UNIVERSITÀ DEGLI STUDI
DI GENOVA

Fly You Fools! The Unintended Consequences of the Negative Interest Rate Policy.

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"At the end of the day negative interest rates
are taxes in sheep's clothing"

Christopher J. Waller (2016)

"For Japan in particular, the impact of the
negative interest rate policy on the profits of
financial institutions tends to be relatively large"

Haruhiko Kuroda (2016)

"Net interest income has remained quite stable… for
some banks however the negative effect of negative
interest rates can be larger than for others."

Mario Draghi (2017)

"The MPC is very clear that 'lower bound' is a positive
number…I am not a fan of negative rates. We see the
negative consequences through the financial system in
other jurisdictions"

Mark Carney (2016)

"A decrease in the real interest rate to -3 or even -4
percent will make little or no difference, perhaps […]
exposing the economy to greater financial instability."

Joseph Stiglitz (2016)

"The amount of extra stimulus generated by this further reduction of rates (due to negative rates) would not have been negligible by any means… but neither would it likely have been a game-changer."

Ben Bernanke (2016)

"Zero or negative rates undermine, when they become quasi-permanent, the efficient allocation of capital and set the stage for bubbles, bust and crises."

Kemal Dervis (2016)

"Far from encouraging lending and spending, negative interest rate at the central bank might work in the opposite direction."

William White (2014)

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INTRODUCTION

The aim of this doctoral thesis is to study the recent use of negative interest rates focusing on the impact that the negative interest rate policy (NIRP thereafter) has on bank profitability, lending and sovereign bond holding. After providing a definition and contextualisation of NIRP, this thesis addresses three different research questions.

The first research question will focus on the impact of NIRP on bank profitability and consequently on financial stability. A cut in interest rates into negative territory may increase bank profitability if there is significant loan growth and margins are unaffected, or/and if banks boost fee and commission income on the back of greater lending. However, 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. If the latter is the case, the decline in profits can erode bank capital bases and further limit credit growth thus stifling NIRP monetary transmission effects. The first paper addresses this serious concern. It examines whether or not, after the introduction of NIRP, banks margins and profits have been negatively affected. Furthermore, it investigates if negative rates have promoted a change in bank business model. The contraction of net interest margin could have affected banks business model promoting a switch from interest-based to fee-based activities.

The second paper is strongly linked to the first. If NIRP decreases banks profitability eroding capital base, banks may be reluctant to lend limiting monetary policy potential and expected outcome. The second research question addresses this point. It tries to capture whether or not after the implementation of NIRP banks increased or decreased lending in comparison with a control group who has not been affected by negative rates. The effect of NIRP on bank lending may further be aggravated in the European context where banks have been facing slow economic recovery, historically high levels of non-performing loans, and a post GFC and European sovereign debt crisis deleveraging phase. In this economic environment, banks could have employed the excess liquidity provided by central banks unconventional monetary policy measures to buy corporate and government debt securities rather than lending. This behaviour links to the third research question.

The third research question investigates banks sovereign bond holding during the low and negative interest rate environment that has characterised the period after the 2007/2008 Financial Crisis and European Sovereign Debt Crisis. In such a situation, banks may prefer to hold sovereign bonds rather than lending for the following reasons. First, prudential regulation favours sovereign debt over loans as it assigns neither capital charges (zero-risk-weights) nor portfolio concentration limits. Banks with low capital ratio may increase return on equity by shifting from low to high yield sovereigns without altering regulatory capital requirements. Second, in a period with slow economic recovery, historically high level of non-performing loans, increasing loan loss provisions and low interest rates, sovereign debt can act as a substitute for credit affecting banks' lending decision. The same reasons, as previously described, can negatively affect bank profitability suggesting that banks may have an incentive to purchase high yield sovereign debt securities to improve profitability conditions (*carry trade hypothesis*).

CHAPTER 1:

A GENERAL INTRODUCTION TO THE NEGATIVE INTEREST RATE POLICY

1.1 Transmission Channels and Transmission Problems of Negative Interest Rates

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[2] and aggregate demand (as illustrated below).

$$M \uparrow \rightrightarrows\ i_r \downarrow \rightrightarrows I \uparrow \rightrightarrows AD \uparrow$$ [3]

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 raises 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.

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

As conventional monetary policy tools, NIRP is assumed to lower short-term money market and bond rates (Hannoun, 2015; Jackson, 2015; Jobst and Lin, 2016; Arteta et al. 2016). As

[1] See Mishkin (1995) for an overview of the transmission channels of monetary policy.
[2] Business and consumer investment decisions are included in this category.
[3] M↑ and M↓ refer to lessening and tightening monetary policies, respectively.

positive, negative rates can also lower long-term rates by acting on both investors' arbitrage differences in risk-adjusted expect returns and maturities of debt securities. As a result, deposit and lending rates decline improving borrowers funding costs (banks) and budget constrain (households and firms). This effect should encourage economic agents to increase investment and consumption.

As shown by figure 1 and 2, the introduction of negative rates (red vertical line in the graphs) contributed to a further reduction in lending as well as deposit rates.

Figure 1. European Lending Rates over the Period 2010-2017.

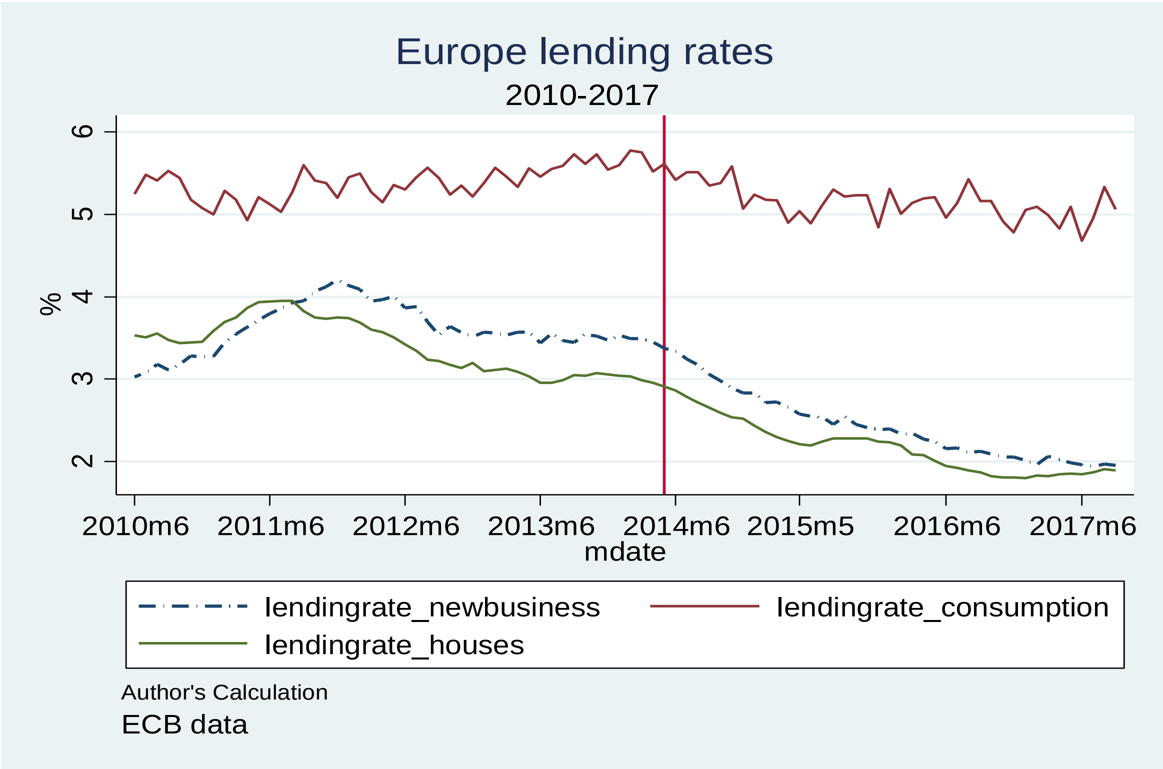
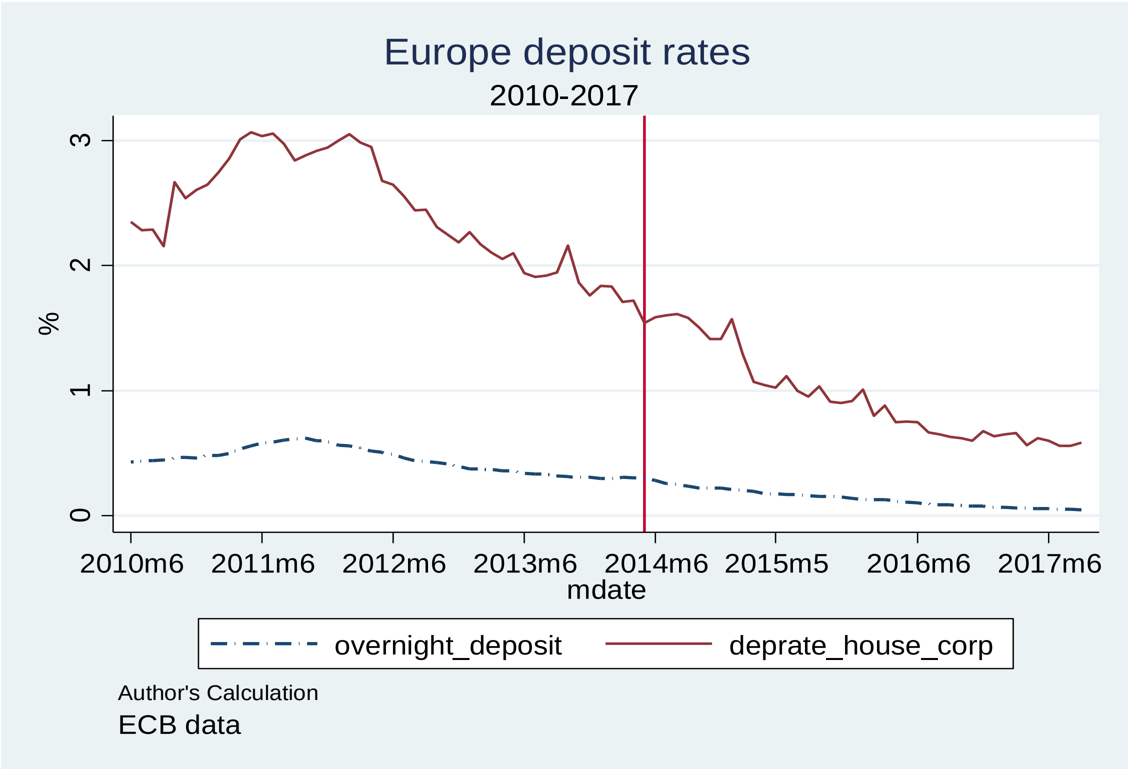


Figure 2. European Deposit Rates over the Period 2010-2017.



The interest rate channel can be distorted when rates are cut into negative territory. Commercial banks, in fact, might be reluctant to impose negative rates to costumer fearing to lose the deposits base. Hence, deposit rates (funding cost for banks) can be less affected by the policy (downward stickiness). This tendency, combined with efforts to maintain net interest margin, could potentially reduce the pass-through to lending rates as well.

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.

The Lending Channel

Bernanke and Blinder (1988), Bernanke and Gertler (1995) pointed 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 banks 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 at the account of the central banks. Therefore, NIRP encourages banks to use them to increase lending.

However, a cut in interest rates into negative territory may increase bank profitability if there is significant loan growth and margins are unaffected, or/and if banks boost fee and commission income on the back of greater lending. Nevertheless, 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. If the latter is the case, the decline in profits can erode bank capital bases and further limit credit growth thus stifling NIRP monetary transmission effects.

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 rate[4], which in turn improve firm cash flow (less interest expenses).

$$M \uparrow \rightrightarrows i \downarrow \rightrightarrows \textit{cash flow} \uparrow \rightrightarrows I \uparrow \rightrightarrows AD \uparrow$$

This situation is also particularly suitable for banks in term of moral hazard and adverse selection. Low firm net worth requires high 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 the lenders will not be paid back. This can lead to high non-performing loans in the banks' portfolio that can ultimately limit banks' willingness and ability to lend reducing investment and aggregate demand.

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

[4] In this situation, the nominal level of 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 flow (Mishkin, 1995).

The aforementioned effect links also 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 received if the investment pays off are much higher than the losses if the project is unsuccessful. Therefore, bank denied loans to investors when interest rate is 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 effect on prices. This lowers the value of firms' liabilities in real term (reduced debt burden) as debt contract are usually fixed in nominal terms. For the aforementioned described mechanisms, higher prices increase net worth, which can reduces asymmetric information raising investments and aggregate demand.

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

1.1.3 Asset Valuation

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 flow from assets (Hannoun, 2015). Tobin's Q theory (see Tobin, 1969) presented a mechanism through which monetary policy affects equity prices. According to the monetarists, accommodative monetary policies leave economic agents with excess money holding. Among the other alternatives, individuals can allocate excess liquidity increasing the demand for stocks and consequently their prices (search for yield). For the Keynesian, this mechanism operates in a similar fashion. Lessening monetary policies make bonds less attractive in comparison 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 (the Tobin's Q ratio). When the market value of a company is high (q is high) respect 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 previously mentioned 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 constrain is determined by the long-run individuals' resources, namely human capital, real capital and financial wealth. When equity prices increase financial wealth increases and so consumption.

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

These effects under NIRP could potentially lead to distort asset valuation and lead to risk of assets bubbles.

1.1.4 Portfolio Rebalancing Channel or Risk-Taking Channel

The portfolio rebalancing channel operates similarly to the asset valuation channel. In a low or negative interest rates 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 can provide major lending to firms and households to keep up profitability (usually low when interest rates are low). They can also buy towards long-term government bonds in an attempt to increase yields on the security holding. 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)

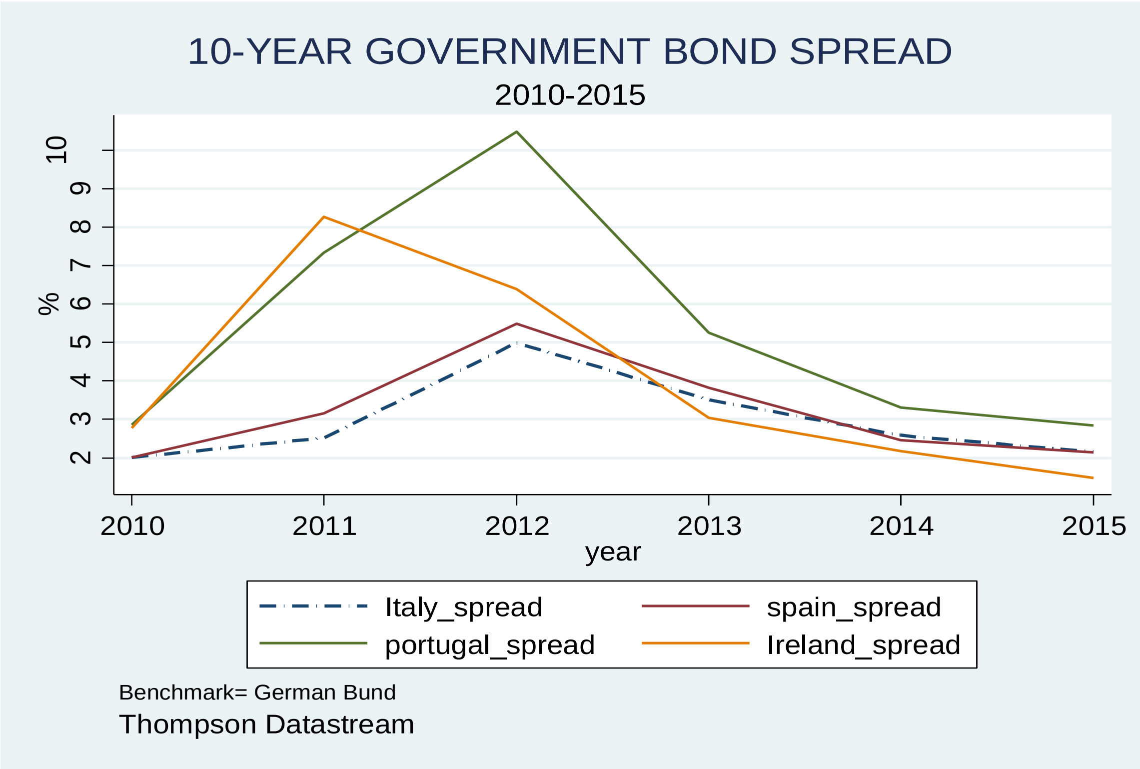
$$M\uparrow \rightrightarrows i\downarrow \rightrightarrows search\ for\ yield\uparrow \rightrightarrows lending\uparrow \rightrightarrows I\uparrow \rightrightarrows AD\uparrow$$

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

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 3). Moreover, according to Heider et al. (2016), banks affected by NIRP (deposit-based) started both to lend more to riskier borrower in comparison with wholesale-based banks and, at the same time, to be perceived as riskier (Nucera et al. 2017).

Figure 3. Ten year government bonds spread (German Bund= benchmark).

[5] For an explanation of the risk-taking channel, see Borio and Zu (2008).



1.1.5 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 experimenting a reduction in rates to foreign countries. This leads to domestic currency depreciation (E↓). When domestic currency depreciates, domestic good becomes cheaper than foreign goods, thereby causing a rise in net export (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 previously mentioned as lower (higher) domestic interest rate should reduce (increase) financial inflows and lessen exchange rate appreciation (depreciation).

1.1.6 The Reflation Channel

As suggested by Hannoun (2015), central banks tempt 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.

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

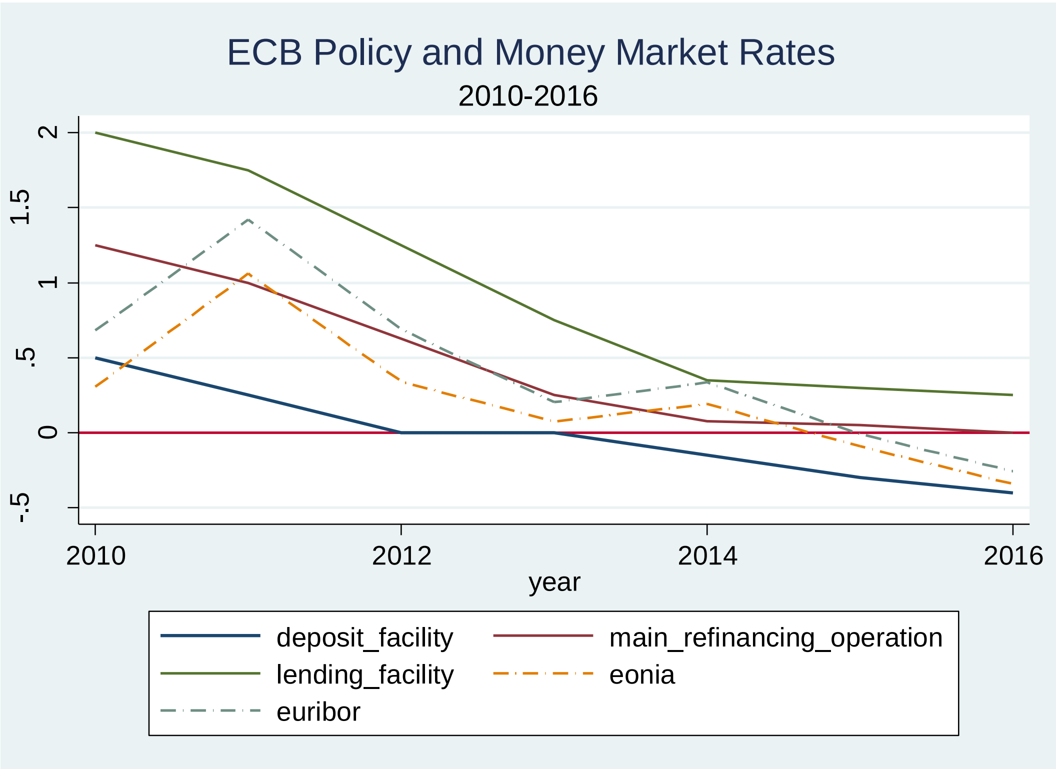
Detecting the signs of a downward price spiral are very hard to detect in Europe.

1.2 The Implementation of Negative Interest Rates

1.2.1 Euro Area

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 interest rate paid on excess reserves (IOER) – by -0.10 basis points in response to subdued inflation figures. The ECB operated further reduction 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 main refining operation as well as the lending facility followed the reduction of the deposit facility. As shown by figure 4, money market rates (Eonia and Euribor), always very close to the main refinancing operation, entered into negative territory after the introduction of NIRP.

Figure 4. European Central Bank Policy Rate and Money Market Rates over the period 2010-2016.



1.2.2 Sweden

The Swedish central bank (Sveriges Riksbank) introduced negative interest rates in July 2014 to fight against deflationary pressure. The introduction of NIRP was accompanied by different unconventional monetary policy measures such as large-scale government debt purchase program that led to 800 billion Swedish Krona balance sheet expansion. 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

The Denmark central bank cut its certificate of deposits into negative territory on 5 September 2014. The main reason was to reduce financial inflows and upward exchange rate pressure. After the introduction of a negative interest rate on certificate of deposits, the interbank rate turned negative together with the 1-month Copenhagen Interbank Offered Rate (CIBOR). The amount of reserves that commercial banks can hold at the central bank is limited. When commercial banks exceed this limit, the excess is 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, has been in place before the introduction of NIRP.

1.2.4 Switzerland

As for 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 its available policy rates below zero in an effort to avoid excessive financial inflows. Being banks behaviour and the possible negative effect of negative interest rates on profitability a concern, 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 the lowest (-75 basis point), 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.

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 concern related to price stability. As Switzerland, the Norwegian central bank (Norges Bank) uses a tiered reserves system. However, Norges Bank does pay a positive interest rate if commercial banks do not exceed a specific amount of excess reserves. It charges excess reserve 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.

1.2.6 Japan

The Bank of Japan (BoJ) adopted NIRP on 29 January 2016. The main aims were providing additional monetary policy stimulus and to fight against deflationary spirals. As most of the central banks previously 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 negative interest rate of -0.1, The impact of NIRP on profitability has been the major concern of BoJ. Net interest margin experienced a severe compression as lending rates strongly declined after the NIRP introduction.

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CHAPTER 2: Bank Margins and Profits in a World of Negative Rates[6]

Abstract

This paper investigates the influence of negative interest rate policy (NIRP) on bank margins and profitability. Using a dataset comprising 7242 banks from 33 OECD member countries over 2012-2016 and a difference-in-differences methodology, we find that bank margins and profits fell in NIRP-adopter countries compared to countries that did not adopt the policy. The results are robust to a variety of checks. This adverse NIRP effect appears to have been stronger for banks that were small, operating in competitive system as well as in countries where floating loan rates predominate.

JEL: E43, E44, E52, G21, F34

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

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1. Introduction

Since the Global Financial Crisis (GFC), policy-makers have been facing a challenging economic situation dominated by economic stagnation, high unemployment and deflation. As a first 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[7]. 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 rates policy (NIRP) in order to provide further economic stimulus to constantly weak economies[8]. The aim of NIRP (see Couere'. 2016) is to increase the cost to banks of holding excess reserves at the central bank encouraging them to take them back on the balance sheet. This should lead to beneficial outcomes for the real economy coming mostly from a greater supply and 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[9] into "uncharted" negative territory deserves serious consideration and analyses. In this regard, the "how low for how long" question has raised concern about the long-term effect of this policy on financial intermediaries' performance and on the economy as a whole (see, McAndrews, 2015)[10]. A cut in interest rates into negative territory may increase bank profitability if there is significant loan growth and margins are unaffected, or/and if banks boost fee and commission income on the back of greater lending. However, 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. If the latter is the case, the decline in profits can erode bank capital bases and further limit credit growth thus stifling NIRP monetary

[7] See Reifschneider and Williams (2000) and Chung et al (2012) for the impact of the zero lower bound constraint and Gambacorta et al. (2012), Borio and Zabai (2016) and Hamilton et al. (2012) for the effectiveness of unconventional monetary policies.
[8] See Bech and Malkhozov (2015) for a discussion of the implementation mechanisms of NIRP in adopting countries. The time of introduction of NIRP is noted in Table A1 in the appendix.
[9] $12 trillion of bonds in 2016 were traded at negative yield (see Kunz 2016).
[10] There has been discussion that negative rates promote bubbles in the bond and housing markets. In our analysis, we will focus on the performance of the banking sector.

transmission effects. This influence of NIRP on bank performance may further be aggravated in the European context where banks have been struggling to maintain (respectable) levels of profitability because of a slow economic recovery, historically high levels of non-performing loans, and a post GFC and European sovereign debt crisis deleveraging phase.

We contribute to the existing literature, which focuses on low and/or more 'normal' interest rate environments by evaluating the impact of an unexplored monetary policy instrument as the NIRP on net interest margins (NIMs) and bank profitability. We employ a bank-level database comprising 7242 banks in 33 OECD countries for the period 2012-2016 and a difference-in-differences methodology. This methodology allows us to draw conclusion as to whether banks' NIMs and profitability in NIRP adopter countries were impacted differently than countries that did not adopt the policy. Moreover, it permits us to analyse both macroeconomic and bank-level factors that affect performance in the uncharted territory of NIRP. We find that NIM and return-on-assets (ROAs) show a strong contraction after NIRP implementation. Our results highlight that NIM contraction reduces banks' profitability, despite the case that lower rates can boost bank profits 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, operating in countries where markets are more competitive and floating interest rates predominate.

The paper proceeds as follow. Section 2 reviews the academic literature on the impact of interest rates on bank profitability and margins. Section 3 introduces our data and methodology. Section 4 presents our results along with several robustness checks and the final section concludes.

2. Literature Review

Our 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[11]. One of the first empirical papers dates back to the early 1980s, in which the switch from low to high interest rates determined by the "Volcker doctrine"[12] 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) finds that, while drastic interest rate changes can threaten bank stability, large U.S banks mitigate these risks by hedging against interest rate risk modifying assets and liabilities in order to have similar average maturities. Hancock (1985) notes that if monetary policy does not affect the spread between interest earning assets and liabilities, an increase in interest rates tends to boost bank profits. Demirgüç-Kunt and Huizinga (1999) were among the first to investigate the effect of real interest rates on bank margins and profitability. Using cross-country and bank-specific data on margins, they find that high real interest rates are associated with higher NIMs and profitability - especially in emerging economies where deposit rates are frequently targeted by policymakers to be below-market rates. English (2002), studying the link between interest rate risk exposure and bank margins in ten OECD countries over the period 1979-1999, points out that the average yield on bank assets is more closely related to long-term rates than the average yield on liabilities, hence a steep yield curve should be associated with higher NIMs. In a similar fashion, Albertazzi and Gambacorta (2009) also use data of ten OECD countries over 1981-2003 and aggregate income statement data to show that short-term and long-term rates have a differential influence on bank margins[13]. While short-term rate seems to have no impact on margins, a 1% increase in long-term rates increases NIMs from 1% after a year to up to 4% in the long-run, hence margins react mainly to the slope of the yield curve. The relation between the slope of the yield curve and bank profitability has been evidenced also by Alessandri and Nelson (2014) with reference to the UK banking sector. Again, their findings suggest that in

[11]The literature on the determinants of net interest margins and profits is extensive. We refer to section 3 for a select overview of studies on the determinants of bank margins and profits.
[12] Paul Volcker, Chairman of the Federal Reserve during the period 1979-1987, is credited with ending the high level of inflation in the United States by using tight monetary policies and high interest rates.
[13] In their model Albertazzi and Gambacorta (2009) define short-term and long-term interest rate using the 3-month interbank rate and the rate on long term government bonds, respectively.

the long-run (measured using ten-year government bond yields) higher interest rates have an unambiguous positive effect on bank profitability and margins.

Size and specialness appear to be key factors that enable banks to hedge against interest rate risk avoiding excessive NIMs and profit volatility in 'normal' operating environments. In this regard, Angbazo (1997) finds that 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. Specialness, assets composition and size are also found to be important by Hanweck and Ryu (2005). Using a sample of U.S banks, they underline how small regional banks and mortgage specialists are particularly affected by the volatility of interest rates.

There are also a limited number of studies that focus specifically on bank profitability and margins in a low interest rate environment. Genay and Podjasek (2014) indicate that U.S banks face decreasing NIMs and returns during periods of low interest rates – and (again) the effect is particularly strong for small institutions. However, they also suggest that the benefits of low rates (in terms of boosting economic activity) outweigh the costs. Opposing findings have been reported by Covas et al. (2015) who show that, during a period of low interest rates (2010-2015 in their sample), NIMs decline more markedly for large U.S banks (70 basis points against 20 for small banks[14]) because small banks benefit more from a fall in deposit costs. Claessens et al. (2017), investigating 47 countries, find that low interest rates have a significantly greater impact on bank ROAs and NIMs than high rates. Although profitability appears to be less affected than margins, persistently low interest rates also reduce the ability of banks to be profitable. Hence, while a cut in interest rates has the short-term effect of negatively impacting NIMs, in the long-term there is an adverse pass through to profitability. Busch and Memmel (2015), studying the German market during 'normal' and low interest rate periods, find a small but positive effect of long-term rates on bank margins. However, they state that, during periods of low interest rates, the ZLB constraint on deposit products puts additional stress on banks' margins.

Empirical analysis of the influence of NIRP on bank margins and profits links to the unconventional monetary policy (UMP) literature. NIRP is one type of UMP together with Quantitative Easing (QE) (large-scale asset purchases) and policy guidance that manages down

[14] Small banks are defined in this study as having assets less than $50 billion.

long-term interest rate expectations. These policies not only reduce market interest rates but expand and modify the size and composition[15] of both central bank's and commercial bank's balance sheets that can impact margins and profitability. In this regard, Lambert and Ueda (2014), using a sample of U.S banks over 2007-2012 report a negative relation between the size of central bank's assets and NIMs. When central banks expand their balance sheets this helps push down interest rates reducing bank funding costs but the influence is offset by reduced revenues from new loans. Deposit rates are more 'sticky-downward' than loan rates and compresses margins reducing profits. Similar results have been displayed by Alessandri and Nelson (2014) who show that Bank of England balance sheet expansion has a negative influence on NIMs[16].

Our contribution to the literature is important in three respects. First, as outlined in the aforementioned studies, persistently low interest rates are found to adversely impact bank profits and margins. If this is valid for low interest rates, breaking the ZLB with negative rates might even be more problematic given the reluctant attitude of banks to start charging customers for their deposits ("stickiness"). Secondly, the literature on NIRP is still 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. Moreover, studies examining the effects of NIRP (see Jobst and Lin (2016), Arteta et al. (2015), Bech and Malkhozov (2015)) point to the compression of NIMs as lending rates for new loans decline and existing (variable-rate) loans re-price while deposit rates remain sticky-downward[17], but they do not use bank-level data to explicitly test to see if this is actually the case. If this is indeed the case, all other things being equal, it will lead to a reduction in profitability and this may reduce the effectiveness of this new monetary policy tool if banks reduced profits curtails lending activity. Third, we perform various robustness checks to validate our results. These provide more information on specific type of banks and countries financial features that can influence the impact of NIRP.

Our paper adds to the aforementioned literature by examining the impact of NIRP on margins and profits using a dataset comprising 7242 banks in 33 OECD countries over 2012-2016 and

[15] See Bernanke and Reinhart (2004) for an explanation of unconventional monetary policies.
[16] Both studies apply panel regressions and GMM estimation.
[17] The relation between monetary policy changes and the stickiness of deposits has been extensively analysed (see Freixas and Rochet (1997) for a review).

a difference-in-differences methodology. Our main finding is that bank margins and profits fell in NIRP-adopter countries compared to countries that did not adopt the policy. The results are robust to a variety of checks. The adverse NIRP effect on bank performance appears to have been stronger for banks that were small, operating in competitive system as well as in countries where floating loan rates predominate.

3. Methodology and Data

3.1 Methodology

To capture the effect of NIRP on ROA and NIMs we use a difference-in-differences 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. (2016)). The advantage of this approach is that it allows to use a panel data set-up to compare a treated group of banks (those impacted by the policy change) with those that are not affected (the control group or untreated banks). The approach also helps to control for the 'omitted variable bias'[18]. Our baseline specification takes the following form:

$$Y_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 \left(Treated_{ij} * Post_{jt} \right) + \varphi_t + \gamma_i + \varepsilon_{ijt} \quad (1)$$

Where Y_{ijt} is the NIM (or ROA)[19] 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[20], and β_3 represents the average difference in NIM and ROA between countries that switched to NIRP and countries that did not. We also include γ_i, and φ_t, to capture, respectively, bank and year fixed effects and limit the potential for bias

[18] For example, regulatory changes (such as Basel III) may affect treated and untreated bank performance alike, regardless of the NIRP intervention. But as these changes may affect banks similarly, the difference-in-differences approach avoids this bias by differencing away common trends affecting both groups

[19] Following Borio et al (2015) and Claessens et al. (2017), we define bank net interest margins as the difference between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets. Return on assets is calculated by dividing bank's net income by its assets.

[20] The vast majority of NIRP countries in our sample introduced NIRP in 2014, hence $Post_{jt}$ taking value 1 from 2014. However, since Sweden, Norway and Switzerland introduced NIRP in 2015 we adapted the $Post_{jt}$ dummy accordingly.

in estimates of β_3. We include bank-specific dummies to control for time-invariant, unobservable bank characteristics that can shape bank NIMs and ROAs. We include year fixed effects to control for possible shocks over the sample period that can affect bank NIMs and ROAs 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. We use robust standard errors to control for heteroscedasticity and dependence (see Bertrand et al. (2004); Petersen (2007) and Donald and Lang (2007).

We introduce bank- and country-specific controls in a second specification that takes the form:

$$Y_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 (Treated_{ij} * Post_{jt}) + \beta_4 X_i + \varphi_t + \gamma_i + \varepsilon_{ijt} \quad (2)$$

where X_i is a vector of bank- and country-specific characteristics to capture cross-bank and cross-country heterogeneity over time that can affect NIMs and ROAs[21]. Bank-specific variables are a combination of balance sheet and performance measures. Our control variables are in-line with the literature on the determinant of NIMs and profits. We include four bank-specific and two country-specific control variables that have been shown in the literature to explain banks' performance. The first variable is size (size) measured by 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, hence we expect profits and margins to have the opposite signs in relation to size. 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*) as a proxy for bank risk aversion. A positive relation is

[21] The inclusion of covariates in a difference-in-differences 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 NIMs and ROAs independently by the introduction of NIRP. On the other hand, the introduction of covariates can cause two main problems. First, when banks are relatively homogeneous in both the treatment and control group, additional covariates can weaken, instead of strengthening, the likelihood that both groups maintain the parallel trend, hence violating our assumption. Second, time varying covariates can change or be influenced by the post-treatment period, leading to endogeneity problems. We assess this problem in several ways. First, we test the control variables for multicollinearity using the *variance inflation factor* (VIF). A mean VIF of 1.07 suggests that our controls are not highly correlated. Second, we provide t-test statistics to show that the control variables are not homogenous among treated and untreated banks (see section 3.2 and Table 1). Finally, to avoid the possibility that time varying control variables can be influenced by the intervention (the NIRP introduction), we test the control variables as dependent variables in the difference-in-difference specification. As expected, the test (not reported) suggests that our control variables are not affected by the intervention.

expected between this variable and margins[22]. Risk averse banks will require higher margins to cover the greater cost of equity. A positive relation is expected also with reference to profitability as suggested by Berger (1995). Banks with higher franchise value and well-capitalised face lower expected bankruptcy and funding costs. We also use liquidity (Carbo and Fernandez (2007) and a credit risk measure (Carbo and Fernandez (2007); Poghosyan (2012) and Almarzoqi and Naceur (2015)) to explain bank margins. In this context, we use the ratio of liquid securities to total assets (liquidity) and the loan loss provision to gross loans ratio (credit risk), respectively. We expect that less liquid and credit riskier banks, apply a premium to margins.

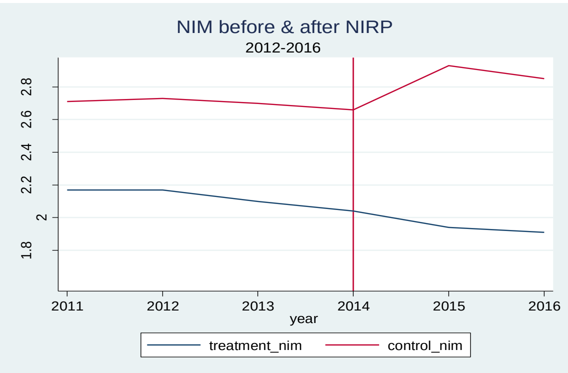
The country-specific variables are broad measures of macroeconomic performance and include GDP growth (GDP growth) and consumer price inflation (inflation). Athanasouglu et al (2008) recognise a twofold GDP growth effect on bank performance. On one hand, GDP growth has a positive effect on bank profits 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. The economic uncertainty induced by high inflation rates is compensated for by higher spreads.

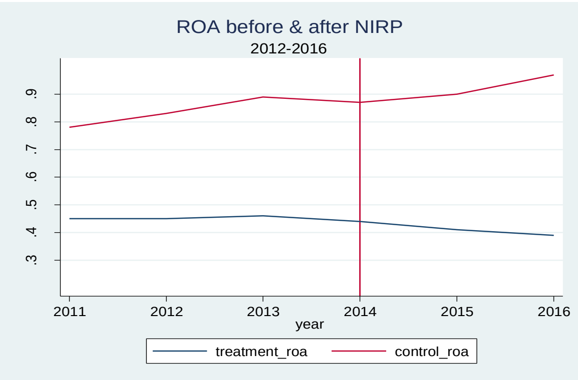
The difference-in-differences approach requires that three assumptions hold. First, the control group must constitute a valid counterfactual for the treatment[23]. Second, assignment of the treatment has to be exogenous with respect to bank performance. In other words, the policy action (‘intervention’) should affect bank performance and not vice versa. As explained in the introduction, the aim of NIRP is to increase the cost to banks of holding excess reserves at the central bank encouraging them to take them back on the balance sheet and increase the supply of loans. Hence, influencing bank performance (profits and margins) is not the policy-makers main target but rather reflects a secondary effect. Moreover, Figure 1 shows that, prior to the introduction of NIRP, NIMs and ROAs moved in a similar direction but the relationship changed thereafter. This is confirmed when we examine the third requirement of a ‘parallel

[22] Macroeconomic theorists such as Gertler and Kiyotaki (2011) suggest a negative relation. A higher net worth (equity) relative to the capital stock reduces the expected default probability (everything else equal). Thus, banks can charge lower margins to customers.
[23] We provide evidence that this assumption holds in the next section.

trend assumption'[24]. Figures 1 depicts levels of NIMs and ROAs 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, 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 the worst performance since 2011 with level falling below 2% for NIM in 2014-2015 and below 0.40% for ROA in 2015.

Figure 1. Average NIM/ROA among treated banks (blue line) and non-treated banks (red line) from 2011 – 2016.





3.2 Data

We rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information mostly from two main sources[25]. The macroeconomic series are from Thompson DataStream and the bank balance and performance data are from Orbis Bank Focus. Since Orbis comprises of cross-country banks that operate in more than one countries, the balance sheet data can either refer to consolidated values across subsidiaries or unconsolidated accounts based on the country of bank headquarters. To avoid concerns of banks that operate in more than one countries in both treated and not treated groups, we retain bank accounts that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but

[24]According to Bertrand et al. (2004) and Imbens and Wooldridge (2009) the difference-in-differences is valid only under the restrictive assumption that changes in the outcome variable (in our case bank profits and NIM) over time would have been exactly the same in both treatment (countries that experienced NIRP) and control groups (no NIRP) in the absence of the intervention (the introduction of NIRP).
[25] See Table A1 for the dating of NIRP.

not with an unconsolidated subsidiary. Our sample covers 7242 financial institutions (commercial banks, savings banks, cooperative banks and bank holding companies) from 33 OECD countries over 2012 - 2016[26]. The treated countries include those of the Euro Area, Hungary, Sweden and Switzerland.[27] Descriptive statistics for bank ROAs and NIMs, other bank balance sheet variables, and the macroeconomic series in the treatment and control groups of countries are shown in Table 1.[28]

Panel A and B of Table 1 presents summary statistics on the aforementioned balance sheet data. Panel C displays macroeconomic condition and monetary policy variables descriptive statistics[29]. Bank profitability and margin may also be driven by other macroeconomic, market and monetary policy factors. Accordingly, we control for a wide range of potentially important explanatory control variables in the regression models. Following Carbo and Fernandez (2007), Maudos and Fernandez de Guevara (2004), Hawtrey and Liang (2008) Maudos and Solis (2009), Lepetit et al. (2008), Almarzoqi and Naceur (2015) and Entrop et al. (2015), we use the Lerner index (Lerner index) to control for competition in the banking sector[30]. The Lerner index is the difference between the price and the total margin cost as a proportion of the price and has been taken from the World Bank Global Financial Development Database. It ranges between 0 (perfect competition) and 1 (monopoly). It is inversely proportional to banking competition. NIRP is expected to have a more marked impact in more competitive systems as changes in policy rates are likely to be passed on more effectively.

[26] 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 unobservables and other factors that affect the treatment outcome leading to omitted variable bias threatening the validity of the model.

[27] We exclude Japan in our sample as the country only adopted NIRP in early 2016, which provides too short a period to examine the impact of NIRP on profits and margins.

[28] We also estimate Pearson correlation coefficients for the macroeconomic variables in the treatment and control group. The significance of coefficients suggests that the countries in the two groups experienced a similar macroeconomic environment validating the fact that the control group constitutes a valid counterfactual scenario for the treatment. This finding, together with the parallel trend assumption that we report in Figures 1 and 2, further supports our decision to choose a difference-in-differences methodology in our analysis. We 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.

[29] Equality of means t-test is also performed.

[30] We prefer the non-structural Lerner index measure of competition over a concentration measure such as the Herfindahl-Hirschman Index (HHI). There are, in fact, different views about competition and concentration in the literature. Claessens and Laeven (2003), for example, point out that there are some countries, such as U.S, that shows levels of monopolistic competition in banking despite the relatively low level of concentration and large number of banks, while countries like Canada are highly competitive, although the level of concentration is high and number of banks relatively small. Beck and Hesse (2009) suggest that concentration measures are not satisfactory measures of the degree of market competition in the banking industry.

As other UMP policies, including central banks' asset purchase programs (Di Maggio et. al, 2016; Rodnyanski and Darmouni, 2016; Kandrac and Schulsche, 2016; Chakraborty et. al, 2017), were conducted at the same time as NIRP we include variables to account for these effects. In-line with Gambacorta et al. (2014), Lambert and Ueda (2014), and Alessandri and Nelson (2015) we employ the log growth rate of a country's central bank balance sheet *(CB_GR)*. We also use the log growth rate of the monetary base *(M0_GR)* as further controls to isolate the impact of other UMP's on bank NIMs and ROAs. According to the aforementioned studies other UMP's are also expected to compress margins and therefore (we expect) bank profits. This is investigated in the robustness check section 4.2 of the paper.

Finally, we 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. One would expect the impact of NIRP to be greater in countries where floating rates are more prevalent. Following Albertazzi and Gambacorta (2009) we 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 to identify countries where the bulk of lending is at a variable or fixed rate.

Table 1. Descriptive Statistics Control and Treatment Group

	I. Treatment group:					II. Control group				
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev**	**Min**	**Max**
Panel A: Bank Profitability and Margin										
NIM	16956	2.00%***	0.90%	0.52%	3.08%	9017	2.74%***	1.36%	0.39%	6.15%
ROA	17133	0.43%***	0.50%	0	1.26%	9268	0.91%***	0.75%	-0.10%	3.26%
Panel B: Bank Balance Sheet Data										
Size	17186	13.78***	1.59%	11.51	16.58	9658	14.35***	2.02%	11.21	17.63
E/TA	17182	10.14%***	4.75%	4.07%	21.76%	9654	16.55%***	13.91%	5.47%	51.27%
Liquidity	16444	21.49%***	15.04%	0.01%	46.68%	8715	22.23%***	20.00%	0.01%	64.85%
Credit risk	9888	5.88%***	5.47%	0.48%	17.25%	6081	2.69%***	2.62%	0.19%	8.46%
Panel C: Macroeconomic Conditions and Monetary Policy										
GDP growth	20456	0.25%***	0.56%	-0.19%	6.62%	46240	0.52%***	0.17%	-1.13%	1.89%
Inflation	20456	0.99%***	0.77%	-1.73%	4.39%	46244	1.51%***	1.17%	-1.73%	8.93%
CB_GR	15342	-7.34%***	14.22%	-22.06%	23.44%	25066	16.93%***	13.59%	-14.33%	37.80%
M0_GR	13448	8.35%***	12.78%	-7.89%	51.56%	44788	9.65%***	8.00%	-26.63%	18.77%
Deposit Rate	3486	0.69%***	1.01%	-0.18%	5.29%	3988	4.31%***	5.34%	0.03%	16.77%
Lending Rate	4788	4.02%***	1.24%	2.68%	9.00%	43385	3.25%***	0.78%	0.80%	9.26%
Lerner Index	20456	0.16***	0.78%	0.67	0.41	45400	0.32	0.04%	0.11	0.44
Floating-Fixed Rate	18208	71.39%	18.08%	32.95%	98.10%					

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 asset ratio; Size is the natural logarithm of bank total asset; 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 reserve to gross loans; Lerner is the Lerner index; GDP_GR is the yearly growth rate of real GDP; Inflation is the yearly Consumer Price Index 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; Lending Rate is the country level aggregate of lending rate in percentage; Spread is the difference between lending and deposit rates; Floating-Fixed Rate is the share of variable loans in total loans to household and non-financial corporation taken from the ECB Statistical Warehouse Database. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

4 Empirical results

4.1 Baseline results

The results from estimating equations (1) and (2) are presented in table 2 and 3. All the estimates include fixed bank and time effects. Table 2 and 3 report the estimates where the dependent variables are the NIMs (Table 2) and ROAs (Table 3), respectively. For both variables we incrementally introduce a set of bank and country control variables[31]. Our main interest is the size, sign and statistical significance of the coefficient of β_3 that represents the average difference in the change of NIMs and ROAs between countries that adopted NIRP and those that did not, denoted in the table as the *NIRP-effect*. The baseline results reported in columns 1 of Tables 2 and 3 excludes all control variables. The coefficient of *NIRP-effect* is sizeable, negative and statistically significant at the 1% level for both dependent variables, indicating that countries where central banks implemented NIRP experienced a decline in NIMs and ROAs of around 12.60% and 6.27% respectively, relative to those countries where central banks did not follow the same policy[32]. In-line with expectations the size of the coefficient on NIMs are nearly double that of ROA. This leads to two preliminary conclusions. First, NIRP directly causes a compression of banks' margins suggesting that they are unable to reduce deposit rates to the same extent as loan rates. Second, the contraction in NIMs (as a key component of bank profitability) indirectly drags down bank ROAs 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 lower/negative rates boosting non-interest income (via increased security valuations, trading income and such like)[33]. The remaining columns of the tables present the results from adding bank- and country- specific controls sequentially. The baseline regression result holds up well in the face of all controls—though the size of the coefficient is diminished somewhat (with the marginal effect varying between 9.06% (column 8) and 13.10% (column 2) for NIM, and

[31] In trying to avoid biased estimation, we remove credit risk in the ROAs regression as it causes an excessive variation in the NIRP-effect coefficient.

[32]This has been known for a long time. Samuelson (1945) mentioned:" the banking system as a whole is immeasurably helped rather than hindered by an increase in interest rate".

[33]We later test this to see whether NIRP resulted in an increase in non-interest income. For this exercise, we run two difference-in-differences baseline regressions (Table A2 in the appendix) using the ratios of non-interest income to gross income and net fees and commission to total assets (according to Jobst and Lin (2016) and Arteta et al. (2015) banks should increase fees and commissions to compensate for the decline in interest earnings). The result suggests that NIRP-affected banks experienced an increase in non-interest income (NII), and fees and commissions (FEE), relative to those banks unaffected by the policy. This provides an explanation of the differences between NIMs and ROAs with the former declining more markedly than the latter.

between 3.54% (column 7) and 6.20% (column 1) for ROA)[34]. The coefficients on the *NIRP-effect* remain negative and significant at the 1% level in all estimates. The covariates are mostly significant at conventional levels (although with small coefficients) with signs in-line with the literature on the determinants of NIMs and ROAs. The E/TA variable is positively correlated with NIMs suggesting that less leveraged and more profitable banks register higher margins. In contrast, liquidity, and credit risk are negatively related to NIM indicating that banks that are less liquid and with large non-performing assets apply higher margins to compensate for greater risks. Size and E/TA appear to be the main factors driving bank ROAs, while less liquid banks are the ones, in our sample, that show the largest profit reductions. Among the macroeconomic variables, the inflation rate displays a strong positive coefficient for both NIMs and ROAs suggesting that the low inflation decade since the GFC is another factor affecting banking sector performance[35].

[34] As suggested by Roberts and Whited (2013), a large discrepancy of the treatment coefficient with and without controls should raise a 'red flag'. In our case, variation in the NIRP-Effect coefficient occurs when country control variables are introduced. To assess this problem we run two additional regressions removing country control variables and bank fixed effects and introducing country fixed-effects. The NIRP-Effect coefficient is significant and displays smaller variation with respect to the addition of country controls. This suggests that our country measures are not fully able to capture unobservable factors as country fixed effects. The results are not reported. However, they are available upon request.

[35] Similar tests (not reported) have been undertaken using another bank profitability measure (ROE). Although the NIRP-effect coefficient remains negative and is statistically significant, it does not hold-up well when the controls are introduced. This is not surprising. ROE is more variable and easy to manipulate by managers via share buy-backs, provisioning and other earnings management techniques. As our estimates also show, it is more strongly influenced by macroeconomic conditions. That is why the empirical banking literature has a strong preference for using ROA as a profits indicator. ROE results are not reported here but are available from the authors on request.

Table 2. NIRP and NIMs

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	NIM(1)	NIM(2)	NIM(3)	NIM(4)	NIM(5)	NIM(6)	NIM(7)	NIM(8)
NIRP-Effect	-0.1260***	-0.1310***	-0.1250***	-0.1138***	-0.1177***	-0.1160***	-0.1070***	-0.0856***
	(0.0145)	(0.0148)	(0.0149)	(0.0152)	(0.0153)	(0.0146)	(0.0148)	(0.0158)
Size		-0.0371	0.0208	0.0022	-0.0952***			-0.0698
		(0.0228)	(0.0270)	(0.0317)	(0.0495)			(0.0509)
E/TA			0.0053***	0.0057***	0.0105***			0.0108***
			(0.0013)	(0.0014)	(0.0029)			(0.0029)
Liquidity				-0.0010***	-0.0023***			-0.0024***
				(0.0003)	(0.0006)			(0.0006)
Credit risk					-0.0056***			-0.0041**
					(0.0016)			(0.0017)
GDP growth						-0.0619***	-0.0234*	-0.0029
						(0.0137)	(0.0131)	(0.0195)
Inflation							0.0505***	0.0416***
							(0.0061)	(0.0070)
Adj. R2	0.0553	0.0558	0.0603	0.0668	0.1109	0.0577	0.0636	0.1270
N.Banks	7242	7242	7241	6895	4895	7241	7241	4894
N.Obs	25973	25973	25965	24592	15474	25969	25969	15470

Table 3. NIRP and ROA

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	ROA(1)	ROA(2)	ROA(3)	ROA(5)	ROA(6)	ROA(7)	ROA(8)
NIRP-Effect	-0.0627***	-0.0620***	-0.0579***	-0.0374***	-0.0611***	-0.0576***	-0.0312***
	(0.0119)	(0.0120)	(0.012)	(0.0121)	(0.0120)	(0.0120)	(0.0123)
Size		0.0060	0.0437**	0.0442*			0.0496*
		(0.0158)	(0.020)	(0.0260)			(0.0262)
E/TA			0.0033***	0.0057***			0.00584***
			(0.0012)	(0.0017)			(0.0017)
Liquidity				-0.0000			-0.0000
				(0.0000)			(0.0000)
GDP					-0.0104	0.0058	0.0074
					(0.0130)	(0.0143)	(0.0153)
CPI						0.0227***	0.0251***
						(0.0054)	(0.0054)
Adj. R2	0.0080	0.0080	0.0140	0.0190	0.0086	0.0095	0.0210
N.Banks	7359	7358	7357	6939	7358	7358	6938
N.Obs	26401	26400	26394	24767	26397	26397	24763

4.2 Robustness checks

In this section, we report results from a range of robustness checks that offer variations from our choice of controls used in the baseline model. As previously described, the aim of NIRP is to induce further reductions in interest rates as banks 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 of NIMs[36]. We control for this effect by including in our analysis lending and deposit rates. The results are reported in panel A of table 4 (column 1-4). As expected, the NIRP coefficient becomes larger and is more significant. There is a strong positive relation between NIMs and the level of deposit rate and lending rate. It is interesting to note that lending rates have a larger impact on NIM than deposit rates - a 1% increase/decrease in lending rates leads to a 5.48% increase/decrease in NIM while for deposit rates the effect is a 1.45% change. This result suggests that, in a low and negative interest rates environment as in our sample, NIMs are more sensitive to changes in lending rather than deposit rates - confirming that deposits are downward 'sticky'. Furthermore, the effect of deposit and loan rates on ROAs is insignificant[37].

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, we 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 are reported in panel B of table 4 (column 1-3) and are important for two reasons. First, they are in-line with the studies of Lambert and Ueda (2014) and Alessandri and Nelson (2014) underlining the possible negative effect of UMP on margins. The coefficients of central banks asset growth (CB_GR)

[36] However, in countries like Sweden and Denmark, where banks operate in a highly concentrated banking system and do not rely on retail deposit funding, banks can eventually decide to lower retail deposit rates below zero. In section 4.2, we test the role of market competition and bank funding structure on different bank behaviours in a negative interest rate setting.
[37] A similar test has been undertaken computing bank-level loan and deposit rates. Following Carbo and Fernandez (2007), we define the price of loans as the ratio of interest income on loans and the price of deposits as the ratio of interest expenses on deposits. The results (not reported) are in-line with our aggregate measures.

and M0 growth (M0_GR) are negative and statistically significant (column 1 and 3). Second, the effect of UMP is diametrically the opposite for ROA (column 2 and 4). Hence, while UMP and NIRP play a complementary role in driving down NIMs, the latter appears to have cancelled out a substantial amount of the stimulus impact of central bank balance sheet expansion in terms of boosting bank profits.

As a further robustness check, we alter our country sample and focus only on European countries where the treatment group includes only European NIRP adopters and the control group includes only European non-NIRP adopters. These results are reported in panel C of the table 4 (column 1 and 2). The coefficients of NIRP in both cases remains negative and statistically significant (in the case of NIM the relationship is stronger than in the baseline regression)[38].

As a final robustness check, we 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 our choice of difference-in-differences estimation. If the estimated coefficients on the 'false' NIRP are not statistically significant, we can be more confident that our baseline coefficient is capturing a genuine monetary policy shock. In panel D of the table we report results from estimates in which we extend our 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 our baseline estimation.

[38] We follow the studies conducted by 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.

Table 4. Robustness checks

	NIM (1)	ROA(2)	NIM (3)	ROA (4)
a. Lending and deposit rates				
NIRP-effect	-0.1993***	-0.0792***	-0.1493***	-0.0436***
	(0.0163)	(0.0131)	(0.0288)	(0.0218)
lending rate	0.0548***	0.0156		
	(0.0163)	(0.0121)		
deposit rate			0.0145***	0.0090
			(0.0198)	(0.0161)
Adj. R2	0.0440	0.0058	0.0396	0.0103
N.Obs	10901	11112	5678	5738
N.Banks	3142	3210	1719	1737
b. Unconventional Monetary Policy (UMP)				
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)
Adj. R2	0.0723	0.0090	0.0612	0.0121
N.Banks	7238	7354	5335	5422
N.Obs	25212	25627	19486	19809
c.NIRP and the EU				
NIRP-effect	-0.179***	-0.0507***		
	(0.0267)	(0.0175)		
Adj. R2	0.0950	0.0119		
N.Banks	5527	5623		
N.Obs	19897	20244		
d.fake-NIRP	-0.0173	-0.0080		
NIRP-effect	0.0175	0.0161		
Adj. R2	0.0000	0.0001		
N.Banks	7183	7307		
N.Obs	20123	20472		

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

4.2 Size, Competition and Asset Composition

As suggested by Jobst and Lin (2016), Brunnermeier and Koby (2016) and Bech and Malkhozov (2015), the contraction in NIMs and erosion of profitability should be more marked for small banks operating in competitive markets and with floating rate assets. In this section, using the difference-in-differences framework, we create NIRP-adopter treatment groups and non-adopter control groups according to various bank-specific factors that the literature on NIRP suggest might affect bank behaviour in a negative interest rate setting. Specifically, we focus on bank size, market competition and asset interest rate composition. First, we examine the impact of NIRP on NIMs and ROAs by running percentile regressions based on size. The results reported in Tables 5 are important in two respects. First, the largest banks show a significantly smaller contraction in margins (4.1% compared to 21.1% for the smallest (panel A in columns 1 and 4)) and statistically insignificant influence on profitability. Following dell'Ariccia et al. (2010), this result suggests that NIRP enables large wholesale funded banks to take greater advantage of a declining funding costs partially offsetting pressure on margins and profitability. Second, the coefficients get larger in magnitude as banks size shrinks. This is in-line with the literature mentioned in section 1 indicating that large banks, through hedging and diversification, are better able to protect themselves against interest rate risk[39].

As a second test, we assess the impact of NIRP in the context of competitive conditions in banking markets. In this case, we use the Lerner index as a proxy for competition conditions[40]. Sørensen and Werner (2006) argue that banks operating in a less competitive environment make slower adjustments to interest rates (and therefore to NIMs), 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

[39] If small banks do not increase non-interest income from NIRP, we can confidently say that the policy has a larger impact on reducing their ROA. In Table A3 (Panel A and Panel B) in the Appendix, we provide percentile regressions based on bank size for the impact on non-interest income and fees and commissions. The results confirm our hypothesis that small banks are the most affected (negatively) by NIRP in term of NIMs and ROAs as well as the least affected (positively) by NIRP in respect of non-interest income. Regressions (not reported) that include M0_growth as a control for UMPs also suggest a similar positive effect of UMPs on non-interest income and fees and commissions for large banks, while small banks are just marginally affected.

[40] For this exercise, similar tests were also undertaken using the Boone index and the Herfindahl-Hirschman Index (HHI). The results obtained are in-line with the Lerner index. The results are not reported. However, they are available upon request.

markets because of the associated pressure on NIMs. As the Lerner index varies between 0 and 1, we define a competitive market as those banking markets with a Lerner index smaller than 0.50, vice versa for non-competitive. The results, reported in panels A and B of table 6, 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 and margins.

Table 5. Bank size, NIM and ROA

All the percentile regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	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(4)
Panel a.								
NIRP-effect	-0.0410**		-0.1460***		-0.1830***		-0.2110***	
	(0.0191)		(0.0229)		(0.0267)		(0.0437)	
Panel b.								
NIRP-effect		0.0261		-0.0519***		-0.0709***		-0.108***
		(0.0162)		(0.0188)		(0.0227)		(0.0279)
Adj. R2	0.0324	0.0041	0.0820	0.0142	0.1050	0.0138	0.1020	0.0212
N.banks	1944	1855	2064	2115	2164	2195	2090	2159
N.Obs	6145	6514	6222	6637	6389	6629	6226	6621

Table 6. Banking sector competition and interest rate asset composition

		NIM	ROA		NIM	ROA
	Panel A. Competitive			***Panel B. Non-competitive***		
NIRP-effect		-0.0798***	-0.0695***		-0.0327	0.0680***
		(0.0372)	(0.0248)		(0.0205)	(0.0207)
Adj. R2		0.0964	0.0039		0.0187	0.0030
N.Banks		4559	4640		3361	3443
N.Obs		15096	15259		10877	11142
	Panel C. Fixed-rate			***Panel D. Floating-rate***		
NIRP-effect		0.0222	0.0286*		-0.0368**	0.0031
		(0.0155)	(0.0141)		(0.0141)	(0.0107)
Adj. R2		0.0058	0.0017		0.0244	0.0008
N.Banks		3689	3773		6436	6543
N.Obs		13095	13411		23066	23454

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

As a final test, we try to disentangle the effect of NIRP for floating-rate and fixed-rate countries[41]. According to Jobst and Lin (2016), Brunnermeier and Koby (2016) and Albertazzi and Gambacorta (2009), 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 rate loans/assets should be strongly adversely impacted 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 household and non-financial corporations. Again, we split the sample dividing the treatment group into floating and fixed rate countries. For this exercise, we consider a floating rate country as having a share of variable rate loans to total loans greater than 50%, and vice versa for fixed-rate countries[42]. The results are presented in panel C and D of table 6. While

[41] As already mentioned in section 4.2, splitting control and treatment groups in different sub-groups allows us to reduce biases and unobservable variables associated with just one comparison, hence limiting the omitted variables bias.

[42] Germany, Austria, Estonia, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal, Sweden and Slovenia are, according to our computation, floating rate countries. Denmark, France, Hungary, Norway, Netherlands and Slovakia are fixed rate.

it is noticeable that there is a reduction in NIMs in floating rate countries (as expected), the results display also an increase in bank profits for floating rate countries as their margins are less affected by NIRP.

5. Conclusions

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 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 limit a bank's ability to lend. Empirical evidence on the impact of NIRP on bank behavior/performance is scant. In this paper, we 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 compared to those countries in which central banks did not follow this policy. This result holds 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 lending and deposit rates, other UMPs, for sub-sample analysis and to (possible) changes prior to the introduction of NIRP. Finally, our findings support recent discussion and preliminary analysis of the effect of NIRP on bank-specific factors (size, competition and interest rate asset composition) that make banks profitability more vulnerable in a negative interest rate environment.

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Appendix

Table.A1 Time of Adoption of NIRP.

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

Table A2. NIRP, non-interest income, and fees and commissions

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	NII (1)	FEE (2)
NIRP-effect	2.7970***	0.0002***
	(0.2840)	(0.0001)
Adj. R2	0.0276	0.0050
N.banks	7360	6880
N.Obs	25744	24701

Table A3. NIRP, non-interest income, and fees and commissions

All the percentile regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	Bank Size>75th percentile		Bank Size>50th & <75th percentile		Bank Size>25th & <50th percentile		Bank Size>25th percentile	
	NII(1)	FEE(1)	NII(2)	FEE(2)	NII(3)	FEE(3)	NII(4)	FEE(4)
Panel A.								
NIRP-effect	2.507***		3.399***		3.219***		0.744	
	(0.443)		(0.491)		(0.606)		(0.842)	
Panel B								
NIRP-effect		0.0004***		0.0003***		0.0002		-0.00004
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Adj. R2	0.0157	0.0114	0.0345	0.00548	0.0669	0.00511	0.0174	0.0196
N.banks	1950	1765	2079	1970	2165	2076	2091	1945
N.Obs	6499	6197	6476	6234	6493	6309	6276	5961

CHAPTER 3: "You could lead a horse to water but you could not make him drink" *Milton Friedman*

Did Negative Interest Rates Improve Bank Lending?[43]

Abstract

In this paper, we employ a bank-level dataset comprising 6558 banks from 33 OECD member countries over 2012-2016 and a difference-in-differences methodology to analyze whether NIRP resulted in a change in bank lending in NIRP-adopter countries compared to those that did not adopt the policy. Our results suggest that following the introduction of negative interest rates, bank lending was weaker in NIRP-adopter countries than in countries that did not adopt the policy. The result is robust to a wide range of checks.

JEL: E43, E44, E52, G21, F34

Keywords: Negative interest rates, monetary policy transmission, bank lending, difference in differences estimation

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1 Introduction

The global financial crisis 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.[44] 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 NIRPs 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 the deposit funding base. Such behavior has an adverse influence on bank profitability, which can limit credit growth if banks charge higher lending rates or fees to cover losses, or if a diminished

[44] See Bech and Malkhozov (2016) for a discussion of the implementation mechanisms of NIRP in adopting countries. The time of introduction of NIRP is noted in Table A1 in the Appendix.

capital base makes banks more reluctant to lend. Other associated distortions in asset valuations can create asset price bubbles threatening financial stability. 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 (see Section 2). Our paper 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, we employ a bank-level dataset comprising 6558 banks from 33 OECD member countries over the period 2012-2016 and use a difference-in-differences methodology. The methodology provides a sound basis for drawing conclusions as to whether NIRP resulted in a change in bank lending in NIRP-adopter countries 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 frameworks. In contrast to the conclusions of most of the recent research in the area, we 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.

The paper proceeds as follows. Section 2 reviews the related academic literature on NIRP. Section 3 introduces our data and methodology. Section 4 presents our results along with several robustness checks to address threats to validity and a final section concludes.

2. Related literature

Until the global financial crisis, 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. After the crisis, various studies highlight mechanisms through which UMP (policy guidance, LSAPs and NIRP) can have an impact. Curdia and Woodford (2011) provide a model with heterogeneous agents and imperfections in private financial intermediation to demonstrate that UMP will affect the economy provided either an increase in banks' reserves boosts lending to the private sector, or that UMP changes expectations about future interest-rate policy. Brunnermeier and Sannikov (2016) show that UMP can work against adverse feedback loops that precipitate crises by affecting the prices of assets held by constrained agents. Drechsler et al. (2016) point out the role played by LSAPs, equity injections, and asset guarantees in supporting risky asset prices. Del Negro et al. (2017) investigate the effects of interventions in which the government provides liquidity in exchange for illiquid private paper once nominal interest rates reach the zero bound. Similarly, 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 increases the reversal rate and should only be employed after interest rates cuts have been exhausted.[45]

UMP relates to policies that guide longer-term interest rate expectations and expand and change the composition of central bank's 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. Studying the Term Auction Facility, Berger et al. (2017) find an increase in both short- and long-term lending for most loan categories. Focusing on the effect of UMP on bank lending in the U.S, Rodnyansky and Darmouni (2016) confirm that quantitative easing and mortgage backed securities purchases facilitated an increase in mortgage lending. However, Chakraborty et al. (2017) show that increased mortgage lending may crowd-out commercial lending at the same time. Bowman et al. (2015) examine the effectiveness of the Bank of Japan's injections of liquidity into the interbank market in promoting bank lending (using bank-level data from 2000 to 2009). They 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. (2015) report no evidence of a traditional bank lending

[45] Our later empirical analysis test dimensions of the Brunnermeier and Koby (2016) hypothesis.

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.[46]

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's 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. (2017) 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. Ball et al. (2016) survey recent 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. They also conclude that there is no clear relationship between NIRP and bank credit expansion. Arteta et al. (2016) suggest that lending rates generally decline under NIRP, particularly in countries with greater bank competition, but 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). In two recent studies that focus on NIRP in the Euro area Bräuning and Wu (2017) suggest that negative rate policy reduces loan rates and boosts lending to businesses and households. In a similar study using bank level data, Demiralp et al. (2017) also find that banks increase lending as a reaction to NIRP. However, the latter studies may provide misleading inferences as the authors do not compare the differential effects of policy rates on bank lending behaviour in NIRP adopter and non-adopter countries.

Empirical analysis of the impact of NIRP is also linked to the bank lending channel literature. Kashyap and Stein (2000) and Altunbas et al. (2017) provide evidence of the bank lending channel for the transmission of conventional monetary policy. Maddaloni and Peydro (2011) find that low short-term interest rates for an extended period soften lending standards for household and

[46] 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.

corporate loans. Jimenez et al. (2014) show that lower overnight interest rates induce less capitalized banks to lend to riskier firms and Jimenez et al. (2012) illustrate that tighter monetary policy and deteriorating economic conditions substantially reduce lending by distressed banks. Agarwal et al. (2017) estimate banks' marginal propensity to lend out of a decrease in their cost of funds to show that banks were reluctant to lend to riskier borrowers in the aftermath of the global financial crisis. This paper makes a significant contribution to the empirical literature on the impact of UMP on bank lending by focusing specifically on the effectiveness of the most recent UMP innovation: the adoption of negative central bank policy rates.

3. Methodology and data

3.1 Methodology

We examine two periods and two monetary policy regimes; NIRP and traditional monetary policy, using a difference-in-differences methodology. This methodology has been recently used in a variety of banking and financial sector issues (Beck et al (2010); Calderon and Schaeck (2013); Berger et al. (2014); Fiordelisi et al. (2016)) and more specifically to analyse bank lending channel effects (Bonaccorsi di Patti and Sette (2015); Adams-Kane et al. (2017). The advantage of this approach is that it allows to use a panel data set-up to compare a treated group of banks (those impacted by the policy change) with those that are not affected (the control group or untreated banks). The approach also helps to control for the 'omitted variable bias'[47]. Our baseline specification takes the following form:

$$\Delta L_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 (Treated_{ij} * Post_{jt}) + \varphi_t + \gamma_i + \varepsilon_{ijt} \quad (1)$$

where ΔL_{ijt} is the growth rate of lending 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

[47] For example, regulatory changes (such as Basel III) may affect treated and untreated bank lending alike, regardless of the NIRP intervention. But as these changes may affect banks similarly, the difference-in-differences approach avoids this bias by differencing away common trends affecting both groups.

decided to implement NIRP and 0 before that period, and β_3 represents the average difference in the change in bank lending between countries that switched to NIRP and countries that continued with traditional monetary policy. We also include γ_i, and φ_t, to capture, respectively, year and country fixed effects and limit the potential for bias in estimates of β_3[48].

We introduce bank- and country-specific controls in a second specification that takes the form:

$$\Delta L_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 \left(Treated_{ij} * Post_{jt}\right) + \beta_4 X_i + \varphi_t + \varepsilon_{ijt} \quad (2)$$

where X_i is a vector of time variant bank- and county-specific characteristics to capture cross-bank and cross-country heterogeneity over time that can affect bank lending[49]. Bank-specific variables are a combination of balance sheet and performance measures and include total assets, the ratio of equity to total assets, return on average equity, and the liquidity ratio. Country-specific variables are key measures of economic performance and include real GDP growth, consumer price inflation, and the rate of unemployment[50].

The difference-in-differences approach requires several assumptions hold. First, the control group must constitute a valid counterfactual for the treatment. Table 1 provides descriptive statistics and Pearson correlation coefficient for macroeconomic variables in the treatment and control group. The significance of coefficients suggests that the countries in the two groups experienced a similar macroeconomic environment validating the fact that the control group constitutes a valid counterfactual scenario for the treatment.[51]

[48] We include country-specific dummies to control for time-invariant, unobservable country characteristics that can shape bank lending. We 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. We use robust standard errors to control for heteroscedasticity and dependence (see Bertrand et al. (2004); Petersen (2007) and Donald and Lang (2007). We also estimate equation 2 substituting country fixed effects with selected country control variables and bank fixed effects.

[49] According to Roberts and Whited (2012), if assignment to treatment and control groups is not random but dictated by an observable rule, including covariates in the difference-in-differences regression satisfies the conditional mean zero assumption required for unbiased estimates.

[50] Country control variables will substitute country fixed effects and used as a further robustness check to control for the omitted variable bias.

[51] We 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.

(Insert Table 1 here)

The second is the zero correlation assumption often referred as the ‘parallel trend’ assumption[52]. Figure 1 depicts the average growth rate of gross, mortgage, and commercial and industrial loans from 2012 to 2016 for both NIRP adopter and non-adopter countries. The difference in the average growth of the three measures was constant in the pre-treatment period, indicating that the parallel trend assumption holds. Since June 2014, when policy rates in most of the NIRP adopter countries turned negative, increasing gap developed for gross, mortgage, and commercial and industrial loan growth rates in the treated and untreated countries. Overall, Figure 1 suggests that banks in NIRP adopter countries reduced their lending after the treatment period compared with NIRP non-adopter countries.[53]

(Insert Figure 1 here)

3.2 Data

We rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information from two main sources. The macroeconomic series are from Thompson DataStream, and 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 not treated groups, we use bank account data that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but not with an unconsolidated subsidiary. Our sample covers commercial banks, savings banks, cooperative banks and bank holding companies from 33 OECD countries over 2012 - 2016[54], giving us a total of 23,247

[52]According to Bertrand et al. (2004) and Imbens and Wooldridge (2009) the difference-in-differences is valid only under the restrictive assumption that changes in the outcome variable (in our case bank lending) over time would have been exactly the same in both treatment (countries that experienced NIRP) and control groups (no NIRP) in the absence of the intervention (the introduction of NIRP).

[53] Further falsification tests will confirm our decision to choose a difference-in-differences methodology in our analysis.

[54] 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 unobservables and other factors that affect the treatment outcome leading to omitted variable bias threatening the validity of the model.

observations. The treated countries include those of the Euro Area, Hungary, Sweden and Switzerland.[55] 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 2.

Panel A of Table 2 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, we group bank lending behaviour into three types: gross loans, mortgage loans and C&I loans. We use the log growth rate of gross loans; mortgage loans and commercial and industrial (C&I) loans as our measures of interest.

Panel B of Table 2 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). Bank size is defined as the natural logarithm of total assets and is used to control for different characteristics across relatively large and small banks. Bank lending may also be driven by other bank level characteristics including equity strength, profitability and liquidity condition. Accordingly, we control for bank equity, profitability and liquidity ratios in the regression models. 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), we 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.

Furthermore, we include country GDP growth, inflation and the unemployment rate to account for macroeconomic heterogeneity across countries. Earlier literature also highlighted the major transmission channels of other UMP policies including central banks' asset purchase programs (Di

[55] We exclude Japan in our sample as the country only adopted NIRP in early 2016, which provides too short a period to examine the impact of NIRP on bank lending.

Maggio et. al, 2016; Rodnyanski and Darmouni, 2017; Kandrac and Schulsche, 2017; Chakraborty et. al, 2017). In line with Gambacorta et al. (2014), we employ the log growth rate of a country's central bank balance sheet as further controls to isolate the impact of other UMP's on bank lending behavior.

A further issue is that bank lending may be driven by loan demand from households and corporates. To address this concern, we 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.[56] Based on data from these two surveys, we construct loan demand indices for the Euro area and US, focusing on increases or decreases in loan demand. Panel C of Table 2 presents summary statistics of macroeconomic conditions, monetary policy and loan demand indices.

(Insert Table 2 here)

4. Empirical results

4.1 Baseline results

The results from estimating equations (1) and (2) are presented in Tables 3 to 5. All the estimates include fixed country and time effects. Table 3 reports results for estimates where the dependent variable is the (natural logarithm) growth rate of gross loans with control variables added sequentially. Our main interest is the size, sign and statistical significance of the coefficient on β_3, which is the average difference in the change in bank lending between countries that adopted NIRP and countries that did not, and which we denote in the table as the *NIRP-effect*. The baseline result reported in column 1 of Table 3 excludes all control variables. The coefficient on NIRP is sizeable, negative and statistically significant at the 1% level, indicating that countries in which central

[56] 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

banks implemented NIRP experienced a decline in total bank lending of around 7.2% relative to those countries in which central banks did not follow this policy. The remaining columns of the table present the results from adding bank-specific controls sequentially. The baseline regression result holds up well in the face of all controls and the coefficient on *NIRP-effect* remains negative and significant at the 1% level in all estimates[57]. Of the bank-specific control variables, bank funding structure and profitability appear to be the major factors driving lending.

(Insert Table 3 here)

In Tables 4 and 5 we report results from estimates for mortgage loans and C&I loans, respectively. As is the case for gross loans, the coefficients on *NIRP-effect* are all sizeable, stable, negative and statistically significant, including the presence of all control variables. Countries where central banks implemented NIRP experienced a decline in mortgage loans of around 3% relative to countries that pursued other monetary policies; the decline in C&I loans was more marked, however, falling by almost 16%. Once again, funding structure and profitability appear to be the main bank-specific factor driving C&I and mortgage loan growth[58].

(Insert Table 4&5 here)

4.2 Robustness tests

In this section, we report results from a range of robustness checks that offer variations from our choice of controls used in the baseline model. NIRP was brought into the UMP mix by central banks several years after 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 the central bank's balance sheet to increase the level of the monetary base in order to boost nominal spending

[57] Small variation in the treatment coefficient is an essential prerequisite for the difference-in-differences estimation.
[58] We control for the omitted variable bias by replacing country fixed effects with selected macroeconomic variables (GDP growth, consumer price index and unemployment) as well as with bank fixed effects. The results are reported in Tables A2, A3 and A4 in the Appendix. The NIRP-Effect coefficient is negative and statistically significant. However, the coefficient displays larger variation with respect to the addition of country controls. This suggests that country fixed effects are better able to capture unobservable factors than the set of country control variables.

(Bernanke and Reinhart 2004). We proxy for the use of other UMPs by including a variable that takes account of central bank balance sheet size. Results reported in panel A of Table 6 are for each of the three categories of bank lending. The results including the log growth rate of the size of central bank balance sheets are reported in columns 1, 2 and 3 suggest that NIRP and central bank assets purchases had the opposite impact on bank lending. Thus, estimates suggest that central banks that introduced NIRP to boost lending undermined other aspects of UMP that had the same objective.

Our second robustness check aims to control for the effect of credit demand on bank lending behavior. To this end, we 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). We 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 where the coefficient on NIRP remain negative and statistically significant. The results demonstrate that the negative relationship between NIRP and bank lending is not driven by loan demand.

For a third robustness check, we alter our country sample where the treatment group includes only European countries so the control group includes only European non-NIRP adopters. These results are reported in panel C of the table. The coefficients on NIRP in the cases of gross loans and mortgage loans remain negative and statistically significant, though somewhat smaller than in the baseline case, but for C&I lending the coefficient is no longer significant[59].

As a final robustness test, we 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 reason—thereby invalidating our choice of difference-in-differences estimation. We model false NIRP periods for 2012 and 2013. If the estimated

[59] We 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.

coefficients on the ‘false’ NIRP are not statistically significant or negative, we can be more confident that our baseline coefficient is capturing a genuine monetary policy shock. In panel D and E of the table we report the results .The coefficients on the NIRP variable in 2013 are all positive and statistically significant in the cases of total loans and C&I loans, and positive and insignificant in the case of mortgage loans adding further support to the validity of our baseline results. Again, the 2012 falsification test shows positive coefficients (although not significant) indicating an increase in lending in the treatment groups when compared with the control. The results also reaffirm and strengthen the parallel trend assumption further lending support to the conclusion that differential bank lending behavior is driven by NIRP.

(Insert Table 6 here)

4.3 NIRP and the reverse interest rate hypothesis

In this section, we report results from a test of aspects of the Brunnemeier and Koby (2016) ‘reversal rate hypothesis’ within a 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[60]. Specifically, we focus on banks’ capitalization, funding structure, business model, interest rate exposure, and competitive conditions in the banking market. First, we 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 our 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 7. The coefficients on NIRP for gross and business loans are negative and statistically significant in both sets of estimates but suggest a substantially larger decline in lending by under-capitalized banks after the introduction of NIRP. For mortgage loans the coefficient of well-capitalized banks loses significance indicating that above median capitalised banks do not reduce lending after NIRP. Specifically, banks with capital below the median reduced gross loans,

[60] As already mentioned in section 4.2, splitting control and treatment groups in different sub-groups allows us also to reduce bias and unobservable variables associated with just one comparison.

mortgage, and business loans by 7.4%, 3.9% and 9.42% more in comparison to banks with above median capital. This is consistent with the Brunnemeier and Koby (2016) assertion that suggests that in situations of economic uncertainty and changing regulation, binding capital requirements can limit the pass-through of accommodative monetary policies to bank lending[61]. Second, we consider how NIRP interacts with bank funding structure. We distinguish between retail deposit-based and wholesale deposit-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.[62] This is confirmed by the results reported in panels C and D of table 7, where the coefficients on NIRP are highly significant in both sets of estimates but indicate that NIRP resulted in a markedly larger decline in lending by retail deposit-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.

We assess the impact of banks' 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 our purposes, a bank is defined as interest-dependent if the interest earnings share of total earnings is above the median for banks in our 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 the table 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. In the case of gross lending, for example, the effect of NIRP in reducing lending by interest-dependent banks was about twice that compared to fee-based banks.

Our 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, we proxy market

[61] 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.
[62] For this exercise, we consider as retail deposit banks those with retail deposits greater that 50% of total liabilities.

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.[63] We define markets as competitive with a HHI value below 1000 (the median value in our 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 7 support this view: the impact of NIRP on bank lending in competitive markets is negative and statistically significant for each category of lending, suggesting that banks in these markets have little option but to generate alternative income from other sources to maintain profitability. In more concentrated markets in contrast, the impact of NIRP is positive and statistically significant in the case of gross loans suggesting that banks in these markets are better able to maintain profitability and interest margins.

(Insert Table 7 here)

5. Conclusions

Since 2012, several central banks have adopted NIRP aimed at boosting real spending by facilitating an increase in the supply and demand for loans. The policy has 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. However, in this paper, we 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

[63]The US Department of Justice 'generally consider 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. We 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 are highly competitive, although the number of banks is relatively small. For this reason we also cross-checked using Boone and Lerner indicators. Their estimations are available upon request.

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 (possibile) changes in bank behavior prior to the introduction of NIRP. Finally, our results are 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.

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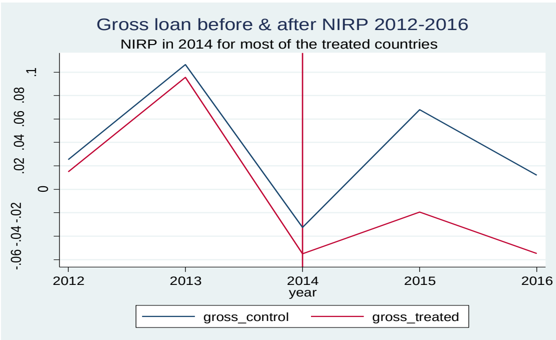
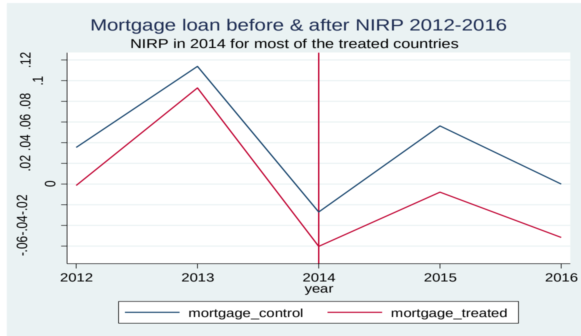
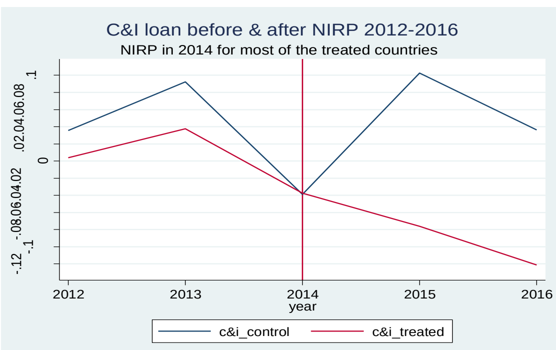
Figure 1. Parallel Trend Assumption



(a) Average logarithm growth of gross loans among treated banks (red) and non-treated banks (blue) before & after NIRP



(b) Average logarithm growth of mortgage loans among treated banks (red) and non-treated banks (blue) before & after NIRP



(c) Average logarithm growth of C&I loans among treated banks (red) and non-treated banks (blue) before & after NIRP

Table 1. Descriptive Statistics Macroeconomics Indicators and Pearson Correlation Test in the Control and Treatment Group during the Period 2007-2016.

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	0.35	0.19	0.47	0.64	0.9021***
Inflation	2.04	1.47	1.53	1.22	0.8659***

Table 2. 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										
GDP growth	10092	0.41%	0.66%	-0.19%	6.62%	56604	0.44%	0.28%	-1.13%	1.89%
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	0.5%	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

Note: 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 asset; 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's 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; 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.

Table 3. Baseline regressions: NIRP and total gross lending

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.

	(1)	(2)	(3)	(4)	(5)	(6)
NIRP-Effect	-0.0719***	-0.0719***	-0.0720***	-0.0810***	-0.0821***	-0.0839***
	(0.0038)	(0.0038)	(0.0038)	(0.0040)	(0.0039)	(0.0040)
Log(TA)		0.0005	-0.0004	-0.0001	-0.0010**	-0.0009*
		(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)
E\TA			-0.0007***	-0.0001	-0.0001	-0.0000
			(0.0001)	(0.0002)	(0.0002)	(0.0002)
Funding_structure				0.0224***	0.0220***	0.0233***
				(0.0051)	(0.0051)	(0.0052)
ROE					0.0031***	0.0032***
					(0.0002)	(0.0002)
Liquidity						0.0102
						(0.0066)
Year-FE	Y	Y	Y	Y	Y	Y
Country-FE	Y	Y	Y	Y	Y	Y
R2	0.24	0.24	0.241	0.2823	0.2863	0.2926
N.Banks	6558	6552	6551	5883	5869	5783
N.Obs	23247	23237	23233	20905	20829	20481

Table 4. Baseline Regression: NIRP and total mortgage loans

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.

	(1)	(2)	(3)	(4)	(5)	(6)
NIRP-Effect	-0.0302***	-0.0302***	-0.0299***	-0.0396***	-0.0389***	-0.0374***
	(0.0086)	(0.0086)	(0.0086)	(0.0089)	(0.0089)	(0.0090)
Log(TA)		0.0007	0.0001	0.0002	-0.0001	0.0001
		(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0008)
E\TA			-0.0014***	-0.0010**	-0.0007	-0.0011**
			(0.0004)	(0.0005)	(0.0004)	(0.0004)
Funding_structure				0.0054	0.0025	0.0010
				(0.0115)	(0.0114)	(0.0116)
ROE					0.0023***	0.0024***
					(0.0004)	(0.0004)
Liquidity						-0.0167
						(0.0118)
Year-FE	Y	Y	Y	Y	Y	Y
Country-FE	Y	Y	Y	Y	Y	Y
R2	0.246	0.247	0.247	0.2566	0.2577	0.2579
N.Banks	2740	2740	2740	2673	2672	2663
N.Obs	9733	9732	9730	9510	9503	9454

Table 5. Baseline Regressions: NIRP and C&I loans

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.

	(1)	(2)	(3)	(4)	(5)	(6)
NIRP-Effect	-0.1550***	-0.1550***	-0.1540***	-0.1590***	-0.1590***	-0.1590***
	(0.0087)	(0.0087)	(0.0087)	(0.0090)	(0.0091)	(0.0091)
Log(TA)		0.0071***	0.0066***	0.0074***	0.0067***	0.0067***
		(0.0012)	(0.0012)	(0.0014)	(0.0014)	(0.0014)
E\TA			-0.0004	0.0004	0.0005	0.0007
			(0.0004)	(0.0006)	(0.0006)	(0.0006)
Funding_structure				0.0483***	0.0459***	0.0473***
				(0.0166)	(0.0165)	(0.0165)
ROE					0.0021***	0.0020***
					(0.0006)	(0.0006)
Liquidity						0.0117
						(0.0180)
Year-FE	Y	Y	Y	Y	Y	Y
Country-FE	Y	Y	Y	Y	Y	Y
R2	0.0624	0.0627	0.0625	0.0638	0.0647	0.0652
N.Banks	3220	3220	3220	3045	3044	3032
N.Obs	11277	11277	11275	10688	10677	10626

Table 6. Robustness checks

	GL_GR	ML_GR	CL_GR
	(1)	(2)	(3)
A. Monetary Policy			
NIRP-effect	-0.0615***	-0.0137	-0.1313***
	(0.0040)	(0.0091)	(0.0095)
CB_GR	0.0947***	0.0584***	0.0286
	(0.0081)	(0.0183)	(0.0204)
Adjusted R^2	0.2546	0.258	0.0662
No. of banks	6530	2723	3201
N. Obs	22505	9539	10659
B. Credit demand			
NIRP-effect	-0.1491***	-0.9170***	-0.2273***
	(0.0044)	(0.0151)	(0.0108)
Loan_Demand	0.0086***	0.0023	-0.0045
	(0.0013)	(0.0039)	(0.0032)
Adjusted R^2	0.4025	0.2585	0.0804
No. of banks	3719	1947	2349
N. Obs	11119	6840	8331
C. NIRP and the EU			
NIRP-effect	-0.0267***	-0.0530***	0.0268
	(0.0066)	(0.0128)	(0.0164)
Adjusted R^2	0.2911	0.34	0.07
No. of banks	5008	2282	2122
N. Obs	17978	8264	7558
D. I° Falsification tests – 'fake' NIRP			
NIRP-effect 2013	0.0176***	0.0119	0.0923***
	(0.0064)	(0.0138)	(0.0142)
Adjusted R^2	0.1905	0.0219	0.0325
No. of banks	6317	2651	3240
N. Obs	23199	9673	11346
E. II° Falsification tests – 'fake' NIRP			
NIRP-effect 2012	0.0075	0.01600	0.0007
	(0.0053)	(0.0110	(0.0129)
Adjusted R^2	0.2649	0.3628	0.0177
No. of banks	5991	2493	2980
N. Obs	11230	4701	5528

All regressions include fixed country and time effects. Robust standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 7. NIRP and bank lending, bank capitalization, funding structure and business model

	GL_GR	ML_GR	CL_GR
A. Undercapitalized			
NIRP-effect	-0.1178***	-0.0542***	-0.1852***
	(0.0055)	(0.0124)	(0.0121)
Adjusted R^2	0.3729	0.2763	0.0912
No. of banks	2909	1355	1742
No. of observations	8050	3788	4869
B. Well-capitalized			
NIRP-effect	-0.0430***	-0.0152	-0.0910***
	(0.0076)	(0.0191)	(0.0168)
Adjusted R^2	0.2657	0.2231	0.0427
No. of banks	2870	1329	1571
No. of observations	7661	3638	4279
C. Wholesale deposit-based			
NIRP-effect	-0.0702***	-0.0196	-0.1314***
	(0.0145)	(0.0152)	(0.0335)
Adjusted R^2	0.0831	0.2200	0.0367
No. of banks	1095	534	275
No. of observations	3239	1482	756
D. Retail deposit-based			
NIRP-effect	-0.0853***	-0.0455***	-0.1700***
	(0.0044)	(0.0103)	(0.0100)
Adjusted R^2	0.3848	0.2762	0.0673
No. of banks	4389	2367	2600
No. of observations	14704	8245	8967
E. Fee-based			
NIRP-effect	-0.0381***	-0.0082	-0.1577***
	(0.0117)	(0.0337)	(0.0364)
Adjusted R^2	0.04	0.06	0.03
No. of banks	2063	327	582
No. of observations	4590	626	1178
F. Interest earnings-based			
NIRP-effect	-0.0833***	-0.0466***	-0.1819***
	(0.0037)	(0.0072)	(0.0178)
Adjusted R^2	0.40	0.32	0.0618
No. of banks	5766	2624	2094
No. of observations	18657	9107	6205
G. Competitive markets			
NIRP-effect	-0.0998***	-0.0495***	-0.1880***
	(0.0042)	(0.0103)	(0.0092)
Adjusted R^2	0.2827	0.2516	0.0716
No. of banks	5191	2302	2716
No. of observations	17644	7837	9777
H. Concentrated markets			
NIRP-effect	0.02777***	0.0030	0.0239
	(0.0079)	(0.0154)	(0.0234)
Adjusted R^2	0.1877	0.2763	0.0800
No. of banks	1728	673	515
No. of observations	5603	1896	1500

All regressions include fixed bank and time effects. Robust standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

APPENDIX

Table A1. Time of Adoption of NIRP.

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

Table A2: Baseline regressions: NIRP and total gross lending

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%,

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NIRP-effect	-0.0738***	-0.0677***	-0.0675***	-0.0728***	-0.0664***	-0.0695***	-0.0692***	-0.0726***
	(0.0034)	(0.0034)	(0.0034)	(0.0033)	(0.0034)	(0.0035)	(0.0064)	(0.0068)
Log(TA)		0.0571***	0.0624***	-0.0000	0.0632***	0.06683***		0.0076
		(0.0082)	(0.0085)	(0.0004)	(0.0089)	(0.0093)		(0.0146)
E/TA			0.0014	-0.0000	0.0010	0.0015*		0.0024*
			(0.0009)	(0.0001)	(0.0009)	(0.0009)		(0.0013)
Funding_Structure				-0.0007***	0.0000	0.0001		0.0001
				(0.0001)	(0.0003)	(0.0003)		(0.0005)
ROE					0.0016***	0.0016***		0.0012***
					(0.0004)	(0.0004)		(0.0006)
Liquidity						0.0004		0.0011***
						(0.0003)		(0.0004)
GDP_GR							-0.0269***	-0.0378***
							(0.0104)	(0.1072)
Inflation							-0.0007	-0.0023
							(00021.)	(0.0021)
Unemployment							-0.0206***	-0.0229***
							(0.0037)	(0.0038)
Adjusted R^2	0.267	0.270	0.271	0.201	0.282	0.294	0.273	0.302
No. of banks	6558	6552	6551	6426	6423	6260	6130	5582
No. of observations	23247	23237	23233	22577	22556	21881	17749	16666

respectively.

Table A3. Baseline Regression: NIRP and total mortgage loans

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NIRP-effect	-0.0376***	-0.0264***	-0.0262***	-0.0335***	-0.0270***	-0.0256***	-0.0182*	-0.0186*
	(0.0068)	(0.0067)	(0.0067)	(0.064)	(0.0067)	(0.0069)	(0.010)	(0.0112)
Log(TA)		0.0955***	0.0911***	-0.0002	0.0911***	0.1063***		-0.0078
		(0.0150)	(0.0153)	(0.0007)	(0.0158)	(0.0166)		(0.0283)
E/TA			-0.0020	-0.0015***	-0.0024	-0.0014		-0.0018
			(0.0019)	(0.0003)	(0.0019)	(0.0019)		(0.0033)
Funding_Structure				-0.0007***	0.0008	0.0008		0.0008
				(0.0002)	(0.0007)	(0.0007)		(0.0010)
ROE					0.0014	0.0013		0.0001
					(0.0009)	(0.0009)		(0.0013)
Liquidity						0.0003		0.0006
						(0.0005)		(0.0007)
GDP_GR							0.0904***	0.0936)***
							(0.0208)	(0.0215)
Inflation							0.0023	0.0034
							(0.0047)	(0.0048)
Unemployment							-0.0260***	-0.0281***
							(0.0073)	(0.0075)
Adjusted R^2	0.285	0.290	0.290	0.186	0.292	0.290	0.290	0.295
No. of banks	2740	2740	2740	2703	2703	2689	2556	2506
No. of observa6ions	9732	9732	9730	9535	9533	9468	7364	7160

Table A4. Baseline Regressions: NIRP and C&I loans

All regressions include fixed bank and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NIRP-effect	-0.1535***	-0.1343***	-0.1349***	-0.1494***	-0.1317***	-0.1324***	-0.1474***	-0.1400***
	(0.0084)	(0.0092)	(0.0093)	(0.0083)	(0.0095)	(0.0096)	(0.0185)	(0.0198)
Log(TA)		0.1362***	0.1534***	0.0047***	0.1560***	0.1626***		0.0561
		(0.0273)	(0.0272)	(0.0012)	(0.0276)	(0.0273)		(0.0447)
E/TA			0.0060***	0.0009*	0.0058**	0.0050*		0.0047
			(0.0026)	(0.0005)	(0.0027)	(0.0028)		(0.0041)
Funding_Structure				-0.0007	-0.0012	-0.0009		-0.0007
				(0.0004)	(0.0014)	(0.0014)		(0.0018)
ROE					0.0024*	0.0029**		0.0031
					(0.0014)	(0.0014)		(0.0019)
Liquidity						0.0018**		0.0025**
						(0.0009)		(0.0013)
GDP_GR							0.0816***	0.1042***
							(0.0363)	(0.0376)
Inflation							0.0084	0.0149
							(0.0128)	(0.0137)
Unemployment							-0.0259***	-0.0246***
							(0.0098)	(0.0103)
Adjusted R^2	0.072	0.076	0.0764	0.215	0.078	0.079	0.067	0.070
No. of banks	3220	3220	3220	3170	3169	3142	2999	2924
No. of observations	11277	11277	11275	11006	10999	10886	8547	8245

CHAPTER 4

Understanding Banks' Sovereign Exposures: Do Balance Sheet Conditions Matter?

Abstract

This paper investigates the influence of bank balance sheet conditions on the size and riskiness of sovereign bond holding. Using a newly combined dataset of European banks, we find that banks that are small, less capitalised, more profitable, more liquid, with high non-performing loans and limited lending hold more and riskier sovereign securities. While European and domestic sovereign exposure show similar results, different bank balance sheet features drive the exposure towards (higher risk) GIIPS and (lower risk) CORE countries.

JEL: E43, E44, E52, G21, F34

Keywords: Sovereign exposure, balance sheet characteristics, bond portfolio size, bond portfolio risk

1. Introduction

Historically, it has long been recognised that the well-being of banks and governments are mutually dependent (Ferguson, 2008; Calomiris and Haber, 2014). Yet, despite this view developed countries did not experience any major adverse shifts in sovereign credit risk until the events of the Global Financial Crisis (GFC) (Acharya et al. 2014). Since the GFC and the following Sovereign Debt Crisis (SDC) banks' exposure toward sovereign debt has been at the centre of a vigorous academic and policy debate. Despite an initial phase of fire sales of risky assets and 'flight to safety' effect, exposure to sovereign debt grew considerably (figure 1) raising concerns about the potential negative effects on banks' balance sheets. This has promoted a substantial investigation into the motives of banks' bonds holding behaviour and their implications for financial stability. According to BIS (2011) and Davis and Ng (2011), sovereign credit risk can hurt banks' balance sheet in several ways. First, losses on holdings of government securities can weaken banks' balance sheets, raising riskiness and funding costs. This in-turn can impair lending and consequently economic growth (Gennaioli et al. 2016). Second, high sovereign risk reduces the collateral value that banks can use to raise wholesale funding on the interbank market[64]. Third, sovereign downgrades are generally accompanied by lower rating for domestic banks. This leads to both an increase in funding costs and limited market access to liquidity. Finally, sovereign risk reduces the funding benefits that banks derive from implicit and explicit government guarantees. These factors may provoke spill over (or 'contagion') effects to banks in other countries either directly (through direct exposure to distressed foreign sovereigns) or indirectly (through cross border interbank exposure) threatening bank systemic risk. Hence, understanding the determinants of the size and riskiness of bank's bond holding portfolios is a crucial factor for financial stability.

On one hand, a large literature (Diamond and Rajan, 2011; Garcia and Gimeno, 2014; Ongena et al. 2015; Acharya and Steffen, 2015; Altavilla et al. 2016; Gennaioli et al. 2016; Brunnermeier et al. 2016) has adopted a macroeconomic approach to investigate the determinants of the size and risk of sovereign debt exposure and the different behaviour among banks operating in distressed and non-distressed countries during the crisis[65]. On the other hand, the microeconomic approach (Affinito et al. 2016; Buch et al. 2016) suggests that banks

[64] This problem has been minimized by central bank liquidity interventions.
[65] The macroeconomic approach will be analysed in detail in the next section.

purchase sovereign debts based on their own economic convenience (*economic convenience hypothesis*) and balance sheet conditions that can be explained by different factors. First, prudential regulation favours sovereign debt over loans as it assigns neither capital charges (zero-risk-weights) nor portfolio concentration limits. As suggested by Popov and Van Horen (2015), the preferred regulatory treatment can largely explain the size and direction of sovereign bonds holding. In this regard, banks with low capital ratios may increase return on equity by shifting from low to high yielding sovereigns without altering regulatory capital requirements (see Acharya and Steffen, 2015). Second, banks demand and use government bonds as a store of liquidity and for precautionary reasons (Bolton and Jeanne, 2011; Gennaioli et al. 2014)[66]. Third, in a period with slow economic recovery, historically high levels of non-performing loans, increasing loan loss provisions and low interest rates, sovereign debt can act as a substitute for credit affecting banks' lending decision (Altavilla et al. 2016). The same reasons can negatively affect bank profitability suggesting that banks may have an incentive to purchase high yield sovereign debt securities to improve profitability conditions (*carry trade hypothesis*)[67]. Finally, banks with different size and business models can have a different appetite for holding sovereign bonds rather than other financial assets (Buch et al. 2016).

In this study, we follow the microeconomic approach as it allows us to explore the aforementioned factors that can explain banks' economic convenience to hold sovereign debt securities. In particular, we focus on bank balance sheet characteristics that can shape the size and riskiness of sovereign bond holdings. By employing a newly combined dataset of European banks across the period 2010-2015, we find that banks that are small, less capitalised, more profitable, more liquid, with high non-performing loans and limited lending hold more and riskier sovereign securities. Finally, while European and domestic sovereign exposure show similar results, different bank balance sheet features drive the exposure towards (higher risk) GIIPS and (lower risk) CORE countries[68].

[66] In this contest, the new Basel III's liquidity measures can be another factor influencing sovereign bond demand (see Bonner, 2015).

[67] Several recent studies (Borio et al. 2015; Claessens et al. 2017; Molyneux et al. 2018) show that protracted periods of low and negative rates can hurt bank profitability through the compression of banks' net interest margin. While low rates can negatively influence banks' net interest income, they can boost bank profits through valuation gains of fixed income securities and via fees and commissions. Hence, banks can reshuffle their bond portfolios by expanding the amount of available for sale and for trading securities.

[68] Following Altavilla et al. 2016, we define CORE countries (Austria, Belgium, Finland, France, Germany, the Netherlands, Estonia, Latvia, Luxembourg and Malta) as those that were stable during the SDC and GIIPS (Greece, Ireland, Italy, Portugal, Spain as well as Cyprus and Slovenia) as vulnerable countries.

The paper proceeds as follow. Section 2 reviews the academic literature on sovereign bonds exposure. Section 3 introduces our data and methodology. Section 4 presents our results along with several robustness checks and the final section concludes.

2. Literature Review

Our study is based on the literature that analyses, from a micro-perspective, the effect of bank balance sheet conditions (or economic convenience) on the size and riskiness of sovereign bond exposures. While there is an extensive macro-perspective literature that studies the determinants of sovereign bonds holding during different phases of the crisis, the micro-perspective literature is still limited. The macro-perspective view is mostly based on the following hypotheses: flight to quality, moral suasion, home bias, regulatory arbitrage and risk shifting.

Garcia and Gimeno (2014) show a ‘flight to quality’ effect during the sovereign debt crisis. Using the liquidity premia in the three major euro area sovereign bond markets (Germany, France and Spain) over the period 2008-2013,the authors divided the ‘flight to quality’ into a ‘flight to safety’ and a ‘flight to liquidity’ effect suggesting that banks recompose their bond portfolios according to the latter rather than the former. The result is confirmed by Beber et al (2009) who find that even before the financial and debt crisis in times of market distress, investors demand sovereign bonds for their liquidity rather than credit quality. Liquidity reasons is also the core explanation of the theoretical model developed by Gennaioli et al. (2014). The authors suggest that domestic banks decide to hold large amount of sovereign debt as store of liquidity.

Ongena et al. (2016) argue that during the crisis banks headquartered in distressed countries increase the purchase of domestic sovereign bonds because of the pressure they received from their governments. This effect, called “moral suasion”[69], determined the large sovereign debt growth in banks’ portfolio over 2010-2012. Moral suasion has been evidence also by Becker and Ivashina (2017). Using a sample of European banks over the period 2010-2015, they find that politically connected and state-owned banks extended less loans to large firms during the crisis. This reflects a form of financial repression and misallocation of private capital

[69] The authors define moral suasion as: “an appeal to “morality” or “patriotic duty” to induce behaviour by the persuaded entity that is not necessary profit maximizing for it”.

information. Using data of the largest European banking groups over the period 2010-2013, Horvath et al. (2015) show a possible home bias problem in European banks' sovereign debt portfolios. When the sovereign is risky, shareholder rights strong and the bank is state-owned, domestic exposure is higher suggesting that home bias is driven by moral suasion. In a similar fashion, De Marco and Macchiavelli (2016) find that government owned banks and banks with politicians on the board of directors display higher home bias than privately owned banks over the period 2010-2013. This finding is again in-line with the moral suasion hypothesis.

Extensive is also the literature (both theoretical and empirical) that studies the nexus between sovereign debt exposures and bank risk-shifting behaviour during the crisis. Acharya et al. (2014), Uhlig (2013), Farhi and Tirole (2014) and Broner et al. (2014) present models where domestic banks risk-shift their exposure toward risky domestic sovereign debt in an attempt to be bailed out in case of default. Acharya and Steffen (2015) indicate that GIIPS and in particular non-GIIPS banks engaged in carry trade during the GFC and the SDC, promoted by favourable regulatory arbitrage and the ECB's long-term refinancing operations (LTRO) . Banks that are undercapitalised, with high risk-weighted adjusted assets and a short-term funding structure risk-shifted their exposure toward risky sovereign bonds[70]. Similarly, Drechsel et al. (2015), using bank-level data over the period 2007-2011, show that banks located in both stressed and non-stressed countries engage in risk shifting. Again, this effect is stronger for weakly capitalised banks. Battistini et al (2014), exploring CDS spreads and yield differentials in 15 European countries over the period 2007-2013, point out that peripheral banks increased sovereign securities holding in response to raising domestic bond yields suggesting possible risk-shifting behaviour.

A recent literature focuses on the degree of substitutability between sovereigns and lending. In this regard, Altavilla et al. (2016), using Italian bank-level data over the period 2007-2015, suggest that balance sheet characteristics such as the amount of loans or bank capital position affect sovereign bonds purchase. Specifically, weakly capitalised banks and banks operating in distressed countries during the crisis curtail lending more than less exposed banks. Popov and Van Horen (2015) also show that preferred regulatory treatment led to both an excessive increase in sovereign holdings and contraction in lending (syndicated lending), with the latter being stronger for GIIPS banks. Finally, Gennaioli et al. (2014), analysing 20,000 banks in 191

[70] They find that also moral suasion and home bias determine carry trade behaviour.

countries and 20 sovereign defaults over the period 1998-2012, find that bond holdings correlate negatively with lending during sovereign defaults[71].

The microeconomic approach (or economic convenience hypothesis) has received much less attention. Two studies appear to have addressed this issue so far. Affinito et al. (2016) argue that balance sheet conditions do matter for sovereign bonds purchase. Studying the determinants of bond purchases in the Italian banking sector over the period 2007-2013, they suggest that liquidity, convenience in term of capital charges (preferred regulatory treatment) and high yields make sovereigns well suited to satisfy banks' need during period of low profitability and credit quality. Using German bank-level data over 2005-2012, Buch et al. (2016) find that large, less well-capitalised and more capital markets based banks hold more sovereigns.

Our contribution to the literature is important in four respects. First, as outlined previously, the micro-perspective literature that analyses the role of banks' balance sheet conditions on the size and riskiness of sovereign bonds holding is still limited and deserve further examination as sovereign credit risk can hurt banks' balance sheet in different ways (BIS, 2011; Davis and Ng, 2011). Second, both Affinito et al. (2016) and Buch et al. (2016) use bank-level data but they limit the analysis to one country (Italy and Germany, respectively). By employing detailed data taken from the European Banking Authority (EBA), we are able to capture cross-country heterogeneity and to extend the analysis on the determinants of sovereign bond holdings incorporating different banks in different European countries[72]. Third, while the majority of the aforementioned literature is mostly focused around the crisis period, we prolong the sample period to 2015 in order to provide a clear picture of the bank balance sheet conditions that can shape riskiness and size of sovereigns holding. Finally, contrary to the literature that uses mostly CDS spread to calculate the riskiness of sovereign bonds holding (Buch et al. 2016; Andreeva and Vlassopoulos, 2016; Acharya et al. 2014; Alter and Shuler, 2012; Alter and Beyer, 2014) we build a new risk-weighted measure of bond portfolios.

[71] The hypotheses are summarize and graphically displayed in figure A1 and A2 in the Appendix. As shown, GIIPS banks engage in 'flight to quality' behaviour at the beginning of the crisis (figure A1). However, since 2011 they received both pressure from governments ("moral suasion") and incentives to risk-shift. This led to a substantial increase in sovereigns purchase. After 2013 GIIPS banks behaviour is less clear. CORE banks' 'flight to quality' is longer (figure A2) suggesting that maybe sovereign debt holding in GIIPS countries is mostly driven by moral suasion and not risk shifting. After 2013, when economic situation improved, CORE banks searched for yield increasing the exposure towards GIIPS government debt.

[72] Although the sample is smaller.

Our paper adds to the existing literature by focusing on bank balance sheet characteristics that can shape size and riskiness of sovereign bonds holding using a newly combined dataset of European banks across the period 2010-2015. Our main finding is that banks that are small, less capitalised, more profitable, more liquid, with high non-performing loans and limited lending hold more and riskier sovereign securities. While European and domestic sovereign exposure show similar results, different bank balance sheet features drive the exposure towards GIIPS and CORE countries.

3. Methodology & Data

3.1 Methodology

To capture the effect of bank balance sheet characteristics on the size and riskiness of sovereign bonds holding we use the following econometric specifications:

$$SOVEXP_{ijt} = \alpha + \beta_1 SIZE_{ijt} + \beta_2 LENDING_{ijt} + \beta_3 LIQUIDITY_{ijt} + \beta_4 BUSINESS\ MODEL_{ijt} + \beta_5 CAPITAL_{ijt} + \beta_6 CREDIT\ RISK_{ijt} + \beta_7 PROFITABILITY_{ijt} + \beta_8 DummyDEBTCRISIS_t + \theta_i + \mu_j + \varepsilon_{ijt} \quad (1)$$

$$SOVRISK_{ijt} = \alpha + \beta_1 SIZE_{ijt} + \beta_2 LENDING_{ijt} + \beta_3 LIQUIDITY_{ijt} + \beta_4 BUSINESS\ MODEL_{ijt} + \beta_5 CAPITAL_{ijt} + \beta_6 CREDIT\ RISK_{ijt} + \beta_7 PROFITABILITY_{ijt} + \beta_8 DummyDEBTCRISIS_t + \theta_i + \mu_j + \varepsilon_{ijt} \quad (2)$$

.Specifically, $SOVEXP_{ijt}$ captures the size of sovereign exposure of bank *i* in country *j* at time *t*. It is calculated by dividing bank sovereign exposure by its assets. $SOVEXP_{ijt}$is split in different subcomponents: $SOVEXPEUR_{ijt}$, $SOVEXPDOM_{ijt}$, $SOVEXPGIIPS_{ijt}$ and $SOVEXPCORE_{ijt}$ that refer to European, domestic, GIIPS and CORE country exposures, respectively. $SOVRISK_{ijt}$ is a measure that indicates the riskiness of bank *i* in country *j* at time *t* bonds holding portfolio[73].The higher the value of $SOVRISK_{ijt}$ the higher the risk of bonds portfolio. On the left hand side of the equation, we fit different balance sheet variables we reckon have an impact on the size and riskiness of sovereign exposure. $SIZE_{ijt}$ is the bank total assets to GDP ratio (Barth et al. 2012). According to Demsetz and Strahan (1997), Saunders et al (1990), large banks are better able to diversify risks as they hold diversified portfolios. Hence, we expect size to be negatively related with both the size and riskiness of sovereigns held in the balance sheet. $LENDING_{ijt}$is the ratio of gross loans on total assets that we use to capture banks' lending operations (Altavilla et al. 2016). During periods of economic distress, government bonds can act as substitutes for lending, so we expect a negative relationship between this variable and both the size and riskiness of sovereign bond portfolios. According to Gennaioli et al. (2014), sovereign debt has an important impact on bank liquidity positions. So, we include $LIQUIDITY_{ijt}$, measured by the ratio of total loans to total deposits, to depict the 'precautionary motive' to hold government securities. Specifically, the loans to deposit ratio is a measure of maturity mismatch risk as it measures the coverage of long-term illiquid loans with stable short-term liquid funding. When maturity mismatch risk increases, banks can decide to reduce this by buying government bonds as they are easy to liquidate. We expect liquid banks to hold more sovereigns than illiquid banks. However, a positive relationship between bank liquidity and the riskiness of a sovereign bond portfolio is possible. Liquid banks can decide to employ their excessive liquidity to buy high-risk-high-yield government bonds as they have a 'liquidity buffer' to do so[74]. We introduce $BUSINESS\ MODEL_{ijt}$, computed as the interest income to operating income ratio, to capture heterogeneity in the income component among banks. Banks with different business models may have a different appetite for government debt (Buch et al. 2016). In-line with Acharya and Steffen (2015), we use the Common Equity Tier 1 capital ratio ($CAPITAL_{ijt}$) to see whether the preferred regulatory environment, that assigns zero-risk-weights to sovereigns in the Euro area, influences bonds

[73] Computation of this variable is provided in appendix A1. $SOVRISK_{ijt}$ provides a risk-weighted measure of a bank bond portfolio. Banks with high exposure towards countries with high spread between the ten-year government bond and the German Bund (benchmark) have higher bond portfolio riskiness in comparison with those banks that hold bonds primarily in a country where the spread is thin. However, this does not mean that banks located in GIIPS countries have per se riskier bond portfolios. Capturing exposure towards each country in the sample, this measure takes each single exposure (weighted on bank total assets) toward a specific country and links it with the risk (the spread) of the same country. The sum of the single country exposure risk gives the overall bond portfolio riskiness. Hence, if a Portuguese bank is 50% exposed to Portuguese government bonds and 50% exposed to German bonds it has medium risk exposure, while a Danish bank holding 25% Danish, 25% Greek and 50% Spanish government bonds has a higher risk exposure.

[74] As during crisis periods government bonds can be subject to a 'drying up' of liquidity. Arguably, this effect is stronger for high credit risk government bonds. Hence, banks with excessive liquidity can bear the risk of holding risky sovereigns.

purchases. If this is the case, we expect weakly capitalised banks to hold more and riskier sovereign debt securities as they can use government bonds to replace loans in order to decrease risk-weighted-adjusted assets and boost the level of capital. $CREDIT\ RISK_{ijt}$indicates the non-performing loans to gross loans ratio (Affinito et al.2016). High non-performing loans worsen capital requirements and profitability. This in-turn can limit bank's incentive to lend. For this reason, we expect a positive sign (for both risk and size) as banks can buy government debt securities to maintain profitability and capital ratios when credit quality is deteriorated. We use return on assets (Gennaioli et al. 2016; Affinito et al. 2016), calculated dividing bank's net income by its assets, to capture overall bank profitability ($PROFITABILITY_{ijt}$)[75]. We expect a negative sign from this, both in term of size and riskiness, as less profitable banks may have an incentive to purchase high yielding government debt securities to increase earnings. We include $DummyDEBTCRISIS_t$, that takes the value 1 during the SDC (2010-2012), 0 otherwise, to control for any difference between the period during the SDC and after the crisis. We also use both time-invariant (θ_i) and year fixed effects (μ_j) to account for potential bank, country unobservable characteristics and macroeconomic factors and trends that can affect size and riskiness of bonds holding[76].

3.2 Data

We build our dataset from various sources. Like Acharya and Steffen (2015), Horvath et al. (2015) Ongena et al. (2016), we also use both EU-wide stress test and EU-transparency exercise data provided by the European Banking Authority (EBA). Since 2010, the EBA has been responsible for stress tests and capitalisation exercises in the European banking sector. The EBA sample covers more than 60% of total assets in the EU (Acharya and Steffen, 2015).

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[75] We prefer return on assets rather than return on equity (RoE) as RoE is more volatile and easy to manipulate by managers via share buy-backs, provisioning and other earnings management techniques. However, RoE will be use as an additional test.

[76] Although several recent and important studies use banks' balance sheet variables on the left and right side of the econometric equation (Jimenez et al. 2014) and others use a similar set-up to explain sovereign bonds holding (Buch et al. 2016; Affinito et al. 2016; Hildebrand et al. 2012; Gennaioli et al. 2016) endogeneity is a concern. To get rid of the omitted variable bias we include bank and year fixed effects, which allows us to avoid the presence of unobservables correlated with the regressors. Following Affinito et al. 2016, we use the Hausman-Durbin-Wu to test for endogeneity of all the regressors in the equation. Since, the dependent variable ($SOVEXP_{ijt}$) is divided by total assets as well as some of the independent variables ($LENDING_{ijt}$; $PROFITABILITY_{ijt}$), we re-estimate the latter using interest earning assets. Finally, we use robust standard errors clustered at the bank level to control for heteroscedasticity and dependence (see Petersen, 2009; Donald and Lang, 2007).

Bank-level accounting data are taken from Bankscope (Orbis Bank Focus) (Gennaioli et al. 2016) as well as from SNL Financial (Horvath et al. 2015)[77]. Our sample covers 51 banks from 19 European countries (14 Eurozone and 4 non-Eurozone) over the period 2010-2015[78].

Panel A and B of table 1 present summary statistics of the aforementioned balance sheet variables. Table 2 provides the correlation matrix among the variables used in our study. As shown, the determinants are not strongly correlated among each other's[79].

4. Results

The results from estimating equation 1 and 2 are presented in table 3. All the estimates include bank and year fixed effects. Column 1-4 report the estimates when we regress the size of sovereign bond holding on the determinants, split into European (column 1), domestic (column 2), GIIPS (column 3) and CORE (column 4) holdings. Column 5 presents the results of the risk measure of bonds holding. As expected, the coefficient of *SIZE* is negatively related (statistically significant at conventional level) with both size and riskiness of bank sovereign exposure indicating that large banks tend to hold fewer and less risky government bonds (although for GIIPS and CORE countries the coefficients are not significant). This reflects a better diversified portfolio of large banks in comparison with small banks. Specifically, a one standard deviation change in bank size leads to a 3.7% change in European sovereign exposure, 2.7% change in domestic exposure and 4.4% of bonds portfolio riskiness. Sovereign bonds appear also to be, during the sample period, a substitute for lending as suggested by the negative coefficient of *LENDING*. Banks that lend more display a smaller and less risky government bond portfolio. Although the effect is not significant for the exposure towards GIIPS and CORE countries, the economic significance of the coefficients is quite large. One standard deviation change in lending leads to a change of 3.7% in the European exposure, 3.9% in the domestic exposure and 10.6% in sovereign risk. This is actually not surprising. In a period with slow economic recovery, high firm mortality rates as well as low interest rates banks might prefer

[77] The decision to combine both databases is twofold. First, since the EBA sample of banks is small, we try to reduce as much as possible the number of missing values. Second, we double check for possible reporting mistakes in the databases.
[78] Contrary to the majority of the studies that focus around the crisis period, have an unbalanced panel dataset, we intentionally select banks that have been subject to EBA monitoring for each year (from 2010 to 2015). This decision allows us to have a balanced panel and consequently a better understanding of banks' bond holding behaviour across all the sample period for the same banks.
[79] We also checked for multicollinearity among the variable using the *Variance Inflation Factor (VIF*).

to invest in safe assets such as government bonds rather than lending. Moreover, motivated by the preferred regulatory environment, they try to maintain profitability by investing in high yield bonds. As expected, the deposits to loans ratio (*LIQUIDITY*) is positively related to European and domestic sovereign exposure as well as to risk (the results does not hold well regarding GIIPS and CORE exposure). Liquid banks can have a 'liquidity buffer' that allows them to invest in high-yield-high-risk sovereigns. Economically, a one standard deviation change in the liquidity position of the bank leads to 1.4%, 2.2% and 5.3% change in European bond holdings, domestic holdings and risk exposure, respectively. Banks with a 'non-interest income oriented' business model display larger European, domestic and CORE exposures as shown by the positive sign of the coefficient (*BUSINESS MODEL*). However, the sign changes direction with reference to the riskiness of bond portfolios. Banks may decide to increase higher yield bond holdings if interest margins are under pressure[80]. The level of capital (*CAPITAL*) is negative related with European, domestic and CORE sovereign exposure. This result is in-line with the majority of the literature (Altavilla et al. 2016; Acharya and Steffen, 2015) suggesting that banks with low levels of capital have an incentive to buy government bonds due to the favourable regulatory treatment. However, it is surprising to notice that less capitalised banks have an appetite for domestic and CORE sovereign debt but not for GIIPS as well as for riskier sovereigns (both statistically insignificant). Arguably, the SDC led to a different perception and definition of safe assets. Hence, banks perceive GIIPS sovereign debt as not as safe even under preferred regulatory treatment. The results on profitability show completely opposite results (*PROFITABILITY*). Profitable banks prefer GIIPS sovereign bonds as they carry high returns (search for yield) rather than CORE bonds. The effect on the overall European sovereign exposure appears to be driven by the former rather than the latter or/and domestic exposures. Non-performing loans (*CREDIT QUALITY*) enter in the regression with a positive sign and are mostly statistically significant. Again, the results seem to be stronger for GIIPS sovereign exposure (CORE coefficient is statistically insignificant). A twofold interpretation here is possible. First, banks with high non-performing loans are mostly located in GIIPS countries. Banks hold mostly domestic debt. This explains the positive relation both in term of size and risk. Second, banks with high non-performing loans ration lending and face profitability problems. Thus, the favourable regulatory treatment of sovereign bonds allows

[80] Several recent studies (Borio et al.2015, Altavilla et al.2017, Claessens et al.2017, Molyneux et al. 2018 underline the impact of low interest rates on the contraction of bank net interest margin and profitability. Hence, banks facing a contraction (mostly retail banks) can engage in 'carry trade' by exchanging low yield bonds to high yields that are riskier.

banks to increase the amount of GIIPS and risky sovereign debt in an attempt to regain profitability without any capital requirement. Finally, as expected, the dummy variable shows a negative coefficient suggesting the ‘flight to quality’ effect (mostly toward U.S Treasury bonds and German Bunds) that happened during the Greek meltdown.

5. Conclusion

Both the Great Recession and the European Sovereign Debt Crisis led to radical changes. Low and negative interest rate environment, high level of non-performing loans as well as weak economic prospects changed banks’ appetite toward sovereign bonds increasing their substitutability with lending. Balance sheet conditions appear to have a strong effect across the sample period with size, capitalisation, profitability, liquidity, credit quality and lending having a strong influence on both size and risk of bond portfolios. As the capitalisation result suggests, the favourable regulatory treatment applied to sovereigns (in Europe) has strongly contributed to this change as weakly capitalised banks might benefit from the regulation and increasing return on equity by shifting from low to high yielding sovereigns without altering regulatory capital requirements. However, as shown by our measure of risk, the SDC led to a different perception and definition of safe assets with weakly capitalised banks increasing just the amount of sovereign securities from stable (CORE) rather than peripheral countries (GIIPS).

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Figure 1. Average European Sovereign Debt Exposure as % of Bank Total Assets over the Period 2010-2015.

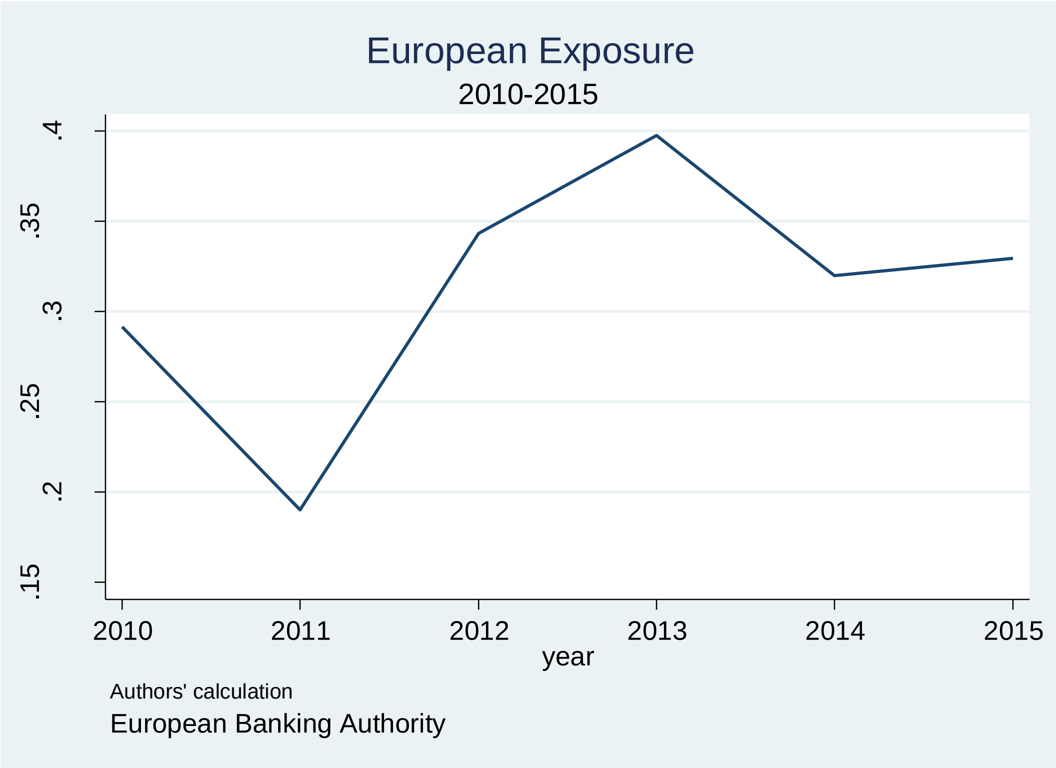


Table 1. Summary Descriptive Statistics

Variable	Obs	Mean	Std	Min	Man
Panel A: Dependent Variable					
sovexpeur	272	9.30%	5.10%	2.40%	17.90%
sovexpdom	272	6.64%	5.28%	1.14%	16.59%
sovexpgiips	272	2.61%	3.65%	0.00%	10.57%
sovexpcore	271	4.28%	4.62%	0.00%	13.25%
sovrisk	276	0.2	0.15	0.02	0.51
Panel B: Bank Balance Sheet Data					
size	273	37.28%	31.26%	0.23%	145.11%
Lending	273	57.54%	15.58%	31.88%	79.25%
liquidity	273	144.59%	50.56%	80.55%	248.23%
Business Model	273	168.43%	180.63%	24.94%	1651.79%
Capital	266	12.62%	2.83%	8.65%	17.83%
Credit quality	252	6.85%	6.26%	0.38%	34.94%
Profitability	273	0.16%	1.04%	-6.79%	3.03%

Note: sovexpeur is the ratio of European sovereign exposure on bank total assets, sovexpdom is the ratio of domestic sovereign exposure on bank total assets, sovexpgiips is the ratio of giips sovereign exposure on bank total assets, sovexpcore is the ratio of core sovereign exposure on bank total assets, sovrisk is calculated as explained in the appendix A1, size is the ratio of bank total on gdp, lending is the ratio of gross loans on bank total assets, liquidity is the ratio of loans on deposits, business model is the ratio of net interest income on operating income, capital is the common equity Tier1, credit quality is the ratio of non-performing loans on gross loans, profitability is the ratio on net income on bank total assets.

Table 2. Covariance Matrix

variable	sovexpeur	sovexpdom	sovexpgiips	sovexpcore	sovrisk	size	lending	liquidity	business model	capital	credit quality	profitability
sovexpeur	1											
sovexpdom	0.9985*	1										
sovexpgiips	0.9811*	0.9867*	1									
sovexpcore	0.9985*	0.9980*	0.9832*	1								
sovrisk	0.3348*	0.3315*	0.3012*	0.2998*	1							
size	-0.2143*	-0.2176*	-0.1791*	-0.1917*	-0.4836*	1						
lending	0.2354*	0.2341*	0.2091*	0.2071*	0.2793*	-0.1604*	1					
liquidity	0.3418*	0.3398*	0.2965*	0.3231*	0.0408	-0.1073	0.3734*	1				
business model	-0.113	-0.109	-0.1064	-0.0991	0.0575	-0.1302*	-0.1321*	0.1126	1			
capital	0.9045*	0.9034*	0.8957*	0.9601*	0.2975*	-0.2050*	0.2358*	0.3471*	-0.1216*	1		
credit quality	0.3615*	0.4123*	0.6265*	-0.2617*	0.5115*	-0.2499*	0.3175*	-0.1241	-0.1131	-0.1582*	1	
profitability	0.1867*	0.1779*	0.1232*	0.1723*	0.0578	-0.1197*	-0.0563	0.0775	-0.1189*	0.1958*	-0.3463*	1

* refers to 5% statistical significance level.

Table 3. Results: Size and Riskiness of Sovereign Bonds Holding.

	(1) sovexpeur	(2) sovexpdom	(3) sovexpgiips	(4) sovexpcore	(5) sovrisk
totass_gdp (SIZE)	-0.1300***	-0.1070**	-0.0374	-0.0405	-0.2120*
	(0.0406)	(0.0405)	(0.0313)	(0.0249)	(0.1240)
loan_totass (LENDING)	-0.2440***	-0.2090**	-0.1050	-0.0463	-0.6950**
	(0.0803)	(0.0864)	(0.0817)	(0.0447)	(0.2950)
loan_dep (LIQUIDITY)	0.0306**	0.0291**	0.0125	0.0128	0.1130**
	(0.0141)	(0.0144)	(0.0124)	(0.0085)	(0.0501)
intinc_opeinc (BUSINESS MODEL)	-0.0020*	-0.0016*	-0.0009	-0.0012*	0.0518*
	(0.0012)	(0.0009)	(0.0006)	(0.0007)	(0.0290)
CET1 (CAPITAL RATIO)	-0.0034***	-0.0016*	-0.0011	-0.0014*	-0.0050
	(0.0009)	(0.0008)	(0.0007)	(0.0008)	(0.0049)
npls (CREDIT QUALITY)	0.0017**	0.0016*	0.00253***	0.0004	0.0042*
	(0.0007)	(0.0008)	(0.0009)	(0.0008)	(0.0023)
roa (PROFITABILITY)	0.0061**	0.0039	0.0075**	0.0007	0.0084
	(0.0029)	(0.0033)	(0.0033)	(0.0012)	(0.0126)
debtcrisis	-0.0276***	-0.0185***	-0.0094**	-0.0156***	-0.5027*
	(0.0059)	(0.0053)	(0.0044)	(0.0054)	(0.0251)
Bank-Year Fe	Y	Y	Y	Y	Y
N	241	241	241	242	242
r2	0.302	0.236	0.286	0.0891	0.236

All regressions include bank and time fixed effects. Robust standard error clustered by banks in parenthesis. ***, ** and * indicate statistically significance at 1%, 5% and 10% level, respectively.

Appendix A1

$SOVRISK_{ijt}$ is computed in the following steps:

1) Calculating the spread differences between country ten years yield government bonds and a benchmark (German bund):

$$Spread_{jt} = 1 + (Ten\ year\ government\ bond\ yield_{jt} - Benchmark_t)$$

2) Computing the sovereign exposure towards each country in the bank portfolio:

$$Sovexpcountry_{ijt} = Sovexp_{ijt}/Totass_{it}$$

3) Calculating the sovereign bond portfolio riskiness

$$Sovrisk_{ijt} = \sum_{1}^{18} Spread * Sovexpcountry$$

Figure A1. GIIPS banks exposure towards domestic sovereigns.

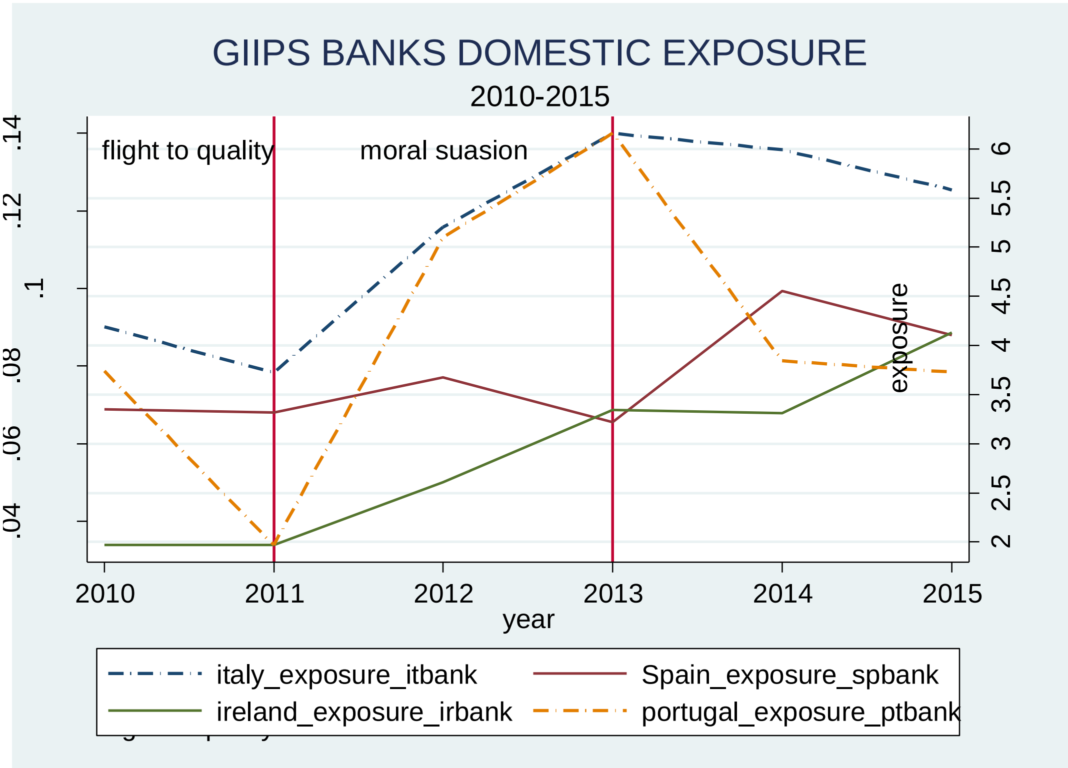
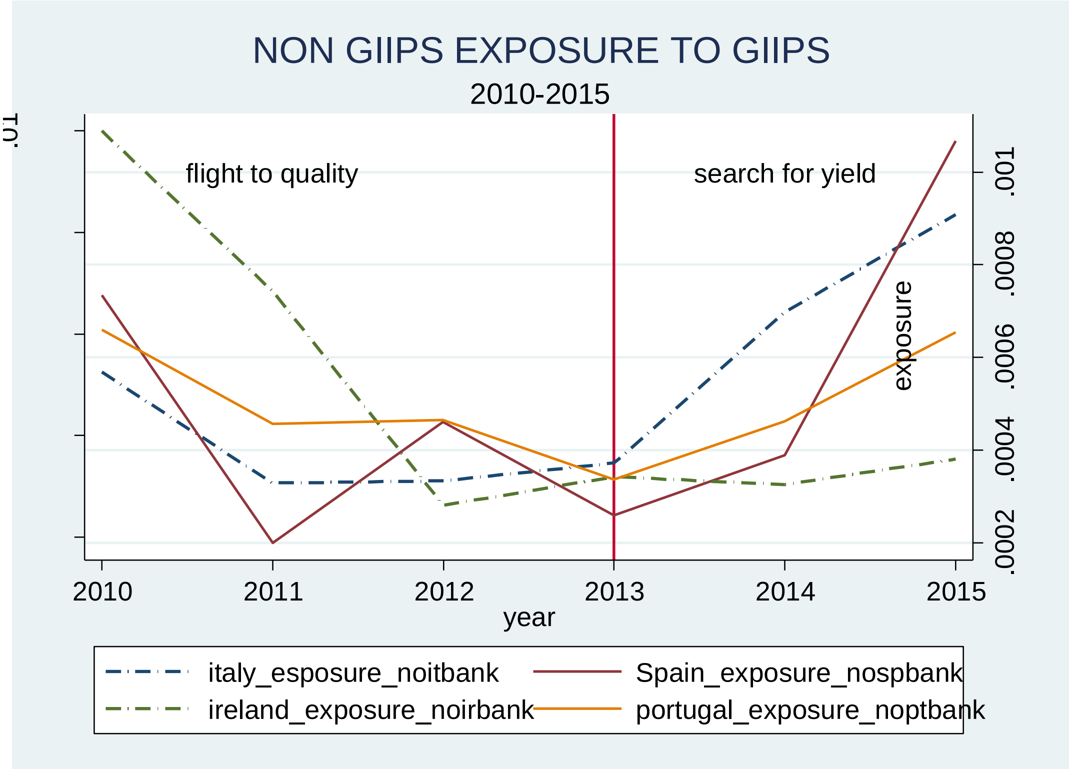


Figure A2. Non-GIIPS banks exposure towards GIIPS sovereigns.


NON GIIPS EXPOSURE TO GIIPS
2010-2015
flight to quality
search for yield
exposure
.0002
.0004
.0006
.0008
.001
.01
2010
2011
2012
2013
2014
2015
year
italy_esposure_noitbank
Spain_exposure_nospbank
ireland_exposure_noirbank
portugal_exposure_noptbank

CHAPTER 5: Should we winsorize data using difference-in-differences?

Abstract

A substantial empirical banking and finance literature uses the difference-in-differences methodology and applies winsorized data to deal with outliers. However, many such studies ignore the fact that the practise of winsorizing data replaces outliers with values that are equal in both the treatment and control groups. To illustrate the severity of this issue, we randomly generate placebo interventions in bank-level data. We show that different winsorization techniques leads to large variability in estimated coefficients, as well as significance levels and standard errors. We also display how the problem can be limited and detected.

Keywords: Winsor, Difference-in-Differences, Outliers, Financial Data, Research Design

1. Introduction

The practice of 'winsorizing' (or 'winsorization') has become a valid and popular tool among researchers to deal with outliers in a distribution of data[81]. This method, named after the 20th century biostatistician Charles Winsor, consists of replacing extreme value/s (or 'outliers') with the value of the highest data point not considered to be an outlier. Thus, winsorizing is the transformation, rather than the outright removal, of the data to limit the impact of outliers[82]. For example, an 80% winsorized mean averages the data below 10% and above 90% rather than eliminating them from the sample mean. The justification for this is to permit the inclusion of the data for significance tests and to maintain sample size. One caution related to winsorizing is that estimating and adding in values based on a percentage distribution simply reinforces the data set and alters legitimately occurring extreme observations that can contain important information (Leone et al 2014). However, other issues emerge in a difference-in-differences (DD) framework. The DD approach (see Card and Krueger 1994; Robert and Whited 2012) determines the difference in trends between two groups, a treatment (group affected) and a control (group not affected) after an intervention/shock. In the data set, values of the dependent variable lie on the same column for both the treatment and the control group. Hence, winsorising data replaces extreme values (different for the treatment and control group prior to winsorization) with values that are equal in both groups. Most studies appear to ignore this issue and subsequently present flawed findings. The application of inappropriate winsorizing techniques can be detected by looking at maximum and minimum descriptive statistics values. Equal min and max values, in both the treatment and control group prior and after the intervention, are a sign of an incorrect use of winsorization[83]. Furthermore, DD winsorization papers tend to avoid detailed summary descriptive statistics in comparison with the DD non-winsorizing raising additional concerns[84].

We use DD placebo interventions and bank level data to demonstrate the severity of this issue. We show that different winsorization approaches can lead to large variations in estimated

[81] 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 outlier mitigation methods.

[82] Trimming and dropping remove data completely from the sample.

[83] We will provide a more detailed explanation of problem detection in the following section.

[84] We notice that DD winsorization papers tend to display first and last percentiles in their descriptive statistics rather than minimum and maximum values. To gain further insight into this problem, we randomly selected 50 DD winsorization and 50 winsorization-no-DD papers (from a total sample of 200 papers). We find that only 13 DD –winsorization papers show minimum and maximum descriptive statistics compared to 37 studies that use the winsorization approach but not DD. These results are in-line with Adams et al. (2017) and Leone et al. (2015) who find that studies typically avoid mentioning outlier mitigation methods and related information.

coefficients, significance levels and standard errors. We contribute to the existing difference-in-differences literature in several ways. First, we investigate issues relating to an important estimation strategy in applied finance / economics (Bertrand et al., 2004; Donald and Lang, 2007; Imbens and Wooldridge, 2009). Second, we detect a problem that appears to be underestimated (or ignored) in the academic literature. Third, by using DD placebo regressions we provide incorrect measurement quantifications. Finally, we suggest ways in which the problem can be detected and solved for future researchers.

The paper is divided as follow. Section 1 explains the problem and its detection. Section 2 introduces our data and methodology. Section 4 presents our results. Section 5 concludes.

2. Detecting the problem

We use a stylised normal density function to show the erroneous application of the winsorization approach for dealing with outliers in a DD framework. Figure 1 shows two data distributions divided between the control (0 on top of the figure) and the treatment (1 on top of the figure). In the treatment group we arbitrarily introduce an outlier that makes the distribution skewed to the left. This gives the researcher a justification for winsorizing[85]. We apply two strategies: normal winsorization and winsorization by group. Figure 2 displays what happens when winsorization is enforced without distinguishing between the two groups. As shown winsorizing replaces the outlier with the smallest value in the two groups (zero in this case). However, zero is a value that does not belong to the treatment groups but rather to the control. Furthermore, zero appears to be an outlier even after winsorization. For the aforementioned issues, Winsor by group (Figure 3) is the appropriate solution as it treats outliers separately.

Figure 1. Normal density function (no-winsorizing)

[85] Examining the most suitable technique (winsorizing, trimming or dropping for example) in this circumstance is beyond the scope of this paper.

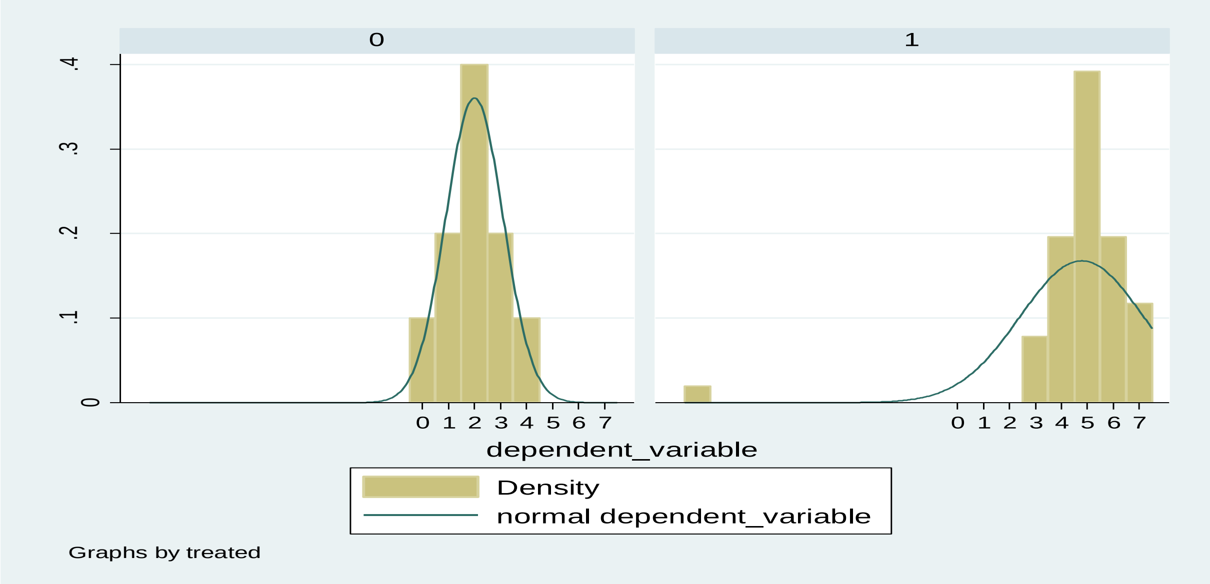


Figure 2. Normal Density Function (winsorizing)

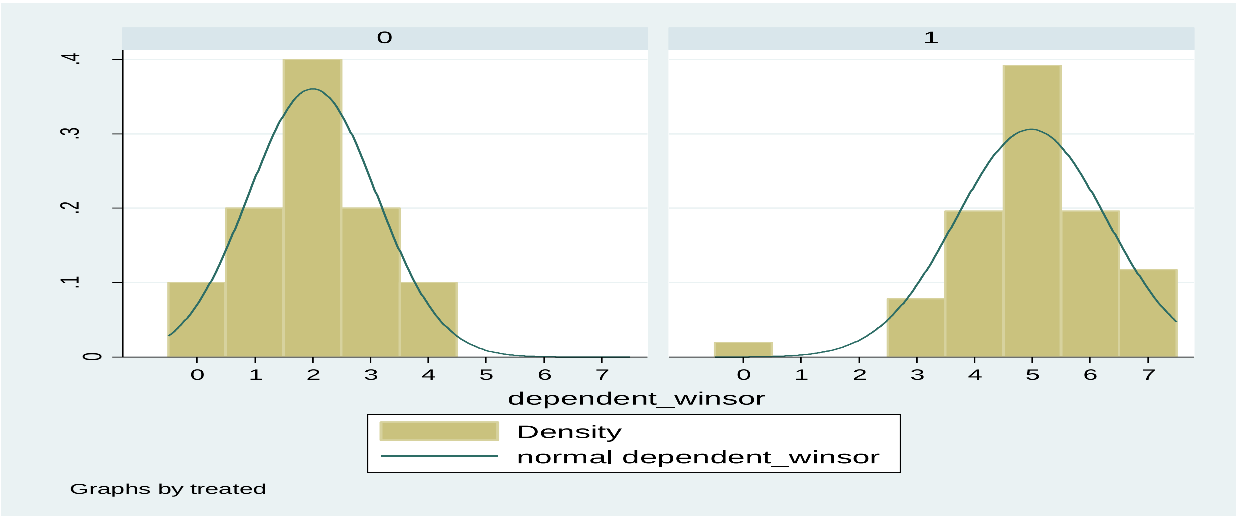
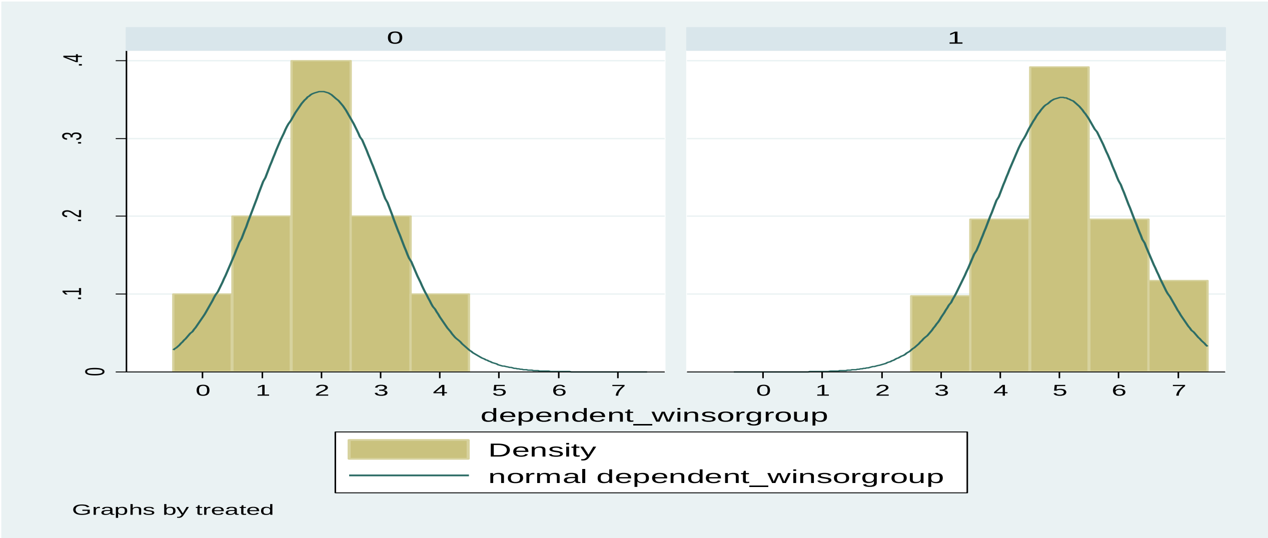


Figure 3. Normal Density Function (Winsor by group)



Picture 1, taken from *Organization Science*, shows how the winsorization problem can be detected when authors provide descriptive statistics divided by treatment and control group. In the paper, the authors state that the variable *Daily efficiency* has been winsorized at 2 standard deviation from the mean. As shown in the picture, *Min* and *Max* display equal values in both treatment and control group. This is a sign that winsorization has been applied without differentiating between the two groups. Since *Daily efficiency* is one of the dependent variables in the study, this can lead to serious estimation problems as further examined.

Picture 1. Winsor Problem Detection in Min and Max Descriptive Statistics

TREATMENT	*Pre-Award*					*Award Period*				
Variable	Obs	Mean	Sd	Min	Max	Obs	Mean	Sd	Min	Max
Tardy	7126	0.04	0.20	0.0	1.0	5742	0.03	0.16	0.0	1.0
Minutes late	7126	-1.73	5.37	-59.7	54.0	5737	-2.19	5.10	-49.0	58.2
Total absences	7846	0.04	0.19	0.0	1.0	6318	0.05	0.21	0.0	1.0
Single absences	7846	0.01	0.07	0.0	1.0	6318	0.01	0.11	0.0	1.0
Daily efficiency	6576	125.6	32.4	54.5	218.0	5669	124.7	36.2	54.5	218.0
Late	7126	0.15	0.35	0.0	1.0	5742	0.10	0.29	0.0	1.0
Monthly absences	7861	0.79	1.65	0.0	8.0	6339	1.03	1.80	0.0	10.0
Total hrs worked	7861	8.25	1.64	0.0	23.7	6339	8.17	1.69	0.0	13.1
Tenure	7861	3373	2681	176	9262	6339	3186	2708	176	9262
Age	7861	43.51	10.05	21.0	62.0	6339	43.63	9.84	21.0	62.0
Male	7861	0.43	0.50	0.0	1.0	6339	0.43	0.49	0.0	1.0
Base salary	7861	25695	845	19240	28600	6339	25495	1363	19240	28600

CONTROL	*Pre-Award*					*Award Period*				
Variable	Obs	Mean	Sd	Min	Max	Obs	Mean	Sd	Min	Max
Tardy	23600	0.03	0.17	0.0	1.0	14081	0.02	0.15	0.0	1.0
Minutes late	23600	-2.12	4.73	-59.4	59	14081	-1.88	5.07	-59	59
Total absences	27449	0.05	0.22	0.0	1.0	16300	0.05	0.22	0.0	1.0
Single absences	27449	0.02	0.13	0.0	1.0	16300	0.02	0.12	0.0	1.0
Daily efficiency	22320	120.3	34.7	54.5	218.0	14148	125.3	35.6	54.5	218.0
Late	23600	0.17	0.38	0.0	1.0	14081	0.14	0.34	0.0	1.0
Monthly absences	27684	1.06	1.76	0.0	15.0	16474	1.13	1.78	0.0	12.0
Total hrs worked	27684	8.01	1.38	0.0	44.0	16474	8.09	1.25	0.0	16.37
Tenure	27684	1720	1920	4.0	8566	16474	1754	1992	60	8566
Age	27684	39.36	12.88	18.0	69.0	16474	39.87	12.79	19.0	69.0
Male	27684	0.34	0.47	0.0	1.0	16474	0.32	0.47	0.0	1.0
Base salary	27522	19850	4899	8320	48526	16474	197334	5167	8320	48526

3. Methodology and Data

3.1 Methodology

To illustrate the effect of different Winsor techniques, we randomly generate placebo interventions and random samples using industrialised countries bank-level data. The DD framework is specified as follow:

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

Where Y_{it} is the dependent variable, equity to total assets (E/TA)[86], of bank i at time t. $Treated_i$ is a dummy variable that takes the value 1 if bank i has been affected by the intervention/shock and 0 otherwise. $Post_t$ is a dummy variable that takes the value 1 after the intervention/shock and 0 before that period[87], and β_3 represents the average difference in the dependent variable between banks in the treatment and control group prior to and after the intervention/shock. As widely used in the empirical banking and finance literature, we include γ_i and φ_t to capture, respectively, bank and year fixed effects as well as to limit the potential for bias in estimates of β_3[88].

We then estimate equation (1) using three different methods. In the first, we do not apply winsorization leaving outliers unchanged. In the second, we apply winsorization indiscriminately on both treated and untreated groups (approach that is technically incorrect). In the third, we winsorize for both treated and untreated bank samples. In-line with the literature we winsorize the treatment variable at 1% and 99%[89].

3.2 Data

Our sample covers 16,675 financial institutions over the period 2008-2016. Bank balance sheet data are from Orbis Bank Focus. The period is split in two subsamples. In the first subsample (2012-2016) we set the intervention in 2014 and we use it to explain the main results. In the second subsample (2008-2012) we set the intervention in 2010 and it will be used as a robustness to confirm our results.

Table 1 presents descriptive statistics of the aforementioned winsorization techniques. E/TA no-winsorization presents the largest standard deviation in both groups due to the number of

[86] We will use the ratio of equity on total assets as an example. However, later in the paper, we will check the robustness of the results using different bank ratios (net interest income on average earning, securities on total assets, non-interest income on gross revenues, liquid assets on deposit and short-term borrowing and deposits on total liabilities) and intervention windows. The decision to use these variables is not casual. We have taken those variables showing a substantial number of outliers in the dataset.
[87] In this case, the dummy variable takes value 1 after 2014 and 0 otherwise (sample period 2012-2016). We use a different sample (2008-2012 with intervention set in 2010) to show the validity of our result
[88] Standard errors are also robust and are clustered at the bank level.
[89] Studies use different winsorization levels such as 10% and 90% or 5% and 95%. However, 1% and 99% level is the most commonly used in the empirical finance literature. On 50 papers we examine 39 use the 1% and 99% winsorization level.

outliers in the sample. As shown in the previous section, E/TA winsorization displays equal minimum and maximum values and a smaller standard deviation similar in both groups. Finally, when winsorization is applied by group (E/TA winsorization by group) the minimum and maximum values differ and standard deviation falls in-line with E/TA no-winsorization. As shown in the table, E/TA winsorization presents two problems. The first concern regards mean values. Winsorized outliers, replaced with equal values in the treatment and control group, move up and down the mean of the treatment and control group, respectively, in comparison to E/TA winsorization by group and E/TA no winsorization. Second, the standard deviation shows smaller variation across the two groups making them more homogenous.

Table 1. Descriptive Statistics control and treatment group (2012-2016)

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

4. Results

Table 2 shows the results derived from estimates of the placebo tests using the three different winsorization approaches. All regressions are estimated using bank and year fixed effects. The first column of table 1 shows the result without winsorization. The coefficient of interest, *Treatment (E/TA),* is statistically insignificant displaying also large standard error. Similar results are found when winsorization is applied separately between treatment and control groups (column 3). However, the results completely change when winsorization is applied without distinguishing between the groups (column 2). The coefficient acquires significance (statically significant at the 1% level) and standard error is smaller. Hence, while the results without winsorization and with winsorization by group suggest no change in the dependent variable between the control and the treatment group prior to and after the intervention/shock, the winsorized coefficient shows a positive and statistically significant change in E/TA in treated banks after the intervention. Thus, providing misleading results - in this case on bank solvency.

Table 2. Winsorization Techniques and DD methodology.

	No-Winsorization (1)	Winsorization (2)	Winsorization by Groups (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)
Number of banks	7467	7467	7467
Number of Observations	26836	26836	26836

To make sure the result is not affected by specific sample selection, we test the latter on multiple random samples and different intervention windows. Table 3 shows the rejection rate of the three different winsorization techniques for two different intervention windows (2008-2012, 2012-2016), 106 random samples[90]and 6 accounting variables[91]. When winsorization is applied on 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 our previous findings.[92].

Table 3. Rejection Rate Winsor Techniques

Placebo windows	N. Samples	N.Variables	No-winsorization Rejection Rate (1)	Winsorization Rejection Rate (2)	Winsorization by Groups Rejection Rate (3)
2012-2016	57	6	21%	75%	36%

[90] Random samples are defined as drawing observation without replacement.
[91] The variables have already been defined (see section 3.1).
[92] We consider as rejected under a 10% p-value significant level.

2008-2012	49	6	18%	69%	37%
	53	6	20%	72%	37%

5. Conclusion

Most studies in the banking and finance literature using difference-in-differences methodology apply winsorized data to deal with outliers. However, some studies ignore the fact that the practise of winsorizing data replaces outliers with values that are equal in both the treatment and control group. In this paper, we have highlighted the problem of an incorrect application of winsorization, how this can be detected and how it results in biased estimates. Hence, the appropriate way to apply winsorization in a DD setting is to do this separately for treated and untreated groups.

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