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Do Negative Interest Rates Affect Bank Risk-Taking?†

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Abstract

We offer early evidence on the impact of negative interest rate policy (NIRP) on banks' risk-taking. Our primary result shows banks in NIRP-adopter countries reduce holdings of risky assets by around 10 percentage points following implementation of NIRP in comparison to banks in non-adopter countries. We augment this result by identifying NIRP's impact on other aspects of banks' risk-taking behaviour; NIRP is associated with reductions in banks' loan growth and average loan price (by 3.7 percentage points and 59 basis points) and a rebalancing of asset portfolios towards safer assets. Secondly, we find the NIRP-effect is heterogeneous; post-NIRP risk-taking increases at strongly capitalised banks and at banks operating in less competitive markets that exploit market power to insulate net interest margins and profitability. Our robust empirical evidence supports the "de-leverage" hypothesis which suggests that banks acquire safer, liquid assets to bolster their capital positions rather than searching for value by acquiring riskier assets. We base our evidence on a sample of 2,584 banks from 33 OECD countries across 2012 to 2016, and from models that employ a difference-in-differences framework.

Keywords: NIRP, Bank Risk-Taking, Monetary Policy, Difference-in-Differences.

JEL: E43, E44, E52, E58, G21, F34

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1. Introduction

We investigate if grounds exist to substantiate a claim of unintended consequence due to the impact of negative interest policy (NIRP) on banks' risk-taking behaviour. To evaluate this proposition, we test if banks' behaviour complies with ex ante expectations in which banks react to NIRP by increasing both their holdings of riskier, higher-yielding assets and loan volumes (Coeuré, 2016). We term this proposition the "search for yield" hypothesis (following Rajan, 2006). However, while NIRP is expected to incent banks to acquire riskier assets, this outcome is uncertain because risk-taking is determined by other factors particularly bank fundamentals, regulations, and monetary and macroeconomic conditions. For instance, banks could use excess liquidity - provided via central banks' unconventional monetary policy toolkit - to acquire safer assets; this behaviour is rational during periods of economic uncertainty and high firm default rates. Similarly, banks could gain from favourable regulatory treatment of sovereigns; these assets generate returns without requiring capital backing.[1] This scenario constitutes our "de-leverage" hypothesis.

Our empirical framework invokes a difference-in-differences approach to determine the effect of NIRP on banks' risk-taking in countries that adopted NIRP compared to banks in countries that did not. For this purpose, we construct a panel dataset of 2,584 banks in 33 OECD countries. The data cover the period from 2012 to 2016 and yields 6,006 bank-year observations. Given the paucity of empirical evidence on the impact of NIRP, we consider its efficacy and join a vociferous debate on the effectiveness of unconventional policy tools (Ball et al., 2016; Jobst and Lin, 2016; Arteta et al., 2018).

NIRP is perceived as a response to the failure of conventional monetary policy tools to rejuvenate economies post-GFC (Global Financial Crisis).[2] *Ceteris paribus* negative interest rates implicitly raise the opportunity cost to banks of holding larger volumes of negative yielding excess reserves, which should incent banks to acquire riskier, higher-yielding assets. Alongside decreases in loan rates associated with NIRP, this should boost demand for credit and the wider economy (see Coeuré, 2016).

This anticipated effect materialises through two channels. First, and through a deposit rate channel, downward sticky deposit rates compress banks' net interest margins to pressurise profitability, which pushes banks into higher-yielding, riskier assets to maintain profits. Second, and via a yield curve compression channel, NIRP alters portfolio risk as banks exit low-yielding, short-term liquid assets for higher-yield, long-term illiquid assets (Arsenau, 2017).

[1] The EC's Capital Requirement Directive assigns a zero-risk weight for "exposure to Member States' central government … denominated and funded in the domestic currency of that central government" (Hannoun, 2011).
[2] Since 2012, the Eurozone, other European countries (Denmark, Hungary, Norway, Sweden, and Switzerland) and Japan have introduced NIRP. Bech and Malkhozov (2016) discuss the mechanisms for implementing NIRP.

Given the polar positions of the "search for yield" and "de-leverage" hypotheses, we investigate if the NIRP-effect on banks' risk-taking is heterogeneous and varies according to bank- and country-specific factors, such as, capitalisation and competition (Nucera et al., 2017; Altunbas et al., 2018). For well adequately capitalised banks, NIRP can incent increased investment in riskier assets because bigger capital buffers support greater risk-taking (Dell'Ariccia et al., 2010). However, NIRP could lead weakly capitalised banks into riskier behaviour if it induces a gamble for resurrection (De Nicolò et al., 2010; Jimenez et al., 2014). We are motivated by the ambiguous relationship between negative rates, capital and risk-taking to uncover robust empirical evidence on its true nature.

We consider the sensitivity of the NIRP-effect to the competitiveness of national banking markets (see Molyneux et al., 2020). Brunnermeier and Koby (2017) and the IMF (2017) claim competition amplifies banks' exposure to negative rates to produce opposing effects. Banks may respond to keener competitive conditions that pressurise net interest margins by making safer investments. Under less stringent competitive conditions, banks may exploit their market power and increase loan mark-ups to boost profit, which in turn supports their ability to make riskier loans.

Our "de-leverage" hypothesis posits that the GFC and European sovereign debt crisis severely weakened banks' balance sheets, which shifted banks' focus to repairing capital positions in a way contrary to the intended effect of NIRP. Whilst cheaper central bank funds can enhance banks' risk-tolerance and risk-perception to induce greater risk-taking, the "de-leverage" hypothesis contends that banks opt to cleanse their balance sheets by increasing investments in safer assets. Therefore, and to satisfy binding capital requirements, banks can exploit the favourable regulatory treatment of sovereigns and acquire 'safer' liquid assets like government bonds that carry (in Europe) zero risk weighting. We suggest such behaviour is an unintended consequence of NIRP.

In preview, our primary result shows a NIRP-effect whereby NIRP-affected banks reduced holdings of risky assets compared to non-affected banks. It infers that banks intentionally repaired deteriorated balance sheets by acquiring safer assets, such as, zero weighted sovereign bonds rather than increase risk and lending. This scenario is consistent with predictions of the "de-leverage" hypothesis. Our primary result is robust to various specifications and robustness checks. Our second result shows the effect of NIRP on bank risk-taking is heterogeneous. We find better capitalised banks and banks able to exploit market power in less competitive markets hold larger volumes of riskier assets post-NIRP.

The paper proceeds as follows: section 2 reviews salient academic literature, section 3 presents data and methodology. Section 4 discusses results and robustness checks. Section 5 concludes.

2. Literature

A vigorous discussion of the link between low interest rates and banks' risk-taking has been taking place since the GFC. Borio and Zhu (2012) theorize the existence of a "risk-taking channel" in the monetary transmission mechanism. It posits a relationship between expansionary monetary policy and greater bank risk-taking that operates in (at least) two ways. First, low and negative rates on securities motivate banks to switch into riskier assets to deliver nominal returns on liabilities (Brunnermeier, 2001; Rajan, 2006).[3] Second, although cuts in policy rate boost banks' profits via valuation gains on securities and rising asset prices, cuts could alter banks' risk-tolerance, risk-perception and risk-appetite (Adrian and Shin, 2009). Academics are yet to reach a consensus on the net effect of low interest rates on bank behaviour and risk-tolerance.

Plentiful evidence finds accommodative monetary policy leads to increased risk-taking. Angeloni et al. (2015) find interest rate rises make bank liabilities more expensive. This incents banks to de-lever and hold fewer risky assets. It implies that tighter monetary policy reduces banks' risk-taking. Delis and Kouretas (2011) examine a large dataset of Euro area banks between 2001 and 2008. Using the NPL ratio and the amount of risky assets to proxy bank riskiness, they report a strong negative relationship between risk-taking and interest rates.[4] Jimenez et al. (2014) use a database of 23 million loans in Spain (from 2008 to 2012) and find a similar impact on loan credit ratings granted before and after cuts in the ECB overnight rate. While all banks respond to low rates by granting more loans, less capitalised banks with less skin-in-the-game advance more and riskier loans. However, De Nicolò et al. (2010) suggest that high franchise values could discourage banks from gambling for resurrection even if interest rates were to fall.

The adverse and wide-ranging consequences of the GFC prompted policymakers to intervene in markets to restore confidence and create conditions for fast and sustained economic recovery. The regulatory response in Basel 3 is expected to strengthen the financial architecture by raising capital requirements and introducing new liquidity requirements. Concomitantly, policymakers employed new tools or unconventional monetary policies (UMPs), such as, quantitative easing (QE), forward guidance (FG), asset purchase programmes (APP), and NIRP to stimulate perpetually weak economies.[5] Through NIRP, central banks seek to improve the effects of other (current or past) expansionary policies like charging banks for holding excess reserves. One aim of unconventional

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

[4] NPL is the ratio of non-performing loans-to-gross loans. Risky assets are assets that are subject to changes in value due to changes in market conditions or in credit quality at various re-pricing opportunities. They equal total assets less cash, government securities and balances due from other banks.

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

policy tools is to lower long-term interest rate expectations even though the tendency of rates to zero or below affects banks' profitability and risk (Jobst and Lin, 2016; Arteta et al., 2018).

Since central banks started to adopt NIRP, academics have investigated the impact of a negative or time varying lower bound on the yield curve as a new channel of monetary policy. Although evidence unambiguously shows that NIRP and the corresponding time-varying lower bound effectively lower short-term rates, for longer maturities the evidence is mixed and inconclusive. For instance, Lemke and Vladu (2017) use survey-based interest rate expectations to analyse yield curve response to a drop in the perceived lower bound following an ECB rate cut in September 2014. The identify an effect for short-term maturities only. Kortela (2016) finds short rates anchor to the expected path of the ECB's deposit facility rate. This provides a lower bound for interest rates and opens a channel for monetary policy to affect the yield curve via expectations of changes in the deposit facility rate. When this lower bound is more restrictive, the more effective are cuts in the deposit facility rate in lowering both short and long-term interest rates.

Wu and Xia (2020) use a forward-looking shadow rate term structure model to investigate NIRP's effects in the Euro area. Whereas NIRP announcements reduced short-term interest rates by 10 basis points, the observed effect on longer maturities occur only when rate cuts are announced alongside credible forward guidance. In each case, management of the perceived lower bound strengthens the effectiveness of interest rates cuts (Grisse et al., 2017). Utilising a forward-looking approach, Sims and Wu (2020) apply a quantitative DSGE framework and find that NIRP exerts only a small effect only on output growth. The result implies that NIRP requires very large cuts in policy rates to be as effective as rate cuts achieved using conventional monetary policy tools. Sims and Wu attribute the smaller NIRP effect to two main factors: first, downward sticky deposit rates compress banks' profitability in the short-term and, ultimately, its net worth; second, the timing of deployment of other UMPs. For instance, NIRP is less effective if adopted after QE because an already large central bank balance sheet undermines the marginal effect of additional monetary policy tools.

Several studies find effective pass-through is lower when interest rates are negative. Amzallag et al. (2019) report a significant increase in loan rates on residential fixed rate mortgages post-NIRP at Italian banks funded heavily by retail overnight deposits. Bech and Malkhozov (2016) and Basten and Mariathasan (2018) find Swiss banks increase lending rates post-NIRP. Eggertsson et al. (2019) associate lower lending growth with adoption of NIRP in Sweden for banks with high retail deposit shares. The limited pass-through of negative rates to funding structures coerces banks to increase, rather than decrease, loan rates, which creates a contractionary effect on loan volumes. The authors document a fall in bank equity values as cuts push rates into negative territory. Relatedly, Ulate (2019) identifies reductions in banks' net worth as the main channel that curbs the effectiveness of negative interest rates.

Evidence on NIRP's impact on bank profitability is ambiguous. Molyneux et al. (2019) associate NIRP with tighter interest margins that pressurise profits to feed bank instability. However, Lopez et al. (2018) find negative nominal interest rates leave profitability unaffected. Pass-through to rates on banks' liabilities, and gains in non-interest income (such as, capital gains and gains on securities), infer that the monetary policy transmission mechanism should work in a negative interest rate environment. The relatively inelastic demand for deposits associated with periods of slow economic activity, low investment opportunities and greater preference for safer assets, may see pass-through of interest rate cuts into negative territory to depositors; this could alleviate pressure on banks' net interest margins and stimulate both the supply of credit and firm investment (Altavilla et al., 2019). Exploiting data from the Italian administrative credit register and firm-bank relationships, Bottero et al. (2019) identify a portfolio rebalancing channel at work post-NIRP through which banks increase the supply of credit and lower loan rates to constrained albeit viable firms.

However, others find the effect of negative interest rates on bank lending is contradictory, which supports the reversal interest rate hypothesis. Inoue et al. (2019) invoke a quasi-natural experiment using the unexpected NIRP adopted by the Bank of Japan and a bank-firm matched dataset. The contraction in lending by banks with greater exposure to NIRP is stronger; it adversely affects fixed investments at firms that rely more on loans from NIRP affected banks. Molyneux et al. (2020) find NIRP-affected banks reduce mortgages and corporate loans.

Despite claims that unconventional monetary policy is not neutral from a lending perspective, few studies examine banks' riskiness under negative interest rates without reaching consensus. Heider et al. (2019) associate the ECB's use of NIRP in 2014 with lower volumes of syndicated loans although the riskiness of loans increased notably at banks with large deposit volumes. Analysing the impact of the ECB's deposit facility interest rate cuts on bank risk, Nucera et al. (2017) find that risk declined for large banks but increased for smaller banks, particularly banks heavily reliant on customer deposits.[6] A cross-country study of changes in bank risk following NIRP announcements by central banks offers further evidence. Using rates on the credit default swaps of listed banks to proxy risk, Arteta et al. (2018) find NIRP affects financial stability by reducing banks' long-run profitability rather than affecting risk-taking. Hong and Kandrac (2020) assess changes in Japanese banks' risk-taking behaviour post-NIRP. They find that banks operating business models with greater exposure to NIRP significantly lower credit standards and grow loan volumes to a larger extent. Together, these

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

studies confirm that bank-level characteristics and country-specific factors are an important factor in determining how NIRP transmission affects bank behaviour.

Our paper moves the literature a step forward by assessing changes in banks' risk-taking following NIRP. By directly comparing banks in NIRP-adopter and non-NIRP countries, we offer additional evidence on differences in banks' risk tolerance that can hamper the transmission mechanism of monetary policy under a negative interest rate environment.

3. Methodology and Data

We use a difference-in-differences framework to identify the effect of NIRP on banks' risk-taking (Molyneux et al., 2019). We compare the NIRP-effect on risk-taking for a treatment group of banks headquartered in NIRP-adopting countries against a control group unaffected by the policy change. Equation [1] summarizes our baseline model:

$$Y_{i,j,t} = \alpha + \beta_1\left(treated_{i,j} * Post_{j,t}\right) + \beta_2 X_{i,j,t} + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \quad [1]$$

Where Y_{ijt} equals the growth of risky assets for bank *i* in country *j* at time *t*. *Treated* is a binary variable equal to unity if bank *i* in country *j* is affected by NIRP in 2014, 0 otherwise. *Post* is a binary variable equal to unity for years following introduction of NIRP, 0 otherwise. γ_j controls for unobserved time-invariant country-specific characteristics. φ_t controls for time-varying shocks that affect banks' risk-taking. Since most NIRP-adopting countries in our sample introduced the policy in 2014, *Post* equals unity from 2014 year-end. The coefficient β_1 measures the difference in the growth of risky assets between banks in NIRP-adopting countries and countries maintaining positive rates. To control for possible heterogeneity between banks and reduce omitted variable bias, Equation [1] specifies a vector, X, of bank- and country- specific controls to account for factors that can impact banks' risk-taking, which we select with reference to relevant literature (see next section).

The difference-in-differences model must satisfy two suitability requirements if we are to apply it to determine the NIRP-effect on banks' risk-taking. First, the control group must constitute a valid counterfactual for the treatment. To address this concern, we estimate Pearson correlation coefficients for the macroeconomic variables in the treatment and control groups (see Table 1). The significance of those coefficients implies that countries in each group experienced similar macroeconomic environments, which confirms the validity of the control as counterfactual for the treatment.[7]

[7] We arbitrarily chose a longer period (compared to the sample period) to show macroeconomic indicators move together for several years post-GFC.

[Insert Table 1 here]

The second requirement is the parallel trend assumption (Bertrand et al., 2004). Figure 1 shows the growth of risky assets in the treated (NIRP adopting countries in 2014) and control groups from 2012 to 2016.[8] The assumption holds since the trend lines move closer together before central banks began introducing NIRP in 2014. Interestingly and post-NIRP, banks in NIRP-adopting countries realised a remarkable reduction in risky assets whereas banks in non-adopter countries maintained stable growth in risky assets.

[Insert Figure 1 here]

Our panel dataset comprises a sample of 2,584 banks from 33 OECD countries from 2012 to 2016 to yield 6,006 bank-year observations.[9] The number of observations in the treatment and control groups are 3,386 and 2,620, respectively. We source bank-level variables from Orbis Bank Focus and winsorize at the 1% level for treatment and control groups to reflect different group distributions. Since banks operating cross-border subsidiaries pose a problem, to avoid double counting and allocating banks into the wrong group, we use unconsolidated financial statements or consolidated statements so long as the bank does not have an unconsolidated subsidiary.[10]

Table 2 reports descriptive statistics for treated and control groups pre- and post-NIRP. Panels A and D show the indicators we use to identify realised measures of balance sheet risk. Following Delis and Kouretas (2011) we construct the main bank-level variable of interest, *GRisky*, as total assets less cash, government securities and due to banks. Increases (decreases) in *GRisky* indicate higher (lower) realised risk on banks' balance sheets. Further motivation for this indicator follows concerns that banks could engage in regulatory arbitrage to reduce risk-weighted assets to bolster capital adequacy especially if banks use internal-rating based models to assess credit risk (Mariathasan and Merrouche, 2014). Furthermore, variation in adoption rates of internal-rating based models across countries could introduce bias if we select risk-weighted assets to proxy risk (Bruno et al. 2015).

We utilise alternative dependent variables to proxy banks' risk-taking behaviour for robustness. First, *Loan Growth* is the annual growth of gross loans (Heider et al., 2019; Molyneux et al., 2020). Second, *Loan Rates* is the ratio of interest income-to-gross loans to measure banks' average loan price (Molyneux et al., 2019). Third, we denominate *GRisky* by total assets to investigate if banks revise

[8] The sample period is intentionally short. According to Roberts and Whited (2013) and Bertrand et al. (2004), the change in the treatment group should be concentrated around the onset of the treatment. Moving further away means unobservable and other factors can affect the treatment outcome and cause omitted variable bias to threaten the validity of the model.
[9] Table A1 in the Appendix shows NIRP implementation dates by country aside Japan which introduced NIRP in 2016.
[10] Codes U1 and U2 in Orbis Bank Focus.

the relative weightings of riskier and safer assets in their portfolios (Delis and Kouretas, 2011). In specifying these variables, we can quantify the NIRP-effect on banks' loan growth, loan pricing, and portfolio composition. Lastly, and since our main variable (*GRisky*), which captures the variation in risky assets, excludes sovereign bonds we might not fully capture the purchase of riskier government securities that can drive risk-taking behaviour. In a further robustness check, we employ banks' Z-scores (and constituents) as dependent variable(s) reflecting Z's application to measure risk (Beck et al. 2013; Mohsni and Otchere, 2014).[11]

Panels B and E show descriptive statistics for bank-level variables. We measure bank size as the natural logarithm of total assets (*Size*). The too-big-to-fail hypothesis suggests a positive relationship between size and risk-taking; however, prospective portfolio diversification gains, better managerial skills, and easier funding conditions could realise an inverse relationship (Bertay et al., 2013). The ratio of equity-to-assets measures banks' capitalisation (*E/TA*). The capital channel of monetary policy suggests banks' responses to monetary policy impulses vary significantly with capitalisation (Van den Heuvel, 2002; Gambacorta and Mistrulli, 2004). While high levels of prudence support larger volumes of riskier assets, risk-taking at under capitalised banks is constrained by binding capital constraints (De Nicolò et al., 2010; Gambacorta and Shin, 2015). Yet, capitalisation's impact on risk-taking remains ambiguous. We cannot ignore possibilities of banks gambling for resurrection, or thinly capitalised banks assuming excessive risk to increase earnings, which, if retained, would bolster equity, and improve soundness (Calem and Rob, 1999).

We proxy banks' funding structure using the ratio of customer deposits-to-total liabilities (*Funding Structure*). Funding affects banks' sensitivity to interest rate changes. Low and/or negative interest rates can induce greater risk-taking to protect profitability if sticky deposit rates and heavier reliance on (stable) deposit funding realises downward pressure on net interest margins. This scenario exposes deposit-funded banks to monetary policy changes whilst wholesale banks manage the price of liabilities more dynamically (Demirgüç-Kunt and Huizinga, 2010).

The ratio of non-interest income-to-total income is proxy for banks' *business models* and a common measure of diversification (Delis and Kouretas, 2011; Beck et al. 2013; Borio and Gambacorta, 2015). Low interest rates can coerce banks heavily reliant on intermediation business into riskier assets to compensate downward pressure on profitability (Altunbas et al., 2011). Bank liquidity (*Liquidity*) is the ratio of liquid assets-to-customer deposits and short-term funding. Larger volumes of liquid assets can motivate a transfer of resources to more profitable assets suggesting a positive relation between liquidity and growth of risky assets (Acharya and Naqvi, 2012). However, even adequate liquidity

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

can be associated with lower levels of observed riskiness under conditions of weak profitability and few investment opportunities, which could occur if adverse selection effects increase the pool of low-quality borrowers and work to tighten capital requirements. We use return on assets (*ROA* – net income-to-total assets) to proxy banks' profitability. While less profitable banks face incentives to assume greater risks to boost profitability (Poghosyan and Čihak, 2011), profitable banks often use their resources to increase risky lending. We proxy credit risk using the ratio of nonperforming loans-to-gross loans (*NPLs*). Nonperforming loans indicate asset quality and signal possible losses. We expect higher credit risk to ameliorate banks' risk-taking producing an inverse relationship conditional on banks' health (Delis and Kouretas, 2011). To control for heterogeneity across banks' risk profiles, we specify two of the alternative dependent variables described above, namely, *Loan Growth* and *Loan Rates,* as control variables in the baseline regressions.

Panels C and F report banking industry, macroeconomic and monetary policy variables. We control for the effect of GDP growth (*GDP growth*) on banks' risk-taking (Altunbas et al., 2018). Business cycle upturns enhance banks' incomes and profits which strengthen capital positions while lessening risk appetite to suggest an inverse relationship between GDP growth and risk-taking. We specify inflation (*Inflation*) (Mannasoo and Mayes, 2009; Forssbaeck, 2011), and the VIX (*VIX*) (Poligrova and Santos, 2017) to proxy market expectations of stock market volatility. Since higher inflation and expected volatility are associated with lower bank risk-taking, we expect an inverse relationship. We account for the competitiveness of national banking markets in recognition of the differential effects of market structure on banks' risk-taking. Following Schaeck and Cihak (2014), our proxy for competition is the Boone indicator (*Boone*), which measures the sensitivity of bank profit to changes in marginal cost that we source from the World Bank Global Financial Development Database.[12] We specify the level of the policy interest rate (*Policy Rate*) as a control in the baseline regression. For sample country, we source central bank policy interest rates from Thompson DataStream. Our final control is the log growth rate of a country's central bank balance sheet (*CB_GR*) (Lambert and Ueda, 2014). We justify its inclusion because other UMP policies like APP were operational at the same time as NIRP (Di Maggio et. al, 2016; Kandrac and Schulsche, 2016).

[Insert Table 2 here]

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

4. Results, Discussion and Robustness Checks

Table 3 shows results from estimations of equation [1]. While column 1 excludes control variables columns 2 and 3 incrementally add sets of bank and country-specific controls to capture heterogeneity between banks and countries. Each column includes country and year fixed effects. Our interest lies in the magnitude, sign, and significance of β_1, which measures the average difference in the change in banks' risk-taking between NIRP-adopter countries and non-adopter countries (the NIRP-effect).

[Insert Table 3 here]

The NIRP-effect, β_1, is economically meaningful, negative, and statistically significant at the 1 percent level. It shows the amount of risky assets on banks' balance sheets in NIRP-adopter countries declined by around 10 percentage points (column 1) post-NIRP compared to banks in countries that did not introduce NIRP. Unambiguously, this result demonstrates that NIRP effected a decrease in banks' risk-taking. We propose two reasons to explain why NIRP did not facilitate increased risk-taking. First, UMPs like QE (from 2015 in Europe) are a response to worsening macroeconomic conditions and deteriorating bank balance sheets, and provide banks with excess liquidity, which created conditions for banks to delever their post-crisis balance sheets but concomitantly constrained potential supply-side benefits emanating from exceptionally favourable financing conditions. Second, and given the monetary policy objective to increase bank lending, UMP realises an unintended consequence if banks simply use excess liquidity to buy liquid assets like government bonds, which is rational during periods of slow economic recovery and high firm default rates. As noted, EU capital requirements treat EU sovereign exposures as risk-free. That sovereign debt has zero risk weighting incents banks to acquire such government bonds to bolster their capital positions.[13]

Columns 2 and 3 report results from regressions augmented with bank and country controls. We continue to observe a statistically significant yet economically more powerful NIRP-effect in these augmented models. The bank-level controls are mostly significant and clarify formerly ambiguous relations. For instance, the relationship between bank size and risk-taking is inverse. We offer an intuitive explanation for the negative coefficient on E/TA. Leveraged banks invest in riskier assets that carry higher private payoffs in cases of positive outcomes but heavier losses in cases of failure. Banks with less skin-in-the-game face risk-taking incentives and banks under extreme duress may gamble for resurrection. We find relatively profitable banks assume higher risk to refute proposition that less profitable banks purchase riskier assets to boost profitability. While the inverse relationship

[13] We control for the effect of unconventional monetary policies and test for bank deleveraging and regulatory capital arbitrage behaviour on NIRP in the following sections.

between liquidity and risk-taking implies that less liquid banks purchase riskier assets, it also suggests that adequate liquidity can constrain realised balance sheet risk. While relations between funding structure and risk-taking are mostly insignificant, the meaningful economic impact implies that banks with less stable funding sources assume greater risk. Banks operating diversified business models measured by noninterest shares invest more heavily in riskier assets to support diversification arguments. Unsurprisingly, banks afflicted by asset quality issues constrain growth in riskier assets. The coefficients on *Loan Growth* and *Loan Rates* are statistically meaningful signifying that banks with relatively faster lending growth and competitive pricing realise significantly higher levels of growth in risky assets.

Among the country-specific variables, the coefficient on *Policy Rate* is positive and statistically significant. It implies that higher levels of policy rates are associated with greater growth of risky assets at banks. This result is consistent with arguments proposed in this paper. Banks operating in countries where higher interest rates prevail are inclined to hold larger volumes of risky assets compared to banks in NIRP-affected countries.

4.1 NIRP and Alternative Indicators of Banks' Risk-Taking Behaviour

To check the reliability of our main dependent variable (*GRisky*), we specify alternative dependent variables to capture greater heterogeneity in banks' risk-taking behaviour post NIRP. We investigate whether NIRP-affected banks increase loan volumes and/or loan prices using *Loan Growth* and *Loan Rates*, and whether those banks alter the composition of asset portfolios using *GRisky Share* (see section 3 for variable definitions).

Table 4 displays results. We identify a significant NIRP-effect on *Loan Growth* which contracts by approximately 3.7 percentage points for treatment banks post-NIRP. We interpret this result as supporting our deleveraging hypothesis. This result affirms findings in Molyneux et al. (2020) that NIRP-affected banks significantly reduce loan volumes compared to banks in non-adopting countries. In explanation, NIRP compresses banks' net interest margins to pressurise profits and erode capital bases, which in turn incents banks to de-lever their balance sheets and purchase liquid assets like sovereign bonds. We observe a second significant NIRP-effect on *Loan Rates* showing the average price of bank loans falls by 59 basis points in NIRP-adopter countries compared to non-adopters. Altavilla et al. (2019) suggest that reduced capital costs improve creditors' ability to repay loans to lessen banks' loan losses and ameliorate risks. We find a third significant NIRP-effect on *GRisky Share*. It shows NIRP-affected banks rebalance their portfolios by reducing the proportion of risky assets-to-total assets in favour of safer assets by just over 0.4 percentage points, which implies those banks are characterised by lower levels of overall risk.

[Insert Table 4 here]

Several authors (see Acharya et al. 2014; Becker and Ivashina, 2014; Acharya and Steffen 2015) report that banks increased their holdings of riskier sovereign bonds during the European Sovereign Debt Crisis. Since our preferred dependent variable (*GRisky*) excludes sovereign bonds, we may not fully capture the impact of purchases of riskier government securities that can drive banks' risk-taking behaviour. To mitigate this potential anomaly, we employ banks' Z-scores to proxy risk. Table 5 (column 1) shows the NIRP-effect remains positive and statistically significant across specifications. It infers that distance-to-default declines or bank stability improves post-NIRP. The consistency of this result with our baseline regressions reinforces the resilience and reliability of our results.

Lastly, we decompose the Z-score into profitability and leverage constituents (Barry et al., 2011) to determine if the increase in the Z-score in column 1 is driven by bank capitalisation and/or bank profitability.[14] Results in columns 2 and 3 of Table 5 suggest that greater bank stability derives from improvements in bank capitalisation rather than profitability. This adds further credence to the "de-leverage" hypothesis of banks electing to cleanse their balance sheets by acquiring additional safer, liquid assets to bolster their capital positions.

[Insert Table 5 here]

4.2 Capitalisation and Competition

Columns 4 and 5 of Table 3 report results from a set of additional analyses to account for various bank- and country-specific features whose impact might be meaningful in assessing banks' risk-taking incentives under a negative interest rate environment. First, we examine the capital channel view that banks' responses to monetary policy impulses vary by levels of their capitalisation (Van den Heuvel, 2002). To test this proposition, we interact the NIRP-effect with a dummy variable D_Cap, which equals unity for well-capitalised banks (banks in 90th percentile of the distribution of the total capital ratio (Borio and Gambacorta, 2016)), and zero otherwise.[15] The coefficient on the interaction term (Column 4, Table 3) is positive and significant. It shows that the most adequately capitalised banks and with large capital buffers increase volumes of risky assets post-NIRP. We

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

[15] For this exercise, we replace the continuous variable E/TA with D_Cap to avoid multicollinearity issues.

suggest those banks reallocate resources toward riskier, profitable investments to offset the negative impact of NIRP on profits.[16] In contrast, the ability of less capitalised banks to invest in risky assets is constrained by binding capital requirements that dampen the impact of monetary stimulus (De Nicolò et al., 2010). Less capitalised banks could elect to improve their capital ratios by reducing risk-weighted exposures via a deleveraging process. Furthermore, we recognise difficulties for banks to issue new equity or increase retained earnings during crisis episodes.

Our evidence has policy implications as we emphasise a salient role for bank capital in the monetary policy transmission mechanism. Under difficult macroeconomic conditions and negative interest rates that exacerbate pressures on banks' profitability, only well-capitalised banks increase risk-taking (Molyneux et al., 2019). We contend that the impact of capital over minimum requirements is twofold. First, less capitalised banks experience a direct impact due to difficulties in issuing new equity in terms of volume and cost. Second, less capitalised banks face constraints in securing wholesale deposit funding in crisis periods in contrast to strong capitalised banks (Iyer et al., 2014).

Next, we consider if, and how, competitive conditions influence the effect of NIRP on banks' risk-taking. We interact the NIRP-effect with a dummy D_Boone, which equals unity for banks operating in less competitive markets (above median values of the Boone indicator), zero otherwise.[17] We find a meaningful and statistically significant effect of market structure on the speed of transmission of monetary policy (Sorensen and Werner, 2006) and on corresponding bank risk-taking (Boyd and Nicolò, 2006). Column 5 of Table 3 shows that in less competitive markets banks invest relatively more in riskier assets post-NIRP. We contend that higher levels of market power reported at banks operating in less competitive markets affords those banks greater leeway to price over marginal cost (Turk Ariss, 2010). Exercise of market power dampens downward pressure on net interest margins and profitability post-NIRP (Brunnermeier and Koby, 2017).

4.3 Robustness Checks

4.3.1 NIRP, Deleveraging and Sovereign Bond Holdings

We premise that banks opt to hold liquid assets like sovereign bonds to exploit the favourable regulatory treatment in Europe rather than increasing exposure to riskier assets. In this scenario, banks cleanse and deleverage deteriorated post-crisis balance sheets. To offer insight into these possibilities, we examine whether, post-NIRP, treated banks contract in size whilst simultaneously increasing exposure to sovereign debt. For this exercise, we use the growth rate of total assets (*Asset growth*)

[16] Our results comply with findings elsewhere on the relation between capitalisation and risk-taking. Kim and Sohn (2017) and Gambacorta and Mistrulli (2004) find over-capitalised banks willingly increase risk-taking because their larger capital buffers allow them to bear losses whilst maintaining sufficiently high levels of capital.

[17] We replace the variable Boone to avoid collinearity issues with the dummy D_Boone.

and the ratio of government bonds-to-total assets (*Sov. Bond*) as dependent variables in our econometric framework.[18] Panel A (column 3) of Table 6 shows asset growth at banks in NIRP-adopter countries is lower than in non-adopters by 10.8 percentage points, which is a significant difference at the 1 percent level. Column 4 confirms proposition that NIRP-affected banks increase exposure to zero risk-weighted sovereign debt albeit by 0.5 percentage points (albeit statistically significant). As well as supporting the "de-leverage" hypothesis, the results affirm evidence in Altavilla et al. (2017) of a very high degree of substitutability existing between lending and sovereign debt during episodes of distress and economic weakness.

In a further step, we investigate whether the increase in sovereign bond holdings can be attributed to favourable regulatory treatment in Europe. For this exercise, we consider the behaviour of NIRP-affected banks in countries that do not apply favourable regulatory treatment to sovereign bonds: Switzerland and Norway.[19] If Swiss and Norwegian banks do not increase holdings of sovereign bonds, we can be more confident about the "de-leverage" hypothesis proposition that NIRP-affected banks exploit regulatory treatment to embellish their portfolios of government bonds at the expense of other asset classes. Panel B (column 4) shows a negative yet insignificant NIRP-effect; NIRP-affected banks in Switzerland and Norway reduced sovereign exposures by 0.35 percentage points compared to non-affected banks. This finding reaffirms the capital arbitrage motive of purchasing sovereign securities rather than increasing risk-taking under negative interest rates.

4.3.2 Other Unconventional Monetary Policies

It is important to disentangle confounding effects on banks' risk-taking due to NIRP from effects arising from other UMP actions. In terms of implementation, NIRP was a relative latecomer and came after central banks had extensively used QE to acquire assets of distressed firms. *Ceteris paribus* QE expands a central bank's balance sheet to increase the monetary base to stimulate bank lending to ultimately boost nominal spending (Bernanke and Reinhart, 2004). To disentangle potentially confounding effects between NIRP and UMP, we augment our baseline model with a proxy for utilisation of other UMPs, namely, the growth of central bank balance sheets (Lambert and Ueda, 2014; Molyneux et al. 2019). We re-estimate with variables to account both for the NIRP-effect and UMP-effect. Panel C of Table 6 (column 1) shows a meaningful and significant NIRP-effect that dampens banks' risk-taking by 10.9 percentage points after controlling for the effect of UMPs. We recognise that our proxy for UMPs (CB_GR) might not capture the signalling impact of asset purchases or forward guidance. Therefore, and as additional robustness check, in column 2 we test

[18] We exclude Switzerland and Norway as favourable regulatory treatment of sovereign bonds applies to EU countries.
[19] Given Switzerland and Norway adopted NIRP in 2015, the dummy *Post* equals 1 from 2015.

the reliability of our results by employing the "shadow rate" (following Wu and Xia, 2016).[20] The shadow rate measures the overall stance of monetary policy when conventional monetary tools like short-term rates hit the zero lower bound (ZBL). Since short-term rates become ineffective at the ZLB, which induces central banks to employ UMPs, the shadow rate accounts for the effect of UMPs by allowing short-term rates to fall below zero. Our sample size contracts because shadow rate data are available only for the Euro Area, the US and UK. However, those countries are representative of the overall sample while the balance between NIRP-affected and NIRP non-affected countries is maintained. Panel C of Table 6 (column 2) identifies significant NIRP-effect that lowers banks' risk-taking by 13.67 percentage points after we control for the shadow rate, which further validates our baseline findings.

4.3.3 Time Varying NIRP-Effect and Placebo Test

To create a clear treatment date, our baseline analysis consists of countries that introduced NIRP in 2014. However, Norway, Sweden, and Switzerland implemented NIRP in 2015. To assess the effect of NIRP on both early and late adopters, we employ a difference-in-differences estimation with time-varying treatments (Goodman-Bacon, 2018; Goodman-Bacon et al., 2019). This approach allows us to: (i) enlarge the sample of NIRP-affected countries and, (ii) control for differences across countries that adopted NIRP in different years. We re-estimate our baseline regression using countries that adopted NIRP in 2014 and 2015. The result in Panel D of Table 6 shows that banks operating in early and late NIRP-adopter countries significantly reduce risky assets post-NIRP by 9.24 percentage points, which endorses the reliability of our baseline findings.

As additional robustness check, we redefine the dummy *Post* to equal 1 from 2015. In the baseline regression, *Post* equals 1 from 2014 since the majority of countries that adopted NIRP did so in June 2014.[21] While the gap between June and end-2014 captured in *Post* is necessary to ascertain the NIRP-effect on banks' risk-taking, redefining *Post* to equal 1 from 2015 allows for greater heterogeneity in the timing effect of the estimation. Panel E of Table 6 shows the result of the regression that specifies the redefined *Post*. That the coefficient is smaller in magnitude (under 3.1 percentage points) indicates how quick banks reacted to NIRP; the coefficient maintains sign and same statistical significance as the baseline.

Lastly, we eliminate the possibility that risk-taking in the treatment group changed before NIRP was introduced. In this scenario, banks anticipate adverse effects of impending NIRP and amend behaviour or else some bank-specific factors cause a change in risk-taking; a pre-NIRP change in

[20] Shadow rate data for the ECB, Federal Reserve and Bank of England are available at: https://sites.google.com/view/jingcynthiawu/shadow-rates

[21] Hungary as the sole exception implemented NIRP in March.

risk-taking would invalidate our difference-in-differences estimation. To test for this possibility, we re-estimate the model from 2011 to 2014 and introduce a “fake” NIRP in 2013. If the coefficient on the “fake” NIRP-effect is statistically insignificant or differs in sign, we can be confident that our baseline coefficient captures a genuine monetary policy shock. Moreover, “fake” NIRP controls for differences between low and negative interest rate environments (Molyneux et al., 2019). Panel F in Table 6 (column 1) shows the “fake” NIRP-effect is statistically insignificant.

[Insert Table 6 here]

5. Conclusion

We provide early evidence on the impact of negative interest rate policy on banks’ risk-taking. Our first principal result is the identification of an unintended consequence of NIRP, namely, a lower level of risk-taking post-NIRP. We quantify this NIRP-effect as a reduction in risky assets owned by banks in NIRP-adopter countries of approximately 10 percentage points. We find significant NIRP-effects that lower banks’ loan growth and loan price (by 3.7 percentage points and 59 basis points, respectively), and a small albeit significant rebalancing of banks’ asset portfolios out of risky assets in favour of safer assets.

Our second principal result is that NIRP produces a heterogeneous effect on banks’ risk-taking. We find a sensitivity between banks’ risk-taking behaviour and their prudence with the most adequately capitalised banks increasing investments in risky assets post-NIRP. This suggests that regulatory capital arbitrage could inadvertently retard economic recovery if poorly capitalised banks reduce investment in assets that have higher risk weights to comply with risk-based capital requirements (the so-called ‘good risk-taking’). Lastly, and for banks operating in less competitive banking markets, we uncover a NIRP-effect and suggest that those banks exploit their market power to increase risks to insulate net interest margins and profitability from downward pressures associated with NIRP.

Our robust empirical evidence favours the “de-leverage” hypothesis over “search for yield”. It infers monetary policy alone is insufficient to affect banks’ behaviour. Rather, banks offset the opportunity cost on excess reserves attributable to NIRP by purchasing assets that generate returns and exercise limited impact on the composition of risk-weighted assets. In this scenario, banks shift negative yielding reserves into more profitable opportunities and acquire safe assets for capitalisation reasons whilst cleansing post crisis deteriorated balance sheets. Sovereign bonds – protected (in Europe) by favourable regulation – fit this purpose very well.

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Table 1. Descriptive Statistics: Macroeconomics Indicators and Pearson Correlation Test for Control and Treatment Group; 2007-2015

Variable	Mean Control	Mean Treatment	Std. Dev. Control	Std. Dev. Treatment	Pearson Corr.
GDP Growth	0.35	0.19	0.47	0.64	0.9021***
Inflation	2.04	1.47	1.53	1.22	0.8659***

Note: GDP growth is the yearly growth rate of real GDP in percentage. Inflation is the annual Consumer Price Index in percentage. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Figure 1. Average Growth of Risky Assets among treated (red line) and control (blue line) before and after introduction of NIRP (Includes only countries that adopted NIRP in 2014)

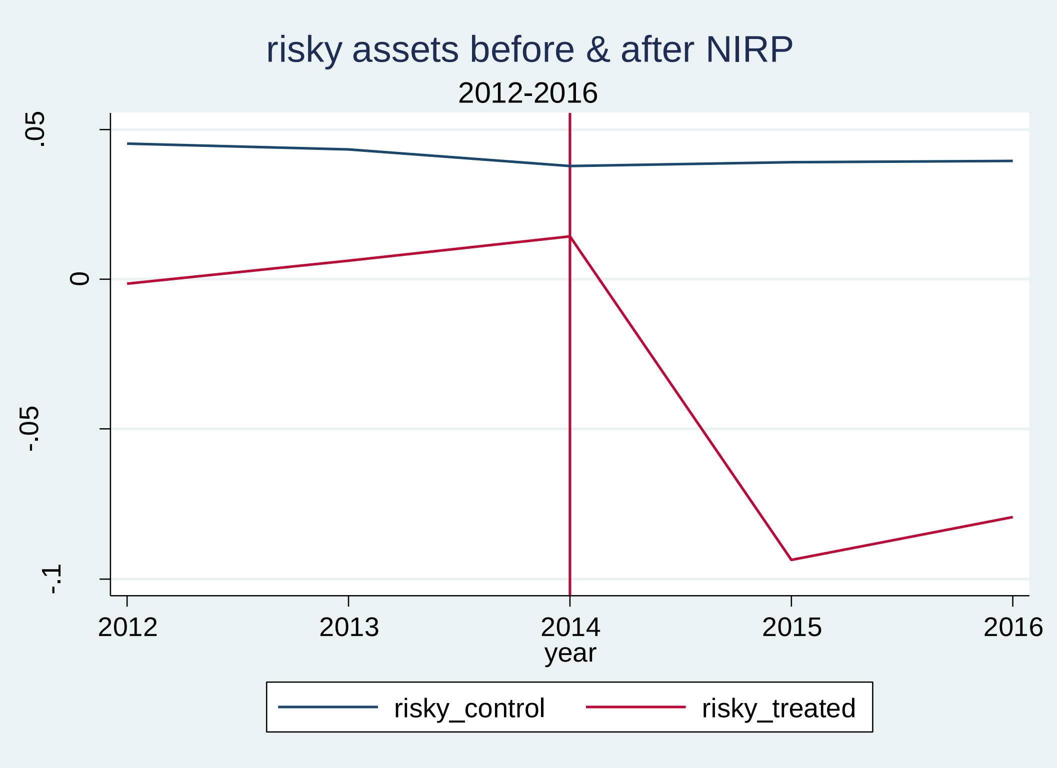

Table 2. Descriptive Statistics

	TREATMENT									
	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel A. Bank Risk Measures										
GRisky	388	0.05%	6.46%	-16.82%	2.73%	3221	-8.71%	5.29%	-16.82%	2.73%
Z-score	8990	69.43	90.41	0.29	649.12	8040	78.65	107.20	0.29	649.12
GRisky Share	1971	79.86	17.35%	5.43%	97.90%	3718	80.43%	17.03%	5.43%	97.90%
Panel B. Bank Balance Sheet Data										
Size	9048	13.76	1.55	11.51	16.32	8138	13.74	1.54	11.51	16.32
E/TA	9046	9.77%	4.81%	3.56%	19.49%	8136	9.95%	4.57%	3.56%	19.49%
Tot. capital ratio	5883	17.85%	4.75%	12.30%	27.53%	5700	16.60%	4.73%	12.30%	27.53%
Funding structure	8217	62.34%	21.67%	20.89%	84.11%	7465	64.55%	20.23%	20.89%	84.11%
Business model	8725	6.92%	6.32%	0.15%	20.17%	7881	7.02%	6.31%	0.15%	20.17%
Liquidity	8570	23.22%	20.73%	5.27%	70.16%	7755	22.66%	20.61%	5.27%	70.16%
ROA	9025	0.42%	0.42%	0.02%	1.41%	8108	0.42%	0.41%	0.02%	0.41%
NPLs	4953	5.56%	4.57%	0.49%	14.41%	4935	5.45%	4.92%	0.49%	14.11%
Loan Growth	8509	4.07%	7.87%	-8.44%	21.52%	7252	3.59%	7.64%	-8.44%	21.52%
Loan Rates	2783	4.61%	0.97%	3.75%	7.26%	4847	3.88%	0.88%	2.37%	5.52%
Asset growth	8796	4.65%	7.47%	-15.12%	13.70%	7955	-7.04%	7.42%	-15.12%	13.70%
Sov. bond	2000	4.04%	4.02%	0.48%	12.87%	3794	4.22%	3.93%	0.048%	12.87%
Panel C. Macroeconomic, Monetary Policy and Banking Industry Data										
GDP growth	10364	0.09%	0.38%	-1.13%	1.22%	10092	0.41%	0.65%	-0.18%	6.61%
Inflation	10364	1.54%	0.96%	-0.91%	5.66%	10092	0.43%	0.76%	-1.73%	4.39%
VIX	10364	15.99	1.78	14.18	17.8	10092	15.44	1.24	14.18	16.67
Boone	10364	-0.03	0.91	-0.55	0.14	10092	-0.04	0.10	-0.64	0.14
CB_GR	10364	17.75%	10.53%	-9.40%	32.17%	13327	7.27%	8.05%	-14.39%	32.17%
Policy Rate	10839	0.68%	0.57%	0.00%	6.78%	9617	0.99%	0.23%	-0.35	2.39%

Table 2. (Continued)

	CONTROL									
	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel D. Bank Risk Measures										
GRisky	1493	3.99%	9.30%	-12.20%	21.33%	1589	4.21%	10.30%	-12.20%	21.33%
Z-score	4795	40.39	57.75	0.00	493.21	4422	45.64	64.51	0.00	493.21
GRisky Share	1515	78.57%	20.61%	5.43%	97.90%	1765	77.11%	21.81%	5.43%	97.90%
Panel E. Bank Balance Sheet										
Size	5008	14.38	0.93	11.60	17.63	4650	14.42	2.00	11.60	17.63
E/TA	5006	15.40%	11.65%	4.76%	42.15%	4648	15.63%	11.59%	4.76%	42.15%
Tot. capital ratio	2772	17.34%	4.52%	12.30%	27.03%	2647	17.30%	4.62%	12.30%	27.03%
Funding structure	3350	69.85%	20.37%	23.48%	88.79%	3185	70.02%	21.61%	23.48%	88.79%
Business model	4662	2.74%	2.31%	-0.40%	7.02%	4316	2.91%	2.32%	-0.40%	7.02%
Liquidity	4342	28.77%	31.81%	2.35%	98.46%	4039	28.89%	31.91%	2.35%	98.46%
ROA	4811	0.99%	0.96%	-0.28%	2.96%	4457	0.97%	0.93%	-0.28%	2.60%
NPLs	3165	2.85%	2.40%	0.14%	7.21%	2916	2.22%	2.22%	0.14%	7.21%
Loan Growth	3735	5.50%	10.17%	-8.44%	21.52%	3759	7.66%	9.49%	-8.44%	21.52%
Loan Rates	7863	5.59%	1.03%	3.75%	7.26%	8146	5.19%	1.06%	3.75%	7.26%
Asset growth	4567	4.39%	11.72%%	-16.39%	23.01%	4483	1.13%	11.69%	-16.39%	23.01%
Sov. bond	1604	6.60%	6.27%	0.02%	19.35%	1905	6.84%	6.15%	0.02%	19.35%
Panel F. Macroeconomic, Monetary Policy and Banking Industry Data										
GDP growth	23298	0.49%	0.20%	-1.13%	1.89%	22942	0.56%	0.14%	-0.18%	1.36%
Inflation	23300	1.96%	0.92%	-0.91%	8.93%	22944	1.04%	1.23%	-1.73%	8.85%
VIX	23300	16.00	1.78	14.18	17.8	22944	15.43	1.24	14.18	16.67
Boone	23300	-0.39	0.04	-0.44	0.22	22944	-0.04	0.04	-0.41	0.21
CB_GR	23300	15.08%	15.15%	-15.65%	32.17%	13327	7.27%	8.05%	-14.39%	32.17%
Policy Rate	22972	0.44%	0.95%	0.05%	7.00%	22616	0.45%	0.68%	0.05%	7.25%

Note: GRisky is the yearly growth rate of risky assets, i.e. the difference between total assets and cash, government securities and advances to other banks. NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank i in country j is affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of total assets; E/TA equals equity-to-total assets; ROA equals net income-to-total assets; Liquidity equals liquid assets-to-customer deposits and short-term funding; Funding structure equals customer deposits-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans; Loan Growth is the yearly growth rate of gross loans; Loan Rates equals interest income-to-gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the annual Consumer Price Index. VIX is the CBOE volatility index. Policy Rate is the policy interest rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 3. NIRP and Risky Assets

	(1) GRisky	(2) GRisky	(3) GRisky	(4) GRisky	(5) GRisky
NIRP-effect	-0.0998***	-0.1190***	-0.1047***	-0.1128***	-0.0967***
	(0.0161)	(0.0151)	(0.0235)	(0.0233)	(0.0250)
Size		-0.0073***	-0.0063***	-0.0060***	-0.0076***
		(0.0017)	(0.0015)	(0.0020)	(0.0018)
E/TA		-0.0027***	-0.0026***		-0.0019*
		(0.0008)	(0.0008)		(0.0010)
ROA		0.0290***	0.0252***	0.0072	0.0208***
		(0.0072)	(0.0060)	(0.0060)	(0.0074)
Liquidity		-0.0009***	-0.0011***	-0.0009***	-0.0010**
		(0.0003)	(0.0002)	(0.0002)	(0.0002)
Funding structure		-0.0372*	-0.0331	-0.0052	-0.0282
		(0.0207)	(0.0205)	(0.0213)	(0.0219)
Business model		0.0011***	0.0010***	0.0006	0.0013***
		(0.0004)	(0.0004)	(0.0003)	(0.0004)
NPL		-0.0019***	-0.0018**	-0.0013**	-0.0013*
		(0.0007)	(0.0008)	(0.0006)	(0.0007)
Loan Growth		0.0047***	0.0047***	0.9159***	0.8920***
		(0.0004)	(0.0004)	(0.0514)	(0.0527)
Loan Rates		-1.0372***	-0.9244***	-0.9567***	-1.0700***
		(0.3781)	(0.3468)	(0.3379)	(0.3902)
GDP growth			0.0059	0.0048	0.0079
			(0.0088)	(0.0088)	(0.0091)
Inflation			-0.0106	-0.0082	-0.0112
			(0.0089)	(0.0090)	(0.0038)
VIX			0.0002	-0.0012	-0.0031
			(0.0035)	(0.0035)	(0.0038)
Boone			0.0713	0.0360	
			(0.0472)	(0.0599)	
Policy Rate			0.0395*	0.0284	-0.0030
			(0.0214)	(0.0214)	(0.0237)
NIRP-effect*D_Cap				0.3029***	
				(0.0960)	
NIRP-effect*D_Boone					0.0854*
					(0.0534)
Observations	6,006	4,204	4,126	4,216	4,126
Number of banks	2,584	1,863	1,833	1,870	1,833
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes

Note: GRisky is the yearly growth rate of risky assets, i.e. the difference between total assets and cash, government securities and advances to other banks. NIRP-effect is the interaction between the dummy treated and the dummy post. It takes value 1 if bank i in country j is affected by NIRP after NIRP implementation, 0 otherwise. NIRP-effect*D_Cap is the interaction between NIRP-effect and the dummy D_Cap, which equals unity for banks in the highest deciles of the distribution of the total capital ratio, 0 otherwise. NIRP-effect*D_Boone is the interaction between NIRP-effect and the dummy D_Boone, which equals unity for above median values of the Boone indicator, 0 otherwise. Size is the natural logarithm of total assets; E/TA equals equity-to-total assets; ROA equals net income-to-total assets; Liquidity equals liquid assets-to-customer deposits and short-term funding; Funding structure equals customer deposits-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans; Loan Growth is the yearly growth rate of gross loans; Loan Rates equals lending rates-to-gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the annual Consumer Price Index. VIX is the CBOE volatility index. Policy Rate is the policy interest rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 4. NIRP and Lending Growth, Loan Rates and GRisky Share

	(1) Loan Growth	(2) Loan Rates	(3) GRisky Share
NIRP-effect	-0.0369***	-0.0059**	-0.0041***
	(0.0105)	(0.0028)	(0.0002)
No. Banks	3,951	5,903	7,411
No. Obs	11,982	2,254	2,766
Country fixed effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Bank controls	Yes	Yes	Yes
Country controls	Yes	Yes	Yes

Note: Loan Growth is the yearly growth rate of gross loans; Loan Rates equals interest income-to-gross loans. GRisky Share equals risky assets-to-total assets. NIRP-effect is the interaction between dummy variables *treated* and *post*. It equals unity if bank i in country j is affected by NIRP after NIRP implementation, 0 otherwise. Bank control are: Size is the natural logarithm of total assets; E/TA equals equity-to-total assets; ROA equals net income-to-total assets; Liquidity equals liquid assets-to-customer deposits and short-term funding; Funding structure equals customer deposits-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans. Country controls: GDP growth is the yearly growth rate of real GDP. Inflation is the annual Consumer Price Index. VIX is the CBOE volatility index. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10.

Table 5. NIRP and Z-Score Decomposition

	(1) Z-SCORE	(2) Profitability Z-SCORE	(3) Leverage Z-SCORE
NIRP-effect	0.0240***	-0.0038	0.0276***
	(0.0056)	(0.0173)	(0.0055)
No. Banks	7,257	6,906	7,272
No. Obs	26,247	23,178	26,357
Country fixed effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Bank controls	Yes	Yes	Yes
Country controls	Yes	Yes	Yes

Note: Z-score equals (ROA plus E/TA)-to-standard deviation of ROA. Profitability Z-score equals ROA-to-standard deviation of ROA. Leverage Z-score equals E/TA-to-standard deviation of ROA. NIRP-effect is the interaction between dummy variables *treated* and *post*. It equals unity if bank *i* in country *j* is affected by NIRP after NIRP implementation, 0 otherwise. Bank controls are: Size is the natural logarithm of total assets; E/TA equals equity-to-total assets; ROA equals net income-to-total assets; Liquidity equals liquid assets-to-customer deposits and short-term funding; Funding structure equals customer deposits-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans; Loan Growth is the yearly growth rate of gross loans; Loan Rates equals lending rates-to-gross loans. Country controls: GDP growth is the yearly growth rate of real GDP. Inflation is the annual Consumer Price Index. VIX is the CBOE volatility index. Policy Rate is the policy interest rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 6. Robustness Checks

	GRisky (1)	GRisky (2)	Asset Growth (3)	Sov. Bond (4)
Panel A. Deleveraging & Sovereign Bonds Holding				
NIRP-effect			-0.1080***	0.0050***
			(0.0051)	(0.0016)
No. Banks			2722	2185
No. Obs			7236	5667
Country fixed effects			Yes	Yes
Year effects			Yes	Yes
Bank controls			Yes	Yes
Panel B. Sovereign holdings in Switzerland and Norway				
NIRP-effect				-0.0035
				(0.0063)
No. Banks				778
No. Obs				2535
Country fixed effects				Yes
Year effects				Yes
Bank controls				Yes
Panel C. Unconventional Monetary Policies (UMPs)				
NIRP-effect	-0.1090***	-0.1367***		
	(0.0220)	(0.0164)		
CB_GR	0.0294			
	(0.0416)			
Shadow Rate		-0.0010		
		(0.0034)		
No. Banks	1860	1677		
No. Obs	3786	3733		
Country fixed effects	Yes	Yes		
Year effects	Yes	Yes		
Bank controls	Yes	Yes		
Panel D. Time Varying Treatment Effect				
NIRP-effect	-0.0924***			
	(0.0166)			
No. Banks	1833			
No. Obs	4126			
Country fixed effects	Yes			
Year effects	Yes			
Bank controls	Yes			
Country controls	Yes			
Panel E. Dummy Post Equal 1 in 2015				
NIRP-effect	-0.0305***			
	(0.0113)			
No. Banks	2731			
No. Obs	6312			
Country fixed effects	Yes			
Year effects	Yes			
Bank controls	Yes			
Country controls	Yes			

	Panel F. "Fake" NIRP
NIRP-effect	-0.0179
	(0.0397)
No. Banks	599
No. Obs	1048
Country fixed effects	Yes
Year effects	Yes
Bank controls	Yes
Country controls	Yes

Note: Panel A reports results for NIRP and deleveraging (column 3) and sovereign bond holdings (column 4). Panel B reports results for NIRP and sovereign bond holding by focusing on Switzerland and Norway. Panel C reports results for the NIRP-effect after controlling for unconventional monetary policy. Panel D reports results for the Time Varying NIRP Effect. Panel E shows results after we redefine dummy variable *Post* to equal 1 from 2015. Panel F reports results of the placebo test. GRisky is the yearly growth rate of risky assets, i.e. the difference between total assets and cash, government securities and advances to other banks. Asset growth is the growth rate of bank total assets. Sov. Bond is the ratio of government securities-to-total assets. NIRP-effect is the interaction between the dummy variables *treated* and *post*. It equals unity if bank i in country j is affected by NIRP after NIRP implementation, 0 otherwise. Bank controls are: Size is the natural logarithm of total assets; E/TA equals equity-to-total assets; ROA equals net income-to-total assets; Liquidity equals liquid assets-to-customer deposits and short-term funding; Funding structure equals customer deposits-to-total liabilities; Business model equals non-interest income-to-total income; NPLs equals non-performing loans-to-gross loans; Loan Growth is the yearly growth rate of gross loans; Loan Rates equals lending rates-to-gross loans. Country controls: GDP growth is the yearly growth rate of real GDP. Inflation is the annual Consumer Price Index. VIX is the CBOE volatility index. Policy Rate is the policy interest rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

APPENDIX

Table A1. Countries in the Sample

NIRP adopted countries and adoption date	NIRP-non-affected countries
Austria (June 2014)	Australia
Belgium (June 2014)	Canada
Denmark (June 2014)	Chile
Estonia (June 2014)	Czech Republic
Finland (June 2014)	Iceland
France (June 2014)	Israel
Germany (June 2014)	South Korea
Greece (June 2014)	Mexico
Hungary (March 2014)	New Zealand
Ireland (June 2014)	Poland
Italy (June 2014)	Turkey
Luxembourg (June 2014)	UK
Netherland (June 2014)	USA
Norway (September 2015)	
Portugal (June 2014)	
Slovakia (June 2014)	
Slovenia (June 2014)	
Spain (June 2014)	
Sweden (February 2015)	
Switzerland (January 2015)	