27, 404-431.

Berger, A. N., Kick, T., Schaeck, K., 2014. Executive board composition and bank risk taking. *Journal of Corporate Finance* 28, 48-65.

Berger, A. N., Black, L. K., Bouwman, C. H. S., Dlugosz, J. 2017. Bank loan supply responses to Federal Reserve emergency liquidity facilities. *Journal of Financial Intermediation* 32, 1-15.

Berkmen, P., 2012. Bank of Japan's quantitative and credit easing: are they now more effective? International Monetary Fund Working Paper 12/2 (January). Washington D.C: IMF.

Bernanke, B. S and Blinder, A. S., 1988. "Credit Money and Aggregate Demand". *American Economic Review*, 2, 435-439.

Bernanke, B. S and Gertler. M., 1995. "Inside the Black Box: The Credit Channel of Monetary Transmission". *Journal of Economic Perspective*, 9, 27-48.

Bernanke, B., Reinhart, V., 2004. Conducting monetary policy at very low short-term interest rates. *American Economic Review* 94, 85–90.

Bernanke, B. 2016. What tools does the FED have left? Part 1: Negative interest rates. *Brookings Institution* (blog), March 18, Washington DC: Brookings Institution.

Bertay, A.C., Demirgüç-Kunt, A., & Huizinga, H. 2013Bo. Do we need big banks? Evidence on performance, strategy and market discipline. *Journal of Financial Intermediation*, 22, 532–558.

Bertrand, M., Mullainathan, S., 2003. Enjoying the quiet life? Corporate governance and managerial preferences, *Journal of Political Economy* 111, 1043-1075.

Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust difference-in-differences estimates? *Quarterly Journal of Economics* 119, 249-275.

Blot, C., Huber, P. 2016. Negative interest rates: incentive or hindrance for the banking system? Monetary Dialogue European Parliament. Directorate General for Internal Policy. EC: Brussels.

Blundell, R., Costa Dias, M., 2002. Alternative approaches to evaluation in empirical microeconomics. *Portuguese Economic Journal* 1, 91-115.

Borio, C., Zhu, H., 2012. Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? *Journal of Financial Stability*, 8, 236–251.

Borio, C., Gambacorta, L., & Hofmann, B. (2015). The influence of monetary policy on bank profitability. *Bank for International Settlements Working Papers* No 514, October. Basel: BIS. https://doi.org/10.1111/infi.12104

Borio, C., Gambacorta, L., 2016. Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness? *Journal of Macroeconomics*, 0, 1–15.

Bottero, M., Minoiu, C., Peydro, J. L., Polo, A., Presbitero, A., Sette, E., 2019. Negative monetary policy rates and portfolio rebalancing: evidence from credit register data. IMF Working Papers 19, Washington DC: International Monetary Fund.

Boyd, J., Levine, R., Smith, B., 2001. Inflation and financial market performance. *Journal of Monetary Economics* 47, 221-248.

Boyd, J.H., De Nicolò, G., 2005. The Theory of Bank Risk Taking. *Journal of Finance*, 3, 1329–1343.

Bowdler, K., Radia, A. 2012., Unconventional monetary policy: The assessment. *Oxford Review of Economic Policy*, 28, 603-621.

Bowman, D., Cai, F., Davies, S., Kamin, S., 2015. Quantitative easing and bank lending: evidence from Japan. *Journal of International Money and Finance*, 57, 15-30.

Bräuning, F., Wu, B., 2017. ECB monetary policy transmission during normal and negative interest rate periods.

Brownless, C., & Engle, R., 2017. SRISK: a conditional capital shortfall measure of systemic risk (Vol. N°37).

Brunnermeier, M.K., Koby, Y., 2016. The reversal interest rate: the effective lower bound of monetary policy. Princeton University Department of Economics Working Paper August 27. Princeton NJ: Princeton University.
https://scholar.princeton.edu/sites/default/files/markus/files/08f_reversalrate.pdf

Brunnermeier, M.K., Sannikov, Y., 2016. The I theory of money. Princeton University Department of Economics Working Paper, August 18.

Bruno, B., Nocera, G., Resti, A., 2015. The credibility of European banks' risk weighted capital: structural differences or national segmentations? Baffi Carefin Centre, Research Paper N. 2015-9.

Bundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 82, 115-143.

Busch, R., Kick, T., 2009. Income diversification in the German banking industry. *Discussion Paper Series 2: Banking and Financial Studies*, 09, Deutsche Bundesbank.

Busch, R., Memmel, C., 2017. Banks' net interest margin and the level of interest rates. *Credit and Capital Markets* 50, *363 -392.*

Butt, N.,Churmz, R., McMahon, M., Morotzz, A., Jochen Schanz, J., 2014. QE and the bank lending channel in the United Kingdom. Bank of England Working Paper 511 (September), London: Bank of England.

Calderon, C., Schaeck, K., 2013. Bank bailouts, competition, and the disparate effects for borrowers and depositor welfare. *World Bank Policy Research Working Paper* 6410, April. Washington: World Bank.

Calem, P., Rob, R., 1999. The impact of capital-based regulation. *Journal of Financial Intermediation*, 8, 317–352.

Carbo, S., Fernandez, F. R. 2007. The determinants of bank margins in European banking. *Journal of Banking & Finance* 31, 2043-2063.

Carlson, M., Shan, H., Warusawitharana, M. 2013. Capital ratios and bank lending: A matched bank approach. *Journal of Financial Intermediation* 22 , 603-687.

Chakraborty, I., Goldstein, I, MacKinlay, A., 2017. Monetary stimulus and bank lending. Finance Down Under 2017 Building on the Best from the Cellars of Finance. June. doi: http://dx.doi.org/10.2139/ssrn.2734910

Chaudron, R. F. D. D. 2018. Bank's interest rate risk and profitability in a prolonged environment of low interest rates. *Journal of Banking & Finance* 89, 94-104.

Chen, Q., Filardo, A., He, D., Zhu, F., 2016. Financial crisis, US unconventional monetary policy and international spillover. *Journal of International Money and Finance* 67, 62-81.

Claessens, S., Coleman, N., Donnelly, M., 2018. Low-for-long interest rates and banks' interest margin and profitability: cross-country evidence. *Journal of Financial Intermediation* 35, 1-16.

Claessens, S., Laeven, L., 2003. What drives bank competition? Some international evidence. *Journal of Money, Credit and Banking* 36, 563-583.

Coeuré B. 2016. Assessing the implication of negative interest rate. Speech at the Yale Financial Crisis Forum in New Haven. July 28, 2016.
doi: https://www.ecb.europa.eu/press/key/date/2016/html/sp160728.en.html .

Cour-Thimann, P., Winkler, B., 2013. The ECB's non-standard monetary policy measures: The role of institutional factors and financial structure. *ECB Working Paper Series*, No 1528, European Central Bank: Frankfurt.

Covas, F, B., Rezende, M., Vojtech, C, M., 2015. Why are net interest margin of large banks so compressed? Board of Governors of the Federal Reserve System, *FEDS Notes*, October. Washington DC: Federal Reserve.

Curdia, V., Woodford, M., 2011. The central bank's balance sheet as an instrument of monetary policy. *Journal of Monetary Economics* 58, 54–79.

Delis, M.D., Kouretas, G.P., 2011. Interest rates and bank risk-taking. *Journal of Banking and Finance*, 35, 840–855.

Dell'Ariccia, G., Laeven, L., Marquez, R., 2010. Monetary policy, leverage and bank risk taking. *International Monetary Fund Working Paper* 10/276 December. Washington DC: IMF.

Dell'Ariccia, G., Laeven, L., Marquez, R., 2014. Real interest rates, leverage and bank risk taking. *Journal of Economic Theory* 149, 65-99.

Del Negro, M., Eggertsson, G.B., Ferrero, A., Kiyotaki, N., 2017. The great escape? A quantitative

evaluation of the Fed's liquidity facilities. *American Economic Review* 107, 824-857.

Demiralp, S., Eisenschmidt, J., Vlassopoulos, T. (2017) Negative interest rates, excess liquidity and bank business models: Banks' reaction to unconventional monetary policy in the euro area. *KOÇ University-Tusiad Economic Research Forum Working Paper Series* No 1708. March. Istanbul: Koç University.

Demirgüç-Kunt, A., Huizinga, H., 1999. Determinants of commercial bank interest margins and profitability: some international evidence, *World Bank Economic Review* 13, May, 379-408. Washington DC: World Bank.

Demirgüç-Kunt, A., Laeven, L., Levine, R., 2004. Regulations, market structure, institutions, and the cost of financial intermediation. *Journal of Money, Credit and Banking* 36, 593-622.

DeYoung, R., Roland, K. P., 2001. Product mix and earnings volatility at commercial banks: Evidence from a degree of total leverage model. *Journal of Financial Intermediation*, 10, 54–84.

DeYoung, R., Rice, T., 2004. Noninterest income and financial performance at U.S. commercial banks. *The Financial Review*, 39, 107-127.

Di Maggio, M., Kermani, A., Palmer, C., 2016, How quantitative easing works: Evidence on the refinancing channel. *National Bureau of Economic Research Working Paper* No. 22638, September, Washington D.C: NBER.

Donald, S., Lang, K., 2007. Inference with difference-in-differences and other panel data. *Review of Economics and Statistics* 89, 221-233.

Drechsler, I., Savov, A., Schnabl, P., 2016. The deposits channel of monetary policy. National Bureau of Economic Research Working Paper No. 22152, April Washington D.C: NBER.

Eggertsson, G., Woodford, M., 2003. The zero bound on interest rates and optimal monetary policy. *Brookings Papers on Economic Activity* 34, 139–235.

Eggertsson, G, B., Juelsrud, R, E., Wold, E, G. 2017. Are negative nominal interest rate expansionary? *National Bureau of Economic Research Working Paper* No. 24039, March. Washington DC: NBER.

English, W, B., 2002. Interest rate risk and bank net interest margin. *Bank for International Settlements (BIS) Quarterly Review*, December, 67-92, Basel: BIS.

Entrop, O., Memmel, C., Ruprecht, B., Wilkens, M., 2015. Determinants of bank interest margin: impact of maturity transformation. *Journal of Banking & Finance* 54, 1-19.

Eser, F., Schwaab, B., 2016. Evaluating the impact of unconventional monetary policy measures: empirical evidence from the ECB's Security Markets Programme. *Journal of Financial Economics* 119, 147-167.

Flannery, M, J., 1981. Market interest rate and commercial bank profitability: an empirical investigation. *Journal of Finance* 36, 1085-1101.

Fiordelisi, F., Ricci, O., Stentella Lopes, F. S., 2017. The unintended consequence of the Single-Supervisory Mechanism launch in Europe. *Journal of Financial and Quantitative Analysis* 52, 2809-2836.

Fujiwara, I., 2004. Evaluating monetary policy when nominal interest rates are almost zero. *Journal of the Japanese and International Economy* 20, 434-453.

Gambacorta, L., Mistrulli, P. E. 2004. Does bank capital affect lending behavior? *Journal of Financial Intermediation* 13, 436-457.

Gambacorta, L. (2009). Monetary policy and the risk-taking channel. BIS Quarterly Review, (December), 43–53.

Gambacorta, L., Hofmann, B. Peersman, G., 2014. The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis. *Journal of Money, Credit and Banking* 46, 615–642.

Gambacorta, L., Shin, H.S. (2015). Why bank capital matters for monetary policy. *Journal of Financial Intermediation*, 0, 1–13.

Gelos, R., 2006. Banking Spreads in Latin America. *International Monetary Fund Working Paper 06/44*, February, Washington: IMF.

Genay, H., Podjasek, R., 2014. What is the impact of low interest rate environment on bank profitability? *Chicago Federal Reserve Letter* 324, July. Chicago.

Gertler, M., Karadi, P., 2011. A model of unconventional monetary policy. *Journal of Monetary Economics* 58, 17-34.

Gertler, M., Kiyotaki, N., 2011. Financial intermediation and credit policy in business cycle analysis. In Friedman, B., and Woodford, M., (Eds.), *Handbook of Monetary Economics*. Elsevier, Amsterdam: Netherlands.

Goddard, J., Molyneux, P., Wilson, J. O. S., 2004. The profitability of European banks: A cross-sectional and dynamic panel analysis. *The Manchester School* 72, 363-381.

Gross, D., 2016. Low rates = low bank profits? Monetary Dialogue. European Parliament. Directorate General for Internal Policy. Brussels: EC.

Gubler, T., Larkin, I., Pierce, L., 2016. Motivational spillovers from awards: Crowding out in a multitasking environment. *Organization Science* 27(2): 286-303 (page 293). https://doi.org/10.1287/orsc.2016.1047

Hancock, D., 1985. Bank profitability, interest rates, and monetary policy. *Journal of Money, Credit and Banking* 17, 189-202.

Hannoun, H., 2015. Ultra-low or negative interest rates: What they mean for financial stability and growth. Bank for International Settlement, Eurofi high-level seminar, doi: http://www.bis.org/speeches/sp150424.pdf.

Heider, F., Saidi, F., Schepens, G., 2019. Life below zero: bank lending under negative policy rates. *The Review of Financial Studies*, 32, 3728-3761.

Hanweck, G., Ryu, L., 2005. The sensitivity of bank net interest margin and profitability to credit, interest-rate, and term-structure shocks across bank product specialisation. *Federal Deposit Insurance Corporation (FDIC) Working Paper* No 2005-02, January. Washington DC: FDIC.

Hawtrey, K., Liang, H., 2008. Bank interest margins in OECD countries. *North American Journal of Economics and Finance* 19, 249-260.

Heckman, J., Ichimura, H., Smith, J.A., Todd, P., 1998. Characterizing selection bias using experimental data. *Econometrica* 65, 1017-1098.

Heider, F., Saidi, F., Schepens, G., 2017. Life below zero: bank lending under negative policy rates. Available at SSRN: https://ssrn.com/abstract=2788204

Ho, T. S. Y., Saunders, A., 1981. The determinants of bank interest margins: Theory and empirical evidence, *Journal of Financial and Quantitative Analysis* 16, 581-600.

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

IMF., 2017. Negative interest rate policies - Initial experiences and assessments. *IMF Policy Paper*. August. International Monetary Fund. Washington DC: IMF.

Inoue, H., Nakashima, K., Takahashi, K. (2019). Credit Allocation and Real Effects of Negative Interest Rates: Micro-Evidence from Japan. Working paper.

Iyer, R., Peydró, J.L., Da-Rocha-Lopes, S., Schoar, A. (2014). Interbank liquidity crunch and the firm credit crunch: Evidence from the 2007-2009 crisis. *The Review of Financial Studies*, 27, 347–372.

Jackson, H. 2015. The international experience with negative policy rates. Bank of Canada Discussion Paper 2015-13.

Jayaratne, J., Strahan, P. E., 1996. The finance-growth nexus: Evidence from bank branch deregulation. *Quarterly Journal of Economics* 101, 639-670.

Jimenez, G., Ongena, S., Peydro, J-L., 2012. Credit supply and monetary policy: identifying the bank balance-sheet channel with loan applications. *American Economic Review* 102, 2301–2326.

Jimenez, G., Ongena, S., Peydro, J-L., Saurina, J., 2014. Hazardous times for monetary policy: what do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking? *Econometrica* 82, 463–505.

Jobst, A., Lin, H., 2016. Negative interest rate policy (NIRP): implications for monetary transmission and bank profitability in the euro area. International Monetary Fund Working Paper 16/172. Washington DC:IMF.

Joyce, M., Miles, D., Scott, A., Vayanos, D. (2012). Quantitative easing and unconventional monetary policy – an introduction. *The Economic Journal*, 122, 271-288.

Kandrac, J., and Schulsche, B., 2017. Quantitative easing and bank risk taking: evidence from lending. (September 25). Available from http://dx.doi.org/10.2139/ssrn.2684548

Kapetanios, G., Mumtaz, H., Stevens, I., Theodoridis, K., 2012. Assessing the economy-wide effects of quantitative easing. *The Economic Journal* 122, 316-347.

Kashyap, A. K., Stein, J.C., 2000. What do a million observations on banks say about the transmission of monetary policy? *American Economic Review* 90, 407–428.

Kick, T., Prieto, E. (2015). Bank risk and competition: Evidence from regional banking markets. *Review of Finance*, 19, 1185–1222.

Kim, D., Sohn, W. (2017). The effect of bank capital on lending: Does liquidity matter? *Journal of Banking and Finance*, 77, 95–107.

Kok, C., Mirza, H., Pancaro, C., 2019. Macro stress testing euro area banks' fees and commissions. *Journal of International Financial Markets, Institutions and Instruments*, 61, 97-119.

Lambert, F., Ueda, K., 2014. The effects of unconventional monetary policies on bank soundness. *International Monetary Fund Working Paper 14/152,* August, Washington DC: IMF.

Lechner, M., 2010. The estimation of causal effects by difference-in-difference methods. *Foundations and Trends in Econometrics* 4, 165-224.

Lenza, M., Pill, H., Reichlin, L., 2010. Monetary policy in exceptional times. *Economic Policy* 25, 295–339.

Leone, J.A., Minutti-Meza, M., Wasley, C.E. 2014. Influential observations and inference in accounting research. *Simon Business School Working Paper No. FR 14-06.* Available at SSRN: https://ssrn.com/abstract=2407967 or http://dx.doi.org/10.2139/ssrn.2407967.

Lepetit, L., Nys, E., Rous, P., Tarazi, A., 2008. The expansion of services in European banking: implications for loan pricing and interest margins. *Journal of Banking & Finance* 32, 2325-2335.

Lopez, J, A. Rose, K. A., Spiegel, M, M. 2018. Why have negative nominal interest rate had such a small effect on bank performance? Cross country evidence. *Federal Reserve Bank of San Francisco Working Paper* 2018-07, June. San Francisco: Federal Reserve Bank of San Francisco.

Lucas, A., Schaumburg, J., Schwaab, B., 2019. Bank business models at zero interest rates. *Journal of Business and Economics Statistics*, 37, 542-555.

Maddaloni, A., and Peydro, J.L., 2011. Bank risk-taking, securitization, supervision, and low interest rate: evidence from the Euro-area and the U.S lending standards. *Review of Financial Studies* 24, 2121-2165.

Mannasoo, K., Mayer, D. (2009). Explaining bank distress in Eastern European transition economies. *Journal of Banking and Finance*, 33, 244-253.

Mariathasan, M., Merrouche, O. (2014). The manipulation of Basel risk-weights. *Journal of Financial Intermediation*, 23, 300–321.

Maudos, J., Fernandez de Guevara, J., 2004. Factors explaining interest margin in the banking sectors of the European Union. *Journal of Banking & Finance* 28, 2259-2281.

Madous, J., Solis, L., 2009. The determinants of net interest income in the Mexican banking system: an integrated model. *Journal of Banking & Finance* 33, 1920-1931.

McAndrews, J., 2015. Negative nominal central bank policy rates: where is the lower bound? Remarks at the University of Wisconsin, May 8, New York Federal Reserve Speeches. https://www.newyorkfed.org/newsevents/speeches/2015/mca150508.html

McShane, R. W., Sharpe, I. G., 1985. A time series/cross section analysis of the determinants of Australian trading bank loan/deposit interest margin: 1962-1981. *Journal of Banking & Finance* 9, 115-136.

Mishkin, F. 1995. Symposium on the monetary transmission mechanism. Journal of Economic Prospective, 9, 3-10.

Mirzaei, A., Moore, T., Liu, G., 2013. Does market structure matter on bank's profitability and stability? Emerging vs. advanced economies. *Journal of Banking & Finance* 37, 2920-2937.

Modigliani, F. 1971. Monetary policy and consumption: linkages via interest rate and wealth effects in the FMP model, in Consumer Spending and Monetary Policy: The Linkages, Conferences Series. Federal Reserve Bank of Boston, Boston, 5, 9-84.

Mohsni, S., Otchere, I. (2014). Risk taking behavior of privatized banks. *Journal of Corporate Finance*, 29, 122–142.

Molyneux, P., Thornton, J., 1992. Determinants of European banking profitability: A note. *Journal of Banking & Finance* 16, 1173-1178.

Nucera, F., Lucas, A., Schaumburg, J., Schwaab, B., 2017. Do negative interest rates make banks less safe? ECB Working Paper N° 2098, European Central Bank: Frankfurt.

Nucera, F., Lucas, A., Schaumburg, J., Schwaab, B. (2017). Do negative interest rates make banks less safe? *Economics Letters*, 159, 112–115.

Petersen, M., 2009. Estimating standard error in finance panel dataset: comparing approaches. *Review of Financial Studies* 22, 435-480.

Peydro, J, L., Polo, A., Sette, E., 2017. Monetary policy at work: Security and credit application registers evidence. *CEPR Discussion Paper* 12011.

Poghosyan, T., Čihak, M. (2011). Determinants of Bank Distress in Europe: Evidence from a New Data Set. *Journal of Financial Services Research*, 40(3), 163–184.

Poghosyan, T., 2013. Financial intermediation costs in low-income countries: the role of regulatory, institutional, and macroeconomic factors. *Economic Systems* 37, 92-110.

Rajan, R.G., 2005. Has finance made the world riskier? European Financial Management 12, 499–533.

Riksbank., 2016. How do low and negative interest rate affect banks' profitability? *Monetary Policy Report* , April 2016, Stockholm: Sveriges Riksbank.

Roberts, M. R., Whited, T. M., 2012. Endogeneity in empirical corporate finance. *Handbook of the Economics of Finance*, Editors G.M. Constantinides, M. Harris and R. M. Stulz, Volume 2 Part A, Chapter 7, 493-572 (NY: Elsevier)

Rodnyansky, A., Darmouni, O., 2017. The effects of quantitative easing on bank lending behavior. *The Review of Financial Studies* 30, 3858-3887.

Roodman, D. 2009. A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics*, 71, 135-158.

Rogoff, K, S., 2015. Debt supercycle, not secular stagnation. Vox, http://www.voxeu.org/article/debt-supercycle-not-secular-stagnation

Rohner. 2015. Swiss alternative bank breaks negative rates taboo. Retrieved at: https://finance.yahoo.com/news/swiss-alternative-bank-breaks-negative-rates-taboo-055303880.html.

Rosenbaum, P. R., Rubin, D. B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70, 41–55.

Sääskilahti, J., 2018. Retail bank interest margins in low interest rate environments. *Journal of Financial Services Research* 53, 37-68

Salas, V., Saurina, J. (2002). Credit risk in two institutional regimes: Spanish commercial and savings banks. *Journal of Financial Services Research*, 22, 203–224.

Saunders, A., Schumacher, L., 2000. The determinants of bank interest rate margins: an international study. *Journal of International Money and Finance* 19, 813-832.

Schaeck, K., Cihàk, M. (2014). Competition, Efficiency and Stability in Banking. *Financial Management*, 215–241.

Schenkelberg, H., Watzka, S., 2013. Real effects of quantitative easing at the zero lower bound: structural VAR-based evidence from Japan. *Journal of International Money and Finance* 33, 327-357.

Shin, H. S. 2016. Bank capital and monetary transmission. *Panel Remarks at the ECB and its Watchers XVII Conference,* Frankfurt, April 7, 2016.

Sørensen, K. C., Werner, T., 2006. Bank interest rate pass-through in the euro area: a cross-country comparison. *European Central Bank Working Paper Series 580*, January. Frankfurt: ECB.

Stiglitz, J. E., Weiss, A. 1981. Credit rationing in market with imperfect information. American Economic Review, 71, 393-410.

Summers, L, H., 2014. Reflections on the new 'Secular Stagnation' hypothesis. Vox http://voxeu.org/article/larry-summers-secular-stagnation.

Tobin, J. 1969. A general equilibrium approach to monetary theory. Journal of Money, Credit and Banking, 1, 15-29.

Turk Ariss, R. (2010). On the implications of market power in banking: Evidence from developing countries. *Journal of Banking and Finance*, 34, 765–775.

Van den Heuvel, S.J. (2002). Does bank capital matter for monetary transmission? Economic Policy Review (FRBNY), (May), 259–265.

Wallace, N., 1981. A Modigliani-Miller theorem for open-market operations. *American Economic Review* 71, 267–274.

Windmeijer, F. 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, 126, 25-51.

Witmer, J., Yang, J. (2016) Estimating Canada's effective lower bound, *Bank of Canada Review*, Spring, 3-14. Ottawa: Bank of Canada.

Whelan, K., & Ryan, E. (2019). Quantitative Easing and the Hot Potato Effect: Evidence from Euro Area Banks. CEPR Discussion Paper No. DP13499