Expansionary Yet Different: Credit Supply and Real Effects of Negative Interest Rate Policy*

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Abstract

We show that negative interest rate policy (NIRP) has expansionary effects on credit supply through a portfolio rebalancing channel. By shifting down and flattening the yield curve, NIRP differs from rate cuts just above the zero-lower-bound and has effects similar to QE. For identification, we exploit ECB's NIRP and the Italian credit register, and, for external validity, European and U.S. datasets. NIRP affects more banks with higher ex-ante liquid assets, including net interbank positions. More exposed banks reduce liquid assets, expand credit supply, especially to financially-constrained firms, and cut loan rates, inducing firms to increase investment and the wage bill.

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"By and large our negative interest-rate policies have been a success."

Mario Draghi (October 2017), President of the European Central Bank

"We do not see negative policy rates as likely to be an appropriate policy response here in the U.S."

Jerome Powell (March 2020), Chair of the U.S. Federal Reserve

"I would say that's the most important question in the world. And I don't know the answer. Now, if we knew the answer, it wouldn't be the most important question."

Warren Buffet (March 2020), answering a question on the impact of negative rates

1 Introduction

Negative interest rate policy (NIRP) is a significant innovation in monetary policy-making, with important implications for finance and the economy overall. As the opening quotes suggest, these implications are at the center of a heated debate among policymakers, market participants, and academics. Long thought as unrealistic, NIRP was adopted in several advanced economies such as Denmark, Switzerland, Sweden, the euro area, and Japan, by charging negative rates on *bank* deposits at central banks. The debate about the effects and the desirability of NIRP remains highly relevant in the current environment of ultra-low interest rates, and even more so after the Covid-19 pandemic.[1]

Despite its importance, systematic evidence on the transmission of NIRP to the economy through the banking system remains scarce. To fill this gap, we exploit comprehensive loan-level data from credit registers and firm-level outcomes, together with the introduction of NIRP by the ECB and other conventional and unconventional monetary policy announcements at the zero-lower-bound (ZLB), to answer two major questions. First, what is the impact of NIRP on credit supply and the real economy? Second, do negative policy rates differ in their transmission to the economy from conventional rate cuts just above the ZLB, and from other unconventional monetary policies (UMPs), such as quantitative easing (QE)?

These questions are particularly important because the effects of NIRP on the economy are a priori unclear. Macroeconomic theory argues that a policy rate cut expands aggregate demand, thereby boosting economic growth and prices, hence it finds in the ZLB a major constraint (Bernanke, 2017; Rogoff, 2016, 2017; Dell'Ariccia et al., 2018). As shown in the opening quotes, Draghi (2017) argues that NIRP has had positive effects.[2] However, other central banks did not adopt NIRP, as the positive

[1] Since 1970 policy rates have been cut by more than 500 basis points (bps) in response to recessions in the U.S. and the euro area (Eggertsson et al., 2019).

[2] This positive assessment was recently reaffirmed by Isabel Schnabel (2020), Member of the Executive Board of the ECB,

aggregate demand channel can be offset by a contraction in credit supply due to the adverse effect of negative rates on banks' net worth (Sims and Wu, 2021). Brunnermeier and Koby (2018) show that there may be a "reversal" interest rate beyond which further rate cuts become contractionary for bank lending, and Wang et al. (2021) estimate a structural model showing that a rate cut may become contractionary even when the interest rates are ultra-low but still positive.[3]

Negative policy rates can affect the real economy through the banking system also through portfolio rebalancing away from liquid assets, that earn very low or negative yields following NIRP, toward higher-yielding assets such as corporate loans (see e.g., Bernanke, 2016; Rostagno et al., 2016, 2019; Schnabel, 2020). In the words of Brunnermeier and Koby (2018): *"as yields on safe assets decrease, banks decrease their lending rates for risky loans in order to substitute their safe assets positions into riskier high-yield ones, another effect which the central bank seeks to induce."* The announcement of NIRP moves the entire yield curve downward—after breaking through the ZLB, market participants expect rates to stay low or negative for long—and this reduces yields on liquid assets, some of which may even became negative. With all liquid assets in the bank balance sheets now earning less (including excess reserves directly taxed by NIRP), banks may have an incentive to preserve profitability by reducing not only excess reserves, but also liquid holdings more broadly, and by acquiring higher yield assets (such as corporate loans). According to this logic, a policy rate cut below zero would work differently from regular policy rate cuts above but close to the ZLB which, by affecting only the short end of the yield curve, do not offer similar rebalancing incentives. Relatedly, QE announcements may induce similar portfolio rebalancing actions by flattening the yield curve and thus reducing the returns on safer assets and encouraging financial institutions to invest in riskier assets (Haldane et al., 2016; Krishnamurthy and Vissing-Jorgensen, 2011).[4]

Portfolio rebalancing can be also seen as a manifestation of the risk-taking channel of monetary policy (Adrian and Shin, 2010; Borio and Zhu, 2012; Dell'Ariccia et al., 2017; Diamond and Rajan, 2012; Jiménez et al., 2014; Rajan, 2005). NIRP may induce banks with more liquid assets to reallocate

in a review of ECB's experience with negative rates: "*the lowering of policy rates into negative territory fostered monetary policy transmission in the euro area, as evidenced by the strong pass-through from policy rates to market rates and higher loan growth.*"

[3]Consistent with these models, NIRP can have a contractionary effect on credit supply through a "retail deposit channel." Given that banks are generally reluctant to charge negative rates on retail deposits, NIRP can put pressure on banks' net interest margins and profits, eroding capital, and reducing lending capacity, leading to lower credit supply (Heider et al., 2019) or a weakened pass-through to loan rates (Eggertsson et al., 2019). Some studies find that these contractionary effects can be dampened by higher aggregate demand (Ulate, 2021), selective pass-through of negative rates to some retail depositors (Altavilla et al., 2021), or higher fees (Altavilla et al., 2018; Lopez et al., 2020).

[4]See, e.g. Paludkiewicz (2021); Albertazzi et al. (2020); Gambetti and Musso (2017); Altavilla et al. (2015) for the euro area; D'Amico and King (2013) for the U.S. It is nevertheless important to note that QE may have limitations as it requires large expansions of central bank balance sheets and reduces the private holdings of assets that are crucial for the repo market.

part of their portfolios to corporate loans, and especially to riskier borrowers, following a search-for-yield strategy. If this mechanism is at play, the effects should be stronger for banks with low capital and the expansion of credit should be directed especially to ex ante riskier firms or to firms that are more financially constrained, such as small and medium-sized enterprises (SMEs). Finally, portfolio rebalancing toward loans could additionally be incentivized by a general improvement in credit quality. NIRP and QE announcements are large monetary policy shocks that can promote recovery in the real economy by improving debt repayment capacity, raising corporate profits, and reducing corporate delinquencies and defaults (Chodorow-Reich, 2014). Thus, higher ex ante risk-taking due to low or negative interest rates needs not to imply higher ex post defaults.

For the main analysis we use the supervisory credit register of the Bank of Italy, that contains detailed information on bank loans to nearly all Italian firms, double-matched with firm and bank balance sheet information. Italy provides an ideal setting for an analysis of NIRP transmission through banks because of its specific context and comprehensive administrative datasets. Italy is a large European economy where the banking sector provides the bulk of firm financing and is part of a monetary union—that is, Italian banks are affected by the ECB monetary policy that are set according to the conditions of the *entire* euro area.

The granular nature of our loan exposure data at the firm-bank-month level allows us to control for unobserved time-varying heterogeneity across firms, mitigating potential concerns that our results work through the effect of NIRP on firms' credit demand. Across all our main lending specifications, we include firm fixed effects that keep firm-level fundamentals constant, including firm-level credit demand (Khwaja and Mian, 2008). Further, we analyze both credit volume and rates, and can test whether rates decline while volumes expand, consistent with a credit supply interpretation.

Our empirical approach exploits cross-sectional variation in ex ante exposure to NIRP across banks. We use two bank-level exposure variables: the net interbank position and overall liquid assets.[5] The net interbank position is computed as interbank loans minus deposits with maturity of up to one week (measured before the NIRP announcement and divided by total assets). We adopt this narrower measure of exposure to NIRP because interest rates on interbank funding up to one week became negative soon after the introduction of the policy. In addition, interbank activity in Italy (and in Europe in general) is sizeable, and most interbank claims have maturity below one week. The banks' liquid balance sheet position is measured as the ratio of securities over assets (Kashyap and

[5]We do not use excess reserves as an exposure variable because they are negligible in Italy, similar to other peripheral European countries (Baldo et al., 2017).

Stein, 2000). This measure is more encompassing in terms of asset size, types, and maturities, and represents 29% of total assets for the average Italian bank. We adopt this broader measure of exposure to NIRP to capture banks' holdings of low-yielding securities given that the downward shift in the yield curve reduced yields across all maturities.

Our main results are as follows. First, after the introduction of NIRP, in the time-series total bank credit growth increases.[6] Further, banks with larger ex ante net interbank position cut interbank loans more and banks with more liquidity reduce the share of liquid assets in their portfolio. Moreover, in the loan-level data, we find that more exposed banks (through higher net interbank position or overall liquidity) increase the supply of corporate loans relatively more after the introduction of NIRP. This effect is present as early as one month after the implementation of the policy and persists for at least six months. We also show that more exposed banks reduce loan rates—a one standard deviation (SD) increase in the net interbank position or in liquidity is associated with a reduction of around 4% in loan rates.

Second, the expansion of credit by more liquid banks is concentrated among low-capital exposed banks, which rebalance their assets by taking more ex ante risk in their loan portfolios. The relative increase in loan supply is stronger vis-a-vis smaller and ex ante riskier firms (where firm risk is measured by its credit rating). Importantly, we find no evidence that this increase in risk-taking translates into higher non performing loans (NPLs), even after five years. Therefore, greater bank risk-taking after NIRP is consistent with higher credit supply to more financially-constrained but viable firms.

Third, the increase in credit supply by more liquid banks is associated with sizable firm-level real effects. A one SD increase in banks' net interbank position (liquidity) is associated with a 2.4 (1.0) percentage points (pps) increase in total credit growth. In addition, more bank credit translates into stronger firm performance, as firms borrowing more from lenders with greater ex ante exposure to NIRP expand economic activity relatively more. A one SD increase in banks' net interbank position (liquidity) is associated with an increase in exposed firms' investments by 6.8 (4.6) pps and in the wage bill by 3.8 (1.0) pps.

Fourth, we show that NIRP works differently than rate cuts just above the ZLB. While NIRP's introduction steered market expectations by "breaking through the ZLB" and inducing both a downward shift and a simultaneous flattening of the yield curve,[7] conventional rate cuts just above the

[6] This development is not specific to Italy as credit growth picked up in the entire euro area after the introduction of NIRP (Cœuré, 2016; ECB, 2020; Schnabel, 2020).

[7] See also Draghi (2016); Cœuré (2017); Grisse et al. (2017). Christensen (2019) shows that the yield curve flattened after

ZLB only affected the short end of the curve. Our tests for the two rate cuts preceding NIRP—-the 2012 deposit facility (DF) rate cut and the 2013 main refinancing operation (MRO) rate cut—-indicate that those events did not induce portfolio rebalancing.[8] By contrast, we find that the March 2016 rate cut further in negative territory was able to shift down and flatten the yield curve, albeit to a smaller extent, and also induce portfolio rebalancing effects. This finding may be related to the fact that market participants do not know exactly where the "effective lower bound" is and therefore new cuts into negative territory retain a surprise element.

Fifth, we show that portfolio rebalancing is not specific to NIRP, but it also manifests after QE announcements that shift the yield curve, with a differential effect on the supply of credit depending on banks' ex ante liquidity. We study the ECB's January 2015 announcement of QE policies and find that banks with ex ante more liquid assets expand more credit supply after QE. For external validity, we analyze the case of the U.S., where NIRP was not adopted but similar shifts in the yield curve occurred after QE. Focusing on two QE events involving large-scale asset purchases by the Federal Reserve in November 2008 and August 2010—both of which flattened the yield curve—we show that ex ante more liquid banks increase credit supply relatively more following these events.

We further probe the external validity of our results with a bank-level analysis across the entire euro area and find that more liquid banks expand lending after NIRP more than other banks, consistent with the portfolio rebalancing channel documented for Italy. Falsification tests show that our baseline lending and real-effects results are not driven by systematic differences across banks in their lending to firms with certain characteristics nor by prior trends. Our results are robust to controlling for valuation effects ("windfall gains") associated with the repricing of securities due to NIRP (or QE in the U.S. analysis) and for the Targeted Longer-Term Refinancing Operations (TLTRO) implemented by the ECB a few months after NIRP. Furthermore, they hold in narrowly defined time windows of one or three months that reduce the potential effect of confounding policies. Finally, in addition to event studies around policy events, we provide direct evidence of the effect of the slope of the yield curve in a bank-firm-quarter panel and show that banks with ex ante more liquid assets, including net interbank positions, increase credit supply relatively more after a flattening of the yield curve.

the announcement of NIRP in all countries which adopted NIRP (including Denmark, Sweden, Switzerland and Japan).

[8] Although one may think that banks hold large liquid assets to take advantage of positive macro shocks to lend more, previous evidence shows that this is generally not the case (Kashyap and Stein, 2000; Jiménez et al., 2012).

Contribution to the literature. Our analysis adds to a nascent literature on NIRP that, so far, offers mixed findings. Some studies emphasize the contractionary retail deposit channel via banks' liability structure (Heider et al., 2019; Eggertsson et al., 2019; Bittner et al., 2020), while others document expansionary effects through bank excess reserves (Basten and Mariathasan, 2018; Demiralp et al., 2021). Altavilla et al. (2021) show that negative rates in Europe are expansionary through a corporate channel—more exposed firms that hold cash at banks respond to negative deposit rates by reducing cash holdings and boosting investment. Compared to this literature, we document expansionary effects of NIRP through a bank *portfolio rebalancing channel* from liquid assets to corporate loans, via shifts in the entire yield curve associated with the introduction of the policy. By contrast, we find no systematic evidence of a contractionary retail deposit channel of NIRP, although Italy may not be the best setting to test this channel, as deposit rates in Italy were higher than in the core euro area before the announcement of NIRP, allowing more room for adjustment. Furthermore, we compare the transmission of NIRP with both conventional cuts in the short rate just above the ZLB, and with other UMPs—specifically, QE. While our main results are for Italy, we also analyze for external validity euro area and U.S. data and policies.

Our paper further contributes to the broader literatures on UMPs such as large-scale asset purchases, liquidity injections, and forward guidance (see, among others, Bhattarai and Neely (2016); Rodnyansky and Darmouni (2017); and Chakraborty et al. (2020) for U.S. policies; and Acharya et al. (2016); Acharya et al. (2019) and Peydró et al. (2021) for European policies), the risk-taking channel of monetary policy (see Adrian and Shin, 2010; Dell'Ariccia et al., 2017; Diamond and Rajan, 2012; Jiménez et al., 2014; Maddaloni and Peydró, 2011, among others), and the bank lending channel of monetary policy (Kashyap and Stein, 1995, 2000; Jiménez et al., 2012; Drechsler et al., 2017). A key contribution of our paper to these strands of literature is to analyze the portfolio rebalancing channel of *negative* interest rates, the effects on bank credit supply, risk taking, and the real economy, and to investigate how NIRP compares to traditional rate cuts just above the ZLB and with other types of UMP, such as QE. Furthermore, our estimates of the elasticity of credit with respect to bank liquidity can inform future theoretical work on the transmission of UMP, including macro-finance models of the transmission of NIRP to the economy through the bank lending channel, in the spirit of Nakamura and Steinsson (2018) and structural banking models emphasizing the expansionary portfolio rebalancing channel of NIRP. Finally, our finding that negative rates are expansionary through banks lends support to the view that policy rate cuts do not become ineffective at the ZLB (Rognlie, 2016; Swanson, 2018; Debortoli et al., 2019).

2 Institutional Background

In this section we discuss the institutional context in which the ECB introduced NIRP and the details of its implementation. In doing so, we lay out the key elements of our empirical strategy.

Italy is part of a monetary union, and hence unlike most countries around the world, monetary policy is not decided by its own central bank, but by the ECB for the entire euro area. Before NIRP, monetary conditions had been tighter in Italy than in several other European countries and the U.S.[9] In Italy, GDP growth was negative in both 2012 and 2013. At that time, the ECB had not yet introduced QE and its balance sheet was shrinking (partly due to early LTRO repayments). By contrast, the U.S. Federal Reserve and the Bank of England already had introduced large scale asset purchase programs (LSAPs) and their balance sheets were expanding. Against the backdrop of negative GDP growth and low and declining inflation in 2013,[10] the ECB decided to cut rates into negative territory in mid-2014. These developments suggest that ECB's monetary policy in June 2014 did not directly address the macroeconomic context in Italy, but rather the slowdown in economic recovery in the euro area as a whole, with the goal of maintaining price stability in the area.

The ECB is not the only central bank to implement NIRP. Since 2012, other major central banks around the world have adopted negative monetary policy rates in an effort to either further ease monetary conditions and to support economic activity (e.g., Japan) or to limit capital inflows and related exchange rate appreciation (e.g., Switzerland and Denmark). In August 2019, policy rates were negative in countries accounting for 25% of world GDP and the amount of debt globally trading at negative yields reached USD 17 trillion.[11] On June 11, 2014, the ECB reduced the deposit facility (DF) rate—the rate it pays on overnight deposits with the central bank in excess of reserve requirements ("excess reserves")—to -0.10%.[12] The rationale behind this rate cut was to further ease monetary conditions by pushing down yields and borrowing costs and to encourage banks to invest in alternative assets, boosting their prices. In the words of Hutchinson and Smets (2017, p. c3), "*the rationale of*

[9] Not only compared to other euro area countries, but also to Switzerland and Sweden, both of which introduced negative policy rates.

[10] In fact, the inflation rate was below 1% at the end of 2013 and further declined in 2014, turning to deflation by the end of the year.

[11] Source: "Market Swing on Trade and Monetary Policy", September 2019, BIS Quarterly Review, Bank of International Settlements.

[12] Euro area banks are required to hold a certain amount of funds as reserves in their current accounts at their national central bank (minimum reserve requirement), which are remunerated at the main refinancing operation rate. Further, they can hold reserves in excess to the minimum reserve requirement either in the Eurosystem deposit facility or as reserve holdings in their current accounts. Differently from the past, ever since the ECB introduced a negative rate on the deposit facility, it treats the current account balances (in excess of the minimum reserve requirement) and the deposit facility in the same way. Both yield negative rates.

this measure was that by extending the scope of conventional monetary policy beyond the ZLB, the entire distribution of short-term rates was shifted downwards and additional stimulus could be provided to the economy." The ECB further cut its DF rate to -0.20% on September 10, 2014, to -0.30% on December 9, 2015, to -0.40% on March 16, 2016 and, finally, to -0.50% on September 18, 2019, when the rules for the implementation of the policy changed with the introduction of the two-tier system for remunerating excess liquidity holdings.

Short-term interbank rates dipped below zero soon after the June 2014 cut of the DF rate. The Euro OverNight Index Average (EONIA), a measure of the cost of funds on the Eurozone overnight interbank market, turned negative for the first time in August 2014. Soon after, the one-week Euro Interbank Offered Rate (EURIBOR) became negative as well and stayed below zero during the entire period of analysis (see Figure 1). Around the NIRP announcement, the declines in the interbank rates at one-month and three-month maturities were smaller and both rates remained positive throughout the period.

Importantly, the announcement of NIRP also affected the middle and long end of the yield curve. In fact, the entire yield curve shifted downward and flattened (see Figure 2). We conjecture that the decline in the yield of liquid assets across all maturities incentivized banks to rebalance their portfolios from liquid assets toward riskier, more illiquid assets (such as corporate loans, especially to SMEs). We discuss these developments and the role they play in our results in detail in Section 3.2.

In May 2014, the growth rate of bank credit to businesses in Italy was negative, at -4.7% on a yearly basis, in an environment of depressed aggregate demand. As shown in Figure 3, immediately after the introduction of NIRP, credit growth picked up, reaching -3.1% at the end of June 2014. While still negative, credit growth continued to rise, reaching -2.3% in December 2014. Besides reflecting demand dynamics, for which we carefully control in the analysis, these developments may have benefitted from other ECB monetary policies implemented around the same time as NIRP. Notably, on June 5, 2014 the ECB announced its TLTRO program and started it in September 2014. The program aimed at boosting bank credit by offering long-term funding to Eurozone banks on attractive terms. If the TLTRO had an expansionary effect on the economy before its implementation and if banks' take-up of TLTRO funds was correlated with their March 2014 net interbank and liquidity positions, we may incorrectly attribute our estimated effects to NIRP instead of this policy. To address this potential concern, we control for the TLTRO with a bank-level measure of ex ante capacity to borrow under the TLTRO, derived from supervisory data. Furthermore, Benetton and Fantino (2021) show that while TLTRO reduced the costs of credit for Italian firms, it only did so after the implementation

of the second round of the program, that is, *only in the second and third quarter of 2015*, and hence outside our baseline time window. (We discuss the TLTRO in more detail and show our main results are robust to controlling for this policy in Section 4.1.)

A few months later, on January 22, 2015, the ECB announced the expansion of its limited Asset Purchase Program (APP). This policy action, implemented starting March 9, 2015, was widely seen as the start of the ECB's QE, with the objective of providing additional monetary policy stimulus and further easing borrowing conditions of households and firms. Specifically, the ECB expanded its existing, quantitatively limited asset-purchase programs of covered bonds and asset-backed securities to include public-sector bonds for a total of 60 billion euros' worth of monthly purchases.[13] Both the announcement and the implementation of this program are largely outside the time window of our baseline results, so we can rule out the APP affecting our estimates. That said, we also analyze the effects of this LSAP QE policy (in addition to previous conventional and unconventional monetary policies) and compare them with NIRP, in order to understand whether—and why—NIRP is special. Finally, we study the last monetary rate cut in the NIRP period (March 2016).

3 Data and Empirical Hypotheses

In this section we explain the different datasets, empirical hypotheses, and identification. For empirical identification, we exploit several matched administrative datasets, together with the introduction of NIRP and other monetary policy events. To pin down the mechanisms, we exploit differences in ex ante bank balance sheet characteristics that are consistent with different channels of transmission (portfolio rebalancing vs. retail deposits), credit supply via volume and loan rates in a within-firm setting, and the change in the yield curve. We also discuss our data and empirical strategy for the analysis of the associated real effects.

3.1 The Credit Register and Other Data

In our main analysis we employ a double-matched administrative bank-firm monthly panel dataset covering the lending activities of Italian banks between 2012 and 2016. The dataset draws on three

[13] The initial asset-purchase programs of covered bonds (CBPP3) and asset-backed securities (ABSPP) were announced in September 2014 and implemented, respectively, in October and November 2014. These initial purchases were so limited quantitatively that only the announcement of January 2015 is considered to be the start of the ECB QE programme, also called LSAP (see, e.g., Paludkiewicz (2021); Albertazzi et al. (2020); Gambetti and Musso (2017), and Altavilla et al. (2015)). That said, in Section 4.1 we show that our results are robust even if we consider a very narrow window of one month around the NIRP announcement.

sources: (i) the loan-level credit register of the Bank of Italy, which reports outstanding loan exposures (with minimum size of 30,000 euros) of all banks operating in Italy vis-a-vis Italian non-financial firms; (ii) supervisory data on bank balance sheets; and (iii) data on firm financials from the proprietary CADS database, owned by Cerved Group, a member of the European Committee of Central Balance-Sheet Data Offices that collects official balance sheet data reported by firms to the Chambers of Commerce, as required by Italian law. All data are monthly, with the exception of firm financials which are yearly and selected bank balance sheet variables which are quarterly (such as capital and net interbank position) or semiannual (income from fees).

Given the relatively small loan size threshold for inclusion of loans in the credit register, its coverage of bank-firm relationships is nearly universal. We drop foreign bank branches and subsidiaries (as their liquidity depends on foreign headquarters) and cooperative or mutual banks (as they are subject to different regulations). Our final regression sample contains more than 167,000 firms with multiple banking relationships, borrowing from 95 banks. Loan exposures (commitments) refer to credit lines, overdraft facilities, and term loans. Data on loan interest rates come from a special section of the credit register (Taxia) and are reported by a representative sample of the largest banking groups and individual banks (covering more than 80% of total bank lending in Italy).[14]

For a robustness test, we also use data from the securities register at the Bank of Italy, with information on the holdings of each security held by each bank in each month, coupled with data on yields and prices from Thomson Reuters Eikon, on the basis of which we construct a bank-level measure of windfall gains (defined as profits or losses due to the revaluation of the securities in the portfolios). For external validity tests, we employ bank-level data for euro area banks from Fitch Connect, supervisory loan-level data for the largest U.S. banks from the Y-14Q, and bank-level survey data from the quarterly Senior Loan Officer Opinion Survey (SLOOS) conducted by the Federal Reserve.

Italian banks play a key role in financing the real economy, as most borrowers are SMEs with limited access to alternative sources of external financing. Commercial banks have a traditional business model focused on loan intermediation and banking services. Retail deposits (collected almost entirely from domestic residents) account for 69% of total funding, wholesale funding for 24%, and Eurosystem financing for the remaining 7%. On the asset side, loans to the private sector account for

[14] For each credit relationship with commitments above 75,000 euros, banks report two numbers each quarter: first, the amount paid as interest and second, the amount of the loan outstanding times the days the amount was outstanding. If the outstanding amount is 100,000 euros for 45 days and 150,000 for the remaining 45 days of the quarter, the reported number is 100,000×45+150,000×45. By dividing the interest payments by the second number we obtain the interest rate paid on the loan, which we annualize (see Sette and Gobbi, 2015).

39% of total assets (with loans to non-financial firms at 60% of the average bank's loan book).

3.2 Identification Strategy

3.2.1 Portfolio Rebalancing vs. Retail Deposit Channel

In the words of the ECB President Mario Draghi: *"negative [policy] rates were introduced for one specific reason: when interest rates reached the zero lower bound, the expectations for the future rates in the long term are only that the rates can go up. So with negative rates we were successful in taking these expectations down"* (Draghi, 2016). NIRP puts downward pressure on the yields of bank liquid assets and shifts banks' risk-reward calculus for asset allocation, with higher-yielding assets such as loans becoming more attractive (Bernanke, 2016; Rostagno et al., 2016, 2019). Moreover, when interest rates become negative, profit margins can shrink if banks do not pass short-term funding rates to retail deposits (Heider et al., 2019; Eggertsson et al., 2019). Therefore, both a portfolio rebalancing channel and a retail deposit channel may operate simultaneously and exert an opposite effect on lending.

We conduct a cross-sectional analysis of bank balance sheets to show that Italian banks with more retail deposits before the introduction of negative rates did not experience a relative decline in profitability in the six months after NIRP (Table A1). In addition, we find evidence suggesting that banks were able to compensate for any compression of intermediation margins from incomplete pass-through of negative rates to retail deposit rates with higher fees on banking services.[15] Table A2 shows that banks with greater ex ante retail deposits generate higher income from fees for deposit services in the months following the introduction of NIRP. Furthermore, retail deposit rates were low but not at zero in Italy before the introduction of NIRP (Bank of Italy, 2015), suggesting that banks had room to adjust such rates downwards before hitting the effective lower bound of deposit rates. Taken together, these findings suggest that the contractionary retail deposit channel may be inactive in the Italian context; we directly test this hypothesis and discuss additional evidence in Section 4 for Italian banks and in Section 4.6 for euro area banks.

3.2.2 Portfolio Rebalancing Channel and Bank Exposure Variables

To identify the portfolio rebalancing channel, we focus on two measures of ex ante bank exposure to NIRP: first, the net interbank position and, second, a broader measure of balance sheet liquidity. Both measures are computed before the enactment of the policy.

[15] Another way to compensate for shrinking intermediation margins, as we discuss later, is to increase lending volumes. In fact, there is an overall increase in lending for all banks after the introduction of NIRP.

The European interbank market is very large and is mainly concentrated in short-term maturities (Upper, 2006). Interest rates in this market were immediately affected by NIRP. The one-week Euro Interbank Offered Rate (EURIBOR) experienced the largest drop compared with interbank rates at longer maturities and soon even became negative. Given that banks generally act as both lenders and borrowers in the interbank market (Angelini et al., 2011; Acharya and Merrouche, 2012), we measure bank-level exposure to NIRP with the net interbank position, computed as the difference between interbank loans and interbank deposits with maturity up to one week, divided by total assets. This measure includes all loans and deposits with banks, both domestic and foreign, as well as repos. Interbank lending at maturities up to one week represents about 70% of total activities in the interbank market.

We use the net interbank position because rates on interbank market were immediately affected by NIRP and even became negative. In addition, we adopt a second measure of bank-level exposure to NIRP, namely the liquid balance sheet position, computed as securities divided by total assets. This measure achieves two purposes. First, it is a broader and more sizeable measure of balance sheet liquidity (in terms of maturities and assets). Second, the downward shift in the yield curve after NIRP affected all maturities so this measure more accurately captures a bank's exposure to low- and potentially even negatively-yielding assets once the policy rate makes its way through markets.[16] Alternative measures of exposure to NIRP, such as the banks' reserve holdings in excess of the minimum reserve requirement, are of limited use in our context as Italian banks effectively did not hold reserves in excess of the amount required by regulation during the sample period.[17]

We compute the net interbank position and the broader liquidity position as of end-March 2014, the closest available date before the implementation of NIRP (on June 11, 2014). Note that our data on bank-level interbank market position are available on a quarterly basis, while data on market expectations show that NIRP was partly expected in May 2014 (Wu and Xia, 2020). In March 2014 the average net interbank position is positive and accounts for 4% of assets, while liquidity accounts for 29% of assets (Table A3). To rule out potential concerns that banks adjusted their liquidity positions ahead of NIRP, Figure A1 shows that there is strong persistence in bank-level net interbank position and liquidity over time: comparing end-December 2013 and end-March 2014 data shows that banks

[16] In our sample, net interbank position and liquidity are weakly negatively correlated. We find similar and robust results if we measure bank-level exposure to NIRP with the sum of these two variables.

[17] Excess reserves in June 2014 account for 0.001% of total assets for the typical bank in our sample, with a highly-skewed distribution (for the vast majority of banks, the share of excess reserves in total assets is negligible). This is not surprising as excess reserves are generally very small in the countries of the periphery of Europe (Baldo et al., 2017).

lie close to the 45-degree line. In addition, Figure A2 shows significant cross-sectional variation in pre-NIRP net interbank position and liquidity.

Consistent with a portfolio rebalancing channel and corroborating the choice of exposure variables, in multivariate bank-level regressions we show that banks with more liquid assets before NIRP reduce liquid assets in the months following the introduction of the policy (Table A4). Comparing the net interbank position in March 2014 against the change in the net interbank position in the following six months (between March and September 2014) shows that banks with greater ex ante exposure are more likely to reduce their net position in the short-term interbank market (column 1) and this reduction is achieved by curtailing interbank lending (column 2) rather than increasing interbank borrowing (column 3). Similarly, we find that banks with more liquidity in March 2014 reduce the amount of liquid assets held on their balance sheets between March and September 2014 (column 4).

3.2.3 NIRP, the Yield Curve, and Portfolio Rebalancing Channel

What is different about the portfolio rebalancing channel during NIRP compared to previous rate cuts just above the ZLB? According to Benoît Cœuré, Member of the Executive Board of the ECB, "*with short-term policy rates approaching levels closer to zero during the early phases of the most recent easing cycle, this channel had become less effective*" (Cœuré, 2017). He goes on to argue that when the ECB changes the key policy rates during normal times, the central bank is able to directly impact the short end of the yield curve, which is the basis of the expectations component. To the extent that market participants see a change in policy rates as the beginning of an incremental series of changes, longer-term rates adjust accordingly. However, in the years before NIRP, market participants believed negative rates were unrealistic and were therefore not pricing the degree of accommodation they normally would have expected. In other words, when nominal rates approach the ZLB, the transmission of short-term policy rate cuts to long-term rates becomes weaker (Ruge-Murcia, 2006).

In Cœuré's (2017) words, the "*decision in June 2014 to introduce negative deposit facility rates restored our ability to steer market expectations, [. . .] by signaling to the market that policy rates could go below zero, we ultimately succeeded in shifting downwards the entire distribution of future expected short-term rates, thereby providing important additional accommodation.*"[18] Figure 2 shows this was indeed the case. We observe

[18] Lemke and Vladu (2017) show theoretically that this was indeed the case. By pushing down the effective lower bound, negative policy rates enabled current and future rates to be negative. In their model, the introduction of NIRP makes the forward curve flatter than it would be if short rates are expected to be constrained by a zero lower bound. An event study of yield reactions to negative interest rate announcements shows that long rates tend to drop in response to downward revisions in the market's believed location of the lower bound (Grisse et al., 2017). Eisenschmidt and Smets (2017) make a similar point by showing the empirical discontinuity in the shape of the forward curve around the introduction of NIRP in

both a downward shift and a flattening of the yield curve only after NIRP and not after the previous rate cuts (above the ZLB) in July 2012 and November 2013 (Figure 4, panels a and b). Rostagno et al. (2016) argue that NIRP was able to "*rehabilitate monetary policy in the low rate world*". Through their impact on the yield curve, negative nominal interest rates reinstated the transmission of monetary policy and facilitated a reallocation of bank assets, with potential benefits for lending and the real economy. The fall in the yield curve at all maturities caused a large decrease in the yield of liquid assets, some of which became even negative. These developments incentivized banks to reduce their holdings of low or negative yielding assets to preserve profitability. In Figure 4 (panel c) we show that a similar flattening of the yield curve took place in January 2015 when the ECB announced its first LSAP QE (via the expanded APP), a feature documented by Eser et al. (2019). In Section 4.4 we conduct a comprehensive comparison between NIRP and other monetary events, including two preceding interest rate cuts near but above the ZLB, and the QE (APP) announcement (see Figure 4). Finally, one may argue that that a flat yield curve puts downward pressure on net interest income in the long run, as the margin between lending rates and borrowing costs compresses (Adrian and Shin, 2010). Despite this possibility, in 2014 and 2015 the net income of large euro area banking groups actually increased. Even net interest income made a positive contribution despite a small decline in interest margins, reflecting an increase in credit volumes after NIRP (ECB, 2016).

3.3 Empirical Specifications

Impact on loan volumes and rates. To identify the effect of negative policy rates on credit supply, we compare loan volumes of banks with different levels of exposure to NIRP before and after the ECB's enactment of this policy in June 2014. Moreover, we examine if banks differently exposed to NIRP change loan rates to the same firm at the same time, i.e. exploiting whether credit volumes vs. rates (depending on bank exposure to NIRP) change in the same way (both increase, consistent with demand), or they change in different way (consistent with supply).

We first use the classic Khwaja and Mian (2008) approach and collapse the monthly credit register data into two, pre- and post-NIRP, periods with windows of ± 3 and ± 6 months around June 2014.[19] We also analyze other rate cuts (before and after the June 2014 introduction of NIRP), as well as QE.

June 2014.

[19] Given that the policy was announced in mid-June 2014, we drop all the observations of this month from the sample. We keep the period of analysis relatively short to minimize the impact of other potentially confounding ECB policies. We conduct several robustness tests related to the timing of NIRP introduction and the length of windows around it (and we also analyze a very short-term window of ± 1 month); see Table A9 and related discussion in Section 4.2.

We compute loan growth at the bank-firm level ($\Delta Loan_{ib}$) as the log difference in the total amount of granted credit (representing total on and off balance sheet loan commitments)[20] by bank b to firm i between the post- and the pre-NIRP periods, and estimate the following equation:

$$\Delta Loan_{ib} = \alpha \; Net\ interbank\ position_b + \beta \; Liquidity_b + \gamma' \mathbf{X}_b + \phi_i + \epsilon_{ib}, \tag{1}$$

where the measures of NIRP exposure are the net interbank position and liquidity (both defined in Section 3.2.2). Given that our measures of bank exposure to negative rates could be correlated with other bank characteristics (Table A5), to isolate the effect of NIRP on bank credit supply through the portfolio rebalancing channel, we include the vector $\mathbf{X}_b$ of bank controls, all measured at end-March 2014: bank size (the logarithm of total assets), regulatory capital (TIER 1 capital divided by total assets), and NPLs (impaired loans divided by total assets)—note also that since the model analyzes differences in credit, not levels, we implicitly control for bank fixed effects.[21] Furthermore, note that there is no systematic relationship between a comprehensive set of firm observables (including size, riskiness measured as distance from default, leverage, and profitability) and bank NIRP exposure, measured either by the net interbank position or liquidity (see Table A6).[22]

Shifts in credit demand and other unobserved firm-specific shocks are captured by firm fixed effects (ϕ_i), so the coefficients of interest α and β are identified by comparing the change in credit to the same firm in the same period by banks with different NIRP exposure. Regression estimates are obtained with the Ordinary Least Squares (OLS) estimator and standard errors are double-clustered at the bank and firm level. Double-clustering allows for residual correlation within banks, since our treatment variable varies at the bank level, as well as within firms, given that credit growth to the same firm may be correlated across banks (for firms with many banking relationships and not fully absorbed by firm fixed effects). In the next section we subject the baseline specification to many robustness tests.

As explained above, we adopt a similar approach to test for the impact of NIRP on loan rates,

[20] As the dependent variable refers to total on and off balance sheet loan commitments, it is invariant to the amount of credit line utilizations, therefore results are not driven by credit lines drawdowns.

[21] While net interbank position is negatively correlated with size, liquidity is negatively correlated with capital and NPLs (Table A5). Moreover, we analyze the same model in other periods to check whether results are driven by NIRP vs. other monetary policies, or by bank unobservables.

[22] We test for the balancing of covariates computing the normalized difference between each quartile average and the average in the other three quartiles. To avoid that results depend on sample size, we follow Imbens and Wooldridge (2009) and analyze the normalized differences—which are the differences in averages over the square root of the sum of the variances. Imbens and Wooldridge (2009) propose as a rule of thumb a 0.25 threshold in absolute terms, i.e. two variables have "similar" means when the normalized difference does not exceed one quarter. Results confirm that firm observables are well balanced across the distribution of bank exposure to NIRP.

where the dependent variable is the change in loan rates applied to loans granted by bank b to firm i between the post- and the pre-NIRP periods, focusing on a ± 6 month window around June 2014. Descriptive statistics for regression variables are reported in Table A3. If portfolio rebalancing by banks due to negative rates is at work, lending by more affected banks will increase, while loan rates will decrease, consistent with a supply interpretation.

Impact on firm performance. We examine the impact of NIRP on the real economy using several firm-level outcomes and a standard methodology used in the literature on the credit and real effects of monetary and financial shocks (see, e.g., in Khwaja and Mian (2008), Iyer et al. (2014), Cingano et al. (2016), Jiménez et al. (2017) and Jiménez et al. (2020)). We focus on three firm-level outcomes: total credit growth, net investment, and wage bill growth in the following specification:

$$\Delta Firm\ Outcome_i = \alpha\ Net\ interbank\ position_i + \beta\ Liquidity_i + \gamma' \mathbf{X}_i + \psi_p + \phi_s + \hat{\delta}_i + \epsilon_i, \tag{2}$$

where the first firm-level outcome is the change in total credit growth at the firm level, calculated as the log difference in total bank credit to firm i between the pre- and post-NIRP periods. The key explanatory variables are the firm-level weighted average of the net interbank position and liquidity of all of the firm's lenders, measured before the introduction of NIRP in March 2014. The vector ($\mathbf{X}_i$) includes a set of firm characteristics (size, riskiness, return on assets) and the same bank control variables as in Equation 1, measured before the announcement of NIRP and calculated as weighted averages of the financial variables across the firm's lenders. The firm-specific weights are given by the share of total credit provided by each lender to the firm i in March 2014. In addition to firm's province (ψ_p) and industry (ϕ_s) fixed effects, we account for unobserved growth opportunities at the firm level with estimates of firm credit demand ($\hat{\delta}_i$) obtained from the previous within-firm model of credit growth in Equation 1.[23]

We also study the response to NIRP of net investment, defined as the growth rate of fixed assets, and the growth rate of the wage bill, two key components of aggregate output. We analyze firm-level real effects in the subsample of manufacturing firms;[24] however, for completeness, we report the analysis for the full sample of firms as well. Furthermore, we focus on the ± 6 month window, as firm financial data are available on a yearly basis. The firm-level dependent variables are thus computed as growth rates between end-2013 and end-2014 values.

[23] See Cingano et al. (2016) or Bofondi et al. (2018) for further details on this approach.

[24] We use the Ateco 2002 from the National Institute of Statistics (ISTAT), the Italian National Institute of Statistics, which include firms with two-digit industry codes between 15 and 37 in the manufacturing sector.

4 Credit Supply

4.1 Main Results

Baseline Results. Table 1 shows the results from our baseline lending regressions for two time windows: ± 3 and ± 6 months around June 2014. For each case, we start by including separately the net interbank position and liquidity (respectively, columns 1 and 2) and then we include both variables at the same time (column 3).

The coefficient on the net interbank position is positive, statistically significant and stable across specifications, and indicates that banks with greater net interbank position before NIRP increase credit supply after the introduction of NIRP more than other banks. The estimated effect of the policy is economically significant. One SD increase in net interbank position is associated with a relative increase of 1.4 pps in the growth of credit supply after three months by more exposed banks (based on the coefficient in column 3 of Table 1). This effect is 1.9 pps after six months.

The estimated coefficient on bank liquidity is also positive, suggesting that banks with more liquid balance sheets react to NIRP by expanding credit supply more than less liquid banks. The magnitude of the effect of liquidity is comparable to that of the net interbank position, as a change in one SD of liquidity is associated with an increase in credit supply by 0.8 pps after three months and 1 percentage point after six months. Given that the average growth rate of credit was -2.1% over the sample period, these effects are economically sizable.

Overall, the results in Table 1 provide evidence for a portfolio rebalancing channel of monetary policy transmission from liquid assets to credit supply after the implementation of NIRP.[25] They confirm our conjecture that NIRP affects banks through liquidity management as banks swap out of low-yielding assets into higher-yielding loans. One may think that banks hold large liquid assets to take advantage of positive macro shocks, but previous evidence shows that this is generally not the case (Kashyap and Stein, 2000).

The Retail Deposit Channel. As discussed in Section 3.2.1, negative policy rates can also affect bank lending through a compression in profit margins. Given that banks may generally be unwilling to pass negative interest rates to retail depositors, there is a potential cost associated with higher retail deposits when monetary policy rates become negative (Heider et al., 2019; Eggertsson et al., 2019). To test this channel, in column 4 of Table 1 we control for banks' reliance on retail deposits

[25] In all columns we also include other bank controls: size, capital and NPL. In Table A7 in the Appendix we report the full results. Bank size has a positive and significant coefficient and capital has a negative and significant coefficient.

(as a share of total assets). The results show no evidence of a contractionary retail deposit channel across the time windows considered. Moreover, the coefficient estimates on our key NIRP-exposure variables remain unchanged.[26] The contractionary retail deposits channel may be inactive in Italy for several reasons. First, despite the fact that retail deposit rates are generally considered sticky at zero, in practice this floor may not bind, neither at zero nor at another level, because of the cost of holding cash.[27] Second, our data show that banks with a funding structure more skewed toward retail deposits (measured in percent of assets in March 2014) increase fees for banking services related to the holdings of deposits after the introduction of NIRP, possibly offsetting the income loss from a compression of intermediation margins. Therefore, there is no loss of profitability for banks more reliant on retail deposits (Table A2), in line with recent evidence showing that bank profitability was generally resilient to NIRP (see, e.g. Arteta et al. (2018), Altavilla et al. (2018), IMF (2017), Lopez et al. (2020) and ECB (2020)).[28] Third, retail deposit rates in Italy were low but not at zero before the introduction of NIRP, so banks had some room for downward adjustment.

Potentially Confounding Policies. As discussed in Section 2, our sample period may raise concerns that other monetary policies confound our results insofar as bank responses to these policies are correlated with their March 2014 net interbank and liquidity positions and affect bank credit. Such worries may extend especially to the TLTRO. The program was announced in June 2014 and was first implemented in September 2014 through eight quarterly auctions. According to the TLTRO's guidelines set by the ECB, the program take-up has a maximum threshold (or "borrowing allowance") equal to 7% of the total amount of bank loans to non-financial corporations and households (including non-profit institutions serving households) resident in Member States whose currency is the euro, except loans to households for house purchases, as of April 2014.

To control for this policy, we construct a bank-level measure of ex ante "capacity to borrow under the TLTRO" from supervisory data, defined as the share of the outstanding amount of loans and net lending to euro area non-financial corporations and households, excluding loans to households for house purchase, divided by total assets, as of end-April 2014. In the last column of Table 1, we add this additional variable to the bank controls and show that differences in borrowing limits under

[26] See Section 4.2 for additional evidence inconsistent with the contractionary retail deposit channel.

[27] Several German banks were reported to charge negative interest rates on large customer deposits in 2016. See Financial Times (August 11, 2016) and Altavilla et al. (2021).

[28] The experience of Denmark and Sweden, in particular, shows that NIRP did not reduce bank profitability due to banks' adoption of higher fees and commissions for banking services (Turk, 2016; Madaschi and Pablos Nuevos, 2017). More generally, the evidence indicates that bank profitability indicators are quite stable and do not react to monetary policy (Drechsler et al., 2021; Zimmermann, 2019).

the TLTRO do not correlate with changes in loan supply immediately after June 2014. Furthermore, our coefficients of interest (on the net interbank position and liquidity) remain statistically significant with very similar magnitude to the baseline coefficients.[29]

Another relevant ECB policy is the first LSAP QE (APP). However, the QE announcement took place on January 22, 2015, that is, more than three months after the end of the time window of our baseline results. As a result, QE is unlikely to affect our estimates. In Section 4.4 we focus on QE to test whether it also affected bank lending through a portfolio rebalancing channel.

To address any residual concerns that our results may be driven by other ECB policies in the time window of our main regressions—such as the second reduction of DF rates, the implementation of the TLTRO or the very limited purchases of asset-backed securities and covered bonds announced in September 2014 (all discussed in Section 2), we shrink the window of analysis. Specifically, we estimate specifications in which we compute loan growth as the log difference in total loans granted between July 2014 (one-month post-NIRP window) and April 2014 (one-month pre-NIRP window). Given that the introduction of NIRP was already expected by market participants in May 2014 (Wu and Xia, 2020), we drop observations from both May and June from the sample. As seen in Table A8 (columns 1-3), evidence for the portfolio rebalancing channel is present even in this narrow time window, which rules out effects from other ECB policies announced or enacted in September 2014. Furthermore, we continue to find no evidence of a retail deposit channel (columns 4 and 5).

4.2 Robustness of the Baseline

In Table A9 we test the robustness of our benchmark specification for loan volume regressions to a number of different data treatments and subsamples, in an effort to alleviate remaining concerns about identification. In this analysis, we take the specification in column 3 of Table 1, in which we jointly include the net interbank position and liquidity, as our preferred baseline specification, and focus on the ± 3 month period around June 2014.

We start by saturating our preferred baseline specification with control variables for banks' liability structure, namely secured repo funding, bank-issued securities, foreign funding (deposits from non-residents), and interbank deposits (all expressed in percent of total assets). While some of the coefficients on these additional controls are statistically significant, adding these variables leaves our coefficients of interest statistically significant and almost identical in size to the baseline (column 1).

[29] This is consistent with Benetton and Fantino (2021) who show that banks more exposed to the TLTRO start to reduce interest rates to firms only in the second and third quarter of 2015, beyond our sample period.

Notice that in this specification the coefficient on retail deposits is *positive* and statistically significant at the 10% level, *contrary* to predictions of the retail deposits channel of NIRP. In columns 2 and 3 we explore the retail deposit channel further. First, we remove net interbank position and leave retail deposits with the standard bank level controls (column 2). Second, we restrict the analysis to large firms (with above-median total assets in March 2014), which makes our results more directly comparable to Heider et al. (2019), whose sample includes large firms that borrow in the syndicated loan market (column 3). In both specifications, the coefficient estimate on retail deposits is *positive* and statistically insignificant.[30]

Second, we consider the possibility that the announcement of NIRP led to an increase in the fair value of securities on bank balance sheets (windfall gains) with an associated increase in net worth, potentially confounding our results. We first note that that lower policy rates benefit both securities (via prices) and loans (e.g., via a reduction in provisioning, delinquencies and write-offs). In any case, the evidence we find does not support this concern. We show that the profits of banks with ex ante more liquid assets did not improve relatively to other banks in the months after the NIRP announcement (Table A1). This could be explained by the fact that in Italy, in April 2014, less than 9% of securities are recorded in the trading portfolio, where unrealized gains and losses from price fluctuations are recognized in the income statement. Instead, a very large part of the securities held by banks (more than 40%) are recorded at historic cost. This is consistent with evidence from Bundesbank data on German banks (Tischer, 2018), and from European Banking Authority stress testing data for a broad set of European banks (De Marco, 2019).[31] However, to further reassure that that our result on bank liquidity—defined as securities over assets—is not driven by valuation gains from the repricing of securities after NIRP, we also control for a direct measure of these gains, which we construct following the approach of Acharya et al. (2019).[32] While this measure of windfall gains is

[30] In unreported regressions we show that the coefficient of retail deposits is negative and significant only when included as the only variable in the 3-month window. Simply controlling for bank size makes the estimated coefficient statistically insignificant. We further explore the possibility that the retail deposit channel is at work for banks operating in more concentrated deposits markets or for banks that ex ante had lower average deposit rates, and find no robust evidence that retail deposits matter for the transmission of NIRP to bank lending in Italy. In interpreting these results, one should keep in mind that the initial conditions of the Italian banking system, in particular that deposit rates were further above zero compared, say, to those in Germany or the core Euro area more broadly, imply our results on the retail deposit channel should not be generalized.

[31] Moreover, over the sample period Italian regulations stated that for government bonds recorded at fair value in the available-for-sale portfolio, unrealized gains or losses did not impact the regulatory capital. This rule changed in October 2016).

[32] For each security in the bank's securities portfolio, we calculate the change in price around the NIRP announcement (the difference between the price at end-June 2014 and that at end-April 2014) and multiply these price changes for the holdings of each security outstanding in the bank portfolio before the announcement (end-April 2014). Finally, we add up the individual gains over all the securities in bank portfolios and express them as percent of total equity. Since we also

positively correlated with liquidity (the correlation conditional on bank controls is 0.24), its inclusion in the model does not affect the estimated coefficient on bank liquidity, which remains positive and significant, and unchanged in size (column 4). An additional argument against this potential concern is that our estimates of the impact of NIRP are different from those of policy rate cuts above the ZLB, which are similarly associated with windfall gains. More generally, they are different from results on the role of bank liquidity in the bank lending channel of monetary policy for the U.S. (e.g., Kashyap and Stein, 2000) and Spain (e.g., Jiménez et al., 2012).

Third, we consider an alternative timing for measuring bank exposure to NIRP. Measuring bank-level NIRP exposure at end-March 2014 could miss adjustments made by banks ahead of ECB's decision to take the DF rate below zero on June 11, 2014. Given that our data on interbank market participation are available on a quarterly basis, the only other feasible date for measuring the net interbank position is end-June 2014. But this is an *ex post* measure and may reflect adjustments that took place between June 11 and June 30, 2014. That said, using end-June 2014 exposure to NIRP in the lending regressions leaves our main results unchanged (column 5).

In column 6 we estimate the baseline specification with Weighted Least Squares (WLS), taking the logarithm of loan size as weight. The estimates show that the point estimate on the net interbank position and liquidity are similar to the coefficient estimates in the unweighted (OLS) regressions.

Lastly, we consider alternative timings of NIRP. We start by taking into account the fact that the pass-through from negative policy rates to overnight interbank rates was not simultaneous: EONIA only turned negative in August. As these rates remained positive through most of the period between June and August 2014, we remove observations for these months and redefine the ± 3 window around the period June-August 2014. Column 7 shows that the baseline effects remain statistically significant and close in magnitude to that of Table 1, column 1. In addition, we account for NIRP being partly expected the month before its enactment (Wu and Xia, 2020) by re-centering the baseline analysis on the ± 3 months around May and June 2014—and hence dropping the observations of these months from the sample. As seen in column 8, our results are unaffected by the shift of our time window by one month.

know in which portfolio each security is held, we restrict our analysis to securities held in the marked-to-market portfolios. Further, including the changes in value of the securities recorded at historic costs leaves the results unchanged.

4.3 NIRP vs. Other Monetary Policy Events

Here we examine the extent to which NIRP differs from conventional and unconventional monetary policies. For this purpose, we conduct four tests which center the period of analysis on four different monetary policy events.

First, we consider the last DF rate cut before NIRP—by 25 basis points to 0% on July 11, 2012. That policy rate cut translated into a decrease in short-term yields, while the long end of the yield curve remained largely unchanged (Figure 4, panel a). The second event, in November 2013, is the last cut of the interest rate on the MRO, from 0.50 to 0.25%, before the DF rate went negative. The interest rate on the MRO was the key reference rate before the introduction of negative rates on the deposit facility. In that event, the rate cut did not flatten the yield curve; if anything, long term yields at end December 2013 increased compared to September 2013 (see Figure 4, panel b). Third, we examine the announcement of the first LSAP QE in January 2015. In that event, the yield curve flattened (Figure 4, panel c), as it did after NIRP, even though the DF rate remained unchanged at -0.20%.[33] Fourth, we test whether the portfolio rebalancing channel is unique to the introduction of negative rates or, instead, persists after rate cuts deeper into negative territory. For this purpose, we focus on the March 2016 announcement, when the ECB further cut the DF rate to -0.40 basis points. This event was associated with a further (but lesser) flattening of the yield curve (Figure 4, panel d).[34]

Regression results for these tests are reported in Table 2.[35] We find that during the previous rate cuts in positive territory (the first two events discussed above), the impact of monetary policy is different from our findings for NIRP. For the July 2012 DF rate cut, the coefficients of net interbank position and liquidity are both negative and statistically significant. Liquidity yields a negative and significant coefficient (for the ± 3 month window) after the reduction of the interest rate on the MRO as well. These results are consistent with the standard bank lending channel of monetary policy (Kashyap and Stein, 2000; Jiménez et al., 2012), according to which a monetary easing has weaker

[33] Gambetti and Musso (2017) similarly find that the QE announcement in January 2015 was followed by a flattening of the yield curve. The authors explain that the announcement was to some extent expected. However, they also report that according to market polls and anecdotal evidence from newspapers, the large scope of asset purchases was not fully expected and hence did surprise the markets.

[34] In the press release that announced the cut of interest rate to -0.30 on December 3, 2015 there is also the announcement of an extension of the APP programme. Since analysts expected a much larger extension of the monthly purchases of securities under the APP programme there was a strong negative reaction in the market on the day of the announcement: the DAX and the CAC 30 lost 3.6% and the Euro appreciated 3% against the US Dollar. This presence of confounding information makes this event less suitable for the identification of the NIRP impact.

[35] Similar to the baseline regressions, we analyze the impact of other monetary policy announcements on bank credit supply in the ± 3 (panel A) and ± 6 (panel B) month windows around these dates. We measure banks' net interbank position and liquidity, in the last available date before the policy announcements, that is, in June 2012, September 2013, December 2014, and December 2015, respectively.

effects for banks with higher liquidity buffers as such banks do not need external liquidity as much to expand lending.[36] By contrast, after the QE (APP) announcement, we find that more liquid banks expand lending.[37] Economically, the effect is smaller than for NIRP: one SD of liquidity is associated with an increased in credit supply by 0.6 (0.8) pps after three (six) months. However, the coefficient of net interbank position is smaller than for NIRP and statistically insignificant. This result is not surprising given that QE is not associated with a drop in short-term rates.

Finally, the effect of the March 2016 interest rate cut is similar to that of NIRP introduction. This result suggests that the portfolio rebalancing channel is not a one-off effect due to the break through the ZLB, but rather the result of the shifting down and flattening of the yield curve, which was also achieved, albeit to a lesser extent, after the March 2016 rate cut as well. We interpret this result as suggesting that market participants may not know exactly where the "effective lower bound" is, so deeper cuts below zero retain a surprise element which drives the shift of the yield curve. This result also alleviates potential concerns that our baseline finding was caused by rates not being "low enough" or low "for long enough" to dampen bank profitability. In other words, this evidence would suggest that the reversal rate (Brunnermeier and Koby, 2018) has not yet been reached even with the DF rate at -0.40% and negative rates in place for almost two years. We still find evidence of an expansionary portfolio rebalancing channel and no sign of a contractionary retail deposit channel, similar to the initial DF rate cut in mid-2014 (column 4 of Table 2).[38]

Taken together, our tests suggest that the NIRP announcement, as well as later cuts below zero, activate a portfolio rebalancing mechanism—banks rebalance their portfolios from liquid assets toward corporate loans. This channel is not at play after policy rate cuts above zero but close to the ZLB. By contrast, the QE announcement generates portfolio rebalancing effects similar to NIRP.

4.4 Falsification Tests

An important identifying assumption in our empirical framework is "parallel trends," which would be violated if our NIRP bank exposure variables were positively correlated with pre-NIRP loan growth. To rule out pre-existing trends in loan growth, we run regressions that are similar to our

[36] Consistent with portfolio rebalancing being confined to monetary policy actions that are able to shift down and flatten the yield curve, we estimate bank-level regressions similar to those reported in Table A4 around the two rate cuts of July 2012 ans November 2013 and find no evidence of adjustment in banks' net interbank position and liquidity after either event (Table A10).

[37] This is consistent with the results in Rodnyansky and Darmouni (2017) and Albertazzi et al. (2018), who show—for the U.S. and the euro area—that banks which benefitted more from QE lent more to firms.

[38] The estimated coefficients for the portfolio rebalancing are larger in 2016 but the standard deviations of the variables are smaller.

baseline specification (Table 1, column 3), but center the ±3 and ±6 month windows on different months before the NIRP announcement. Table A11 reports the estimated coefficients for the net interbank position and liquidity (both measured at end-March 2014). The top panel is for the ±3 month window and reports results centered on December 2013, January 2014, and February 2014, the last month for which the post-NIRP 3-month window does not include June 2014 (that is, November 2013-May 2014). The bottom panel looks at the ±6-month window around September, October, and November 2013. The results indicate that the coefficients estimated in the months before NIRP are generally close to zero and statistically insignificant. The negative coefficients on liquidity in some specifications can be explained by the fact that, as discussed in Section 4.3, in November 2013 the ECB lowered the interest rate on the MRO without flattening the yield curve (see Figure 4, panel b).

4.5 The Slope of the Yield Curve and Portfolio Rebalancing

So far we have documented the portfolio rebalancing channel in a cross section of banks around policy episodes when the yield curve shifts downward and flattens. To provide more direct evidence of the effect of the slope of the yield curve, we construct a quarterly bank-firm-level panel dataset covering the lending activities of Italian banks between 2012:Q4 and 2019:Q4. Then we estimate a standard lending equation in which granted credit is a function of the slope of the yield curve—measured as the difference between the 10-year Euro Interest Rate Swap (Eurirs) and the Euro OverNight Index Average (Eonia)—interacted with the net interbank position and the liquidity variables. The model includes the same bank-level controls as in the baseline specification (bank size, capital, retail deposits, NPL), their interaction with the slope of the yield curve, and macroeconomic variables (inflation and unemployment rate).

The results are shown in Table 5. Columns 1 and 2 report the results separately for net interbank position and liquidity, while column 3 includes both variables (and their interaction with the slope) together. We saturate the model with firm×time and bank fixed effects and in column 4 we add the other macroeconomic controls (unemployment and inflation), while in the most demanding specification (column 5) we also include bank-firm pair fixed effects. Our findings confirm that bank lending responds to changes in the slope differentially depending on bank liquidity and net interbank position: when the yield curve flattens, credit supply increases more for ex ante more liquid banks and for those with a larger net interbank position.[39] The point estimates of the coefficient on

[39]The coefficient of the interaction with the slope is not significant when net interbank is include alone, but turns significant when liquidity is also included in the model and when the model is saturated with fixed effects and controls.

the interaction term between the slope of the yield curve and liquidity are economically meaningful. If we compare banks at the first and third quartile of the liquidity distribution and consider a one SD reduction in the slope of the yield curve, then credit growth is 0.4% higher in more liquid banks; the same computation leads to 0.3% higher credit growth for net interbank position (column 5).

The overall evidence so far implies that, around the ZLB, an easing of monetary policy that shifts down and flattens the yield curve, incentivizes banks to rebalance their portfolio from lower-yield liquid assets to higher-yield corporate loans, consistent with banks preserving profitability and a lowering of risk premia (Hanson and Stein, 2015; Brunnermeier and Sannikov, 2016). The monetary policy action that generates the easing can be negative interest rates, but is not necessarily limited to this policy. Similar shifts in the yield curve can also be achieved through QE, as shown in Section 4.3 and as we discuss in the next section for the case of the U.S.

4.6 External Validity

Our focus on the experience of Italian banks raises the question whether our evidence so far applies more broadly beyond the case of Italy. For instance, differences in sovereign risk premia may make the reversal rate (Brunnermeier and Koby, 2018) country-specific, so that negative rates are contractionary in some countries, but expansionary in others. Furthermore, differences in initial deposit rates across banks in different euro area countries may influence the potency of the retail deposit channel. Furthermore, the portfolio rebalancing channel may be at work in other settings where NIRP is not in place, but where monetary policy actions shifted the yield curve in a similar way. To address these questions and provide some external validity for our results, we replicate the baseline analysis in a large panel of euro area banks, and then consider the U.S. experience with quantitative easing.

NIRP and Portfolio Rebalancing Across Euro Area Banks. The benefit of examining the effect of NIRP across euro area countries comes at the cost of a weaker identification strategy, as with bank-level data, we can neither analyze loan-level volumes and prices nor can we properly control for firm-level credit demand with borrower fixed effects. We obtain annual data on balance sheet variables for 1,838 commercial during 2010–2016 from Fitch Connect. Using this (unbalanced) sample, we estimate the following equation:

$$\begin{aligned}\Delta Loan_{bt} \quad = \quad & \alpha_0\, Liquidity_{bt} + \alpha_1\, Liquidity_{bt} \times Post\ NIRP_t + \\ & \beta_0\, Retail\ deposits_{bt} + \beta_1\, Retail\ deposits_{bt} \times Post\ NIRP_t + \gamma' \mathbf{X}_{bt} + \phi_b + \tau_t + \epsilon_{bt},\end{aligned} \tag{3}$$

where $\Delta Loan_{bt}$ is the change in the ratio of gross loans over total assets between $t+1$ and t. Liquidity and retail deposits are defined as in the main analysis and scaled by total assets. In these data there is no common measure of exposure to the short-term interbank market, therefore the two key variables of interest are the interactions of liquidity and retail deposits with the Post-NIRP dummy (equal to one starting at the introduction of NIRP). The coefficients α_1 and β_1 test for the portfolio rebalancing and the retail deposit channels, respectively. The set of bank controls ($\mathbf{X}_{bt}$) mimics the main analysis and includes: loan-to-asset ratio, capital (TIER 1/assets), size (log-assets), return on assets, and NPL. All variables enter as stand-alone controls and in interaction with the Post-NIRP dummy. The model also includes bank (ϕ_b) and year (τ_t) fixed effects. Standard errors are clustered at the bank level.

The results are shown in Table 6, which reports the coefficients of the key interaction terms. Columns 1–2 do not include NPLs as a control variable to maximize sample size, and columns 2 and 4 include a triple interaction with GIIPS countries (Greece, Ireland, Italy, Portugal and Spain) to test for differential lending behavior across euro area regions. The estimates consistently show that more liquid banks have higher loan growth rates after NIRP, even until 2016, with no significant differences between the core and the periphery of the euro area. Furthermore, there is no evidence of a retail deposit channel. Overall, these results broadly confirm our main findings for Italy, but in a significantly larger sample of European banks.

Quantitative Easing in the U.S. We also study the bank portfolio rebalancing channel in the U.S. context, where NIRP has not been adopted. Specifically, we focus on two QE announcements in the wake of 2008 financial crisis: QE1 in 2008–2009 and QE2 in 2010–2011 when LSAPs conducted by the Federal Reserve put downward pressure on long-term interest rates and flattened the yield curve (see Figure 5). We use loan-level data from the FR Y-14Q H.1 "Corporate Loan Data Schedule," a supervisory database maintained by the Federal Reserve since 2011. Between 30 and 40 bank holding companies (BHCs) report their commercial and industrial (C&I) loan exposures and their terms as part of the FR Y-14Q data collection effort every quarter, covering approximately 75% of the total U.S. C&I loans (Favara et al., 2021). The data include bank-firm C&I loans commitment with a reporting

threshold of $1 million. For each individual loan facility, we also observe the year of origination, which allows us to examine loan originations over the period of interest.[40] We match each reporting BHC to its main commercial bank's balance sheet information from the merger-adjusted Call Report.

We examine banks' lending decisions following each QE announcement by relating the growth rate of lending volume in the six months before and after the announcement as a function of banks' ex ante liquidity (securities-to-assets ratio), main characteristics (size, capital, retail deposits, and NPLs), and windfall gains (losses) from securities holdings. Given our sample selection and short period of time around QE, most firms do not borrow repeatedly and we cannot include firm fixed effects. Instead, we define individual borrowers to comprise clusters of firms that are all located in the same state and two-digit NAICS industry, and we include these fixed effects to control for common demand shocks to all firms in the same state and industry.

The results are reported in Table 7, where columns 1-3 show the estimates for QE1, columns 4-6 refer to QE2, and columns 7-9 to QE3. Across specifications that include fixed effects for firms located in the same state and two-digit NAICS industry and a full set of bank controls, bank liquidity has positive and statistically significant coefficients after the announcement of QE1 and QE2. The estimates suggest that banks with ex ante larger liquid assets reallocate toward corporate loans. In the 12 months centered on the first QE event, median loan volume growth was negative at -5.9% while around the second event the economy had started recovering and median loan volume growth was $+9.1\%$. Therefore, the results indicate that banks with ex ante more liquid assets reduced credit supply less after QE1 and increased credit supply more after QE2 compared to other banks. Turning to economic magnitudes, the estimates in columns 3 and 6 indicate that a change in one SD of liquidity is associated with an increased in credit supply by 0.3 pps six months after QE, a smaller effect than what found around the ECB's QE announcement in January 2015 (Table 2, panel B, column 3).[41] In addition, the coefficient estimates on realized gains (losses) on securities are positive and statistically significant (columns 3 and 6), suggesting that QE also boosted loan volumes through

[40] In particular, while the first reporting year of the data is 2011, we observe loans originated in the previous years and that have not yet matured by the reporting date. For QE1 the loans in our sample were originated around 2008–2009 (therefore, these loans have longer maturity on average than the typical loan in the credit registry) and for QE2 they were originated around 2010–2011. Given the coverage of Y-14Q data, we select loans with longer maturity as of 2011 and 2012 that were on banks' books around the two initial QE episodes. In addition, the number of loans is lower compared to an analysis after 2011 where we could use all the loans, so the fixed effects that we will add cannot be as strict as in the baseline analysis. Finally, the Y-14Q sample is skewed toward larger banks and firms, as data submissions are only required from banks with more than $100 billion in total consolidated assets and business loans are over $1 million. The results should be interpreted with these caveats in mind.

[41] Since the effect of portfolio rebalancing is stronger for SMEs, the smaller effect found for the U.S. QE could be due to the U.S. sample being skewed toward larger firms.

asset valuation effects, in line with existing studies (Rodnyansky and Darmouni, 2017). By contrast, the coefficient estimate on liquidity is never statistically significant for the QE3 placebo test (columns 7-9), consistent with the lack of flattening of the yield curve.

We complement this evidence with an analysis of confidential microdata from the quarterly Senior Loan Officer Opinion Surveys conducted by the Federal Reserve to assess changes in lending standards and terms on C&I loans and credit lines. The results from the surveys—controlling directly for bank-level loan demand and discussed in Appendix A.3 (Table A14)—also support the view that the portfolio rebalancing channel is not specific to NIRP, rather it is a more general channel of monetary policy transmission by which shifts in the yield curve—regardless of the monetary policy instrument used to achieve them—matter differentially depending on banks' ex ante liquidity. Taken together, these results provide evidence of external validity of this channel in the context of UMPs other than NIRP.

4.7 Bank and Firm Heterogeneity

Thus far, our findings show that NIRP-exposed banks rebalance their portfolios away from liquid assets to bank loans. There are two important dimensions worth exploring better to understand the mechanism behind this rebalancing. If banks rebalance their portfolio to preserve profitability in a search-for-yield strategy, the results should be stronger for banks with ex ante low capital and the expansion of credit supply should be stronger to ex ante riskier firms and SMEs. Therefore, in this section we investigate whether our baseline results differ across banks with high and low regulatory capital, and whether credit supply increases homogeneously across firms, or whether it does so more toward certain types of firms.

Table 3 shows the results of the baseline specification separately for (ex ante) low and high capital banks, defined by splitting the sample around the median value of the ratio of TIER 1 capital over total assets. For liquidity, the results show that the greater increase in credit supply for banks with more ex ante liquid assets is driven by low capital banks. The coefficients on the interaction term between liquidity and the low capital dummy are positive, statistically significant, and larger than in the baseline for both the 3- and the 6-month window (Table 1, column 3). By contrast, the point estimate of the interaction with the high capital dummy is closer to zero and statistically insignificant. The results are similar for the net interbank position, but the standard errors are larger for the ± 6 month window.

Turning to firm heterogeneity, we focus on two key firm dimensions—riskiness and size—which

are relevant for the following reasons. First, riskier and smaller firms are typically more credit constrained and monetary easing should lead banks to expand credit toward marginal, financially-constrained borrowers, too. Second, if banks rebalance their portfolios toward higher yielding assets, they should expand credit especially toward higher yielding loans. Riskiness and size are good proxies for the yield banks can extract from borrowers because risky and small borrowers are typically charged higher loan spreads and have fewer opportunities to substitute across lenders. We split the sample between (ex ante) small and large firms, and firms with (ex ante) weak and strong credit ratings, around the median values of total assets and the Altman z-score, respectively (at end-2013).

The results are shown in Table 4, where the first three columns refer to the ± 3 month window and the last three columns to the ± 6 month window. We are testing whether the expansion of credit is stronger for certain type of firms, therefore we include bank fixed effects in all the specifications to absorb unobserved bank heterogeneity and focus on the interaction terms between firm characteristics and the banks' net interbank position and liquidity, respectively. The results consistently show that the relative expansion of credit supply by more NIRP-exposed banks, measured either by the net interbank position or by the liquidity ratio, is significantly higher for ex ante riskier firms (with high z-score or low credit rating) and smaller firms.

Note that the increase in ex ante risk-taking by more NIRP-exposed banks does not translate into higher levels of ex post NPLs, even five years after the introduction of NIRP. In Table A12 we report bank-level regressions where the dependent variable is the change in the NPL ratio over one year (top panel) and five years (bottom panel) after the introduction of NIRP and the regressors are bank characteristics measured at end-March 2014. The results show that more NIRP-exposed banks do not experience a bigger deterioration in loan quality (despite higher lending, and to ex ante riskier firms), which suggests that banks extend loans to ex ante riskier yet viable firms. Finally, we explore the possibility that banks more reliant on retail deposits, even though they do not contract lending, concentrate their lending on riskier firms, as found by Heider et al. (2019) and Bittner et al. (2020). The results, reported in panel C, show that the coefficient of the interaction term between retail deposits and risky firms is positive and significant at 10% level in the ± 3 month window. However, the same coefficient is statistically insignificant in the ± 6 month window, and so are the coefficients on interaction terms between retail deposits and firm size.

4.8 Transmission to Loan Rates

Our analysis so far has focused on the impact of NIRP on bank loan volume decisions. But another margin of adjustment is pricing. Eggertsson et al. (2019) use bank-level data and variation in the share of deposit funding across Swedish banks to document a weaker pass-through from the policy rate to loan rates during the NIRP period. By contrast, using loan-level data, we compare the change in the interest rates on loans granted to the same firm by at least two banks with different exposure to the policy, before and after NIRP introduction. Documenting a strong pass-through of negative policy rates to bank loan rates in our approach would further strengthen a supply-side interpretation of the impact of NIRP on bank credit.

Table 8 reports the estimates for net loan rates, separating credit lines and overdraft facilities from term loans. Across columns, the results indicate that negative policy rates affect lending rates through banks' net interbank position and the broader measure of liquidity, although the effect is stronger on credit lines and overdraft facilities than on term loans. Using the estimates in column 3, a change in one SD in the banks' net interbank position (liquidity) is associated with a 29 bps (29 bps) reduction of loan rates on credit lines and overdraft facilities after six months; this effect is economically meaningful, as it corresponds to almost a 4% reduction (the median net loan rate in 7.9%). The effects for loan terms are smaller at 5 bps or a 1.3% reduction of loan rates after six months.

We find qualitatively similar results for gross interest rates, which capture the total cost of borrowing. In this case, the size of the effects on credit lines and overdraft facilities are even larger. A one SD change in the banks' net interbank position (liquidity) leads to 89 bps (62 bps) reduction of loan rates after six months, which corresponds to a 7.6% (5.4%) reduction of gross rates on credit lines and overdraft facilities (Table A13). Finally, our results are robust to controlling for retail deposits and show no evidence that NIRP affects loans rates through the retail deposit channel (column 4). Hence, we find no evidence of a contractionary retail deposit channel of NIRP on lending volumes and on loan rates, measured either in net or gross terms.

5 Real Effects

Our analysis of credit register lending data shows that NIRP-exposed banks increase credit supply in response to NIRP. But did this positive effect on credit translate into better outcomes in the real sector? To answer this question, we estimate firm-level regressions where the dependent variable is the growth rate of total firm-level credit in the ± 6 month window around June 2014. The net interbank

position and liquidity are defined at the firm level as the average net position in the interbank market and average liquidity ratio of the firms' lenders in March 2014, weighted by the share of total credit granted to the firm by each lender. We control for the same (weighted) bank characteristics as in the loan-level baseline regressions, firm characteristics (size, riskiness and return on assets), firm-level demand (measured as the estimated firm fixed effects from the firm-bank loan-growth regressions), and location and industry fixed effects.

The results—reported in the first column of Table 9—show that the coefficients on the net interbank position and liquidity are positive and statistically significant, both in the sample of manufacturing firms (panel A) and in the full sample of manufacturing and services firms (panel B). Using the estimates for the full sample, we find that a one SD change in a firm's lenders' net interbank position (liquidity) is associated with a 2.4 (1.0) pps increase in total credit for that firm. These effects are economically large given that the average change in total firm-level credit in the $\pm$6 month window is 1.7%.

Next, we determine whether more credit translates into stronger firm performance. In the remaining columns of Table 9 we use the same specification but consider the following firm outcomes: the growth rate of fixed assets (investment expenditure, column 2) and the growth of total payroll (wage bill, column 3), which are key components of aggregate output. In the sample of manufacturing firms (panel A) we find that firms borrowing from lenders with greater exposure to NIRP (before the introduction of NIRP) expand economic activity relatively more. Looking at the coefficient estimate for the net interbank position, firm investment increases by 6.8 pps and the wage bill by 3.8 pps more for firms borrowing from banks with (one SD) larger ex ante net interbank position. Similarly, a one SD increase in banks' ex ante liquidity is associated with a 4.6 pps increase in firm investment and with one percentage point increase in the wage bill in response to NIRP.[42]

6 Conclusions

At the onset of pandemic crisis, many countries cut policy rates and/or adopted additional expansionary monetary policy measures, with little space to reduce rates further without NIRP. In this paper we bring new evidence by exploiting the ECB's introduction of NIRP in mid-2014 and the comprehensive matched credit register data from Italy, as well as data on the euro area and the U.S. for external validity. Our key contribution to the literature is to document that NIRP has expansion-

[42]Results for wage bill growth are similar in the full sample of firms (panel B). This is not the case for investment, as manufacturing firms arguably are more dependent on credit to finance fixed assets.

ary effects on credit supply and the real economy through a portfolio rebalancing channel, similar to QE, and different from conventional policy rate cuts just above the ZLB.

The announcement of NIRP shifted down and flattened the entire yield curve. The reduction in yields across all maturities, with yields on some liquid assets becoming negative, incentivizes banks to rebalance their portfolio away from low or negative yielding assets to higher-yielding assets, such as corporate loans. The relative increase in credit supply is stronger vis-a-vis smaller and ex ante riskier firms. As a result of the expansion in credit supply, firms that borrow from more exposed banks experienced positive real effects via higher investments and wage bills. We find no evidence of higher delinquencies even five years after NIRP, suggesting that credit was extended to viable but financially constrained firms. The portfolio rebalancing channel is not active after previous rate cuts just above the ZLB, which did not induce a similar shift of the yield curve, but is present after the ECB's 2016 rate cut, which went further into negative territory, and after NIRP in a broader set of banks across euro area countries. Further, we document portfolio rebalancing effects after the 2015 introduction of QE in the euro area and after the 2008 and 2010 QE announcements in the U.S., which similarly shifted down and flattened the yield curve.

Overall, our evidence suggests that the portfolio rebalancing channel is a more general channel of monetary policy transmission by which shifts in the yield curve—regardless of the monetary policy instrument used to achieve them—affect banks differentially, depending on their ex ante liquidity, stimulating credit supply and the real economy. Looking forward, a promising area of research includes theoretical and empirical work on how monetary policies that affect the entire yield curve may affect the reversal rate and impact the economy through bank lending.

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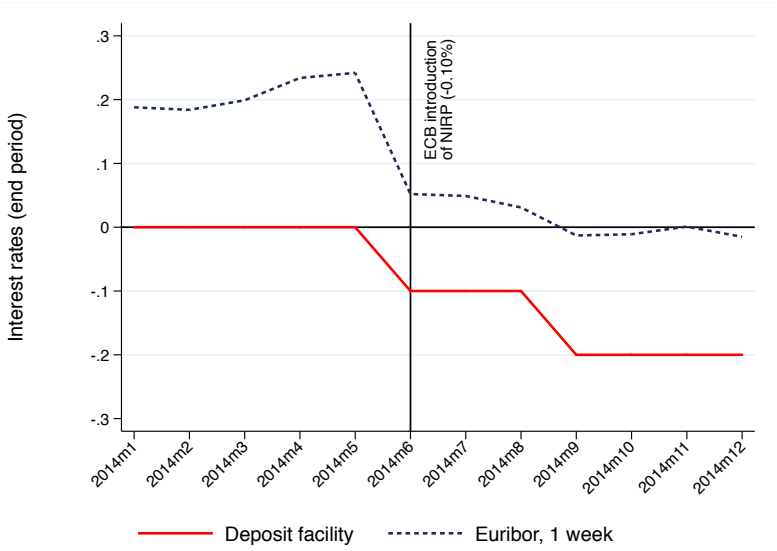
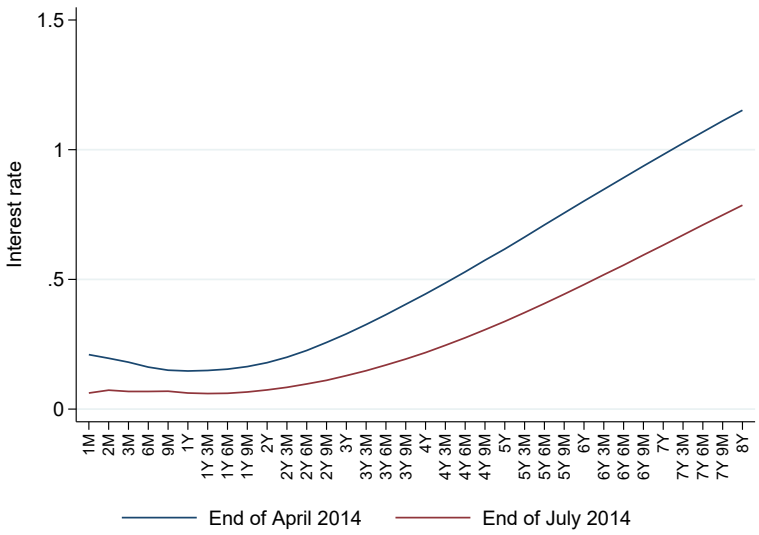
Figures and Tables

Figure 1: Policy and Interbank Rates, January 2014–December 2014



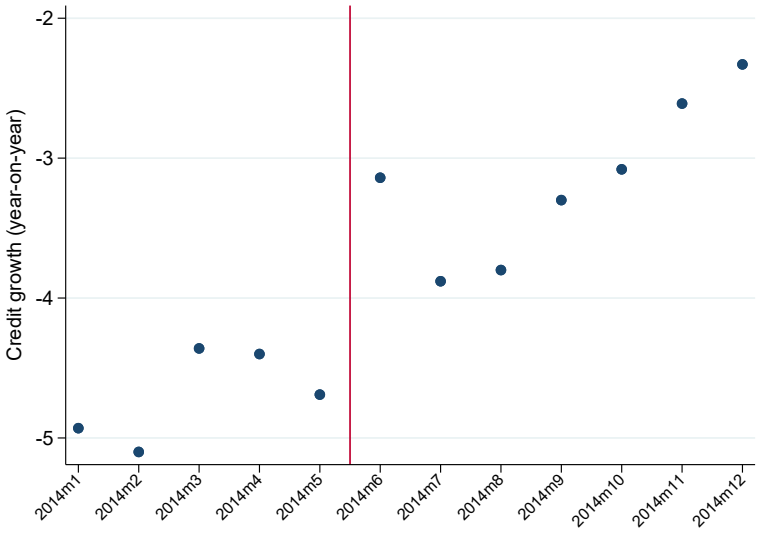
Notes: The chart plots the ECB Deposit Facility rate and the Euribor one-week interest rate, at monthly frequency, taking the end-month values. The solid vertical line corresponds to end June 2014, and separates the pre-NIRP (January 2014–June 2014) from the post-NIRP (July 2014–December 2014) windows. Source: Thomson Reuters Eikon.

Figure 2: Forward Curves with Negative Policy Rates



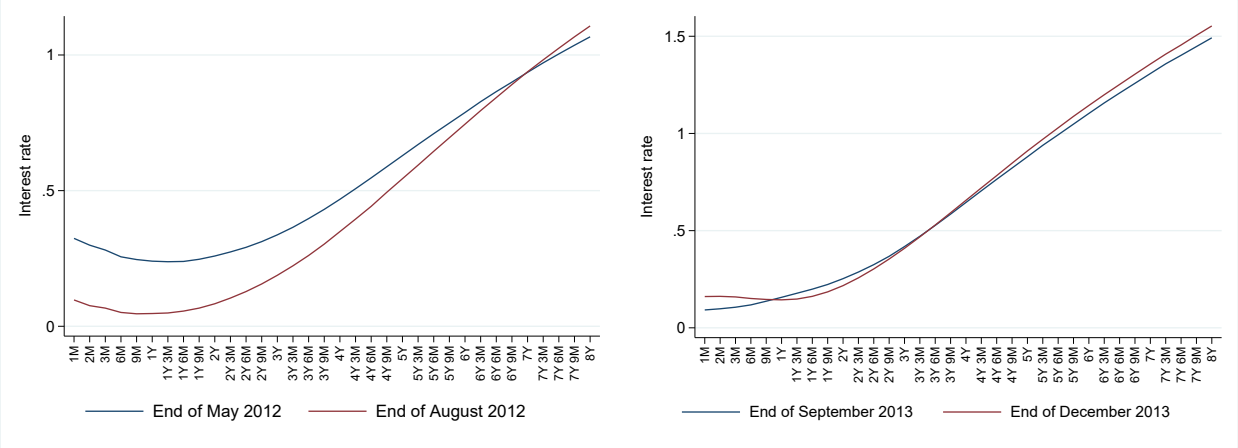
Notes: The charts plot yield curves before and after the ECB introduction of negative policy rates in June 2014. Source: Thomson Reuters Eikon.

Figure 3: Aggregate Credit Growth to Non-Financial Corporations in Italy, 2014



Notes: The chart plots the year-on-year growth rate of total bank credit to non-financial corporations. Source: Bank of Italy.

Figure 4: Forward Curves with Conventional and Unconventional Monetary Policy



(a) July 2012 (DF rate cut in positive territory)

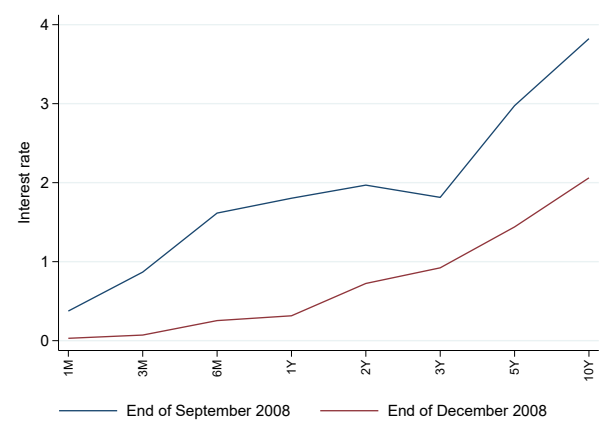
(b) November 2013 (MRO rate cut in positive territory)

(c) Jan. 2015 (QE (APP))

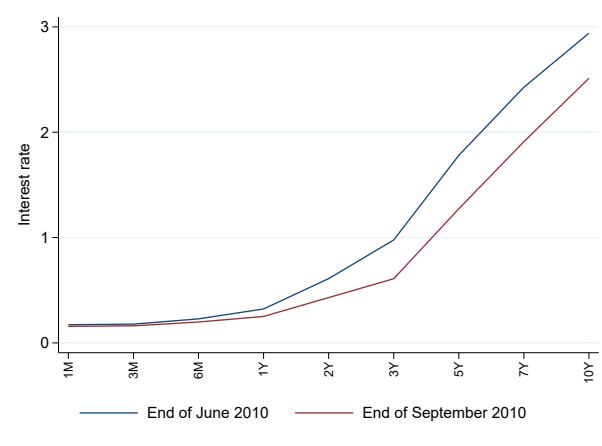
(d) March 2016 (DF rate cut in negative territory)

Notes: The charts plot the yield curves before and after: the ECB DF rate cut of July 2012 (panel a), the ECB MRO rate cut of November 2013 (panel b), the ECB announcement of QE (expanded asset purchase programme) in January 2015 (panel c), and the ECB interest rate cut of March 2016 (panel d). Source: Thomson Reuters Eikon.

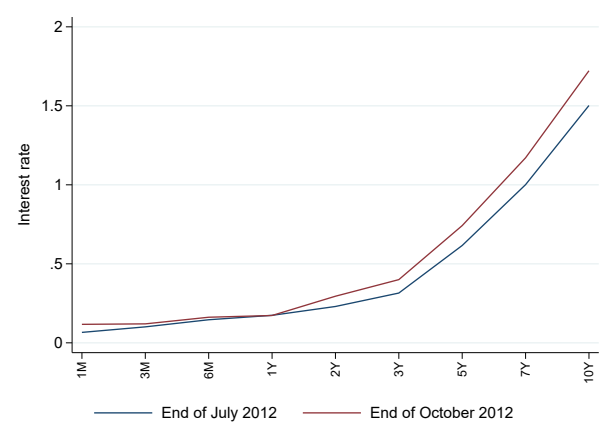
Figure 5: Forward Curves around QE announcements in the U.S.



(a) QE1 (November 2008)



(b) QE2 (August 2010)



(c) QE3 (September 2012)

Notes: The charts plot risk-free yield curves before and after the Federal Reserve's announcements of QE1 in November 2008 (panel A), QE2 in August 2010 (panel B), and QE3 in September 2012 (panel C). Source: Thomson Reuters Eikon.

Table 1: Negative Policy Rates and Bank Credit Supply—Baseline regressions

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP periods ranges between 3 and six months, centered around June 2014, which is excluded from the sample. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Window:	±3 **month around June 2014**				
Net interbank position	0.1438**		0.1283**	0.1249**	0.1232*
	(0.0610)		(0.0597)	(0.0605)	(0.0631)
Liquidity		0.0586***	0.0551***	0.0648***	0.0625***
		(0.0179)	(0.0179)	(0.0194)	(0.0208)
Retail deposits				0.0174	0.0243
				(0.0211)	(0.0251)
TLTRO					-0.0141
					(0.0308)
Observations	495942	495942	495942	495942	495942
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.3726	0.3727	0.3728	0.3728	0.3728
Window:	±6 **month around June 2014**				
Net interbank position	0.1972**		0.1778**	0.1720**	0.1683**
	(0.0803)		(0.0771)	(0.0773)	(0.0800)
Liquidity		0.0735**	0.0686**	0.0854***	0.0803**
		(0.0296)	(0.0288)	(0.0322)	(0.0354)
Retail deposits				0.0300	0.0447
				(0.0315)	(0.0363)
TLTRO					-0.0303
					(0.0460)
Observations	498234	498234	498234	498234	498234
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.4009	0.4009	0.4010	0.4010	0.4010

Table 2: Other Monetary Policy Announcements and Bank Credit Supply

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre- monetary policy announcement. The length of the pre- and post-periods is 3 (Panel A) and 6 (Panel B) months, centered around: 1) July 2012, the latest cut of the DF rate in positive territory (column 1); 2) November 2013, the latest cut of the interest rate on MRO before NIRP (column 2); 3) January 2015, the announcement of QE (expanded asset purchase programme) (column 3); and 4) March 2016, the other rate cut in negative territory (column 4). In each model, the month of the policy announcement is excluded from the sample. Net interbank position in the interbank market is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Liquidity is the ratio of securities over total assets, as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: ± 3 months window around:			
	DFR cut in positive territory July 2012	MRO cut in positive territory November 2013	QE (APP) January 2015	Other DFR cut in negative territory March 2016
Net interbank position	-0.2264***	-0.1136	0.0873	0.1619***
	(0.0562)	(0.0690)	(0.0580)	(0.0352)
Liquidity	-0.0866**	-0.0813***	0.0686***	0.1064***
	(0.0403)	(0.0189)	(0.0208)	(0.0218)
Observations	560352	512130	479977	471293
R^2	0.3769	0.3803	0.3671	0.3666
	Panel B: ± 6 months window around:			
	DFR cut in positive territory July 2012	MRO cut in positive territory November 2013	QE (APP) January 2015	Other DFR cut in negative territory March 2016
Net interbank position	-0.2970***	-0.1664	0.1320	0.3019***
	(0.0740)	(0.1150)	(0.0797)	(0.0498)
Liquidity	-0.1472***	-0.0717**	0.0936***	0.1509***
	(0.0529)	(0.0225)	(0.0298)	(0.0391)
Observations	562857	514457	481942	471293
Bank controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3997	0.4062	0.3924	0.3878

Table 3: Negative Policy Rates and Bank Credit Supply—Bank Heterogeneity

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post-and the pre-NIRP period. The length of the pre- and post-NIRP period ranges between 3 (columns 1 and 3) and 6 (columns 2 and 4) months, centered around June 2014, which is excluded from the sample. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of end-March 2014. The coefficients on these two variables are reported for low and high capital banks, defined splitting the sample around the median of the distribution of the ratio of TIER 1 capital over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; and ii) NPL, defined as non-performing loans scaled by total assets. These two variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Window around June 2014:	(1) ±3 months	(2) ±6 months	(3) ±3 months	(4) ±6 months
Net interbank position x low capital	0.3130**	0.2950		
	(0.1415)	(0.2002)		
Net interbank position x high capital	0.0387	0.0949		
	(0.0488)	(0.0667)		
Liquidity x low capital			0.0683***	0.0948***
			(0.0200)	(0.0303)
Liquidity x high capital			0.0199	0.0078
			(0.0226)	(0.0328)
Observations	495942	498234	495942	498234
Bank controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3728	0.3944	0.3728	0.3944

Table 4: Negative Policy Rates and Bank Credit Supply—Firm Heterogeneity

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post-and the pre-NIRP period. The length of the pre- and post-NIRP period ranges between 3 (first three columns) and 6 (last three columns) months, centered around June 2014, which is excluded from the sample. Panel A looks at the heterogeneous effects of net interbank position across firm's rating and size. Panels B and C replicate this analysis considering the heterogeneous effects of liquidity and retail deposits, respectively. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. The standalone net interbank position and other bank controls—liquidity, capital, size and NPL, as in the baseline (Table 1)—are absorbed by the bank fixed effects, as they are time-invariant (measured as of end-March 2014). Risky firms are defined as those above the median of the Altman z-score (Altman, 1968), measured on a scale from 1 to 9, 1 = best, 9 = worst. Small firms are defined as below the median of total assets. All these splits are done using data as of end-2013. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Window:	(1)	(2)	(3)	(4)	(5)	(6)
	±3 **month around June 2014**			±6 **months around June 2014**		
Panel A: Net interbank position						
Net interbank position x risky	0.1532**		0.1473*	0.1503		0.1431
	(0.0764)		(0.0766)	(0.1249)		(0.1262)
Net interbank position x small		0.0994*	0.0892*		0.1340**	0.1201*
		(0.0518)	(0.0516)		(0.0629)	(0.0640)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3676	0.3670	0.3944	0.3950	0.3943
Panel B: Liquidity						
Liquidity x risky	0.0633**		0.0596**	0.1125***		0.1114***
	(0.0279)		(0.0282)	(0.0405)		(0.0412)
Liquidity x small		0.0522***	0.0475**		0.0301	0.0211
		(0.0180)	(0.0181)		(0.0240)	(0.0248)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3676	0.3670	0.3944	0.3950	0.3944
Panel C: Retail deposits						
Retail deposits x risky	0.0359*		0.0362*	0.0537		0.0532
	(0.0186)		(0.0186)	(0.0324)		(0.0328)
Retail deposits x small		-0.0025	-0.0049		0.0115	0.0079
		(0.0090)	(0.0091)		(0.0095)	(0.0109)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3675	0.3670	0.3944	0.3950	0.3944

Table 5: Effect of the Slope of the Yield Curve on Credit Supply: Panel-data Evidence

Notes: This table reports OLS estimates of a lending equation in which the dependent variable is the logarithm of total granted credit computed at the bank-firm level on a panel dataset at the bank-firm-quarter level spanning the period 2012:Q4 and 2019:Q4. Liquidity is the ratio of securities over total assets. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. The slope is the difference between the 10-year Euro Interest Rate Swap (Eurirs) and the Euro OverNight Index Average (Eonia). Bank controls include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; iii) NPL, defined as non-performing loans scaled by total assets; and iv) the ratio of retail deposits over total assets. The macroeconomic variables are the Italian inflation and unemployment rate. Standard errors, double clustered at the bank and time level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Net interbank position × slope	-0.1499		-0.3983***	-0.4032***	-0.5386***
	(0.1232)		(0.1159)	(0.1292)	(0.1371)
Net interbank position	0.2093		0.5046***	0.5476***	0.7478***
	(0.1737)		(0.1650)	(0.1569)	(0.1726)
Liquidity × slope		-0.1383***	-0.1801***	-0.0949**	-0.0983**
		(0.0487)	(0.0498)	(0.0411)	(0.0461)
Liquidity		0.2159	0.2545*	0.0503	0.2785**
		(0.1348)	(0.1340)	(0.1132)	(0.1138)
Observations	6515304	6515304	6515304	6515304	6461311
Bank controls	Yes	Yes	Yes	Yes	Yes
(Bank Controls) × slope	Yes	Yes	Yes	Yes	Yes
Other macro variables	No	No	No	Yes	Yes
Firm × Time FE	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	-
Bank × Firm FE	No	No	No	No	Yes
R^2	0.7490	0.7490	0.7490	0.7490	0.9608

Table 6: Negative Policy Rates Rates and Lending in the Euro Area

Notes: The table presents OLS estimates of model 3. The dependent variable ($\Delta Loan_{bt}$) is the change in gross loans over total assets at the bank level between $t+1$ and t. Liquidity is the ratio of securities over total assets. Retail deposits are measured as a share of total assets. The Post NIRP dummy is equal to 1 starting in 2013, so that $\Delta Loan_{bt}$, defined as change in loans-to-assets between December 2014 and December 2013, is the first post NIRP period. The set of bank controls includes: i) the ratio of gross loans over assets; ii) equity over assets; iii) the logarithm of assets; iv) the return on assets; and v) the ratio of NPLs over gross loans. All these variables are included as stand alone controls and also interacted with the Post NIRP dummy. The model also includes bank and year fixed effects. Standard errors, clustered at the bank level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Liquidity x Post NIRP	0.0342***	0.0327***	0.0394***	0.0365***
	(0.0058)	(0.0055)	(0.0095)	(0.0087)
Liquidity x Post NIRP x GIIPS		0.0415		0.0749
		(0.0841)		(0.1168)
Retail deposits x Post NIRP	0.0025	0.0008	-0.0023	-0.0077
	(0.0054)	(0.0063)	(0.0071)	(0.0086)
Retail deposits x Post NIRP x GIIPS		-0.0313		-0.0169
		(0.0451)		(0.0482)
Observations	10,825	10,825	7,359	7,359
Bank controls	Yes	Yes	Yes	Yes
Bank NPLs	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
R^2	0.3994	0.4005	0.4611	0.4646

Table 7: Portfolio Rebalancing: U.S. QE Events and Credit Register Data

Notes: This table depicts portfolio rebalancing by U.S. banks with greater liquidity toward corporate loans after the announcements of QE1, QE2, and QE3 (dated November 2008, August 2010, and September 2012, respectively). The dependent variable is the log-change in lending volume at the bank-borrower between the six months preceding and the six months following November 2008, August 2010 and September 2012; and is winsorized at the 95th percentile. Liquidity is the securities-to-assets ratio; Size is the logarithm of total assets; Capital is the ratio of TIER 1 capital over risk-weighted assets; NPL is scaled by total gross loans; Retail deposits is scaled by total assets; and Windfall gains is the ratio of realized gains (losses) from securities holdings over total assets. Borrowers are defined as clusters of firms in the same state and 2-digit NAICS industry. All balance sheet characteristics are measured before the QE announcement, respectively in 2008:Q2 (columns 1-3), 2010:Q2 (columns 4-6), and 2012:Q2 (columns 7-9). Standard errors are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1. Source: Federal Reserve Y-14Q and Call Reports.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Episode:	QE 1 (2008-2009)			QE 2 (2010-2011)			QE 3 (2012-2013)		
Liquidity	3.7984**	4.1059**	4.9184**	3.7336*	3.7196*	3.5707*	0.1392	-0.3290	-0.3993
	(1.586)	(1.582)	(1.811)	(1.872)	(2.046)	(1.837)	(0.614)	(0.616)	(0.620)
Size		0.0909	0.1189*		0.1961	0.1929		0.1452*	0.1366*
		(0.077)	(0.070)		(0.140)	(0.141)		(0.074)	(0.079)
Capital		12.3908**	13.3975**		-3.2434	-4.5846		-0.1350	-0.3728
		(6.051)	(6.284)		(6.500)	(6.904)		(2.012)	(2.103)
NPL		7.9124	6.4674		-7.1470	-8.1605		-0.5419	-0.0424
		(14.764)	(14.627)		(5.950)	(5.691)		(2.996)	(3.151)
Retail deposits		-2.8360	-2.8309		-1.1056	-0.1941		-1.0217**	-0.9222**
		(1.821)	(1.831)		(1.174)	(0.956)		(0.430)	(0.395)
Windfall gains			2.7701*			5.9089**			1.5943
			(1.440)			(2.861)			(1.984)
Firm state × industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	688	688	688	1,258	1,257	1,257	3,693	3,680	3,680
R^2	0.321	0.329	0.330	0.293	0.294	0.296	0.231	0.238	0.238

Table 8: Negative Policy Rates and Loan Rates

Notes: The table presents OLS estimates of model 1. The dependent variable is the change in net loan rates at the bank-firm-month level, calculated as difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP period is of six months, centered around June 2014, which is excluded from the sample. Panel A reports the results for the change in net loan rates on credit lines and overdraft facilities, while Panel B reports the results for term loans. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: Credit lines and overdraft facilities, net rates			
Net interbank position	-0.0349*		-0.0270**	-0.0267*
	(0.0176)		(0.0124)	(0.0133)
Liquidity		-0.0218**	-0.0209**	-0.0211**
		(0.0091)	(0.0087)	(0.0104)
Retail deposits				-0.0004
				(0.0042)
Observations	205091	205091	205091	205091
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3796	0.3821	0.3825	0.3825
	Panel B: Term loans, net rates			
Net interbank position	-0.0059*		-0.0044*	-0.0048*
	(0.0030)		(0.0024)	(0.0025)
Liquidity		-0.0041**	-0.0039**	-0.0036*
		(0.0017)	(0.0016)	(0.0020)
Retail deposits				0.0005
				(0.0013)
Observations	113801	113801	113801	113801
Firm FE	Yes	Yes	Yes	Yes
R^2	0.4100	0.4108	0.4109	0.4109

Table 9: Negative Policy Rates, Firm-level Credit Supply and Real Effects

Notes: The table presents OLS estimates of model 2. The dependent variable is, alternatively: 1) loan growth at the firm-month level, calculated as log difference between the 6-month post- and the 6-month pre-NIRP period, 2) net investment, defined as the growth rate of fixed assets between 2014 and 2013; and 3) the growth rate of the wage bill between 2014 and 2013. The set of control variables includes firm characteristics and and firm-level bank characteristics. Firm characteristics include: i) size, measured as the logarithm of total assets; ii) the return on assets; iii) a dummy for risky firms, defined as those above the median of the Altman z-score, measured on a scale from 1 to 9, 1 = best, 9 = worst; and iv) credit demand, measured as the estimated firm fixed effects from the baseline firm-bank loan-growth regression (Table 1, column 1). Firm-level bank characteristics include: i) size, defined as the logarithm of total assets; ii) capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These control variables are firm-level averages of bank characteristics, weighted by the share of total credit granted to the firm by each bank, as of March 2014. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. The sample includes manufacturing firms (Panel A) or all firms (Panel B). Standard errors, clustered at the main bank level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Panel A: Manufacturing firms		
	Loan growth	Net investment	Wage bill growth
	(1)	(2)	(3)
Net interbank exposure	0.2888***	0.6345***	0.3520***
	(0.0600)	(0.2133)	(0.1070)
Liquidity	0.0563***	0.3272***	0.0665**
	(0.0143)	(0.0989)	(0.0295)
Observations	49701	48134	47350
Firm-level bank controls	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
R^2	0.6327	0.0314	0.0616
	Panel B: All firms		
	Loan growth	Net investment	Wage bill growth
	(4)	(5)	(6)
Net interbank exposure	0.2307***	0.1837	0.3259***
	(0.0473)	(0.2648)	(0.1130)
Liquidity	0.0692***	0.2113*	0.0743**
	(0.0115)	(0.1278)	(0.0303)
Observations	141390	134248	127297
Firm-level bank controls	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
R^2	0.6213	0.0257	0.0624

Expansionary Yet Different:
Credit Supply and Real Effects of Negative Interest Rate Policy

Online Appendix

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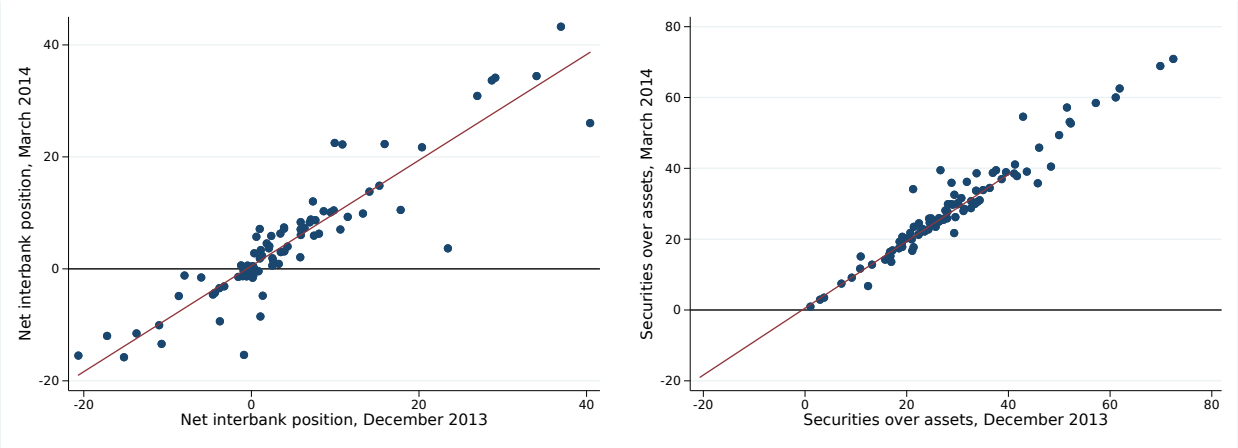
A.1 Additional Figures

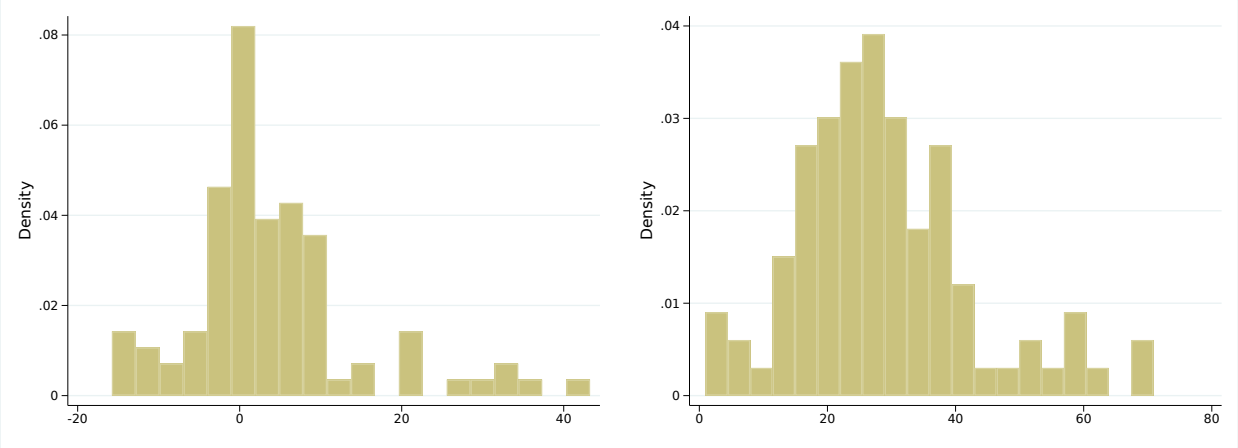
Figure A1: Net Interbank Position and Liquidity in December 2013 and March 2014



(a) Net interbank position (b) Liquidity

Notes: The chart plots the correlation between the net interbank positions (calculated as the ratio of interbank loans minus interbank deposits with maturity up to one week, in percent of total assets) and liquidity (calculated as the ratio of securities over total assets, in percent) measured in December 2013 and March 2014. The variables are winsorized at the 1^{st} and 99^{th} percentiles. Source: Bank of Italy.

Figure A2: Net Interbank Position and Liquidity



(a) Net interbank position (b) Liquidity

Notes: The chart plots the distribution of: i) the net interbank position, measured as interbank loans minus interbank deposits with maturity of up to one week, in percent of total assets (panel a); and ii) liquidity, measured as securities in percent of total assets (panel b). Both variables are measured as of March 2014 and are winsorized at the 1^{st} and 99^{th} percentiles. The sample includes 95 banks. Source: Bank of Italy.

A.2 Additional Tables

Table A1: Negative Policy Rates and Bank Profitability

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variables are: i) the change in return on equity (column 1), and ii) the change in the net interest margin over the six months following the introduction of NIRP, June-December 2014. The net interbank position, defined as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets; liquidity, defined as the ratio of securities over total assets; and retail deposits, computed as a share of total assets, are all measured as of end-March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. Also the control variables are measured before the announcement of NIRP. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1) Δ ROE	(2) Δ NIM
Interbank position	0.3909	0.1345
	(7.1347)	(0.1505)
Liquidity	0.7732	0.1030
	(7.2762)	(0.1248)
Retail deposits	3.1337	-0.0496
	(5.7906)	(0.0857)
Observations	90	90
Bank controls	Yes	Yes
R^2	0.1155	0.1490

Table A2: Negative Policy Rates and Fee Income on Bank Deposits

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is the change in banks' income from fees on bank deposits over the six months following the introduction of NIRP, June-December 2014 (data on income from fees is available bi-annually). Retail deposits are measured as a share of total assets, as of end-March 2014. Bank control variables include: i) Net interbank position, defined as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets; ii) Liquidity, defined as the ratio of securities over total assets; iii) Size, defined as the logarithm of total assets; iv) Capital, defined as the ratio of TIER 1 capital over total assets; and v) NPL, defined as non-performing loans scaled by total assets. Also the control variables are measured before the announcement of NIRP. Data on income from fees are missing for 12 banks in our baseline sample. If we assume that these banks have no income from fees, results on the full sample of 95 banks do not change (e.g., the point estimates and significance level are almost identical). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)
	Change in fee income from bank deposits	
Retail deposits	0.0031***	0.0024***
	(0.0007)	(0.0007)
Observations	83	83
Bank controls	No	Yes
R^2	0.2111	0.3886

Table A3: Descriptive Statistics

Notes: Panel A refers to bank-level variables. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. Liquidity is the ratio of securities over total assets. Size is defined as the logarithm of total assets. Capital is the ratio of TIER 1 capital over total assets. NPL is non-performing loans scaled by total assets. Retail deposits are measured as a share of total assets. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Secured Repo is the ratio of secured repo funding over total assets. Liabilities vis-a-vis non resident is the ratio of foreign funding (deposits from non-residents) over total assets. Securities issues is the ratio of bank-issued securities over total assets. Interbank deposits is the ratio of interbank deposits over total assets. Windfall gain is the sum of individual revaluation gains over all the securities in the marked-to-market portfolios around NIRP as a fraction of a bank's total equity. All these variables are measured as of March 2014. Income fees over assets refer to fees on bank deposits and it is measured as of June 2014. Panel B refers to loan-level variables. Δ *Loan* is measured as log difference between the average total exposure of a given firm with a given bank in the post-NIRP period (July-September 2014) and the correspondent average total exposure in the pre-NIRP period (March-May 2014). Net rates are the average loan rates charged by a given bank to a given firm on credit lines and credit facilities, and on term loans. Panel C refers to firm-level variables. Δ *Loan* is the loan growth at the firm-month level, calculated as log difference between the post- and the pre-NIRP period. Net investment is the growth rate of fixed assets between 2014 and 2013. Wage bill growth is the growth rate of the wage bill between 2014 and 2013.

	Mean	St.Dev.	Median	Obs.
Panel A: Bank-level variables				
Net interbank position, March 2014	4.200	10.810	1.862	95
Liquidity, March 2014	28.670	13.950	25.940	95
Size	7.667	2.310	7.598	95
Capital	8.533	5.768	7.079	95
NPL	4.348	3.555	3.868	95
Retail deposits, March 2014	45.260	16.120	44.650	95
TLTRO	35.670	12.560	36.370	95
Secured Repo	2.918	8.172	0.000	95
Liabilities vis-a-vis non-resident	1.390	2.240	0.245	95
Securities issued	14.520	10.200	14.560	95
Interbank deposits	13.780	9.785	12.760	95
Windfall gain	1.378	1.525	0.919	95
Income fees	0.124	0.107	0.099	83
Panel B: Loan-level variables				
Δ *Loan*	-2.137	20.435	0.000	495,942
Net rates, credit lines and overdraft facilities	8.375	3.129	7.928	205,091
Net rates, term loans	3.916	1.569	3.827	113,801
Panel C: Firm-level variables				
Δ *Loan*	-1.693	20.380	-0.899	141,390
Net investment	11.463	77.175	-2.564	134,248
Wage bill growth	-1.123	31.991	1.258	127,297

Table A4: Negative Policy Rates, Net Interbank Position, and Liquidity

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable measures the change between March and September 2014 of banks': 1) net interbank position (column 1); 2) interbank loans with maturity up to one week over assets (column2); 3) interbank deposits with maturity up to one week over assets (column 3); and liquidity, measured as the ratio of securities over total assets (column 4). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Δ net interbank position after NIRP (1)	Δ interbank loans after NIRP (2)	Δ interbank deposits after NIRP (3)	Δ liquidity after NIRP (4)
Net interbank position	-0.2180**	-0.1644**	0.0536	0.0530
	(0.0851)	(0.0741)	(0.0545)	(0.0501)
Liquidity	-0.0398	-0.0080	0.0318	-0.1016**
	(0.0407)	(0.0369)	(0.0214)	(0.0394)
Observations	95	95	95	95
Bank controls	Yes	Yes	Yes	Yes
R^2	0.1985	0.1643	0.0338	0.1509

Table A5: Net interbank position, Liquidity, and Bank Characteristics

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is, alternatively, the net interbank position (column 1) and liquidity (column 2). The net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of June 2014. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Net interbank position (1)	Liquidity (2)
Size	-2.2878***	-0.3338
	(0.4614)	(0.5773)
Capital	0.2630	-0.8104***
	(0.2178)	(0.2526)
NPL	0.0725	-1.8584***
	(0.3030)	(0.3580)
Observations	95	95
R^2	0.3340	0.2425

Table A6: Balancing of Observable Firm Characteristics

Notes: The table report, for each variable, the average values computed by quartile of bank exposure to NIRP, considering the net interbank position (Panel A) or liquidity (Panel B). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. Liquidity is the ratio of securities over total assets. Firm size is the log of firm's assets; Z-score is the Altman Z-score (Altman, 1968) computed by CERVED; Equity/Debt is the ratio of the book value of equity to firm's debt; Profitability is the ratio of earnings before interest taxes, depreciation and amortization (EBITDA) to firm's assets. In parentheses we report the normalized differences (the difference between the quartile average and the average of the other three quartiles, normalized by the square root of the sum of the corresponding variances). According to the rule of thumb proposed by Imbens and Wooldridge (2009), two variables have "similar" means when the normalized difference is less than 0.25.

	1^{st} Quartile	2^{nd} Quartile	3^{rd} Quartile	4^{th} Quartile
	Panel A. Net interbank position			
Firm size	7.639 (0.004)	7.721 (0.071)	7.547 (-0.075)	7.642 (0.006)
Z-score	5.118 (-0.048)	5.188 (0.001)	5.142 (-0.031)	5.315 (0.086)
Equity/Debt	0.528 (0.053)	0.487 (-0.009)	0.498 (0.008)	0.453 (-0.060)
Profitability	5.959 (0.005)	5.726 (-0.020)	6.144 (0.026)	5.792 (-0.013)
	Panel B. Liquidity			
Firm size	7.602 (0.021)	7.681 (0.064)	7.568 (0.070)	7.723 (0.057)
Z-score	5.375 (0.102)	5.113 (0.081)	5.256 (0.060)	5.346 (0.086)
Equity/Debt	0.425 (0.083)	0.521 (0.069)	0.464 (0.054)	0.445 (0.057)
Profitability	5.443 (0.041)	5.924 (0.002)	5.958 (0.006)	5.698 (0.0190)

Table A7: Negative Policy Rates and Bank Credit Supply—Baseline regressions, all variables

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP periods ranges between 3 and six months, centered around June 2014, which is excluded from the sample. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Size is defined as the logarithm of total assets. Capital is defined as the ratio of TIER 1 capital over total assets. NPL is defined as non-performing loans scaled by total assets. Retail deposits are measured as a share of total assets. All these variables are measured as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Window:	±3 **month around June 2014**				
Net interbank position	0.1438**		0.1283**	0.1249**	0.1232*
	(0.0610)		(0.0597)	(0.0605)	(0.0631)
Liquidity		0.0586***	0.0551***	0.0648***	0.0625***
		(0.0179)	(0.0179)	(0.0194)	(0.0208)
Size	0.1446**	0.2300***	0.2378***	0.3391***	0.3313***
	(0.0635)	(0.0611)	(0.0601)	(0.1163)	(0.1176)
Capital	-0.1749**	-0.0996*	-0.1328**	-0.1477**	-0.1615***
	(0.0796)	(0.0523)	(0.0542)	(0.0572)	(0.0596)
NPL	-0.0889	-0.0517	-0.0604	-0.0603	-0.0467
	(0.0686)	(0.0628)	(0.0625)	(0.0630)	(0.0739)
Retail deposits				0.0174	0.0243
				(0.0211)	(0.0251)
TLTRO					-0.0141
					(0.0308)
Observations	495942	495942	495942	495942	495942
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.3726	0.3727	0.3728	0.3728	0.3728
Window:	±6 **month around June 2014**				
Net interbank position	0.1972**		0.1778**	0.1720**	0.1683**
	(0.0803)		(0.0771)	(0.0773)	(0.0800)
Liquidity		0.0735**	0.0686**	0.0854***	0.0803**
		(0.0296)	(0.0288)	(0.0322)	(0.0354)
Size	0.1562	0.2617**	0.2725***	0.4467**	0.4298**
	(0.1119)	(0.1003)	(0.0989)	(0.1767)	(0.1803)
Capital	-0.1940	-0.0952	-0.1412	-0.1668*	-0.1964*
	(0.1234)	(0.0930)	(0.0982)	(0.1002)	(0.1040)
NPL	-0.0810	-0.0334	-0.0453	-0.0451	-0.0158
	(0.1202)	(0.1204)	(0.1201)	(0.1213)	(0.1278)
Retail deposits				0.0300	0.0447
				(0.0315)	(0.0363)
TLTRO					-0.0303
					(0.0460)
Observations	498234	498234	498234	498234	498234
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.4009	0.4009	0.4010	0.4010	0.4010

Table A8: Baseline regressions—Negative Policy Rates and Bank Credit Supply, 1-month Window

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the July 2014 (the post-NIRP period) and April 2014 (the pre-NIRP period). May and June 2014 are excluded from the sample. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Window:	±1 **month around May-June 2014**				
Net interbank position	0.1083**		0.0992*	0.0987*	0.0973*
	(0.0512)		(0.0510)	(0.0523)	(0.0545)
Liquidity		0.0356***	0.0329***	0.0343**	0.0323**
		(0.0112)	(0.0110)	(0.0133)	(0.0132)
Retail deposits				0.0025	0.0084
				(0.0145)	(0.0206)
TLTRO					-0.0121
					(0.0245)
Observations	487882	487882	487882	487882	487882
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.3553	0.3553	0.3554	0.3554	0.3554

Table A9: Negative Policy Rates and Bank Credit Supply—Robustness

Notes: The table presents OLS estimates of model 1, with the exception of column 6, which reports the weighted least square (WLS) estimates, taking the logarithm of loan size as weight. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP periods is three months, centered around June 2014, which is excluded from the sample, except in columns 7 and 8 (where the pre- and post-NIRP periods are centered around June-August 2014 and May-June 2014, respectively). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of end-March 2014. In columns 5 the net interbank position and liquidity are measured in June 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Retail deposits are measured as a share of total assets. Secured Repo is the ratio of secured repo funding over total assets. Liabilities vis-a-vis non resident is the ratio of foreign funding (deposits from non-residents) over total assets. Securities issues is the ratio of bank-issued securities over total assets. Interbank deposits is the ratio of interbank deposits over total assets. All these variable are measured as of end-March 2014. In column 3 the sample excludes firms in the bottom half of the sample distribution of total assets, measured in March 2014. Windfall gain, included in column 4, is defined as the change in the value of securities in the marked-to-market portfolio over total equity. In column 7 the pre- and post-NIRP period are computed using a ±3 month window around June-August 2014, which are excluded from the sample. In column 8, the pre- and post-NIRP period are computed using a ±3 month window around May-June 2014, which are excluded from the sample. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Net interbank position	0.1325**			0.1327*		0.1025*	0.1414**	0.1607**
	(0.0561)			(0.0676)		(0.0608)	(0.0697)	(0.0661)
Net interbank position, June 2014					0.1070**			
					(0.0533)			
Liquidity	0.0836***	0.0696***	0.0561**	0.0558***		0.0524***	0.0697*	0.0749***
	(0.0253)	(0.0191)	(0.0221)	(0.0177)		(0.0199)	(0.0375)	(0.0175)
Liquidity, June 2014					0.0611***			
					(0.0165)			
Retail Deposits	0.0598*	0.0200	0.0171					
	(0.0358)	(0.0207)	(0.0222)					
Secured Repo	-0.0511							
	(0.0664)							
Liabilities vis-a-vis non-resident	0.3049**							
	(0.1261)							
Securities issued	0.0802**							
	(0.0381)							
Interbank deposits	0.0248							
	(0.0431)							
Windfall gain				0.0982				
				(0.2901)				
Observations	495942	495942	269511	495942	495942	441684	483648	490397
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3732	0.3727	0.3280	0.3728	0.3727	0.3531	0.3838	0.3767

Table A10: Negative Policy Rates, Net Interbank Position, and Liquidity, Placebos

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variables are: i) the change in the net interbank position (columns 1 and 3), and ii) the change in liquidity (columns 2 and 4) over the six months following two rate cuts episodes, one in July 2012 (columns 1-2) and the second in November 2013 (columns 3-4). The net interbank position is defined as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. Liquidity is defined as the ratio of securities over total assets. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. Also the control variables are measured in the quarter before the rate cut. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Δ net interbank position	Δ liquidity	Δ net interbank position	Δ liquidity
Episode:	DFR rate cut in July 2012		MRO cut in November 2013	
	(1)	(2)	(3)	(4)
Net interbank position	0.0791	-0.0626	0.0767	-0.0012
	(0.0957)	(0.0467)	(0.0733)	(0.0580)
Liquidity	-0.0546*	-0.0126	0.0556	0.0261
	(0.0305)	(0.0393)	(0.0383)	(0.0451)
Observations	95	95	95	95
Bank controls	Yes	Yes	Yes	Yes
R^2	0.0973	0.0741	0.0897	0.0868

Table A11: Negative Policy Rates and Bank Credit Supply—Parallel Trends

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre- monetary policy announcement. In panel A, the length of the pre- and post-periods is three months, centered around: 1) December 2013 (column 1); 2) January 2014 (column 2); and February 2014 (column 3). We do not expand our sample beyond February 2014 as the ± 3 months window around March 2014 will include June 2014 (and the introduction of NIRP) in the post-period. In panel B, the length of the pre- and post-periods is six months, centered around: 1) September 2013 (column 1); 2) October 2013 (column 2); and November 2013 (column 3). We do not expand our sample beyond November 2013 as the ± 6 months window around December 2013 will include June 2014 (and the introduction of NIRP) in the post-period. In each model, the month of the policy announcement is excluded from the sample. Net interbank position in the interbank market is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)
	Panel A: ± 3 months windows		
	Sep 2013-Mar 2014	Oct 2013-Apr 2014	Nov 2013-May 2014
Net interbank position	-0.0097	0.0072	0.0425
	(0.0467)	(0.0482)	(0.0479)
Liquidity	-0.0950***	-0.0678*	-0.0087
	(0.0292)	(0.0367)	(0.0252)
Observations	508784	506734	507318
R^2	0.3787	0.3778	0.3762
	Panel B: ± 6 months windows		
	Mar 2013-Mar 2014	Apr 2013-Apr 2014	May 2013-May 2014
Net interbank position	0.0104	0.0035	0.0296
	(0.0740)	(0.0681)	(0.0665)
Liquidity	-0.0125	-0.0351	-0.0530*
	(0.0221)	(0.0237)	(0.0279)
Observations	522720	518876	514457
Firm FE	Yes	Yes	Yes
Bank controls	Yes	Yes	Yes
R^2	0.4061	0.4062	0.4061

The negative coefficients of liquidity in some specifications can be explained by the fact that, as discussed in Section 4.3, in November 2013 the ECB lowered the interest rate on the MRO without flattening the yield curve (see Figure 4, panel b).

Table A12: Negative Policy Rates and Non-Performing Loans

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is the change in banks' non-performing loans (NPL) scaled by total assets over: (i) the 12 months period following the introduction of NIRP, March 2014-March 2015 (top panel), and (ii) the 60 months period following the introduction of NIRP, March 2014-March 2019 (bottom panel). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Data on the change in banks' non-performing loans is missing for 1 bank in our baseline sample, as the bank is not operative in March 2015. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)
	Period: March 2014 - March 2015		
Net interbank position	-0.0150		-0.0101
	(0.0119)		(0.0242)
Liquidity		0.0127	0.0102
		(0.0107)	(0.0138)
Observations	94	94	94
R^2	0.4027	0.4046	0.4067
	Period: March 2014 - March 2019		
Net interbank position	-0.0170		-0.0020
	(0.0430)		(0.0442)
Liquidity		0.0313	0.0307
		(0.0314)	(0.0319)
Observations	91	91	91
Bank controls	Yes	Yes	Yes
R^2	0.3759	0.3804	0.3804

Table A13: Negative Policy Rates and Gross Lending Rates

Notes: The table presents OLS estimates of model 1. The dependent variable is the change in gross lending rates, which include commissions and fees, at the bank-firm-month level, calculated as difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP period is of six months, centered around June 2014, which is excluded from the sample. Panel A reports the results for the change in gross lending rates on credit lines and overdraft facilities, while Panel B reports the results for term loans. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: Credit lines and overdraft facilities, net rates			
Net interbank position	-0.1005***		-0.0819***	-0.0815***
	(0.0282)		(0.0157)	(0.0174)
Liquidity		-0.0478***	-0.0449***	-0.0452***
		(0.0136)	(0.0122)	(0.0143)
Retail Deposits				-0.0006
				(0.0053)
Observations	188690	188690	188690	188690
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3959	0.3974	0.3979	0.3979
	Panel B: Term loans, net rates			
Net interbank position	-0.0063**		-0.0047*	-0.0051*
	(0.0030)		(0.0025)	(0.0026)
Liquidity		-0.0042**	-0.0040**	-0.0037*
		(0.0017)	(0.0016)	(0.0020)
Retail Deposits				0.0005
				(0.0012)
Observations	113842	113842	113842	113842
Firm FE	Yes	Yes	Yes	Yes
R^2	0.4094	0.4102	0.4103	0.4103

A.3 U.S. QE: Evidence from Survey Data

We complement the evidence on U.S. QE episodes discussed in Section 4.6 with an analysis of microdata from the quarterly Senior Loan Officer Opinion Surveys (SLOOS) conducted by the Federal Reserve. The purpose of the survey is to gather qualitative and quantitative information about bank credit availability and loan demand, as well as on lending practices in the U.S. bank loan market.[43] We use the confidential bank-level responses to test if the probability with which banks report tightening C&I lending standards is relatively lower for more liquid banks in the two quarters after each QE announcement. These data have the benefit that we can control for concurrent shifts in loan demand directly using banks' own assessment of how loan demand changes each quarter. The smallest participating bank in the SLOOS has total assets of about $2 billion and 75–80 banks participate in each survey round.

The dependent variable is a dummy variable taking value one for banks that reported that they tightened lending standards "somewhat" or "considerably" in response to the question "*Over the past three months, how have your bank's credit standards for approving applications for C&I loans or credit lines—other than those to be used to finance mergers and acquisitions—to large and middle-market firms and to small firms changed?*" (and zero otherwise). Since the banks give separate responses for large versus small firms (with less than USD 50 million in annual sales), we stack the responses across the two size groups and across all surveys to obtain a panel at the bank-survey-borrower size level (where borrower size is either large or small firms). Then we regress the dependent variable on the key variable of interest—bank liquidity—and other balance sheet controls, including a dummy variable that takes value one for banks reporting stronger loan demand over the quarter (and zero otherwise). For each event, we study changes in lending standards in the two quarters before and after the QE announcement. Bank balance sheet variables are measured at quarter-end before the announcement.

As shown in Table A14, the results support the idea of a portfolio rebalancing channel. Banks with more liquid assets before QE are relatively less likely to tighten C&I lending standards after each QE event. The coefficient estimates are positive and significant across all specifications. Notwithstanding that these results are based on banks' self-assessments of changes in lending standards and loan demand, and on a sample skewed toward larger banks, we believe they are nevertheless suggestive of our channel.[44]

[43] For more information, see https://www.federalreserve.gov/data/sloos/about.htm.

[44] In results not reported, we examine the QE3 event in September 2012, which was not followed by a flattening of the yield curve (Figure 5, panel C), as a placebo test. We find no systematic relation between ex ante bank liquidity and the probability of changing credit standards after that announcement.

Table A14: Portfolio Rebalancing after U.S: QE: Evidence from Survey Data

Notes: This table depicts the link between C&I lending standards of U.S. banks and liquidity after the QE1 and QE2 events taking place in 2008–2009 and 2010–2011 respectively. The dependent variable is a dummy variable taking value one for banks that report tightening C&I lending standards "somewhat" or "considerably" in each quarter (and zero otherwise). Columns 1–4 refer to the QE1 event (November 2008) and the data represent stacked survey responses during 2008:Q2–Q3 (pre-Q1 period) and 2008:Q4–2009:Q1 (post-QE1 period). Columns 5–8 refer to the QE2 event (August 2010) and the data represent stacked survey responses during 2010:Q1–Q2 (pre-QE2 period) and 2010:Q4–2011:Q1 (post-QE1 period). The data are at the bank-survey-borrower size group level, where borrower size group refers to either large and middle-market firms or small firms (with annual sales below $50 million). All balance sheet characteristics are measured before the QE announcement, respectively in 2008:Q2 (columns 1-4) and 2010:Q2 (columns 5-8). All regressions include bank controls (size, capital, NPL, and retail deposits), a dummy variable that controls for shifts in loan demand and takes value 1 for banks that report an increase in loan demand over the quarter (and zero otherwise), survey fixed effects, and a dummy variable for observations that refer to large and middle-market firms (firm size FE). In columns 4 and 8 we control for realized gains (losses) on from securities holdings to allow for potential QE-induced valuation effects on bank balance sheets. Standard errors are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1. Source: Federal Reserve SLOOS and Call Reports.

Episode:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	QE 1 (2008-2009)				QE 2 (2010-2011)			
Liquidity × Post	-1.6249***	-1.5174***	-1.5481***	-1.5710***	-0.3759**	-0.3815**	-0.3826**	-0.3827**
	(0.346)	(0.419)	(0.427)	(0.419)	(0.189)	(0.189)	(0.189)	(0.190)
Liquidity × Post	0.3730	0.2532	1.2375	1.2680	-0.0894	-0.0869	-0.0381	-0.0286
	(0.943)	(0.960)	(0.902)	(0.896)	(0.161)	(0.162)	(0.169)	(0.176)
Loan demand × Post		-0.2423	-0.1988	-0.1957		-0.0317	-0.0312	-0.0300
		(0.173)	(0.174)	(0.173)		(0.033)	(0.033)	(0.032)
Loan demand		0.0239	-0.0010	-0.0059		-0.0052	-0.0049	-0.0053
		(0.103)	(0.101)	(0.100)		(0.033)	(0.034)	(0.034)
Windfall gains				-1.2566				-0.2893
				(1.067)				(0.434)
Bank controls	No	No	Yes	Yes	No	No	Yes	Yes
Bank state	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey (quarter) FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	424	422	422	422	440	439	439	439
R^2	0.289	0.294	0.322	0.325	0.141	0.145	0.149	0.150