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NEGATIVE INTEREST RATES, EXCESS LIQUIDITY AND RETAIL DEPOSITS: BANKS' REACTION TO UNCONVENTIONAL MONETARY POLICY IN THE EURO AREA

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Negative interest rates, excess liquidity and retail deposits: Banks' reaction to unconventional monetary policy in the euro area[1]

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Abstract

Negative interest rate policy (NIRP) is associated with a particular friction. The remuneration of banks´ retail deposits tends to be floored at zero, which limits the typical transmission of policy rate cuts to bank funding costs. We investigate whether this friction affects banks' reactions under NIRP compared to a standard rate cut in the euro area. We argue that reliance on retail deposit funding and the level of excess liquidity holdings may increase banks' responsiveness to NIRP. We find evidence that banks highly exposed to NIRP tend to grant more loans. This confirms studies pointing to higher risk taking by banks under NIRP and contrasts results that associate NIRP with a contraction in bank loans. Broader coverage of our loan data and the explicit consideration of banks' excess liquidity holdings are likely reasons for this different result compared to some earlier literature. We are the first to document the importance of banks' excess liquidity holdings for the effectiveness of NIRP, pointing to a strong complementarity of NIRP with central bank liquidity injections, e.g. via asset purchases.

Keywords: negative rates, bank balance sheets, monetary transmission mechanism
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1. Introduction

In June 2014, the European Central Bank (ECB) cut its deposit facility rate (DFR) to negative territory, an unprecedented move as no other major central bank had used negative rates before.[2] The ECB´s decision to introduce negative rates was part of a monetary stimulus package aimed at fending off deflationary risks in a situation in which policy rates had reached zero. More generally, decreasing levels of equilibrium interest rates all around the world and declining trend growth rates have elevated the practical relevance of this new monetary policy tool, as monetary policy is more likely than in the past to operate in the vicinity of the lower bound of policy rates. Kiley and Roberts (2017) note that the "zero lower bound" could, in the future, be binding up to 40 percent of the time. In view of this, the assessment of the effectiveness of negative interest rate policy (NIRP), which is the topic of this paper, is of high importance for policy makers and academics all around the world. In this paper, we show that NIRP has been expansionary in the euro area by encouraging banks to increase their lending activity.

Rate cuts resulting in negative policy rates are unlikely to operate in the same fashion as conventional rate cuts because banks may not be able to charge their retail customers negative rates on their deposits. Banks' inability to adjust some of their funding costs may be due to the forces of competition – in combination with the high regulatory value of retail deposits due to their stability – as well as the existence of paper currency, which offers an alternative store of value with a yield of zero. This particular friction associated with NIRP should have an impact on banks' profitability as the remuneration of their assets declines as a consequence of NIRP while a significant part of their funding costs remain unchanged, leading to declining intermediation margins. In line with this argument, several papers in the

[2] This followed a similar decision by the Danish central bank (Danmarks Nationalbank) in July 2012. Subsequently, the Swiss National Bank and the Swedish Riskbank introduced negative policy rates in December 2014 and February 2015, respectively, see Jackson (2015). The Bank of Japan followed in January 2016.

literature (Brunnermeier and Koby; 2017, Eggertsson et al.,2017) come to the conclusion that negative rates are either contractionary or they could potentially be contractionary as they may induce banks to cut their lending, increase lending rates or both.

In principle, an alternative reaction to the compression of bank profitability is also possible. Banks may attempt to tilt the composition of their balance sheets towards higher-yielding assets in order to reinstate the average return they earn across their entire portfolio. This can be viewed as a particular version of the standard portfolio rebalancing mechanism that is typically associated with the operation of non-standard monetary policy measures, such as quantitative easing (e.g. Krishnamurthy and Vissing-Jorgensen, 2011). To the extent that this rebalancing results in the shifting of portfolios towards loans to the real economy, it will have expansionary effects. Whether this mechanism dominates the contractionary one described above is essentially an empirical question and this paper sets out to answer it for the euro area.

We contribute to the literature on the effectiveness of NIRP by highlighting the role of excess liquidity (central bank reserves in excess of banks' reserve requirements, EL henceforth) in the transmission mechanism. Most of the literature uses the variation in retail deposit intensity to identify the effects of NIRP on banks. We add banks' EL holdings to the standard identification approach. Bank individual EL is a critical variable to complement retail deposit intensity for the identification of the impact of NIRP. This is because banks' costs of holding EL increase proportional to their retail deposit intensity and these costs are uniquely related to NIRP and not to any other concurrent monetary policy measure. Bank individual EL thus captures banks' heterogeneous treatment by NIRP and neglecting this component and focusing only on the retail deposit intensity might underestimate the true impact of NIRP on bank balance sheets.

For our identification, we exploit the interaction of the cross-sectional variation of retail deposit intensity *and* banks' EL holdings. Our approach allows us to better isolate the effects of NIRP from other policy easing measures .Another way of looking at our identification is that it allows us to combine two crucial elements in banks' reaction to NIRP: the motive and the opportunity to react. Banks are primarily motivated by the squeeze of their intermediation margins – captured by their retail deposit intensity – and react according to their opportunity set captured by the availability of negative-yielding assets in the form of EL that can quickly be redeployed towards higher-yielding uses. The joint presence of the two – motive and opportunity – is necessary for this transmission channel of the NIRP to be activated. This points to an important complementarity of NIRP with other easing measures aimed at injecting central bank liquidity into the banking system, e.g. asset purchase programmes: EL injected by the central bank activates expansionary effects of NIRP over and above what could be expected from a standard rate-cut.

Using confidential bank-level data covering around 70% of main assets and 80% of total loans of euro area banks in a sample running until September 2017, we find that NIRP has been expansionary by inducing highly-exposed banks to increase their lending activity in an effort to mitigate the adverse impact of NIRP on their profitability. This contrasts some earlier papers, e.g. Heider et al. (2019), which find that banks that are more reliant on deposit funding reduce their (syndicated) loans during NIRP. Our different result partly reflects the much wider coverage of our sample: Syndicated loans account for only 3% of euro area loans, whereas our sample includes the vast majority of euro area bank loans, including syndicated loans.

More importantly, as our paper pays particular attention to the role of EL, which provides stronger incentives for banks to engage in portfolio rebalancing during NIRP, we cover a channel that is not explicitly considered in most of the earlier literature[3]. Our findings are also consistent with Lopez et al., 2018, who establish stylized facts for banks reaction to NIRP and show that high deposit banks give out more loans and reduce their central bank reserves during NIRP. Finally, in line with the bulk of the literature (Heider et al, 2019, Bubeck et al., 2019, Bottero et al., 2018), we find support for the result that banks highly exposed to NIRP take on more risk, as they effectively convert a risk-less asset – EL – into a risky one – bank loans.

We start the paper with a discussion of the particular friction associated with NIRP and why banks may operate differently under these circumstances. Section 3 discusses the channels that banks may use to adjust their balance sheets in the face of negative rates. Section 4 describes our empirical strategy and approach to identification and section 5 reports our results. In section 6, we consider several robustness checks and section 7 concludes.

2. Are negative rates special?

2.1. The pass-through of negative interest rates to financial market rates and retail deposit rates in the euro area

The ECB introduced negative rates in June 2014 by lowering the DFR to -0.10 percent. Further rate cuts followed (September 2014, December 2015 and March 2016) bringing the rate on the ECB's deposit facility to -0.40 percent.[4]

The initial transmission of DFR cuts to short-term money market rates took longer than usual, likely due to the time needed by financial market participants to adjust to the new environment (e.g. changes to IT systems, legal documentation). Nevertheless, all rate cuts

[3] An exception is Altavilla et al. (2018) who also use EL as explanatory variable in one of their robustness tests.
[4] The negative rate is not only applied to recourse to the deposit facility but to all parts of banks' current accounts with the Eurosystem in excess of their reserve requirements. The same applies to other potential "loopholes", e.g. the remuneration of government deposits as well as deposits in the context of reserve management services offered by the ECB were also lowered in the process to (at least) -0.40%.

after May 2015 did pass through immediately to short-term interest rates such as the EONIA (Figure 1). The overnight index swap (OIS) curve was in negative territory for maturities of up to four years and short-term government bonds of the highest credit quality were trading at yields well below the DFR, demonstrating that the pass-through of negative rates to euro area financial market rates was eventually complete.

A different picture emerges when we look at rates paid by banks for deposits of households and non-financial corporations (NFC) (Figure 2). Comparing the distribution of deposit rates across a representative sample of euro area banks in June 2014 and September 2017, it is clear that both types of deposit rates have declined during the NIRP period, with both distributions having most of their mass at zero at the end of our sample period. This piling up of deposit rates at zero suggests the existence of a zero lower bound for bank deposits, although there are some banks that do report rates below zero for their household and, more prominently, NFC deposits. By further zooming in on the case of German banks, Eisenschmidt and Smets (2019) show that the zero lower bound on bank deposits only holds for retail deposits. Potential explanations for this friction associated with NIRP include the existence of paper currency that offers a way to avoid any negative rates on deposits, in combination with low switching costs of households who normally hold relatively small-sized deposits. From the banks' side, competition in the deposit market combined with the regulatory and commercial value of deposits due to their stickiness as well as costs associated with switching to a different business or funding model imply that they are reticent to lower retail deposits rates below zero (see Drechsler et al., 2017a and 2017b, for a discussion on the value of retail deposits for banks in the US).

2.2. The transmission mechanism of monetary policy under NIRP

Banks are important for the transmission of monetary policy to the economy, especially for bank-centred financial systems such as the one in the euro area. Changes in monetary policy rates trigger reactions in bank behaviour but the theoretical and empirical literature studying these reactions typically refers to environments where policy rates are adjusted (and remain) in positive territory. It is therefore ex ante unclear whether these mechanisms carry over when policy interest rates are reduced to levels below zero.

According to the standard *interest rate channel*, a change in the policy rate is transmitted to deposit and loan rates through the banking system. However, the effective zero lower bound on retail deposits implies that a significant part of banks' funding cannot be re-priced further once this threshold is reached, which could induce a change in the standard transmission mechanism.[5] The presence of NIRP imparts some heterogeneity in the banking system as it prevents banks with high reliance on retail deposits from fully adjusting their funding costs. The resulting squeeze in profit margins may impair the standard interest rate channel because high deposit banks might start raising loan rates instead of lowering them in response to a policy easing to protect their profit margins. Heider et al. (2019) investigate this possibility and note that there is no evidence of higher loan rates charged by high deposit banks in the Euro area. Meanwhile Basten and Mariathasan (2018) and Eggertsson et al. (2017) provide evidence of an increase in fees and lending rates following rate cuts into negative territory in Switzerland and Sweden. Lopez et al. (2018) find that banks that rely

[5] The "specialness" of NIRP, at least in a temporary sense, may also derive from a range of institutional features of the financial system. In some jurisdictions there may be legal restrictions to the application of negative rates to bank customers or at least uncertainty regarding the legal standing of such an arrangement. Some financial contracts (e.g. money market funds or floating rate notes) may not foresee the possibility of payments from the lender to the borrower (see Witmer and Yang, 2015) and in any case the logistics of collecting interest payments from holders of securities can be intractable. Similarly, some IT systems may not be designed to cope with negative rates. Other examples of possible institutional restrictions include the tax treatment of negative interest rate income, which is often not symmetric to the treatment of positive interest rate income, e.g. payments triggered by negative interest rates may not tax deductible, while positive interest rate income is generally taxable. Finally, internal risk management practices and rules in banks may in some cases prevent transactions that imply a loss on principal, such as holding negatively remunerated central bank reserves. While some of these institutional features may be adapted in light of the introduction of NIRP, such changes are typically implemented slowly.

more on deposit funding are more vulnerable to losses in interest income when interest rates are negative because they are less capable of raising non-interest income.

According to the *bank lending channel*, expansionary monetary policy measures increase banks' willingness to provide loans (Bernanke and Blinder, 1998). Several papers support the notion that the bank-lending channel remains intact under NIRP (e.g. Albertazzi et al., 2017; Bräuning and Wu, 2017; Basten and Mariathasan, 2018) while others argue that the bank lending channel is less effective in a low interest rate environment (Borio and Gambacorta, 2017) or that it breaks down once the zero bound on deposits is reached (Eggertsson et al., 2017). We argue that this channel may in fact be strengthened by NIRP for two reasons. Firstly, the charge on reserves may motivate banks to extend more loans in an effort to reduce their reserve holdings and avoid it. Secondly, from the perspective of depositors, the zero lower bound on deposit rates leads to a decrease in the opportunity cost of holding retail deposits and increases the demand for such deposits. Banks may respond to this increased deposit funding by issuing more loans. Thus, while NIRP reduces the ability of banks to pass on lower rates to their borrowers and may thus reduce the effectiveness of the interest rate channel, the policy may amplify the bank lending channel by increasing the cost of holding EL, in particular for banks with a high share of retail deposit funding on their balance sheet. The identification strategy employed in this paper is based on this idea.

The exchange of very safe assets such as central bank reserves for riskier assets like loans and bonds can also be seen through the lens of the *risk-taking channel*, which emphasises the role of risk perceptions and risk tolerance (Borio and Zhu, 2008; Adrian and Shin, 2009; Jimenez et al., 2014; Dell'Ariccia et al., 2016). The increase in asset prices and collateral values prompted by lower policy rates can boost banks' capacity and willingness to take on more risk. For instance, banks may rely on risk measures that are based on market equity prices, such as expected default frequencies, and make use of Value-at-Risk frameworks for their asset-liability management, all of which are likely to allow higher risk taking in an environment of lower rates. Moreover, "sticky" rate-of-return targets defined in nominal terms can prompt a *"search for yield"* effect when interest rates are reduced, which necessitates higher risk tolerance. In fact, the promotion of portfolio rebalancing by encouraging lenders to invest in riskier assets when the returns on safer assets decline is considered to be one objective of quantitative easing policies (Aramonte et al., 2015; Heider el al., 2019). This channel is likely to be further reinforced by the existence of negative rates.

While NIRP may stimulate bank balance sheet adjustment due to negative charges on EL and increased risk taking, there might be "tipping points" beyond which banks cannot tolerate further squeezes in their profits and adopt different strategies (Bech and Malkhozov, 2016). This argument is further taken up in Brunnermeier and Koby (2017) who argue that below some level of the policy rate (which is not necessarily zero) further reductions can in fact be contractionary owing to the financial instability they induce and the ensuing contractionary effects on bank lending. As the theory incorporates offsetting factors, determining the net impact of NIRP on bank lending is ultimately an empirical question, to which we turn in section 4.

3. Strategies for bank balance sheet adjustments under NIRP

If banks reduce their EL holdings to avoid the additional costs during NIRP, this adjustment process normally involves changes to other items on the banks' balance sheets. The general adjustment channels that we consider are depicted in Figure 3. Starting from a stylized balance sheet illustrated on the upper left panel, we consider asset swaps in the form of loan creation (lower right) or the acquisition of other assets, such as securities (lower left), financing by lower EL holdings. In addition, banks may consider balance sheet reduction (non-roll over of bank funding) illustrated on the upper right panel. We test for the presence of these three channels in the empirical analysis.

There is one important caveat regarding the potential for banks' balance sheet adjustments to reduce their holdings of EL: banks cannot change aggregate EL (in the short-run at least). While any individual bank can plausibly expect that a strategy to reduce its EL will be successful, it will not work for the system as a whole (see also section 4.2 in Ryan and Whelan, 2019). Some banks will inevitably end up with EL holdings. The system as a whole can only reduce EL by repaying borrowing from the Eurosystem or by acquiring banknotes. Typically, however, banks do not borrow from the Eurosystem in order to hold funds at the deposit facility and earn a negative spread.[6] Instead, banks borrow to cover liquidity needs (e.g. in the weekly refinancing operations with a maturity of one week) or even funding needs (e.g. in the refinancing operations with long maturities like the long-term refinancing operations (TLTROs)). This implies that the funds borrowed are paid out to other banks within the closed system in which central bank reserves circulate. Moreover, in a context where the central bank is engaging in large-scale asset purchases, most of the EL in the system is not actively generated by banks´ borrowing from the central bank but passively received when central bank asset purchases are settled. In both cases, the banks that end up holding the EL are different from the ones that have borrowed from the Eurosystem because banks that hold EL do so primarily for reasons that are linked to their role and position in the

[6] An exception refers to episodes of acute turmoil in money markets, when banks may for precautionary reasons choose to simultaneously borrow from the central bank and hold the funds borrowed with the central bank as liquidity buffers. Such episodes were observed in the early stages of the financial crisis. Such a situation was not, however, observed during the NIRP period.

financial system.[7] Overall, there is very limited scope for individual bank EL to be reduced by repaying borrowing from the central bank.[8]

4. Empirical strategy

In line with the conceptual discussion in the previous section, our empirical analysis focuses on tracing out three possible bank balance sheet adjustments triggered by the introduction of NIRP: loan extension, acquisition of other assets, and decline in wholesale funding.

4.1 Data

We make use of a confidential dataset containing balance sheet data for 252 euro area banks at the monthly frequency. Because monthly data may be subject to more random volatility, we report the empirical results obtained using quarterly averages. Nevertheless, the results are highly robust to using the monthly frequency as well (not shown). The Eurosystem central banks collect the data with a view to reach a high degree of representativeness of the euro area banking sector, containing a broad range of banks of different sizes and business models from all euro area countries. Importantly, banks contained in the sample cover a large fraction of loans to the euro area economy (between 70% and 85% of all bank loans, depending on the country). We exclude banks from Cyprus and Greece because these banks were affected by domestic economic and banking crises. We also exclude banks that are particularly affected by the APP, such as banks that are directly exposed to the

[7] For example, a bank with high retail deposit intensity in its funding strategy will maintain some retail deposit generating infrastructure (a network of branches and offices) and it will be difficult for the bank to fully control the amount of retail deposits it takes in through this infrastructure.

[8] Prudential regulation also imposes constraints on banks' adjustment space as is reflected in a multitude of regulations that govern the possible evolution of a bank's balance sheet (e.g. capital needed for loans, liquidity regulations constraining the funding strategy and leverage ratios limiting balance sheet size expansion stemming from particular items). For example, a bank may be constrained in its ability to extend lending by binding capital requirements or by liquidity regulation in which the exchange of a high-quality liquid asset for a loan that does not qualify as such would have adverse implications for regulatory liquidity ratios.

implementation of Eurosystem asset purchases,[9] banks handling large amounts of euro liquidity on behalf of non-euro entities (see Eisenschmidt et al., 2017) or banks handling the cash leg of an APP transaction for non-euro area banks. For these banks, standard balance sheet adjustment channels described above are unlikely to be viable options, owing to their specific role in the implementation of the APP and the financial system architecture more broadly. This leaves us with 196 banks with balance sheet data from 2011.Q1 until 2017.Q3.

4.2 Identification

The introduction and further roll-out of NIRP occurred in tandem with the announcement of other non-standard monetary policy measures by the ECB. In particular, the first reduction of the DFR to negative territory in June 2014 coincided with the announcement of the first wave of TLTROs. The next reduction of the DFR to -0.20 percent was decided in September 2014, together with the announcement of the asset backed securities purchase programme (ABSPP) and the third covered bond purchase programme (CBPP3). The rate cuts of December 2015 and March 2016 coincided with extensions of the ECB's expanded asset purchase programme (APP), which started in March 2015 and was broadly expected by financial markets as early as September 2014.

This confluence of various policy measures can have a bearing on banks' decisions and thus renders the identification of the effects of NIRP based purely on the timing of its introduction problematic. For example, it is plausible to expect the APP to have induced significant portfolio rebalancing effects (Albertazzi et al., 2018). The availability of long-term funding at an attractive price through the TLTRO can also be expected to incentivise the acquisition of assets and more generally changes to banks' balance sheets as the targeting elements of this measure would be expected to spur increased lending in particular.

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[9] Banks affected by the APP typically display a strong co-movement of their main assets with their excess liquidity after March 2015, dwarfing other balance sheet changes. We exclude all those banks for which we observed an average EL ratio over main asset in excess of 10% over the APP period. In a second step, we manually checked all banks selected by that criterion to verify their close connection to the APP.

Against this backdrop, our identification of the impact of NIRP relies on the cross-sectional variation of the two characteristics of the banks in our sample that are directly connected with NIRP: banks' retail deposit intensity and EL holdings. Bank's retail deposit intensity is the standard identification approach in the empirical literature on NIRP. We add banks' EL holdings to that standard identification, exploiting an additional variable capturing the heterogenous treatment of banks by NIRP. Considering the cross-sectional variation in these two characteristics jointly allows us to better identify effects that are exclusively linked to NIRP and not to any other concurrent monetary policy measure.

The volume of EL held by each bank is distinct and changes through time. Banks' EL holdings (and their expectations of the additional EL that they will receive in the future) represent the direct cost of NIRP for banks. These costs translate into pressure for banks to adjust their balance sheets. Moreover, for a given level of EL, banks' incentives for balance sheet adjustment triggered by NIRP will differ depending on their exposure to retail deposits. In line with the discussion in section 2, we expect that banks that rely on traditional retail deposit funding to be more responsive to NIRP compared to banks that use funding options with a higher interest rate pass-through.

A prerequisite for using banks' EL holdings as exposure variable is its exogeneity with respect to the treatment. To formally test this argument, we consider the EL ratio as the dependent variable in equation (1) and test whether being in the group of banks with high EL ratios prior to NIRP is the key determinant for the level of their EL ratio during NIRP.

$$\mathrm{EL}_{\mathrm{i,t}} = \mathrm{T}_{\mathrm{t}} + \beta_1 \mathrm{Avg\_EL}_{\mathrm{i}} + \beta_2 Retail\ Ratio_{\mathrm{i,t-1}} + \beta_3\ Liquidity\ ratio_{i,t-1} + \beta_4\ Leverage\ ratio_{i,t-1} + \beta_5\ r_{i,t-1}^{Loan} + \varepsilon_{it} \qquad (1)$$

where $EL_{i,t} = \frac{Excess\ Liquidity_{i,t}}{Assets_{i,t}}$, Avg_EL$_i$ is the average EL ratio of bank *i* in the year before NIRP,[10] $Retail\ Ratio_{i,t} = \frac{Retail\ Deposits_{i,t}}{Assets_{i,t}}$, $Liquidity\ ratio_{i,t} = \frac{Liquid\ assets_{i,t}}{Assets_{i,t}}$, $Leverage\ ratio_{i,t} = \frac{(Capital+Reserves)_{i,t}}{Assets_{i,t}}$, and $r_{i,t-1}^{Loan}$ is the composite loan rate.

Our identification assumption relies on high EL banks – based on average EL levels in the year before NIRP – remaining high EL banks under NIRP, i.e. that banks do not switch between the categories such that low EL banks indeed provide a valid counterfactual for high EL banks during NIRP. Table A2 shows the regression results. We note that the coefficient associated with Avg_EL$_i$ is highly significant and not significantly different from one, suggesting a one to one relationship between Avg_EL$_i$, which is the average EL ratio in the year before NIRP and future levels of EL. This finding strongly supports our identification assumption which posits that a bank's EL position is primarily a function of its place in the financial system and its business model. While banks can change their EL holdings somewhat, these changes are of second order relative to the fundamental determinants of banks' relative EL position.

We conceptualise our identification strategy and its links to the literature in Figure 4, which is key to understand our empirical approach. Figure 4 compares the balance sheets of two stylized bank funding models, considering only the elements relevant for our research question. Bank A is entirely funded by retail deposits and hence faces a zero lower bound in passing the policy rate changes onto deposit rates. Meanwhile Bank B is entirely funded in the wholesale market with complete interest rate pass-through (r denotes the applicable interest rate). Under positive rates without EL (upper left panel of Figure 4) both banks can expect the same net present value (NPV) of their stream of profits, providing a general

[10] The year before NIRP is defined as the interval from 2013.Q2 through 2014.Q2.

equilibrium rationale for the existence of both business models at the same time.[11] In the presence of EL (upper right panel), both bank types earn a positive rate of return for their EL holdings (e.g. DFR) and, again, have equal NPVs, as the costs of holding EL in a positive rate environment are unrelated to banks' funding structure. Note that the insight from the upper right panel of Figure 4, i.e. that EL does not change banks' fundamental business prospects, is also backed by empirical research (see Ennis and Wollman (2015) for the case of the US).

Things change once policy rates are lowered below zero. The wholesale-funded bank is not affected as its liabilities fully reprice. The retail deposit-funded bank, however, is negatively affected as its liabilities cannot reprice fully and the NPV of its profits declines relative to the NPV of the profits of the wholesale-funded bank (lower left panel of Figure 4). This situation is worse when the banking system is forced to hold EL (e.g. due to asset purchases). The NPV of the profits of the retail deposit-funded bank further deteriorates relative to the one of the wholesale-funded bank as it has to hold costly EL (lower right panel of Figure 4).

This classification of effects of NIRP on banks with and without EL also helps understanding the differences in the literature: Papers relying on retail deposit intensity (e.g. Heider et al, 2019; Eggertsson et al., 2017) base their identification on the channel described in the lower left panel of Figure 4. Meanwhile, our approach identifies the transmission channel described in the lower right panel of Figure 4. In this way, we are able to capture the incidence of the direct costs of the NIRP and the scope for portfolio adjustment through EL holdings while also capturing the exposure to the indirect effects associated with margin compression through the retail deposit funding intensity.

[11] The NPV is represented by the thickness of the red and black bars next to the balance sheets of both types of banks. NPV is used in this stylised illustration as a summary metric that allows us to compare the dynamic effects of different rate and asset/liability structure constellations.

A more fundamental adjustment option for affected banks would be to change their funding models (i.e. to reduce their reliance on retail deposits). Such decisions, however, are of a more long-term nature and do need to be weighed against the fixed costs associated with switching to a new funding model as well as the benefits of the new funding model under positive interest rates. In an environment where negative rates are considered temporary, we would rather expect the retail deposit-funded banks to adjust their EL holdings instead of changing their business models.

5. Empirical results

5.1. Bank loans

We start with the question whether NIRP prompts banks to extend more loans, over and above what would be implied by the standard determinants of loan issuance. In line with the established approach in the literature we use a Difference-in-Differences (DD) methodology in our estimation.[12] The DD methodology assumes that except for the treatment, treated and non-treated entities are affected by economic conditions in the same way. The advantage of this methodology is that it accounts for the potential endogeneity between the economic control variables and the dependent variable, if the underlying assumptions about the treated and non-treated groups are valid.

As a starting point, we consider the following equation for bank loans (Y_{it}) consistent with the literature on NIRP:

$$Y_{it} = T_t + B_i + \beta_1 Avg\_RR_i D^{NIR} + \varepsilon_{it} \tag{2}$$

[12] Our results are robust if we split banks into three quantiles based on the size of retail deposits in the year before NIRP and estimate a panel fixed effects model. The results are available from the authors upon request.

where Avg_RR_i is the average retail deposit ratio of bank *i* in the year before NIRP. D^{NIR} is a dummy variable that is equal to 1 for the period after June 2014 when the deposit facility rate moved to negative territory. We include bank fixed effects (B_i) to control for unobservable time-invariant bank-specific factors that affect the decision to extend loans. Moreover, our specifications include time fixed effects (T_t) to control for aggregate shocks. The errors are clustered at the bank level. The estimation sample covers the period from 2010.Q1 to 2017.Q4. To avoid that our results are unduly influenced by outliers, all bank-level flow data are winsorized at the 1 and 99 percent levels.

The interaction term $Avg\_RR_i D^{NIR}$ captures the treatment intensity of bank *i* that is associated with its reliance on retail deposits. If banks with a high reliance on retails deposits are indeed more motivated than low deposit banks to turn their EL into loans during the NIRP period, we would expect $\beta_1 > 0$.

Table 1 displays the estimation results. Columns 1-2 show the results for the full sample. The first column refers to the ratio of winsorized NFPS loan flows to total assets as the dependent variable ($Y_{i,t} = Loan\ ratio_{i,t} = \frac{Loans_{i,t}}{Assets_{i,t-1}}$, where $Loans_{i,t}$ is the quarterly flow in loans to the non-financial private sector (i.e. to households and non-financial corporations) in period t and $Assets_{i,t-1}$ is the stock of assets at the end of period t-1). The second column shows the results using the log difference of the stock of loans to the non-financial private sector as the dependent variable. We prefer to focus on flow data, which are insulated from reclassifications and other changes in stocks that do not refer to actual transactions. Nevertheless, in order to provide continuity with the literature, we also report the results using stock data. Unlike previous literature (e.g. Heider et al., 2019, Eggertsson et al., 2017), we do not find a negative and significant coefficient. At the same time, we do not find a positive coefficient either. Restricting the sample to "high deposit" banks in columns

3-4 does not change the results. High deposit banks are defined as those banks whose average retail deposit ratios in the year before NIRP were above the median.

These results could be triggered by the exposure to the treatment being relatively heterogeneous within our high deposit group, given that we have a broader cross-section than some of the previous studies in the literature, which either focus on a specific country (e.g. Eggertsson et al., 2017) or a specific credit market segment, such as syndicated loans (e.g. Heider et al., 2019). In view of this and in line with the identification strategy proposed in section 4.2 we explicitly consider the role of EL in equation (3) in order to better identify exposure to treatment:

$$Y_{it} = T_t + B_i + \beta_1 Avg\_EL_i D^{NIR} + \varepsilon_{it} \tag{3}$$

where Avg_EL_i is the average EL ratio of bank *i* in the year before NIRP.

Columns 1-2 of Table 2 show the results from estimating (3) for the full sample. While the coefficient for interaction term $Avg\_EL_i D^{NIR}$ is positive, it is not significant for our benchmark specification using flow data (column 1). Next, we restrict our sample to high deposit banks. Consistent with the transmission mechanism and the identification strategy described in section 4.2, we expect these banks to be more responsive to their EL holdings during NIRP. Indeed, the interaction term is positive and highly significant in the third column, suggesting that higher values of EL are associated with increased lending during NIRP. Based on the results presented in Table 2, the NIRP effect corresponds on average to 17 percent of the quarterly lending by high retail deposit banks.[13]

The fourth column in Table 2 considers log differences of stock NFPS loans as the dependent variable. This is consistent with Eggertsson et al., 2017, who focus at Swedish

[13] In order to estimate the economic significance of our results, we calculate the ratio: $\frac{\beta_1 \times Avg\ EL\ Ratio}{Loan\ flow_i}$ where Loan $flow_i$ is the sample average value of loan flow ratio of high deposit banks during NIRP, Avg EL Ratio is the sample average value of EL ratio for high deposit banks in the year before NIRP, and β_1 is the coefficient estimate from equation (1).

banks and consider the log difference of loans instead of log levels. This way, the trend component of the stock variable can be eliminated and the dependent variable gets “closer” to the net flow variable that we prefer to use in our benchmark regressions. The coefficient estimate associated with the interactive term is once again positive and highly significant supporting our findings in the third column.

Further support for our identification is provided in columns 5 and 6 where this time we restrict our sample to low deposit banks, which are defined as those banks whose average retail deposit ratios during the year before NIRP were below the median. Our identification mechanism argues that these banks are less exposed to frictions during NIRP and hence they are less likely to attempt to reduce their EL by extending loans. Indeed, the coefficient associated with the interaction term, $Avg\_EL_i D^{NIR}$, is insignificant.

Columns 3-4 in Table 2 test the transmission channel that is proposed in our paper, which is described in the lower right panel of Figure 4. In contrast, columns 3-4 in Table 1 test the channel described in the lower left panel in Figure 4, to provide a comparison to the previous literature. The earlier literature focuses on the role of NIRP through retail deposits, and overlooks the role played by EL. We note that once the role of EL is taken out from the equation, the significant relationship between bank loans and high retail deposits disappears.

For the conclusions stemming from the DD specification in equation (3) regarding the role of NIRP in influencing lending behaviour to hold, it is necessary to assume that the lending of low EL banks provides an appropriate counterfactual for the lending of high EL banks in the absence of NIRP. We assess the validity of this assumption in several ways. First, we plot the average loans extended by high EL and low EL banks in the high-deposit sample in Figure 5. High EL and low EL banks are defined as banks with average EL ratios above and below the median in the year before NIRP. The upper panel shows the full sample of banks while the lower panel focuses on high deposit banks. For both samples, we note that bank lending moves roughly in parallel across the high EL and low EL two groups since 2008, well before the start of our sample period in 2010.

Next, we check whether characteristics of high versus low EL banks that are relevant for their lending decisions change significantly between the pre and post-treatment period. If this is the case, it could indicate that there are relevant time-varying differences in the two groups which would could blur the identification of NIRP. Table A1.1 presents averages of relevant balance sheet features across banks in the bottom and top terciles of average EL holdings. The top panel reports these averages for the pre-NIRP period, while the bottom one refers to the NIRP period. The last column reports the value of the t-statistic for a test of whether the difference in means between the two groups is equal to zero. In the pre-NIRP period, low EL banks have higher levels of retail deposits, they are more liquid, smaller in size, they have larger wholesale funding ratios and higher leverage ratios. As shown in the bottom panel, this pattern of differences is broadly preserved in the NIRP period. The only exception is the leverage ratio, where the difference between the two groups is no longer significant in the NIRP period. As, however, in the pre-NIRP period the high-EL group had a lower leverage ratio (implying lower capitalisation in the way the ratio is defined), this would have motivated, if anything, lower – not higher - lending by this group.

Finally, a potentially relevant concern is that there may be confounding effects from changes that are not related to NIRP and not properly differenced out by the DD estimation. If such factors affected banks' lending decisions and impacted treated and non-treated banks in different ways, our identification would be invalid. One such potentially confounding factor is the introduction of the Basel III Liquidity Coverage Ratio (LCR), which came into force in January 2015, albeit with a 4-year phasing-in period. If low EL banks had systematically lower LCR than their high EL peers, they may have restrained their lending in order to improve their liquidity position and comply with the regulatory requirement. In this case the post-treatment difference in lending between high EL and low EL banks would be driven by this regulatory change rather than NIRP. To check the validity of this argument, we calculate a proxy for the liquidity position of banks in our sample including EL, which is reported in row 7 of table A1.1. As shown in the table, the two sets of banks have statistically indistinguishable average liquidity positions, as measured by this proxy, both in the pre and in the post-treatment periods. This provides us with comfort that a different intensity of motivations to comply with liquidity regulatory requirements is not confounding our results.

5.2. Security holdings

We follow the same logic as in the previous section to identify the effects of NIRP for bank security holdings in the framework of portfolio adjustment. We focus on government bond holdings and distinguish between those issued by domestic governments and by other euro area sovereign issuers.

We replace the dependent variable used in equation (2) with bond holdings. Tables 3 and 4 show the results for non-domestic and domestic bond holdings respectively. Overall, our findings do not support a significant adjustment of bond holdings during NIRP. This finding is consistent with Ennis and Wolman (2015) who find no evidence of substitution between excess reserves and other forms of liquid assets for the US (albeit for a period with positive interest rates).

5.3. Wholesale funding

Wholesale funding refers to uninsured bank liabilities such as inter-bank loans and debt securities issued that provide additional funding opportunities beyond retail deposits. Wholesale funding, owing to its uninsured nature, tends to be costlier than retail deposits and can, in some cases, be adjusted flexibly. At the same time, in a NIRP environment it is not subject to an effective lower bound and can therefore become relatively less costly than retail deposits. As discussed in Section 3, one potential impact of NIRP could be to motivate banks to use their EL to pay back wholesale funding debt, but we would expect this channel, if anything, to be more muted than the others due to the potential beneficial impact wholesale funding can have on banks' funding cost under NIRP.

Table 5 shows the results from estimating equation (2) for wholesale funding. We find evidence of a significant increase in wholesale funding during NIRP which is particularly significant for low deposit banks. This finding suggests that banks that rely less on deposits and more on wholesale funding choose to expand their external funding further for higher levels of EL, likely to transfer the higher costs of EL by taking advantage of the perfect pass through of NIRP to the cost of this funding source. Overall, our findings are in line with our expectation that the wholesale funding channel is an unlikely adjustment path for banks to reduce their EL holdings under NIRP, as it potentially conveys a cost advantage to banks.

6. Robustness analysis

In the previous section, we documented that high deposit banks with higher levels of EL holdings extend more loans during NIRP. We check the robustness of this result in several ways.

First, we consider an alternative cut off point for various reductions in DFR in the positive territory to determine if the NIRP period is indeed special. Our goal is to understand whether other reductions in the DFR that took place in the positive territory trigger reactions similar to the reductions in negative territory. To that end, we construct a dummy variable, D^{12}, to capture the 25 basis points easing in July 2012 and the further easings in the positive territory that followed. We interact this dummy variable with Avg_EL_i and add it to our specification. If the extension of bank loans by high deposit banks with high EL exposure is simply a response to expansionary monetary policy, then we might expect the coefficient associated with D^{12} to be significant as well and perhaps even dominate the coefficient β_1. However, the results shown in the first column of Table 6 illustrate that this is not the case. $Avg\_EL_i \times D^{NIR}$ is the only significant interaction term, suggesting that it is only during NIRP that the transmission channel that operates through banks' EL holding is operative. The second column considers another robustness check, analysing the impact of progressive steps into the negative territory, compared to the period when the DFR was positive. Accordingly, we split the NIRP period into four partially overlapping sub samples: D^{NIR} starts from the first rate cut and covers all successive cuts in the negative territory, D^{DFR2} covers the period after the second rate cut in September 2014 which lowered the deposit facility rate to -20 basis points. D^{DFR3} covers the period after the third cut into the negative territory in December 2015, and D^{DFR4} covers the period after March 2016 when DFR=-0.40.

The first period with a negative DFR (D^{DRF1}) was relatively short (3 months), left short-term money market rates largely above zero due to a sluggish pass-through, and was generally associated with lower levels of EL. In contrast, the cut in the DFR to -0.30 percent in December 2015 (D^{DRF3}) marks the point when financial markets revised their expectations regarding the future path of short rates because what was previously thought to be the lower bound (essentially because of previous communication by the ECB on the topic) had to be revised downwards.[14] Thus, we would expect our results to be driven by the later NIRP sub-periods rather than the earlier sub-periods. In addition to determining which phase of NIRP was more influential, this robustness check also allows us to see whether the data contains any hint regarding a potential reversal rate. For example, while we might find an overall effect where banks expand their loan supply in the face of negative rates, this effect might get smaller and ultimately reverse, depending on the degree of negativity of the DFR.

[14] Grisse et al. (2017) note that if rate cuts below zero shifts the believed lower bound, this affects the long term rates and strengthens the transmission mechanism. Wu and Xia (2017) support this argument. Lemke and Vladu (2017) show evidence of a decline in the lower bound during NIRP.

The third column considers another robustness check for bank loans by controlling for the APP period explicitly. The APP variable is constructed based on Blattner and Joyce (2016), which yields the probability of the ECB implementing APP based on survey evidence. The variable starts with a positive probability in September 2014 and increases gradually to 1 by January 2015.

Looking at the first row and the second column of Table 6, we observe that there is not a gradual empowerment of the NIRP process but the rate cuts as a whole are significant. Most importantly, we find no indication of the banking system approaching a "reversal rate" which would have manifested itself in negative responses (coefficients) at the later stages of NIRP. The third column indicates that the aggregate impact of EL is still significant for the high deposit banks even after we control for APP according to Blattner and Joyce (2016).

The last column in Table 6 considers yet another robustness check and includes country fixed effects instead of cross section fixed effects. We observe that our benchmark specification is robust to this test as well, suggesting that our findings are not driven by country specific differences that may have affected their lending behaviour.

Appendix A2 considers another robustness check where we consider a time varying exposure to treatment by estimating a panel specification with fixed effects and allow our EL variable to change over time. Our results are robust to this specification as well, which suggests that high deposit banks with high EL ratios are associated with more loan issuance during NIRP. No similar adjustment is observed for holdings of securities or wholesale funding.

7. Conclusions

The existing theoretical and empirical literature on banks' role in the monetary policy transmission mechanism is inconclusive on bank reactions to changes in policy rates when these changes take place in negative territory. Using confidential bank-level data for the euro area which cover a very representative share of total loans, we approached this question empirically, using a novel identification approach. We jointly consider banks' exposure to the charge on EL and their reliance on retail deposit funding, as an essential identification mechanism for the impact of NIRP on banks. We find evidence that banks indeed operate differently under negative rates. Banks that are highly exposed to NIRP (i.e. funded by large amounts of retail deposits and holders of EL) extend significantly more loans to the NFPS during the NIRP compared to the pre-NIRP period. These results suggest the presence of a strong complementary between NIRP and other easing measures injecting central bank liquidity into the banking system, e.g. asset purchase programmes: EL injected by the central bank activates expansionary effects of NIRP over and above what could be expected from a standard rate-cut. The charge on EL seems to encourage banks to take action to avoid it, thereby catalysing more active portfolio rebalancing. Our results are coherent with results in the literature on the impact of NIRP in that we do find evidence of higher risk taking by banks, as risk-free EL is converted into loans. However, in contrast to some of these contributions, we find that high retail deposit banks increase their lending during NIRP. We document that the difference in the results stems from our use of a broader dataset for bank loans and the explicit incorporation of the role of EL during NIRP.

Figures

Figure 1: Key policy-controlled interest rates and interbank overnight rates

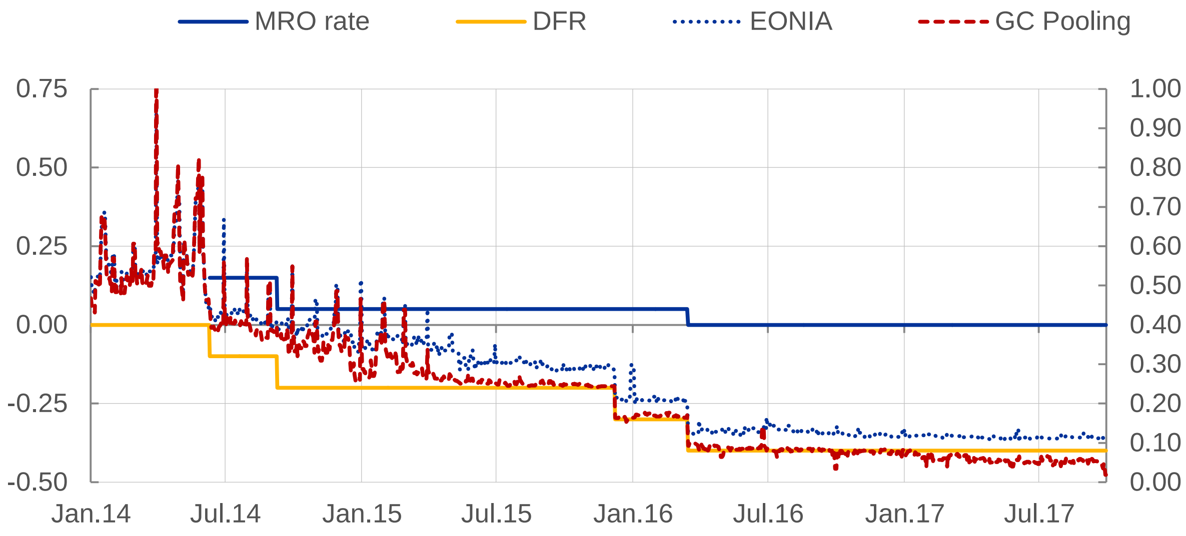
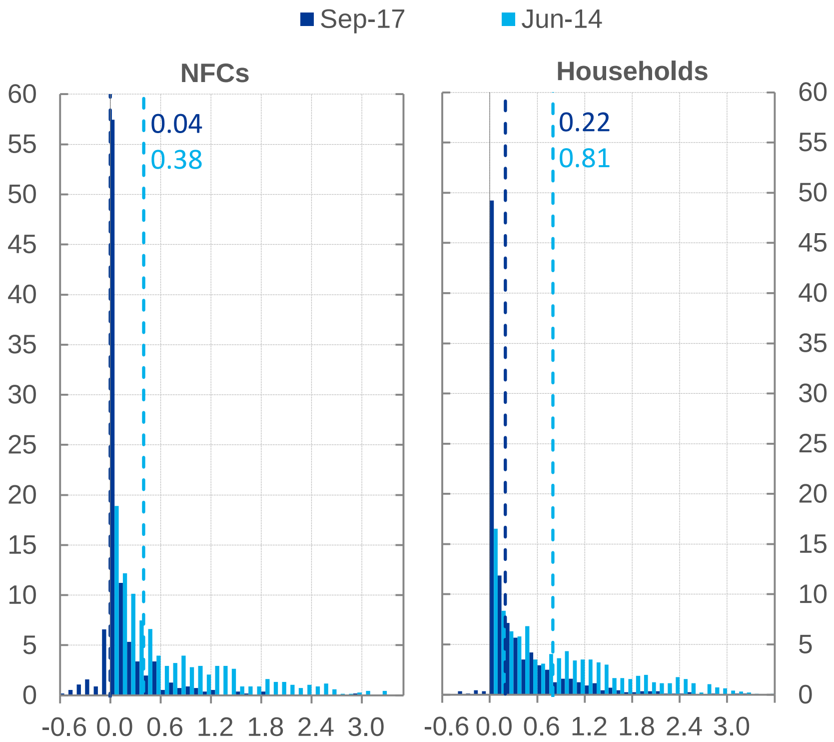

MRO rate
DFR
EONIA
GC Pooling
0.75
0.50
0.25
0.00
-0.25
-0.50
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan.14
Jul.14
Jan.15
Jul.15
Jan.16
Jul.16
Jan.17
Jul.17

Figure 2: Distribution of the remuneration of household and NFC deposits across banks in the euro area – updated 2017Q3



Source: ECB, dashed lines represent mean of distribution

Figure 3: Possible adjustment channels for banks to reduce their excess liquidity holdings

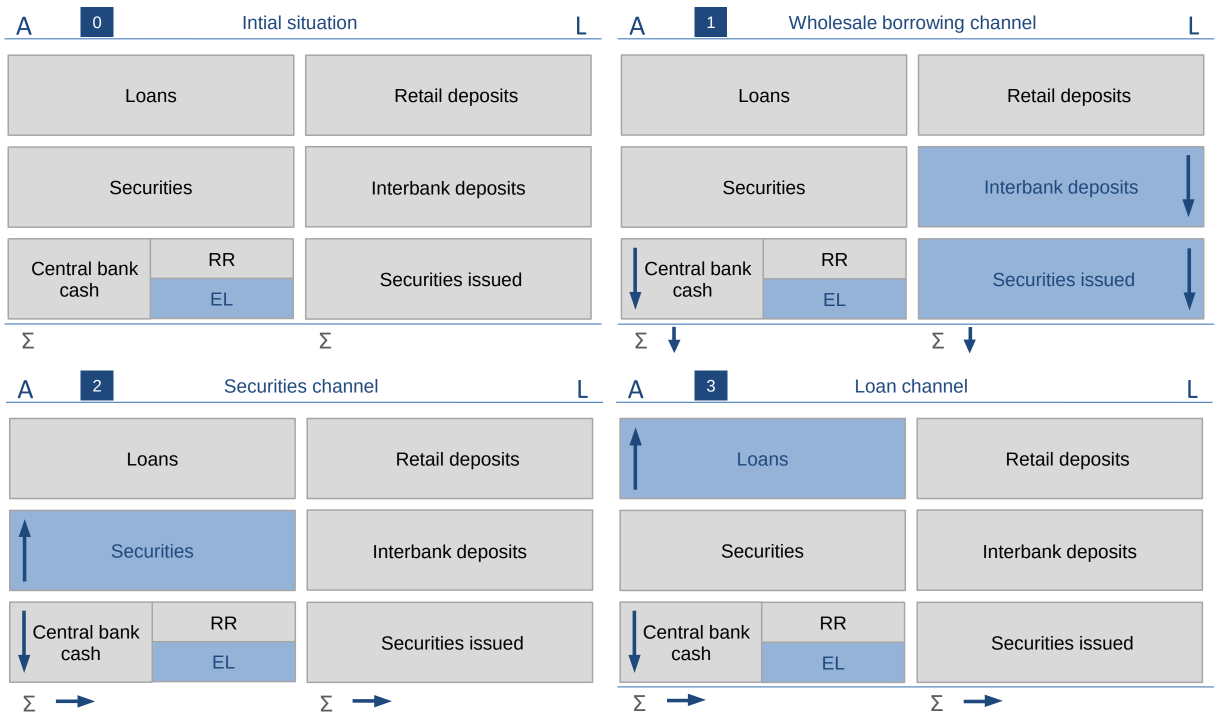


Figure 4: Comparison of two bank funding types under different interest rate environments

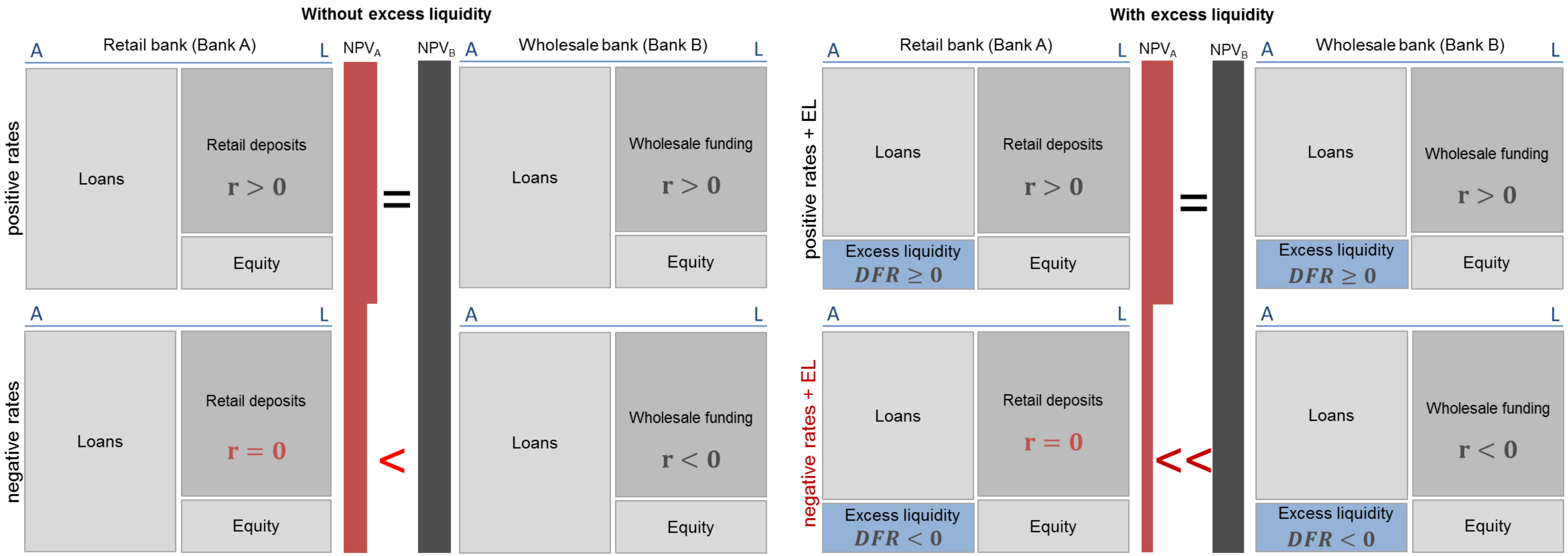
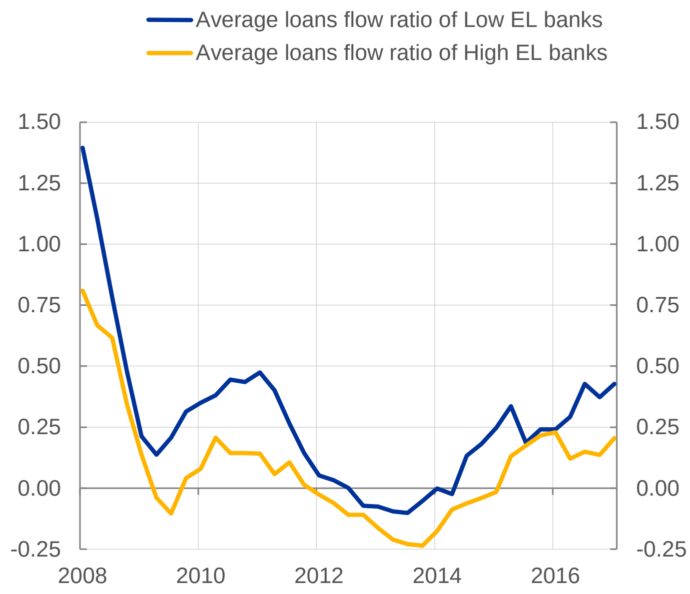
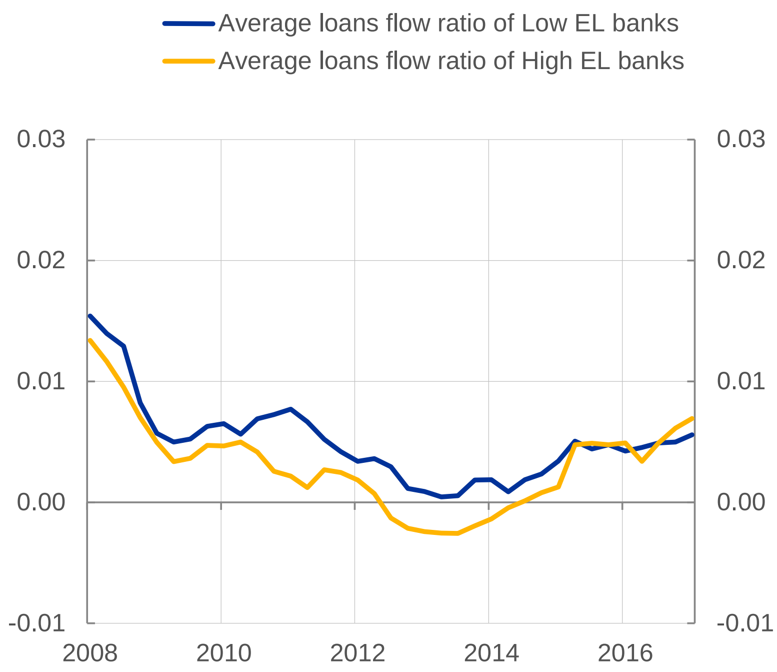


Figure 5: Evolution of Bank Loans by High EL and Low EL Banks

Full Sample



High Deposit Banks



High EL and Low EL banks are defined as those banks with average EL ratios above and below the median in the year before NIRP, respectively.

Table 1: Role of Deposits in Lending Behavior

		(1)	(2)	(3)	(4)
		Full Sample		*High Deposit Banks*	
		Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)
1.	$Avg\_RR_i \times D^{NIR}$	0.00	0.02	0.00	0.07
		0.00	0.02	0.00	0.04
2.	Cross section fixed effects	Yes	Yes	Yes	Yes
3.	Time fixed effects	Yes	Yes	Yes	Yes
4.	Observations	6383	6255	3339	3346
5.	R-Squared	0.13	0.06	0.18	0.05
6.	Number of IDs	214	211	111	111

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

Table 2: Role of EL and Deposits in Lending Behavior

		(1)	(2)	(3)	(4)	(5)	(6)
		Full Sample		*High Deposit Banks*		*Low Deposit Banks*	
		Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)
1.	$Avg\_EL_i \times D^{NIR}$	0.12 0.07	0.68** 0.36	0.18** 0.07	1.27** 0.60	0.10 0.09	0.52 0.34
2.	Cross section fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
3.	Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
4.	Observations	6383	6225	3339	3346	3044	2909
5.	R-Squared	0.13	0.06	0.19	0.05	0.11	0.08
6.	Number of IDs	214	211	111	111	103	100

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

Table 3: Role of EL and Deposits in Nondomestic Bond Purchases

		(1)	(2)	(3)	(4)	(5)	(6)
		Full Sample		*High Deposit Banks*		*Low Deposit Banks*	
		Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)
1.	$Avg\_EL_i \times D^{NIR}$	0.00	0.09	0.01	0.44	0.00	-0.03
		0.01	0.97	0.02	1.23	0.00	1.30
2.	Cross section fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
3.	Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
4.	Observations	6406	4334	3348	2207	3058	2127
5.	R-Squared	0.06	0.05	0.06	0.07	0.06	0.05
6.	Number of IDs	214	173	111	92	103	81

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

Table 4: Role of EL and Deposits in Domestic Bond Purchases

		(1)	(2)	(3)	(4)	(5)	(6)
		Full Sample		*High Deposit Banks*		*Low Deposit Banks*	
		Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)
1.	$Avg\_EL_i \times D^{NIR}$	-0.02	-1.76	-0.11	-3.12	0.00	-0.42
		0.04	1.84	0.14	3.44	0.01	0.96
2.	Cross section fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
3.	Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
4.	Observations	6406	5581	3348	3096	3058	2485
5.	R-Squared	0.05	0.06	0.05	0.06	0.06	0.08
6.	Number of IDs	214	198	111	107	103	81

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

Table 5: Role of EL and Deposits in Wholesale Funding

		(1)	(2)	(3)	(4)	(5)	(6)
		Full Sample		*High Deposit Banks*		*Low Deposit Banks*	
		Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)	Ratio of Winsorized Loan Flow	ΔLn(Loans)
1.	$Avg\_EL_i \times D^{NIR}$	0.13	-0.33	0.27*	0.25	0.09**	-0.49
		0.07	0.32	0.15	0.32	0.04	0.31
2.	Cross section fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
3.	Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
4.	Observations	6406	6335	3348	3348	3058	2987
5.	R-Squared	0.04	0.03	0.04	0.03	0.09	0.03
6.	Number of IDs	214	214	214	214	103	103

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

Table 6: Robustness tests for Bank Lending

		(1)	(2)	(3)	(4)
		High Deposit Banks			
		Ratio of Winsorized Loan Flow	Ratio of Winsorized Loan Flow	Ratio of Winsorized Loan Flow	Ratio of Winsorized Loan Flow
1.	$Avg\_EL_i \times D^{NIR}$	0.22*	0.19**	0.23**	0.13**
		0.13	0.08	0.11	0.06
2.	$Avg\_EL_i \times D^{12}$	-0.09	--	--	--
		0.14	--	--	--
3.	$Avg\_EL_i \times DFR^2$	--	0.02	--	--
		--	0.19	--	--
4.	$Avg\_EL_i \times DFR^3$	--	-0.16	--	--
		--	0.19	--	--
5.	$Avg\_EL_i \times DFR^4$	--	0.10	--	--
		--	0.08	--	--
6.	$Avg\_EL_i \times D^{APP}$	--	--	-0.33	--
		--	--	0.35	--
7.	Cross section fixed effects	Yes	Yes	Yes	No
8.	Time fixed effects	Yes	Yes	Yes	Yes
9.	Country fixed effects	No	No	No	Yes
10.	Observations	3339	3339	3339	3339
11.	R-Squared	0.19	0.19	0.19	0.11
12.	Number of IDs	111	111	111	111

Robust standard errors underneath coefficient estimates.
***p<0.01, **p<0.05, *p<0.1

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Appendix 1

Appendix 1

VARIABLE		Number of Banks	Number of Observations	Mean	Std.dev	t-stat
1.Retail ratio in %	Bottom	84	2,082	30.37	25.66	16.3
	Top	83	2,224	18.65	21.46	
2. Assets	Bottom	84	2,119	49932	74450	-17.88
	Top	83	2,301	121003	168443	
3. Leverage Ratio	Bottom	84	2,107	8.28	9.04	4.40
	Top	83	2,279	6.999	10.15	
4. Liquidity Ratio	Bottom	84	2,052	35.76	21.26	1.90
	Top	81	2,218	26.00	231.57	
5.Wholesale funding in %	Bottom	84	2,083	37.40	27.33	9.44
	Top	83	2,244	29.98	24.31	
6. EL Ratio	Bottom	84	2,107	0.062	0.44	-2.23
	Top	83	2,279	11.11	227.16	
7. Liquidity Ratio (including EL)	Bottom	84	1,956	32.42	19.13	-0.77
	Top	83	1,704	32.92	19.71	

Table A1-1: High EL vs. Low EL Banks (pre-NIRP)

High EL and Low EL banks are defined as those banks in the top tercile and bottom tercile based on average EL ratios in the year before NIRP respectively.

High EL vs. Low EL Banks (NIRP)

VARIABLE		Number of Banks	Number of Observations	Mean	Std.dev	t-stat
1.Retail ratio in %	Bottom	84	956	32.29	25.83	9.99
	Top	83	1,054	21.26	23.64	
2. Assets	Bottom	84	963	50940	83603	-11.84
	Top	83	1,054	128701	187370	
3. Leverage Ratio	Bottom	84	956	9.96	27.97	-0.07
	Top	83	1,054	10.03	12.02	
4. Liquidity Ratio	Bottom	84	943	36.96	22.73	6.05
	Top	81	1,028	25.69	52.84	
5.Wholesale funding in %	Bottom	84	956	31.41	39.67	4.39
	Top	83	1,054	25.05	23.95	
6. EL Ratio	Bottom	84	956	0.24	5.14	-8.19
	Top	83	1,054	13.95	51.52	
7. Liquidity Ratio (including EL)	Bottom	84	910	32.50	18.83	-0.46
	Top	83	881	32.92	19.85	

High EL and Low EL banks are defined as those banks in the top tercile and bottom tercile based on average EL ratios in the year before NIRP respectively.

Table A1-2: Robustness of Excess Liquidity Ratio

Dependent variable: $EL\ ratio_{i,t} = \frac{EL_{i,t}}{Assets_{i,t-1}}$

1.	Avg_EL_i	0.882***
		0.055
2.	$RR_{i.t-1}$	-0.013***
		0.003
3.	$Liquidity\ Ratio_{i.t-1}$	-0.002
		0.005
4.	$Leverage\ Ratio_{i.t-1}$	-0.008
		0.021
5.	$r_{i.t-1}^{loan}$	-0.001**
		0.000
6.	Time fixed effects	Yes
7.	Observations	5543
8.	R-Squared	0.30
9.	Number of IDs	196

Robust (White period) standard errors underneath coefficient estimates.
*** p<0.01, ** p<0.05, * p<0.1
Regression includes a constant and time fixed effects.

Appendix 2

In the DD specification that is considered in the main text, the exposure to treatment is measured as average EL holdings in the year before NIRP, which is constant over time. In this section, we consider an alternative specification that allows us to consider the time varying dimension of our exposure to treatment variable. We specify an equation that is similar to the loan regression in Cornett et al. (2011), to estimate the impact of NIRP on bank loans.

$$
\begin{aligned}
Y_{i,t} = {} & \mathrm{T_t} + \mathrm{B_i} + \beta_0 \mathrm{Y}_{i,t-1} + \beta_1 \mathrm{EL_{i,t-1}}(1 - \mathrm{D^{NIR}}) + \beta_2 \mathrm{EL_{i,t-1}} D^{NIR} \\
& + \beta_3 \mathrm{EL_{i,t-1}}(1\text{-}D^{NIR}) RR_{i,t-1} + \beta_4 EL_{i,t-1} D^{NIR} RR_{i,t-1} \\
& + \beta_5 (1\text{-}D^{NIR}) RR_{i,t-1} + \beta_6 D^{NIR} RR_{i,t-1} \\
& + \beta_7 Liquidity\ ratio_{i,t-1} \\
& + \beta_8 Leverage\ ratio_{i,t-1} + \beta_9 BLS\ demand_t \\
& + \beta_{10} r^{Loan}_{i,t-1} + \beta_{11} Unemployment_{j,t-1} + \varepsilon_{i,t}
\end{aligned}
\qquad ((A.1)
$$

where $Y_{i,t} = Loan\ ratio_{i,t} = \frac{Loans_{i,t}}{Assets_{i,t-1}}$ is the same dependent variable used in our baseline specification, $EL\ ratio_{i,t} = \frac{Excess\ Liquidity_{i,t}}{Assets_{i,t}}$. $Liquidity\ ratio_{i,t} = \frac{Liquid\ assets_{i,t}}{Assets_{i,t}}$, $Leverage\ ratio_{i,t} = \frac{(Capital+Reserves)_{i,t}}{Assets_{i,t}}$, $RR_{i,t} = \frac{Retail\ Deposits_{i,t}}{Assets_{i,t}}$. The following variables are scaled by $1/100$ for comparable coefficient estimates: $BLS\ demand_{j,t}$ is a proxy for loan demand measured from the BLS survey,[15] $r^{Loan}_{i,t-1}$ is composite loan rate, and $Unemployment_{j,t-1}$ is the unemployment rate. The subscript *i* denotes individual bank *i*, and *j* is the country where the bank is located in.

[15] Note that country results for the BLS are used, which ensures cross-sectional variation across countries and therefore does not lead to collinearity problems with the time fixed effects.

Liquid assets are defined as the sum of interbank lending, holdings of government bonds, holdings of debt securities issued by MFIs, holdings of debt securities issued by the private sector, and holdings of equity. Retail deposits are defined as deposits (of all maturities) of households and r_i^{Loan} is the composite lending rate of bank *i*.

We control for the potential endogeneity between macroeconomic variables, bank balance sheet components and the dependent variable by lagging the right hand side variables, which is standard practice in the literature (see e.g. Cornett et al., 2011; Kashyap and Stein, 2000). Carpenter et al. (2014) provide further evidence of a lagged adjustment of loan demand to economic activity. In the robustness section, we also consider a "difference in differences" methodology to address endogeneity issues and illustrate that our results are robust under this approach.

Our strategy for identifying the effects of the NIRP period on bank loan issuance is operationalised in equation (A.1) by interacting the EL ratio with a dummy variable for the NIRP period and by interacting EL with Retail Ratio (RR), which is our measure of banks' retail deposit intensity. If banks are indeed more motivated to turn their EL into loans during the NIRP period, we expect $\beta_2 > \beta_1$. Furthermore, if this response is proportional to their holdings of retail deposits, then we expect $\beta_2 + \beta_4 > \beta_1 + \beta_3$.

Equation (A.1) is estimated as a panel fixed effects model. We include bank fixed effects (B_i) to control for unobservable time-invariant bank-specific factors that affect the decision to extend loans.[16] Moreover, our specifications include time fixed effects (T_t) to control for aggregate shocks. The errors are clustered at the bank level. The estimation sample covers the period from 2007.Q3 to 2018.Q1. The relatively long time dimension of our dataset with 43

[16] Pooled OLS estimates without fixed effects (not reported in the paper) as well as a model that replaces bank fixed effects with country fixed effects give qualitatively similar results.

quarters does not require the use of an Arellano and Bond (1991) type of estimator to address the dynamic structure.[17]

Banks that have more funding through retail deposits are more likely to issue loans ($\beta_5, \beta_6 > 0$). Banks that have more liquid balance sheets or higher capital ratios are expected to issue more loans as well ($\beta_7, \beta_8 > 0$). An increase in demand should increase the volume of loans ($\beta_9 > 0$). We also control for demand with the unemployment rate. An increase in the unemployment rate should lead to a decline in loan issuance ($\beta_{11} < 0$).

Table A2-1a shows the estimation results. We drop the i and j indices to simplify the notation. EL is lagged in order to avoid potential endogeneity. The flow nature of our dependent variable with minimal autocorrelation further helps in eliminating any remaining endogeneity that may arise in a dynamic set up.[18] The coefficient associated with EL (rows 2-3) shows the impact of EL on loans, evaluated when RR=0. The negative and significant coefficient for the high deposit banks (column 3, row 3) likely reflects the economic situation post crisis. This was an environment with parts of the euro area banking sector still de-leveraging while monetary policy reacted to this situation with expansionary measures that led to rising EL while loans for some banks in some countries continued to decline.

As described in the main text, however, there are differences among banks in terms of their exposure to EL. In particular, banks are exposed to a less favourable situation when RR>0,

[17] The Arellano-Bond (1991) estimator is designed for short panels. In long panels, a shock to the cross-sectional fixed effect declines with time and the correlation of the lagged dependent variable with the error term becomes insignificant. Judson and Owen (1999) use Monte-Carlo simulations and show that the so-called "Nickell bias" is no longer significant for panels where the time dimension is larger than 30.

[18] Endogeneity would arise if there is reverse causality from bank loans to EL. There is, however, no reason to expect that the flow of loans in period *t* would influence the stock of EL at the end of the previous period *t-1*. Our framework does indeed suggest that banks that extend more loans would, ceteris paribus, reduce their EL, which would induce a negative bias. To the extent that lagging EL and utilizing flow data for loans does not completely eliminate this bias, our results will err on the conservative side and underestimate the transmission channel that we aim to identify.

which should motivate them to convert their EL into loans, as reflected by the positive and significant coefficient associated with EL×RR during NIRP (column 3, row 5) for high deposit banks. This is consistent with the goal of NIRP and in line with our stylized description of cross sectional differences in Figure 4.

Table A2-1b displays the relevant hypothesis tests. To ascertain whether the NIRP effect is indeed special, it is necessary to jointly consider the coefficients on the double and triple interaction. The first row in Table A2-1b tests whether the joint EL effect is significant in the period before NIRP. The second row tests the same effect for NIRP. The one-sided hypothesis tests whether the joint effect is positive. We note that for the high deposit banks, there is a significant and positive impact such that higher values of EL are associated with more loan extensions. The third row compares the relative magnitudes of the coefficient estimates during the two periods. We observe that the observed response is indeed different (two sided hypothesis) and the response during NIRP period is larger (one sided hypothesis) for medium and high deposit banks.

Based on the results presented in Table A2-1a, the NIRP effect corresponds on average to 8.1 percent of the quarterly lending by high retail banks and 2.8 percent of lending by medium retail banks during the NIRP period. There are approximately 70 banks in each group and this set of banks amounts to 88.6% percent of average non-financial private sector (NFPS) loans in our sample.[19] While this finding is somewhat smaller than the 15 percent increase that is reported in the main text, it is in the same ballpark.

[19] In order to calculate the economic significance of our results, we calculate the ratio: $\frac{ELratio_i(\beta_2+\beta_4 RR_i)}{Loan\ flow_i}$ where Loan flow_i, RR_i and EL ratio_i are the sample average values during NIRP and β_i is the coefficient estimate from equation (1).

The results for our control variables are generally in line with our expectations. Banks that have more retail deposit funding or more liquid balance sheets tend to issue more loans (rows 6-8). A decrease in demand, captured by the increase in the unemployment rate, leads to less loan extension as expected (row 12).

Security holdings

We use the following equation, similar to our loan equation in the previous section:

$$Y_{i,t} = \mathrm{T_t} + \mathrm{B_i} + \beta_0 \mathrm{Y}_{i,t-1} + \beta_1 \mathrm{EL}_{\mathrm{I,t-1}}(1 - \mathrm{D^{NIR}}) + \beta_2 \mathrm{EL}_{\mathrm{i,t-1}} D^{NIR} \quad \text{(A.2)}$$

$$+ \beta_3 \mathrm{EL}_{\mathrm{i,t-1}}(1\text{-}D^{NIR}) RR_{i,t-1} + \beta_4 EL_{i,t-1} D^{NIR} RR_{i,t-1} + \beta_5 (1\text{-}D^{NIR}) RR_{i,t-1}$$

$$+ \beta_6 D^{NIR} RR_{i,t-1} + \beta_7 Liquidity\ ratio_{i,t-1} + \beta_8 Leverage\ ratio_{i,t-1}$$

$$+ \beta_9 \left(r_{i,t-1}^{Loan} - r_{j,t-1}^{10y}\right) + \beta_{10} \Delta r_{j,t-1}^{10y} D^{2014} + \beta_{11} \log(Assets)_{i,t-1}$$

$$+ \beta_{12} Unemployment_{j,t-1} + \varepsilon_{it}$$

where $Y_{i,t} = Securities\ ratio_{i,t} = \frac{Securities_{i,t}}{Assets_{i,t-1}}$. $Securities_{i,t}$ is flow data on either domestic government bonds or non-domestic government bonds . The variable r_j^{10y} denotes the yield on the 10-year government bonds issued in country j, i.e. the country in which the respective bank is located. We interact this variable with a dummy variable after the fourth quarter of 2014 in order to control for the negative interest rate environment. The loan rate as well as the spread of the loan rate with respect to 10-year government bond rate is scaled by $1/100$.

Similar to our logic in the previous section, if banks are more motivated to buy bonds with their EL during NIRP, we expect $\beta_2 > \beta_1$. Furthermore, if this behaviour is more pronounced for higher levels of retail ratios, we expect $\beta_2 + \beta_4 > \beta_1 + \beta_3$.

Tables A2-2 and A2-3 report the estimation results for domestic government bonds, nondomestic government bonds. We do not observe a significant increase in any type of security holding on average during NIRP consistent with our results in the main text.

Better capitalised banks (row 9) tend to be more inclined to acquire non-domestic bonds (Table 3a) and external assets (Table 5a). There is a significant reaction to the opportunity cost of holding non-domestic government bonds (Table 3a, row 11).

Wholesale funding

We consider an empirical specification that is similar to the earlier ones:

$$\begin{aligned} Y_{i,t} = {} & \mathrm{T_t} + \mathrm{B_i} + \beta_0 \mathrm{Y}_{i,t-1} + \beta_1 \mathrm{EL_{i,t-1}}(1 - \mathrm{D^{NIR}}) + \beta_2 \mathrm{EL_{i,t-1}} D^{NIR} \\ & + \beta_3 \mathrm{EL_{i,t-1}}(1\text{-}D^{NIR}) RR_{i,t-1} + \beta_4 EL_{i,t-1} D^{NIR} RR_{i,t-1} \\ & + \beta_5 (1\text{-}D^{NIR}) RR_{i,t-1} + \beta_6 D^{NIR} RR_{i,t-1} + \beta_7\, Liquidity\ ratio_{i,t-1} \\ & + \beta_8\, Leverage\ ratio_{i,t-1} + \beta_9\, BLS\ demand_t \\ & + \beta_{10} \left(r_{j,t-1}^{2y} - r_{i,t-1}^{Deposit}\right) + \beta_{11} Unemployment_{j,t-1} + \varepsilon_{it} \end{aligned} \tag{A.3}$$

where $Y_{\ i,t} = Wholesale\ ratio_{i,t} = \frac{Wholesale\ funding_{i,t}}{Assets_{i,t-1}}$, $r_{j,t-1}^{2y}$ is the yield on the respective two-year sovereign bond, $r_{i,t-1}^{Deposit}$ is the composite deposit rate of each bank. The spread is scaled by $1/100$.

The spread between the two-year sovereign bond rate and the deposit rate is a proxy to capture the relative cost of wholesale funding. Billett and Garfinkel (2004) note that banks' choice between insured and uninsured funding depends on the differential rates charged in the two markets. An increase in this spread reflects an increase in the cost of wholesale funding and hence implies a negative coefficient: $\beta_{10} < 0$. If banks are more motivated to use their EL to pay back their wholesale borrowing during the NIRP period and if this motivation is further reinforced by the bank's business model, then we expect $\beta_2 < \beta_1$. Furthermore, if this behaviour is more pronounced for high deposit holders, we expect $\beta_2 + \beta_4 < \beta_1 + \beta_3$.

Variables such as the leverage ratio indirectly control for banks' unsecured funding costs (Babihuga and Spaltro, 2014) as banks with better capitalisation (i.e. a higher leverage ratio as defined here) should have lower wholesale funding costs and are, therefore, more likely to tap wholesale funding resources: $\beta_8 > 0$.

Table A2-4 shows the estimation results, which does not indicate a significant adjustment during NIRP. Looking at the other control variables, banks that have higher levels of liquid assets tend to rely on less wholesale funding as expected.

Table A2-1a: Effects of NIRP on Bank Loans

Dependent variable: Ratio of winsorized loan flow

VARIABLES	(1) Low retail	(2) Medium retail	(3) High retail
1. Lagged dependent variable	0.052 (0.076)	0.035 (0.038)	0.065** (0.030)
2. $EL\ ratio_{t-1} \times (1 - D^{NIR})$	-0.042*** (0.015)	0.159 (0.111)	-0.120 (0.122)
3. $EL\ ratio_{t-1} \times D^{NIR}$	-0.039** (0.018)	0.034* (0.020)	-0.174** (0.083)
4. $EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1}$	-0.656 (1.568)	-1.003* (0.595)	0.221 (0.225)
5. $EL\ ratio_{t-1} D^{NIR} \times RR_{t-1}$	0.344 (0.321)	-0.120 (0.076)	0.371** (0.162)
6. $RR_{t-1} \times (1 - D^{NIR})$	0.172** (0.072)	0.020* (0.012)	-0.003 (0.012)
7. $RR_{t-1} \times D^{NIR}$	0.091* (0.049)	0.022** (0.011)	0.005 (0.011)
8. $Liquidity\ ratio_{t-1}$	0.026* (0.015)	-0.001 (0.008)	-0.009 (0.019)
9. $Leverage\ ratio_{t-1}$	0.005 (0.037)	-0.009 (0.016)	0.078 (0.096)
10. $BLS\ demand_{t-1}$	-0.002 (0.003)	0.001 (0.001)	0.006* (0.003)
11. r_{t-1}^{Loan}	0.031 (0.105)	-0.158*** (0.057)	-0.073 (0.072)
12. $Unemployment_{t-1}$	-0.062 (0.037)	-0.065*** (0.016)	-0.081*** (0.028)
13. $Constant$	-0.005 (0.008)	0.022*** (0.005)	0.018* (0.011)
Observations	1,953	2,438	2,512
R-squared	0.088	0.132	0.069
Number of ID	60	69	68

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Regressions include cross section and period fixed effects.

Table A2-1b: Hypothesis testing

H0		(1) Low retail	(2) Medium retail	(3) High retail
1. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = 0$	F statistic p-val (two sided)	3.44 0.0686	3.22 0.077	0.02 0.884
2. $EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1} = 0$	F statistic p-val (two sided) p-val (one-sided)	4.51 0.038 0.981	0.01 0.929 0.464	3.52 0.065 0.032
3. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	F statistic p-val (two sided) p-val (one-sided)	0.40 0.529 0.265	3.31 0.073 0.037	2.13 0.149 0.074

Table A2-2a: Effects of NIRP on Domestic Bond Holdings

Dependent variable: Ratio of winsorized flow of domestic sovereign bonds

VARIABLES	(1) Low retail	(2) Medium retail	(3) High retail
1. Lagged dependent variable	0.016	-0.044	0.009
	(0.076)	(0.035)	(0.035)
2. $EL\ ratio_{t-1} \times (1 - D^{NIR})$	-0.003	-0.020	0.167**
	(0.004)	(0.058)	(0.064)
3. $EL\ ratio_{t-1} \times D^{NIR}$	0.002	-0.056*	0.063
	(0.006)	(0.031)	(0.060)
4. $EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1}$	0.089	0.194	-0.166**
	(0.263)	(0.268)	(0.076)
5. $EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	0.001	0.461*	-0.059
	(0.091)	(0.257)	(0.102)
6. $RR_{t-1} \times (1 - D^{NIR})$	0.008	-0.003	0.000
	(0.014)	(0.015)	(0.004)
7. $RR_{t-1} \times D^{NIR}$	0.010	-0.014	-0.005
	(0.015)	(0.014)	(0.005)
8. $Liquidity\ ratio_{t-1}$	-0.002	-0.019***	-0.020**
	(0.005)	(0.006)	(0.008)
9. $Leverage\ ratio_{t-1}$	0.001	0.006	0.011
	(0.008)	(0.011)	(0.015)
10. $r_{t-1}^{Loan} - r_{t-1}^{10y}$	0.025	-0.036	0.029
	(0.026)	(0.023)	(0.070)
11. $\Delta r_{t-1}^{10y} \times D^{2014}$	0.161	0.240	-0.130
	(0.167)	(0.253)	(0.381)
12. $\log(Assets)_{t-1}$	-0.119	-0.247	0.148
	(0.089)	(0.293)	(0.159)
13. $Unemployment_{t-1}$	0.014	-0.020	0.019
	(0.011)	(0.014)	(0.019)
14. $Constant$	0.013	0.034	-0.010
	(0.009)	(0.035)	(0.016)
Observations	1,967	2,439	2,546
R-squared	0.044	0.073	0.046
Number of ID	60	69	68

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Regressions include cross section and period fixed effects.

Table A2-2b: Hypothesis testing

H0		(1) Low retail	(2) Medium retail	(3) High retail
1. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = 0$	F statistic p-val (two sided)	0.05 0.825	1.26 0.266	6.82 0.011
2. $EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1} = 0$	F statistic p-val (two sided) p-val (one-sided	0.18 0.672 0.336	2.81 0.098 0.049	1.83 0.181 0.091
3. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	F statistic p-val (two sided) p-val (one-sided)	0.23 0.632 0.316	1.44 0.235 0.117	3.94 0.051 0.974

Table A2-3a: Effects of NIRP on Non-Domestic Bond Holdings

Dependent variable: Ratio of winsorized flow of non-domestic sovereign bonds

VARIABLES	(1) Low retail	(2) Medium retail	(3) High retail
1. Lagged dependent variable	-0.094	0.066	0.115**
	(0.060)	(0.066)	(0.056)
2. $EL\ ratio_{t-1} \times (1 - D^{NIR})$	-0.001	-0.029	0.025
	(0.002)	(0.067)	(0.047)
3. $EL\ ratio_{t-1} \times D^{NIR}$	-0.002	0.008	0.008
	(0.006)	(0.012)	(0.020)
4. $EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1}$	0.260	0.289	-0.058
	(0.239)	(0.416)	(0.101)
5. $EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	-0.129	-0.034	-0.032
	(0.200)	(0.065)	(0.040)
6. $RR_{t-1} \times (1 - D^{NIR})$	-0.012	0.003	0.001
	(0.010)	(0.003)	(0.001)
7. $RR_{t-1} \times D^{NIR}$	-0.015**	0.009**	-0.000
	(0.007)	(0.004)	(0.001)
8. $Liquidity\ ratio_{t-1}$	-0.001	-0.004	0.001
	(0.002)	(0.002)	(0.003)
9. $Leverage\ ratio_{t-1}$	0.002	0.008**	0.006
	(0.004)	(0.003)	(0.006)
10. $r_{t-1}^{Loan} - r_{t-1}^{10y}$	0.015	0.004	0.016
	(0.011)	(0.010)	(0.019)
11. $\Delta r_{t-1}^{10y} \times D^{2014}$	0.389*	-0.020	0.094
	(0.204)	(0.094)	(0.090)
12. $\log(Assets)_{t-1}$	0.014	0.007	-0.028
	(0.040)	(0.089)	(0.046)
13. $Unemployment_{t-1}$	0.009	-0.004	-0.007
	(0.007)	(0.004)	(0.005)
14. $Constant$	-0.002	-0.000	0.003
	(0.004)	(0.011)	(0.004)
Observations	1,967	2,439	2,546
R-squared	0.052	0.038	0.036
Number of ID	60	69	68

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Regressions include cross section and period fixed effects.

Table A2-3b: Hypothesis testing

H0		(1) Low retail	(2) Medium retail	(3) High retail
1. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = 0$	F statistic p-val (two sided)	0.84 0.362	1.18 0.281	0.24 0.626
2. $EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1} = 0$	F statistic p-val (two sided) p-val (one-sided)	1.07 0.304 0.848	0.03 0.860 0.57	2.86 0.095 0.952
3. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR = EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	F statistic p-val (two sided) p-val (one-sided)	2.11 0.152 0.924	1.32 0.254 0.873	0.61 0.438 0.781

Table A2-4a: Effects of NIRP on Wholesale Funding

Dependent variable: Ratio of winsorized flow of wholesale funding

VARIABLES	(1) Low retail	(2) Medium retail	(3) High retail
1. Lagged dependent variable	-0.062	-0.061*	-0.039
	(0.044)	(0.033)	(0.042)
2. $EL\ ratio_{t-1} \times (1 - D^{NIR})$	-0.038*	-0.343	-0.235***
	(0.020)	(0.387)	(0.081)
3. $EL\ ratio_{t-1} \times D^{NIR}$	-0.306**	0.039	0.286
	(0.136)	(0.059)	(0.243)
4. $EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1}$	5.399**	1.300	0.393**
	(2.118)	(1.604)	(0.149)
5. $EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	2.555	-0.179	-0.467
	(1.833)	(0.259)	(0.343)
6. $RR_{t-1} \times (1 - D^{NIR})$	-0.106	0.068***	0.024*
	(0.114)	(0.019)	(0.013)
7. $RR_{t-1} \times D^{NIR}$	-0.089	0.067***	0.026
	(0.122)	(0.020)	(0.016)
8. $Liquidity\ ratio_{t-1}$	-0.044	-0.018	-0.014
	(0.030)	(0.012)	(0.015)
9. $Leverage\ ratio_{t-1}$	0.051	0.046	0.024
	(0.062)	(0.038)	(0.058)
10. $BLS\ demand$	-0.009	-0.004	0.002
	(0.009)	(0.003)	(0.003)
11. $r_{t-1}^{2y} - r_{t-1}^{Deposit}$	-0.051	-0.002	-0.012
	(0.086)	(0.062)	(0.083)
12. $Unemployment_{t-1}$	-0.077	-0.029	-0.066*
	(0.118)	(0.034)	(0.039)
13. $Constant$	0.034**	-0.009	0.001
	(0.017)	(0.008)	(0.011)
Observations	1,377	2,437	2,444
R-squared	0.099	0.064	0.045
Number of ID	51	69	68

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Regressions include cross section and period fixed effects.

Table A2-4b: Hypothesis testing

H0		(1) Low retail	(2) Medium retail	(3) High retail
1. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = 0$	F statistic	1.94	0.52	0.90
	p-val (two sided)	0.170	0.473	0.348
2. $EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1} = 0$	F statistic	5.13	0.08	0.05
	p-val (two sided)	0.028	0.772	0.823
	p-val (one-sided)	0.014	0.386	0.588
3. $EL\ ratio_{t-1} \times (1 - D^{NIR}) + EL\ ratio_{t-1} \times (1 - D^{NIR}) \times RR_{t-1} = EL\ ratio_{t-1} \times D^{NIR} + EL\ ratio_{t-1} \times D^{NIR} \times RR_{t-1}$	F statistic	7.24	0.33	0.84
	p-val (two sided)	0.010	0.569	0.361
	p-val (one-sided)	0.014	0.715	0.819