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Do Negative Interest Rates Affect Bank Risk-Taking?

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Abstract

We offer early evidence on how negative interest rate policy affects bank risk-taking. We identify a dichotomy between monetary policy and prudential regulation. Our primary result suggests NIRP produced an unintended outcome, which we measure as a 10 per cent reduction in banks' holdings of risky assets. It infers that banks deleverage their balance sheets and invest in safer, liquid assets to meet new and binding capital and liquidity requirements. We find risk-taking behaviour is sensitive to capitalisation and banks with stronger capital ratios take more risks. Similarly, tighter prudential requirements could inadvertently retard economic growth should poorly capitalised banks reduce investment in riskier assets in favour of zero risk-weighted assets, such as, sovereign bonds to comply with risk-based capital requirements. Risk-taking is greater in less competitive markets because stronger market power insulates net interest margins and profitability. We obtain our results from a sample of 2,371 banks from 33 OECD countries between 2012 and 2016, and a difference-in-differences framework.

Keywords: NIRP, Bank risk-taking, Monetary Policy, Difference-in-Differences, Propensity-Score-Matching.

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

1. Introduction

We examine the effect of negative interest rate policy (NIRP) on bank risk-taking. Central banks in a handful of countries turned to NIRP when near zero interest rates failed to rejuvenate economies following the global financial crisis (GFC).[1] NIRP, and the prospect of nominal interest rates below zero, is a new event worthy of further investigation as it fosters incentive for investors to search for yield (Rajan, 2006). Negative interest rates implicitly raise the opportunity cost for banks holding large amounts of negative yielding reserves. *A priori* banks opt to hold riskier, higher yielding assets and increase loan volumes, which together with falling lending rates should stimulate demand for credit and boost the economy. Given the sparse empirical evidence on the impact of NIRP, we consider the efficacy of NIRP and join a vociferous debate on the effectiveness of unconventional tools (Arteta et al., 2018; Ball et al., 2016; Jobst and Lin, 2016). The introduction of NIRP in 2014 followed hard on the heels of the phasing-in of Basel 3 effective from 2013. We consider the possibility of a dichotomy between goals of non-binding monetary policy and binding prudential regulations, which could ameliorate anticipated investment in riskier assets and associated economic benefits.

We begin by testing proposition that NIRP leads to increases in bank risk-taking. One of the objective of NIRP (see Coeuré, 2016) is to increase the cost to banks of holding excess reserves at the central bank. This should motivate banks to invest in riskier assets to boost subdue inflation and economic growth. This effect could materialise through two channels. First, downward stickiness of deposit rates (deposit rate channel) compresses net interest margins and pressurises profitability, which creates incentive for banks to maintain profitability by investing in higher-yield, hence riskier, assets. Second, the yield curve compression channel suggests NIRP motivates banks out of low-yielding, short-term liquid assets into higher-yield, long-term illiquid assets, which alters portfolio risk (Arsenau, 2017). The effect of NIRP will also depend on bank-specific characteristics (capitalisation, funding structure, and diversification) and characteristics of national banking sectors, such as, the degree of competition.

We investigate the impact of bank-specific characteristics and examine what the effects of NIRP are on risk-taking at small banks and at banks with strong capital positions. Whereas NIRP could exert stronger impact on small banks via a deposit channel effect that motivates search for yield, risk-taking could be greater at large banks that could realise gains benefits from diversification (Nucera

[1] The Eurozone, other European countries (Denmark, Hungary, Norway, Sweden and Switzerland), and Japan have introduced NIRP since 2012. Bech and Malkhozov (2016) discuss mechanisms for implementing NIRP.

et al. 2017; Altunbas et al. 2018). The ambiguous relationship between negative rates, capital and risk-taking is sufficient motivation to uncover robust empirical evidence on its true nature. NIRP could engineer increased investment in riskier assets at more prudent banks holding capital buffers to support greater taking of risk (Dell'Ariccia et al., 2010). Similarly, risk-taking could increase at less prudent banks with less skin-in-the-game that may gamble for resurrection (De Nicolò et al., 2010; Jimenez et al. 2014).

Next, we consider if the NIRP-effect is sensitive to the competitiveness of national banking markets. Brunnermeier and Koby (2016) and IMF (2017) claim competition amplifies banks' exposure to negative rates to produce opposite effects. Whereas banks may prefer safer investments if relatively competitive markets exert downward pressure on net interest margins, the association between market power and less competitive markets predicts that banks could raise mark-ups on loans to boost profit, which enhances banks' ability to make riskier loans.

Our final hypothesis contends that binding prudential regulations may influence the composition of banks' risk-weighted assets in a way that counters the intended effect of NIRP especially during periods of economic uncertainty. Cheaper central bank funds could alter banks' risk-tolerance and risk-perception resulting in greater risk-taking. However, concomitant tightening of prudential requirements might tempt banks to de-lever and cleanse their balance sheets by investing more heavily in assets with low or zero risk weighting. Our de-leverage hypothesis suggests banks preferred to invest in safer, liquid assets, such as, sovereign bonds that carry (in Europe) zero risk weight to boost capital positions, which we contend is an unintended consequence of NIRP.

To investigate the above propositions, we construct a panel dataset of 2,731 banks in 33 OECD countries from 2012 to 2016, which yields 6,312 bank-year observations. We use a difference-in-differences framework to determine the effect of NIRP on banks' risk-taking in adopter countries compared with banks in countries that did not implement NIRP whilst accounting for macroeconomic and bank-level factors that affect risk taking in the uncharted territory of NIRP. By way of preview, our primary result shows NIRP realised an unintended outcome, namely, a lower level of risk-taking, which we identify roughly as a 10 per cent reduction in risky assets. This result is robust even when we use the propensity score matching (PSM) to control for sample selection biases. However, additional results show risk-taking increases when banks are sufficiently capitalised or can benefit from market power in less competitive markets. Our evidence points to conflicting objectives between non-binding monetary policy goals and binding bank capital regulations, which could suggest need for greater coordination.

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

2. Literature review

The link between low interest rates and bank risk-taking is at the centre of a vigorous academic debate and has been since the onset of the GFC. Borio and Zhu (2012) theorize the existence of a "risk-taking channel" in the monetary transmission mechanism, which stipulates a relationship between expansionary monetary policy and greater bank risk-taking. This channel operates in (at least) two ways. First, low and negative rates on securities motivate banks to switch to riskier assets to meet the nominal return of their liabilities (Rajan, 2006; Brunnermeier, 2001).[2] Second, since cuts in policy rate can boost bank profit via valuation gains on securities and rising asset prices, cuts could alter bank risk-tolerance, risk-perception and risk-appetite (Adrian and Shin, 2009). Yet, there is not an academic consensus on the net effect of low interest rates on bank behaviour and risk-tolerance.

Recent literature strongly supports the view that accommodative monetary policy leads to increased risk-taking. Angeloni et al. (2015) demonstrate empirically that the risk-taking channel works in both ways. When interest rates raise, liabilities become more expensive, and banks have incentive to de-lever and reduce holdings of risky assets. This implies that rate increases could facilitate lower risk-taking.

Delis and Kouretas (2011) examine a large dataset of Euro area banks between 2001 and 2008. Using the NPL ratio and amount of risky assets to proxy bank riskiness, they report a strong negative relationship between risk-taking and interest rates.[3] Altunbas et al. (2014) consider the expected default frequency (EDF) of listed banks from 16 OECD countries between 1998 and 2008, and observe an increase in bank default probability during the long period of low interest rates.[4] Iannidou et al. (2015) examine Bolivian banks between 1999 and 2003. Under conditions of low interest rates, the average default rate on existing loans falls whilst risks associated with new loans increase. Using a database of 23 million loans in Spain (from 2008 to 2012), Jimenez et al. (2014) report a similar impact on loan credit ratings granted before and after a cut in ECB overnight rates. While all banks grant more loans when rates are low, less capitalised banks grant more and riskier loans, presumably because they hold less skin-in-the-game and may gamble for resurrection**.** De Nicolò et al. (2010) suggest that a high franchise value could discourage banks from gambling for resurrection even if interest rates fall.

[2] Economic theory highlights the difficulty for banks to apply negative rates on customer deposits. For instance, some countries link deposits to a legal guaranteed minimum nominal return (see Gambacorta, 2009).
[3] 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 changes in credit quality at various re-pricing opportunities. They equal total assets less cash, government securities and balances due from other banks.
[4] EDF captures the probability that a firm will default within 12 months. Moody's is the source.

In this regard, different authors highlight the role of regulation in preventing excessive risk-taking by imposing capital standards on banks. Using quarterly Call Report and Federal Reserve Bank Lending Survey data on U.S. banks between 2006 and 2008, De Nicolò et al. (2010) find that when the real interest rate falls (federal funds rate), there are increases in average internal credit risk ratings and banks RWA-density, i.e. the ratio of risk weighted adjusted assets on total assets, raises. However, the authors suggest the effect is more complex and more pronounced at banks with stronger levels of capitalisation. Similarly, Dell'Ariccia et al. (2010) observe that when central banks ease monetary conditions, banks with stronger capitalisation increase leverage and lower their monitoring of credit risk. Agur and Demertzis (2010) confirm this substitution effect on bank debt caused by monetary policy decisions, but emphasise the role of regulators in preventing frictions during protracted periods of low rates. Maddaloni and Peydrò (2011) employ confidential Bank Lending Survey (BLS) data for Euro area countries (from 2004 to 2008) and the Senior Loan Officer (SLO) Survey for the U.S (from 1991 to 2008). They present strong evidence that low short-term rates soften lending standards, leading to an increase in credit risk. Weaker supervision exacerbates this effect.

Other studies examine which bank characteristics affect bank risk-taking. Buch et al. (2011) investigate the pricing, volumes and riskiness of new loans made by U.S. banks over 1997 to 2008. Their analysis does not support the proposition that large domestic banks assume more risks when interest rates (federal funds rate) fall and house prices rise. In contrast, foreign banks reduce risk exposure whereas domestic banks grant riskier loans. Baghat et al. (2013) confirm the impact of bank size reporting that larger financial institutions are less risk averse than small banks based on US data from 2002 to 2012.

The negative and wide-ranging consequences of the GFC were incentive for policy-makers to intervene in market conditions and structures to restore confidence and create conditions for prompt and sustained economic recovery. The regulatory response in Basel 3 strengthens the financial architecture by increasing bank capital requirements and introducing new liquidity requirements to improve the soundness of banks and the banking system. At the same time, policy-makers employed new tools or unconventional monetary policies (UMPs), such as, quantitative easing (QE), forward guidance (FG) and NIRP to stimulate further continually weak economies.[5] Through NIRP, central banks sought to improve the effect of other (current or past) expansionary policies, such as, charging banks for holding excess reserves. The aim of such unconventional tools is to lower long-term interest rate expectations. However, when interest rates tend to zero or below, they can affect bank profitability and riskiness (Arteta et al. 2018; Jobst and Lin, 2016).

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

Clayes and Darvas (2015) analyse experiences of QE in the US, UK and Japan. Their results show that banks did not significantly improve credit standards, leading the authors to suggest that correct and balanced regulation effectively limits banks' propensity to increase leverage. On the contrary, and based on the syndicated loans market in the U.S., Aramonte et al. (2015) find financial institutions increase lending to riskier borrowers when long rates are exceptionally low and expected to remain so. Similarly, Kandrak and Schlusche (2017) show that liquidity injections via QE by the U.S. Federal Reserve did facilitate an increase in the supply of loans; however, the growth of riskier loans outpaced less risky loans. Contrarily, in Europe, APP actions by the European Central Bank simply fed into higher holdings of liquid assets by banks (Baldo et al. 2017). Arguably, banks opted to hold low yielding reserves rather than interbank loans because counterparty exposures are subject to capital charges at various risk weights.[6] Finally, Nakashima et al. (2017) investigate bank lending in Japan between 1998 and 2015, finding that UMPs stimulate lending to riskier firms by high-leveraged banks.

Whilst some contend that monetary policy is not neutral from a stability prospective, a limited literature examines the riskiness of banks under negative interest rates. The ECB's use of NIRP in 2014 is associated with an increase in the riskiness of syndicated loans in Europe between 2013 and 2015, especially for banks with large volumes of deposits (Heider et al. 2017). An investigation of the impact of deposit facility interest rate cuts by the ECB on bank risk shows that whereas risk declines for large banks, it increases for smaller banks, especially those funded mostly with customer deposits (Nucera et al. 2017).[7] Both studies provide clear evidence that firm-level characteristics are important factors in determining the relation between bank behaviour and NIRP transmission. Further evidence comes from a cross-country study of changes in bank risk following announcements of NIRP by central banks. Using rates on credit default swaps of listed banks to proxy risk, Arteta et al. (2018) find that NIRP affects financial stability by lowering bank profit rather than increasing bank risk-taking.

3. Methodology and data collection

We employ a difference-in-differences framework to assess the effect of NIRP on bank risk-taking. Various banking studies use this methodology to evaluate the impact of policy changes (Argimón et al. 2017; Cerqueiro et al. 2016; Fiordelisi et al. 2016). We compare the effect of NIRP on risk-taking

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

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

for a treatment group of banks, namely, banks in NIRP-adopter countries, with a control group of banks unaffected by the policy change. Equation [1] summarizes our baseline model:

$$Y_{i,j,t} = \alpha + \beta_1 treated_{i,j} + \beta_2 Post_{j,t} + \beta_3 \left(treated_{i,j} * Post_{j,t}\right) + \beta_4 X_i + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \qquad [1]$$

Where Y_{ijt} equals 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, 0 otherwise. *Post* is a binary variable equal to unity in years following adoption of NIRP, 0 otherwise. γ_j controls for unobserved time-invariant country-specific characteristics. φ_t controls for time-varying shocks that impact bank risk-taking. Since the majority of countries adopted NIRP in 2014, *Post* equals unity from 2014. The coefficient of β_3 measures the difference in growth of risky assets between banks in NIRP adopter countries and banks in countries maintaining positive rates.[8] To control for possible heterogeneity among banks and to reduce the omitted variable bias, Equation [1] specifies a vector, X, of bank- and country-specific control variables to account for specific factors that might affect risk-taking, which we select with reference to relevant literature (see next section).

The difference-in-differences model must satisfy two requirements to ensure suitability to analyse the effect of NIRP on bank risk-taking. First, the control group must constitute a valid counterfactual for the treatment. To address this concern, we estimate Pearson correlation coefficients (Table 1) for macroeconomic variables in treatment and control groups. The significance of coefficients suggests that countries in each group experienced similar macroeconomic environments, which infers that the control group is a valid counterfactual for the treatment.[9] Furthermore, as a robustness check, we combine the difference-in-differences methodology with the PSM, which pairs each bank with a control unit thereby controlling for banks having similar characteristics.

[Insert Table 1 here]

The second requirement is the parallel trend assumption (Bertrand et al., 2004). Figure 1 shows growth of risky assets in treated and control groups from 2012 to 2016.[10] The assumption holds since

[8] The following section discusses the dependent variable. Only Sweden, Switzerland and Norway introduced negative interest rates in 2015 (Jobst and Lin, 2016).

[9] We arbitrarily chose a longer period (in comparison with the sample period) to illustrate that the macroeconomic indicators move together for several years after the GFC.

[10] 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 could affect the treatment outcome. This could cause omitted variable bias and threaten the validity of the model.

the trend lines move closer together before implementation of NIRP in 2014. Interestingly, post-NIRP, banks in NIRP adopter countries saw a remarkable reduction in risky assets unlike non-adopter countries where banks maintained stable growth in risky assets.

[Insert Figure 1 here]

Our panel dataset is a sample of 2,731 banks from 33 OECD countries from 2012 to 2016. The balanced panel comprise 6,312 bank-year observations.[11] The treatment group has 3,576 observations and 2,736 observations cover the control group. We obtain bank-level variables from Orbis Bank Focus, and winsorize at the 1% level for treatment and control to reflect different group distributions. Banks with cross-border subsidiaries pose a problem. To avoid problems of 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.[12]

Table 2 reports descriptive statistics for treated and control groups before and after NIRP. Panels A and D show the indicators we use to measure changes in banks' risk aversion. 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. This indicator captures changes in bank portfolios and any rebalancing towards riskier assets due to changes in market conditions and/or credit quality that affect asset values. Positive values indicate the growth in risky assets exceeds growth in safer assets (cash, government securities, and due to banks), and vice-versa for negative values. Further motivation for our preferred indicator highlights concerns that banks could engage in regulatory arbitrage to lower risk-weighted assets and improve capital adequacy, especially if using internal-rating based models to assess credit risk (Mariathasan and Merrouche, 2014). Variation in adoption rates of internal-rating based models across countries could introduce bias if risk-weighted assets was to proxy risk (Bruno et al. 2015). As a robustness check, we re-estimate regressions using the log-transformation of bank Z-scores as dependent variable, which is a widely employed measure of risk (Mohsni and Otchere, 2014; Beck et al. 2013).[13]

Panels B and E show descriptive statistics on bank-level variables. We measure bank size by the natural logarithm of total assets (*Size*). The too-big-to-fail hypothesis suggests a positive relation between bank size and risk-taking. However, prospective portfolio diversification gains, better

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[11] Table A1 in the Appendix shows implementation dates of NIRP across countries. We omit Japan because introduction of NIRP took place only in 2016.

[12] Codes U1 and U2 in Orbis Bank Focus.

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

managerial skills and easier funding conditions could work to produce an inverse relationship (Khan et al., 2017; Bertay et al., 2013). The ratio of equity-to-total assets measures bank capitalisation (*E/TA*). The capital channel of monetary policy suggests bank responses to monetary policy impulses vary significantly with capitalisation (Gambacorta and Mistrulli, 2004; Van den Heuvel, 2002). Whereas soundly capitalised banks can increase holdings of riskier assets, binding capital constraints at under capitalised banks mitigates risk-taking (Gambacorta and Shin, 2015; De Nicolò et al., 2010). Notwithstanding, the impact of capitalisation on risk-taking is ambiguous. We cannot exclude the possibility that a bank might gamble for resurrection, or that weakly capitalised banks assume greater risks to increase earnings, which, if retained, could bolster bank equity thereby improving soundness (Calem and Rob, 1999).

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

The ratio of non-interest income-to-total income is proxy for bank *business models* (Borio and Gambacorta, 2015; Beck et al. 2013; Delis et al. 2011). Low interest rates could coerce banks that rely heavily on intermediation business to acquire riskier assets to compensate for downward pressure on bank profitability (Altunbas et al., 2011). Our models specify bank liquidity (*Liquidity*), which we measure using the ratio of liquid assets-to-customer deposits and short-term funding. Larger volumes of liquid assets could facilitate the transfer of resources to more profitable assets, which suggests the relation between liquidity and growth of risky assets is positive (Acharya and Naqvi, 2012). However, even adequate amounts of liquidity could signal risk-aversion under conditions of weak profitability and few investment opportunities, which may occur if adverse selection effects increase the pool of low quality borrowers, and tighter capital requirements. We use return on assets (*ROA* – net income-to-total assets) to proxy bank profitability. Whilst, less profitable banks face incentives to take risks in an attempt to boost profitability (Mare, 2015; Poghosyan and Čihak, 2011), profitable banks could use their resources to increase risky lending. We proxy credit risk using the ratio of nonperforming loans-to-gross loans (*NPLs*). Nonperforming loans reflect the quality of assets and possible losses. We expect higher credit risk will negate bank risk-taking causing an inverse relationship (Delis and Kouretas, 2011; Gonzalez, 2005).

Panels C and F report bank industry, macroeconomic and monetary policy variables. We control for the effect of GDP growth on bank risk-taking (Altunbas et al. 2018; Khan et al. 2017). Upturns in the business cycle should enhance bank income and profit, thereby strengthening equity and lessening banks' appetite for risk. Thus, we expect a negative relationship. We include inflation (Forssbaeck, 2011; Mannasoo and Mayes, 2009), and the VIX (Poligrova and Santos, 2017) to proxy market expectations of stock market volatility. Higher inflation and expected volatility are associated with less risk-taking, indicating an inverse relationship. We account for how competitive national banking markets are because market structure exerts differential effects on bank risk-taking. Following Schaeck and Cihak (2014), our proxy for competition is the Boone indicator, which captures the sensitivity of bank profit to changes in marginal cost. The World Bank Global Financial Development Database is the source of this variable.[14] Our final control is the log growth rate of a country's central bank balance sheet (*CB_GR*) (Alessandri and Nelson, 2015; Lambert and Ueda, 2014). We specify this variable because other UMP policies, such as, asset purchase programs by central banks, were in operation at the same time as NIRP (Di Maggio et. al, 2016; Kandrac and Schulsche, 2016).

[Insert Table 2 here]

4. Results and Discussion

Table 3 presents results from estimations of equations [1]. All models specify country and year fixed effects. Our interest turns to the magnitude, sign and significance of the coefficient of β_3, which measures the average difference in the change in bank risk-taking between countries that adopted NIRP and countries that did not (the NIRP-Effect in Table 3). Our models incrementally introduce a set of control variables to capture heterogeneity among banks.

[Insert Table 3 here]

The baseline result in Table 3, column 1 excludes control variables. The NIRP-effect, β_3, is economically meaningful, negative and statistically important at the 1 per cent level of significance. It infers the amount of risky assets on bank balance sheets in adopter countries declined by around 10 per cent after the introduction of NIRP in comparison to countries that did not adopt. In other words, this result means that NIRP leads to a decrease in bank risk-taking. There are three reasons that explain why NIRP did not increase bank risk-taking. First, the use of UMPs, such as QE (from

[14] Several authors examine the effect of competition on bank risk-taking (see Boyd and De Nicolò, 2005; Jiménez et al. 2013; Kick and Prieto, 2015). For robustness, and because the relationship between market concentration and competition is ambiguous (Claessens and Laeven, 2004), in unreported tests 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.

2015 in Europe), in response to worsening macroeconomic conditions and deteriorating bank balance sheets, provided banks with excess liquidity; in turn, this allowed banks to deleverage their post-crisis balance sheets, which limited potential supply-side benefits arising from exceptionally favourable financing conditions. Second, and given the monetary policy objective to increase bank lending, an unintended consequence of UMP is that banks simply used the excess liquidity to buy safer assets. Arguably, this choice was rational in a period of slow economic recovery, high firm default rates and negative interest rates. Finally, whereas monetary policy actions are not binding for banks, prudential regulations are. Basel capital requirements treat sovereign exposures within the EU as risk-free and assign zero risk weight to government bonds, which creates incentive for banks to acquire such assets. Similarly, more stringent capital regulations and new liquidity requirements work to constrain bank manoeuvres to increase risk-taking.[15]

Columns 2 to 11 report results from regressions augmented with bank- and country- control variables. Whilst we continue to observe a statistically significant NIRP-Effect, its economic importance is stronger in the augmented models.[16] The bank-level controls are mostly significant. Some results help to clarify relationships that previously were ambiguous. Our results show an inverse relationship between bank size and risk-taking. This suggests relative portfolio diversification skills, management quality and favourable funding conditions allow larger banks to control their risk-taking. We offer an intuitive explanation for the observed negative coefficient on E/TA. Leveraged banks invest in riskier assets that carry higher private payoff 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 considerable duress may gamble for resurrection. Our evidence shows relatively profitable banks assume higher risk. This result refutes proposition that less profitable banks invest in riskier assets to boost profitability.

The results on the nexus between liquidity and risk-taking show an inverse relationship that implies less liquid banks invest in riskier assets. We recognise that adequate liquidity can encourage risk-averse behaviour under conditions of weak investment opportunities and binding liquidity regulations. The choice of business model affects risk-taking. Banks that generate sizeable proportions of revenue from noninterest income activities, such as, investment banking, invest more heavily in riskier assets. This result supports diversification arguments. We find that banks burdened with poorer asset quality prefer to constrain growth in riskier assets. The relationship between funding structures and risk-taking is insignificant. However, the magnitude of coefficients is large and

[15] We test for the effects of unconventional monetary policies, deleveraging, and preferential regulation on NIRP in the following sections.
[16] A large discrepancy in the treatment coefficient between the baseline model and augmented models should raise a "red flag" (Roberts and Whited, 2013).

suggests that banks with less stable sources of funding take more risk. Finally, in column 12 we include all bank- and country- characteristics to control for the omitted variable bias. As shown, the coefficient NIRP-Effect keeps the significance level and increases in magnitude providing further validity of our estimation.

4.1 Capitalisation, size and competition

We run a set of additional tests to account for various bank- and country-specific features whose impact could be meaningful in assessing risk-taking incentives in a negative interest rate environment. First, we examine the capital channel view that bank responses to monetary policy impulses varies according to levels of capitalisation (Van den Heuvel, 2002). We test this proposition by restricting our sample into weak and strong capitalised banks, that is, banks in the lowest and highest deciles of the distribution of the total capital ratio (Borio and Gambacorta, 2016), and re-estimating our baseline model. Panels A and B in Table 4 show the effect of NIRP on risk-taking is non-linear. Consistent with the baseline result, panel A shows an inverse relationship for undercapitalised banks. However, the economic importance of the effect is much greater since the decrease in risky assets more than doubles the reduction documented for the whole sample. Our result highlights tension between objectives of monetary policy and prudential regulation. Undercapitalised banks find it difficult to invest in risky assets because they must comply with capital requirements, which acts to dampen the impact of monetary stimulus (De Nicolò et al., 2010). Furthermore, during crisis episodes, banks face difficulties to issue new equity or increase retained earnings. Undercapitalised banks might improve capital ratios by reducing risk-weighted exposures via a deleveraging process, but such action may amplify pro-cyclicality of bank loans (Jiménez et al., 2010). Panel B shows a positive relation for highly capitalised banks, which indicates strong growth in risky assets following adoption of NIRP presumably because this cohort possess large capital buffers (Gambacorta and Shin, 2015). It implies strong capitalised banks can reallocate resources toward riskier, profitable investments to compensate the negative impact of NIRP on profits.[17]

Our evidence offers important policy implications because we highlight the key role played by bank capital in the transmission mechanism of monetary policy. Under difficult macroeconomic conditions and negative interest rates, which exacerbate pressures on bank profitability, only well-capitalized banks increase risk-taking. The impact of capital buffers above minimum requirements is twofold. First, undercapitalized banks experience a direct impact due to difficulties in issuing new equity, in

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

terms of volume and cost. Second, undercapitalised banks face constraints in securing wholesale deposit funding during crisis periods in contrast to strong capitalised banks (Iyer et al. 2014).

We test for the effect of size by splitting the sample into banks holding total assets above and below the median. Whereas we cannot find a significant relation for smaller banks (Panel C), we observe a significant and inverse relation for larger banks (Panel D). In explanation, we allude to greater opportunities to support profitability at larger banks, for instance, changing loan intensity and using cross selling to increase fee and commission incomes (Altunbas et al., 2018; Nucera, 2017). Larger banks show greater tendency to realise economies of scale and scope and are relatively less reliant on retail deposits. This suggests larger banks can benefit from lower wholesale funding costs, which reduces incentive to invest in riskier assets under NIRP (Salas and Saurina, 2002).

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

[Insert Table 4 here]

4.2 Further robustness checks

The difference-in-differences framework assumes the control group is a valid counterfactual for the treatment. Section 3 considered the assumption and reported that the treatment and control groups experienced similar macroeconomic environments pre-crisis. We further test the assumption by using propensity score matching to construct a control sample (Rosenbaum and Rubin, 1983). We estimate a Probit model to obtain the predicted probability (propensity score) that a country will undertake NIRP, matching banks operating in NIRP and non-adopter countries using macroeconomic variables (GDP growth and inflation). To ensure the predicted propensity score controls for bank-specific differences between treatment and control groups pre-NIRP, our PSM model specifies bank size, equity strength, and profitability (see equation 2):

$$p_i = \Pr(D_i = 1 | X_i) = \delta(X_i'\beta + \varepsilon_i) \qquad [2]$$

where D_i is a binary variable describing treatment status, D=1 if a bank is affected by NIRP, and zero otherwise. X_i is a vector of observable macroeconomic variables and bank characteristics in the two years prior to NIRP. δ is a standard normal cumulative distribution function.

Specifically, we implement Kernel matching (Heckman et al. 1998) with weighted averages of all banks in the control group constructing the counterfactual outcome. Kernel matching tends to realise smaller variances because the estimation utilises more information. Table 5 shows results from the Probit model, which generates propensity scores that a country will be affected by NIRP. Each covariate is significant at the 1 per cent level. The results suggest that banks operating in countries with weak economic prospects (lower GDP growth and below-target inflation) have greater probability of being affected by NIRP. Similarly, countries with smaller banks, less capitalised banks and less profitable banks have a higher probability to be a target of NIRP.

[Insert Table 5 here]

Table 6 shows results from the PSM matching difference-in-differences model. When matching banks by macroeconomic conditions and banking characteristics, the NIRP-effect produces a sizeable and statistically significant contraction in risk taking. This provides additional credence to the reliability of our baseline findings.

[Insert Table 6 here]

Earlier, we suggested that compliance with prudential regulations could explain the preference of banks to invest in safer, liquid assets, such as, sovereign bonds rather than increase exposure to riskier assets, which was one of the objectives of NIRP. We also suggested that this process might require banks to cleanse and deleverage deteriorated post-crisis balance sheets. To provide further insight into these possibilities, we examine whether banks in the treatment group reduced in size whilst concomitantly increasing exposure to sovereign debt in comparison to the control group following NIRP. For this exercise, we use the growth rate of total assets (*Asset growth*), and the ratio of government bonds-to-total assets (*Sov. Bond*) as two dependent variables in our difference-in-differences model.

Panel A (column 2) of Table 7 confirms the deleveraging hypothesis as asset growth at banks in NIRP adopter countries is significantly less than at banks in non-adopter countries. Column 3 confirms proposition that banks in NIRP adopter countries significantly increase exposure to safer, and zero risk-weighted sovereign debt. Our result supports arguments in Altavilla et al. (2017) that a very high degree of substitutability exists between lending and sovereign debt in periods of distress and economic weakness.

It is important to disentangle any confounding effects upon bank risk-taking arising from NIRP and other UMP actions. NIRP was a latecomer in terms of implementation and followed on the heels of extensive use of QE by central banks to acquire assets of distressed firms. The rationale of QE is to expand a central bank's balance sheet to increase the monetary base, which should stimulate bank lending and ultimately boost nominal spending (Bernanke and Reinhart, 2004). To disentangle potentially confounding effects from NIRP and UMP, we augment the baseline model with a proxy for the use of other UMPs, that is, the growth of central bank balance sheets (Lambert and Ueda, 2014). Thus, we re-estimate with variables accounting for the NIRP-effect and UMP-effect. Panel B, column 1, clearly shows a significant NIRP-effect that reduces bank risk-taking even after controlling for the effect of UMPs. Interestingly, UMP would appear to simulate investment in riskier assets by banks though the relationship is insignificant at conventional levels.

We apply further tests of robustness. First, we restrict the cohorts of treatment and control groups to banks from European countries only. We fail to find a significant NIRP-effect, which suggests that negative interest rate policy does not engineer differential effects on risk-taking because banks across Europe face comparable economic conditions (see Table 7 panel C, column 1). Second, we try to eliminate the possibility that risk-taking in the treatment group changed before central banks started to use NIRP. It might be the case that banks were anticipating adverse effects of impending NIRP and altered behaviour, or some bank-specific factors caused a change in risk-taking. A presence of pre-NIRP change in risk-taking would invalidate our choice of difference-in-differences estimation. To consider this possibility, we re-estimate the model from 2011 to 2014 and introduce a "fake" NIRP in 2013. If the estimated coefficient on "fake" NIRP-effect is not statistically significant or different in sign, we can be more confident that our baseline coefficient is capturing a genuine monetary policy shock. Moreover, use of "fake" NIRP controls for differences between low and negative interest rate environments. Panel D in Table 7, column 1, shows the "fake" NIRP-effect is insignificant and of opposite sign, which adds further support to the validity of our baseline estimation. Lastly, we test the efficacy of our preferred risk indicator (*GRisky*) by re-estimating using the logarithm of bank Z-scores as dependent variable. Panel E, Table 7, column 4 shows a positive and significant relationship. This infers distance-to-default declines or bank stability improves following NIRP. The implication is consistent with the baseline and further strengthens the reliability of our results.

[Insert Table 7 here]

5. Conclusion

We provide early evidence on the impact of negative interest rate policy upon bank risk-taking. Our results suggest that NIRP has produced an unintended outcome, namely, a lower level of risk-taking that we can quantify as a reduction in risky assets held by banks in the NIRP affected countries of 10 per cent. Whilst implying monetary policy alone is insufficient to change bank behaviour, our evidence points to a dichotomy between non-binding monetary policy goals and binding bank capital regulations. The introduction of NIRP in 2014 followed hard on the heels of the phasing-in of Basel 3 effective from 2013. The policy coordination dilemma saw NIRP trying to engineer investment in risky assets to boost growth at a time when prudential requirements demanded banks hold greater amounts of higher quality loss absorbing capital and introduced new liquidity requirements. We contend that the NIRP-effect sees banks preferring to deleverage their balance sheets and invest in safe assets to meet new and binding capital and liquidity requirements. Bank risk-taking behaviour, however, is sensitive to the level of prudence since banks with stronger capital ratios increase their investment in risky assets. We find also that NIRP leads banks to assume more risks in less competitive markets where higher levels of market power act to insulate interest margins and profitability. Our findings imply that tight prudential requirements 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'). An unambiguous implication for policy is to avoid coordination problems by integrating the efforts of regulators and policymakers.

Bibliography

Acharya, V., Naqvi, H. (2012). The seeds of a crisis: A theory of bank liquidity and risk taking over the business cycle. Journal of Financial Economics, 106(2), 349–366. https://doi.org/10.1016/j.jfineco.2012.05.014

Adrian, T., Shin, H.S. (2009). Financial Intermediaries and Monetary Economics. Federal Reserve Bank of New York Staff Reports, (September), 39.

Agur, I., Demertzis, M. (2012). Excessive bank risk taking and monetary policy. European Central Bank, Working Paper (1457), 34.

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

Altavilla, C., Boucinha M., Peydro, J. L., (2017). Monetary policy and bank profitability in a low interest rate enviroment. ECB Working Paper Series, European Central Bank, N. 2105

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

Altunbas, Y., Marqués-Ibáñez, D., Manganelli, S. (2011). Bank risk during the financial crisis: do business models matter? Working Paper Series, 1–53.

Altunbas, Y., Gambacorta, L., Marquez-Ibanez, D. (2014). Does monetary policy affect bank credit standards? International Journal of Central Banking, 10 (March).

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

Aramonte, S., Lee, L., Stebunovs, V. (2015). Risk Taking and Low Longer-term Interest Rates: Evidence from the U.S. Syndicated Loan Market. Finance and Economics Discussion Series 2015-068. Washington: Board of Governors of the Federal Reserve System. http://dx.doi.org/10.17016/FEDS.2015.068.

Argimón, I., Dietsch, M., Estrada, Á. (2016). Prudential filters, portfolio composition at fair value and capital ratios in European banks. Journal of Financial Stability. https://doi.org/10.1016/j.jfs.2017.03.004.

Arteta, C., Kose, M.A., Stocker, M., Taskin, T. (2018). Implications of negative interest rate policies: An early assessment. Pacific Economic Review, 23(1), 8–26. https://doi.org/10.1111/1468-0106.12249.

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

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

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

Bech, M., Malkhozov, A. (2016). How have central banks implemented negative policy rates? BIS Quarterly Review, (March), 31–44.

Beck, T., De Jonghe, O., Schepens, G. (2013). Bank competition and stability: Cross-country heterogeneity. Journal of Financial Intermediation, 22(2), 218–244. https://doi.org/10.1016/j.jfi.2012.07.001.

Beltratti, A., Paladino, G. (2016). Basel II and regulatory arbitrage. Evidence from financial crises. Journal of Empirical Finance, 39, 180–196. https://doi.org/10.1016/j.jempfin.2016.02.006.

Bernanke, B.S., Reibhart, V.R., Sack, B.P. (2004). Monetary Policy Alternatives at the Zero Bound: an empirical assessment. Brookings Papers on Economic Activity, 2, 1–100.

Bertay, A.C., Demirgüç-Kunt, A., & Huizinga, H. (2013). Do we need big banks? Evidence on performance, strategy and market discipline. Journal of Financial Intermediation, 22(4), 532–558. https://doi.org/10.1016/j.jfi.2013.02.002.

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

Bhagat, S., Bolton, B., Lu, J. (2015). Size, leverage, and risk-taking of financial institutions. Journal of Banking and Finance, 59, 520–537. https://doi.org/10.1016/j.jbankfin.2015.06.018.

Borio, C., Gambacorta, L. (2016). Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness? Journal of Macroeconomics, 0, 1–15. https://doi.org/10.1016/j.jmacro.2017.02.005.

Borio, C., Zhu, H. (2012). Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? Journal of Financial Stability, 8(4), 236–251. https://doi.org/10.1016/j.jfs.2011.12.003.

Borio, C., Gambacorta, L., Hofmann, B. (2015). The influence of monetary policy on bank profitability. BIS Working Papers (Vol. N°514). https://doi.org/10.1111/infi.12104.

Boyd, J.H., De Nicolò, G. (2005). The Theory of Bank Risk Taking. Journal of Finance, LX(3), 1329–1343. https://doi.org/10.1111/j.1540-6261.2005.00763.x.

Boyd, J.H., De Nicoló, G., Jalal, A.M. (2006). Bank Risk-Taking and Competition Revisited: New Theory and New Evidence. IMF Working Papers, 06(297), 1. https://doi.org/10.5089/9781451865578.001.

Brownless, C., & Engle, R. (2017). SRISK: a conditional capital shortfall measure of systemic risk (Vol. N°37). https://doi.org/10.1111/j.1467-629X.1980.tb00220.x.

Brunnermeier, M. K., Koby, Y., Koby, M. (2017). The Reversal Interest Rate: An Effective Lower Bound on Monetary Policy. Working Paper, 1–27. Retrieved from http://scholar.princeton.edu/.

Brunnermeier, Markus K. (2001). Asset pricing under asymmetric information: bubbles, crashes, technical analysis, and herding. Oxford University Press. Print.

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

Buch, C.M., Eickmeier, S., Prieto, E. (2011). In search for yield ? Survey-based evidence on bank risk taking. Discussion Paper Series 1: Economic Studies, Deutsche Bundesbank.

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

Cerquiero, G., Ongena, S., Roszbach, K. (2016). Collateralization, bank loan rates and monitoring. The Journal of Finance, 71, 1295-1322.

Claessens, S., Laeven, L. (2004). What Drives Bank Competition? Some International Evidence. Journal of Money, Credit, and Banking, 36(3b), 563–583. https://doi.org/10.1353/mcb.2004.0044.

Claeys, G., Darvas, Z. (2015). The financial stability risks of ultra-loose monetary policy. Bruegel Policy Contribution, 3.

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

De Nicolò, G., Dell'Ariccia, G.D., Laeven, L., Valencia, F. (2010). Monetary Policy and Bank Risk Taking. IMF Working Paper, (July). https://doi.org/10.2139/ssrn.1654582.

Delis, M.D., Kouretas, G.P. (2011). Interest rates and bank risk-taking. Journal of Banking and Finance, 35(4), 840–855. https://doi.org/10.1016/j.jbankfin.2010.09.032.

Dell'Ariccia, G., Laeven, L., Marquez, R. (2010). Monetary Policy, Leverage and Bank Risk-Taking. IMF Working Paper, WP/10/276.

Demirgüç-Kunt, A., Huizinga, H. (2010). Bank activity and funding strategies: The impact on risk and returns. Journal of Financial Economics, 98(3), 626–650. https://doi.org/10.1016/j.jfineco.2010.06.004.

Di Maggio, M., Kermani, M.A., Palmer, C., Heider, F., Kashyap, A., Lucas, D., Kermani, A. (2016). How Quantitative Easing Works: Evidence on the Refinancing Channel. http://www.nber.org/papers/w22638.

Fiordelisi, F., Ricci, O., Stentella Lopes, F.S., (2016). The unintended consequence of the Single-Supervisory Mechanism launch in Europe. Journal of Financial and Quantitative Analysis, 52 (6), pp. 2809-2836.

Forssbæck, J. (2011). Ownership structure, market discipline, and banks' risk-taking incentives under deposit insurance. Journal of Banking and Finance, 35(10), 2666–2678. https://doi.org/10.1016/j.jbankfin.2011.02.024.

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

Gambacorta, L., Mistrulli, P.E. (2004). Does bank capital affect lending behaviour? Journal of Financial Intermediation, 13(4), 436–457. https://doi.org/10.1016/j.jfi.2004.06.001.

Gambacorta, L., Shin, H.S. (2015). Why bank capital matters for monetary policy. Journal of Financial Intermediation, 0, 1–13. https://doi.org/10.1016/j.jfi.2016.09.005.

González, F. (2005). Bank regulation and risk-taking incentives: An international comparison of bank risk. Journal of Banking and Finance, 29(5), 1153–1184. https://doi.org/10.1016/j.jbankfin.2004.05.029.

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

Heider, F., Saidi, F., Schepens, G. (2017). Life Below Zero: Bank Lending Under Negative Policy Rates. ECB Working Paper Series. https://doi.org/10.2139/ssrn.2788204.

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

Ioannidou, V., Ongena, S., Peydró, J.L., (2015). Monetary policy, risk-taking, and pricing: Evidence from a quasi-natural experiment. Review of Finance, 19, 95-144.

Iyer, R., Peydró, J.L., Da-Rocha-Lopes, S., Schoar, A. (2014). Interbank liquidity crunch and the firm credit crunch: Evidence from the 2007-2009 crisis. Review of Financial Studies, 27(1), 347–372. https://doi.org/10.1093/rfs/hht056.

Jiménez, G., Lopez, J.A., Saurina, J. (2013). How does competition affect bank risk-taking? Journal of Financial Stability, 9(2), 185–195. https://doi.org/10.1016/j.jfs.2013.02.004.

Jiménez, G., Ongena, S., Peydró, J.L., Saurina, J. (2014). Hazardous Times for Monetary Policy: What Do Twenty-Three Million Bank Loans Say About the Effects of Monetary Policy on Credit Risk-Taking? Econometrica, 82(2), 463–505. https://doi.org/10.3982/ECTA10104.

Jiménez, G., Ongena, S., Peydró, J., Saurina, J. (2010). Credit Supply Identifying Channels with Loan Applications and Granted Loans. ECB Working Paper Series.

Jobst, A., Lin, H. (2016). Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area. IMF Working Paper, (172), 1–48.

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

Kandrac, J., Schlusche, B., (2017). Quantitative easing and bank risk taking: evidence from lending. Finance and Economics Discussion Series 2017-125. Washington: Board of Governors of the Federal Reserve System. https://doi.org/10.17016/FEDS.2017.125.

Khan, M.S., Scheule, H., Wu, E. (2017). Funding liquidity and bank risk taking. Journal of Banking and Finance, 82, 203–216. https://doi.org/10.1016/j.jbankfin.2016.09.005.

Kick, T., Prieto, E. (2015). Bank risk and competition: Evidence from regional banking markets. Review of Finance, 19(3), 1185–1222. https://doi.org/10.1093/rof/rfu019.

Kim, D., Sohn, W. (2017). The effect of bank capital on lending: Does liquidity matter? Journal of Banking and Finance, 77, 95–107. https://doi.org/10.1016/j.jbankfin.2017.01.011.

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

Maddaloni, A., Peydró, J.-L. (2011). Bank Risk-Taking, Securitization, Supervision and Low Interest Rates: Evidence from the Euro-area and the U.S. Lending Standards. Review of Financial Studies, 24(6), 2121–2165. https://doi.org/10.1093/rfs/hhr015.

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

Mare, D.S. (2015). Contribution of macroeconomic factors to the prediction of small bank failures. Journal of International Financial Markets, Institutions and Money, 39, 25–39. https://doi.org/10.1016/j.intfin.2015.05.005.

Mariathasan, M., Merrouche, O. (2014). The manipulation of Basel risk-weights. Journal of Financial Intermediation, 23(3), 300–321. https://doi.org/10.1016/j.jfi.2014.04.004.

Mohsni, S., Otchere, I. (2014). Risk taking behavior of privatized banks. Journal of Corporate Finance, 29, 122–142. https://doi.org/10.1016/j.jcorpfin.2014.07.007.

Nakashima, K., Shibamoto, M., Takahashi, K. (2017). Risk-taking channel of unconventional monetary policy in bank lending. Discussion Paper Series DP2017-24, Research Institute for Economics & Business Administration, Kobe University.

Nucera, F., Lucas, A., Schaumburg, J., Schwaab, B. (2017). Do negative interest rates make banks less safe? Economics Letters, 159(2098), 112–115. https://doi.org/10.1016/j.econlet.2017.07.014.

Paligorova, T., Santos, J.A.C. (2013). Monetary Policy and Bank Risk Taking: Evidence from the Corporate Loan Market. https://doi.org/10.2139/ssrn.1991471.

Poghosyan, T., Čihak, M. (2011). Determinants of Bank Distress in Europe: Evidence from a New Data Set. Journal of Financial Services Research, 40(3), 163–184. https://doi.org/10.1007/s10693-011-0103-1.

Rajan, R.G. (2006). Has finance made the world Riskier? European Financial Management, 12(4), 499–533. https://doi.org/10.1111/j.1468-036X.2006.00330.x.

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

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

Salas, V., Saurina, J. (2002). Credit risk in two institutional regimes: Spanish commercial and savings banks. Journal of Financial Services Research, 22(3), 203–224. https://doi.org/10.1023/A:1019781109676.

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

Sorensen, C., Werner, T. (2006). Bank interest rate pass-through in the euro area: a cross country comparison. ECB Working Paper Series, (580). http://ideas.repec.org/p/ecb/ecbwps/20060580.html.

Turk Ariss, R. (2010). On the implications of market power in banking: Evidence from developing countries. Journal of Banking and Finance, 34(4), 765–775. https://doi.org/10.1016/j.jbankfin.2009.09.004.

Van den Heuvel, S.J. (2002). Does bank capital matter for monetary transmission? Economic Policy Review (FRBNY), (May), 259–265. https://doi.org/10.2139/ssrn.831946

Table 1. Descriptive Statistics. Macroeconomics Indicators and Pearson Correlation Test for the Control and Treatment Group during the Period 2007-2015.

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

***, ** and * - significant at 1%, 5% and 10%, respectively.

Figure 1. Average Growth of Risky Assets among treated (red line) and control (blue line) prior and after the introduction of NIRP.

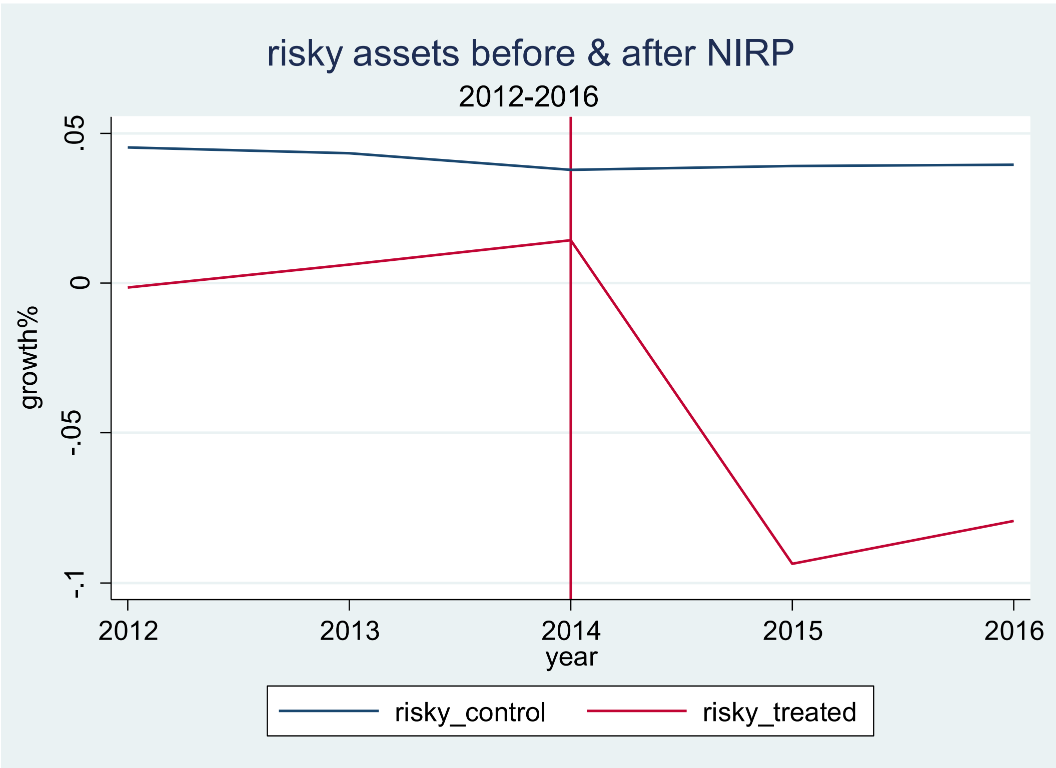

Table 2. Descriptive statistics

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
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%
ROA	9025	0.42%	0.42%	0.02%	1.41%	8108	0.42%	0.41%	0.02%	0.41%
Liquidity	8570	23.22%	20.73%	5.27%	70.16%	7755	22.66%	20.61%	5.27%	70.16%
Funding structure	8217	0.62%	0.21%	0.20%	0.84%	7465	0.64%	0.20%	0.20%	0.84%
Business model	8725	6.92%	6.32%	0.15%	20.17%	7881	7.02%	6.31%	0.15%	20.17%
NPLs	4953	5.56%	4.57%	0.49%	14.41%	4935	5.45%	4.92%	0.49%	14.11%
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										
Boone	10364	-0.03	0.91	-0.55	0.14	10092	-0.04	0.10	-0.64	0.14
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
CB_GR	10364	17.75%	10.53%	-9.40%	32.17%	13327	7.27%	8.05%	-14.39%	32.17%
Unemployment	10364	8.01%	4.75%	4.2%	27.2%	4978	7.90%	4.70%	4.5%	26.3%

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
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%
ROA	4811	0.99%	0.96%	-0.28%	2.96%	4457	0.97%	0.93%	-0.28%	2.60%
Liquidity	4342	28.77%	31.81%	2.35%	98.46%	4039	28.89%	31.91%	2.35%	98.46%
Funding structure	3350	0.69%	0.20%	0.23%	0.88%	3185	0.70%	0.21%	0.23%	0.88%
Business model	4662	2.74%	2.31%	-0.40%	7.02%	4316	2.91%	2.32%	-0.40%	7.02%
NPLs	3165	2.85%	2.40%	0.14%	7.21%	2916	2.22%	2.22%	0.14%	7.21%
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										
Boone	23300	-0.39	0.04	-0.44	0.22	22944	-0.04	0.04	-0.41	0.21
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
CB_GR	23300	15.08%	15.15%	-15.65%	32.17%	13327	7.27%	8.05%	-14.39%	32.17%
Unemployment	23300	7.58%	1.07%	3.1%	10.4%	11383	6.24%	0.62%	3.5%	9.2%

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; Z-score is the ratio of return on assets and equity to total assets on the standard deviation of return on assets; Size is the natural logarithm of bank total asset; E/TA is the ratio of bank equity to total assets; Tot. capital ratio is the ratio of Total Capital (Tier 1 + Tier 2) to risk-weighted assets; ROA is the net income to total asset ratio; Liquidity is the ratio of liquid assets to retail deposits and short-terms funding; Funding structure is the ratio of bank deposits funding to total liabilities; Business model is the ratio of non-interest income to total income; NPLs is the ratio of non-performing loans to gross loans; Asset growth is the growth rate of bank total assets; Sov. bond is the ratio of government securities on total assets; Boone is the Boone indicator at country level. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. VIX is the CBOE volatility index. CB_GR is the growth rate of central bank total assets. Unemployment is the yearly level of unemployment in percentage.

Table 3. NIRP and Risky Assets

	GRisky(1)	GRisky(2)	GRisky(3)	GRisky(4)	GRisky(5)	GRisky(6)	GRisky(7)	GRisky(8)	GRisky(9)	GRisky(10)	GRisky(11)	GRisky(12)
NIRP-Effect	-0.0981***	-0.1010***	-0.0990***	-0.1130***	-0.1170***	-0.1200***	-0.1190***	-0.1182***	-0.0997***	-0.0993***	-0.0993***	-0.1284***
	(0.0144)	(0.0145)	(0.0146)	(0.0144)	(0.0143)	(0.0144)	(0.0144)	(0.0142)	(0.0149)	(0.0147)	(0.0147)	(0.0155)
Size		-0.0035	-0.0082***	-0.0078***	-0.0084***	-0.0095***	-0.0094***	-0.0122***				-0.0125***
		(0.0022)	(0.0022)	(0.0021)	(0.0021)	(0.0023)	(0.0023)	(0.0025)				(0.0025)
E/TA			-0.0045***	-0.0068***	-0.0072***	-0.0063***	-0.0065***	-0.0042***				-0.0042***
			(0.0011)	(0.0012)	(0.0014)	(0.0014)	(0.0014)	(0.0012)				(0.0012)
ROA				0.0463***	0.0456***	0.0453***	0.0494***	0.0412***				0.0410***
				(0.0086)	(0.0088)	(0.0091)	(0.0096)	(0.0412)				(0.0091)
Liquidity					-0.0003	-0.0006**	-0.0006*	-0.0008***				-0.0008***
					(0.0003)	(0.0003)	(0.0003)	(0.0003)				(0.0003)
Funding structure						-0.0257	-0.0286	-0.0193				-0.0197
						(0.0297)	(0.0304)	(0.0261)				(0.0260)
Business model							0.0012*	0.0014***				0.0014***
							(0.0007)	(0.0005)				(0.0005)
NPLs								-0.0040***				0.0041***
								(0.0008)				(0.0008)
GDP growth									0.0048	0.0037	0.0037	0.0068
									(0.0110)	(0.0107)	(0.0147)	(0.0101)
Inflation										-0.0038	-0.0038	-0.0183**
										(0.0073)	(0.0073)	(0.0078)
VIX											-0.0018	-0.0025
											(0.003)	(0.0032)
No. Banks	2731	2731	2731	2701	2683	2601	2579	2042	2730	2730	2730	2041
No. Observations	6312	6312	6311	6206	6173	5991	5945	4599	6311	6311	6311	4598

All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 4. Risky assets, capitalisation, size and competition before and after NIRP

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

All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis.
***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 5. *Propensity score estimation: Probit model*

	GRisky
GDP growth	-3.4318***
	(0.2053)
Inflation	-0.9813***
	(0.0733)
Size	-0.2706***
	(0.0367)
E/TA	-0.0704***
	(0.0129)
ROA	-0.9666***
	(0.1192)
No. Observations	1458
Pseudo R square	0.5118
Log Likelihood	-394.50
LR test (chi square)	827.29

Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 6. Difference-in-differences- PSM

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

All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

Table 7. Robustness checks

	GRisky (1)	Asset Growth (2)	Sov. Bond (3)	Z score(4)
Panel A. Deleveraging & Sovereign Bonds				
NIRP-effect		-0.0868***	0.0062***	
		(0.0079)	(0.0010)	
No. Banks		7386	3368	
No. Observations		25801	9303	
Panel B. Unconventional Monetary Policies (UMPs)				
NIRP-Effect	-0.0864***			
	(0.0158)			
CB_GR	0.0387			
	(0.0430)			
No. Banks	2729			
No. Observations	5835			
Panel C. NIRP and the EU				
NIRP-Effect	-0.0378			
	(0.0259)			
No. Banks	2051			
No. Observations	4081			
Panel D. "Fake"				
NIRP-Effect	0.0418			
	(0.0290)			
No. Banks	799			
No. Observations	1437			
Panel E. Z-score as measure of risk-				
NIRP-Effect				0.0239***
				(0.0056)
No. Banks				7257
No. Observations				26247

All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * - significant at 1%, 5% and 10%, respectively.

APPENDIX

Table A1. Time of Adoption of NIRP.

Country	NIRP adoption date
Austria	June 2014
Belgium	June 2014
Denmark	July 2012
Estonia	June 2014
Finland	June 2014
France	June 2014
Germany	June 2014
Greece	June 2014
Hungary	March 2014
Ireland	June 2014
Italy	June 2014
Luxembourg	June 2014
Netherlands	June 2014
Norway	September 2015
Portugal	June 2014
Slovakia	June 2014
Slovenia	June 2014
Spain	June 2014
Sweden	February 2015
Switzerland	January 2015