DO NEGATIVE INTEREST RATES AFFECT BANK RISK-TAKING?

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Abstract

This paper investigates the effect of NIRP on bank risk taking. Using a sample of 2371 banks in 33 OECD countries for the period 2012-2016 and a difference-in-differences methodology, we find that the amount of bank risky assets contract after the implementation of negative interest rate policies. The controversial impact of negative interest rates is stronger for banks that are large, poorly capitalised and operating in competitive markets. Conversely, only banks with high capitalization and operating in non-competitive markets experience a portfolio rebalancing towards risky asset.

JEL: E43, E44, E52, E58, G21, G32.

Keywords: NIRP, Bank risk-taking, Monetary Policy, Financial Risk Management, Difference in Difference estimation.

1. Introduction

The global financial crisis of 2008-09 resulted in the worst economic recession in advanced economies since the 1930s. Central banks initially responded by reducing policy interest rates sharply. When these rates approached zero without there being the hoped-for recovery in nominal spending, many central banks (CBs) experimented with a range of unconventional monetary policies (UMPs) to provide further stimulus, including: large-scale asset purchases (LSAPs) to raise asset prices and increase the supply of bank reserves, targeted asset purchases to alter the relative prices of different assets (mostly impaired assets, as result of the financial crisis), and forward guidance (FG) to communicate about its future policy rate path. The effectiveness of these policies in raising nominal spending has been at the centre of a vigorous policy and academic debate with no clear consensus emerging. In any event, for many countries the macroeconomic environment has remained challenging.

In this context, since 2012 six European economies (Denmark, the Euro area, Hungary, Norway, Sweden and Switzerland) and Japan have taken unconventional monetary policies a step further by introducing negative interest rate policy (NIRP) aimed at additional monetary policy accommodation[1]. The primary objective of NIRP in the adopter countries was to stabilize inflation expectations and support economic growth, though Denmark and Switzerland aimed also at discouraging capital inflows to reduce exchange rate appreciation pressures (see Jobst and Lin 2016). Support for the real economy was expected to come from a greater supply and demand for loans, with loan supply increasing as banks ran down their (large) excess reserve balances, and loan demand increasing in response to a further fall in lending rates.

As for UMP more generally, NIRP has fuelled debate on the likelihood that it would be successful (see, for example, Arteta et al. 2016; Ball et al. 2016; Jobst and Lin 2016). The key issues to be addressed concerned its efficacy and its limitations in stimulating economic growth and inflation, its effect on the exchange rate and the problems on bank profitability and bank risk-taking that can threaten financial stability. Regarding the last point, the risk-taking channel of monetary policy (see Borio and Zhu, 2008) suggests that, during period of low and negative interest rates, banks engaged in riskier activities through portfolio reallocation and 'search for yield'(Rajan, 2005). This can lead to the promotion of asset bubbles in the housing and bond markets altering bank risk-tolerance and risk-perception. In other words, cheap central bank's fund could led to an underestimation of the intrinsic risk of any investment. On the other hand, macroprudential policies have made enormous

[1] See Bech and Malkhozov (2015) for a discussion of the implementation mechanisms of NIRP in the adopting countries.

efforts to reduce moral hazard and to enhance the 'skin-in-the-game' effect preventing banks to take excessive risks (De Niccolo et al. 2010). Furthermore, liquidity injection via central banks unconventional monetary policies could have acted in the opposite way, helping banks deleveraging and cleaning 'after-crisis' deteriorated balance sheets allowing them to switch from risky to safe assets. Hence, in a period characterised by weak economic prospects, deteriorated bank balance sheets and tight regulations, the effect of low and negative interest rates on bank risk taking may be not unidirectional, as suggested by the risk-taking channel, but could rather lead to a possible reduction.

In this paper, we investigate the effect of NIRP on bank risk taking. We use NIRP for two main reasons. First, negative interest rates provoked a further reduction in the policy rates (already low for UMP) creating incentives for 'searching for yield'. Second, by charging excess reserves, NIRP motivate banks to employ the excessive liquidity for other assets, among which, risky assets. For this purpose, we employ a bank-level database comprising 2731 banks in 33 OECD countries for the period 2012-2016 and a difference-in-differences methodology. This methodology allows us to draw conclusion as to whether banks' risk taking in NIRP adopter countries were impacted differently than countries that did not adopt the policy. Moreover, it permits us to analyse both macroeconomic and bank-level factors that affect risk taking in the uncharted territory of NIRP. We find that the amount of bank risky assets contract after the implementation of NIRP. This effect appears to be stronger for banks that are large, not strongly capitalised and operating in competitive markets. Our data seems also to indicate that risk increases only when banks have high capital buffer and operate in non-competitive environment.

The paper proceeds as follow: section 2 contains a deep review of the academic literature, section 3 presents the methodology implemented while section 4 is the data overview. Section 5 discusses the empirical results of our study. Finally, section 6 presents our main conclusions and future policy implications.

2. Literature review

Since the collapse of the US real estate market in 2007 and the beginning of the global financial crisis (GFC), the link between low interest rates and banks risk-taking has been at the centre of a vigorous academic debate. In this regard, Borio and Zhu (2008) theorized the existence of the so-called "risk-taking channel" in the transmission mechanism to define the relation that could bind expansionary monetary policy and increase bank risk-taking. This channel operates in (at least) two ways. First, low and negative interest rates on securities motivate banks to switch to riskier assets to meet the

nominal return of their liabilities[2] (see also Rajan, 2006; Brunnermeier, 2001). Second, cuts on policy rate can boost bank profits through valuation gains on securities and increasing asset prices (see also Adrian and Shin, 2010). However, there is no academic consensus on the net effect of low interest rates on banking behaviour and increasing risk-tolerance.

A recent literature appears to strongly support the idea that accommodative monetary policy leads to increase in risk-taking. Angeloni et al. (2010) demonstrate empirically that the risk-taking channel works in both ways. When interest rates raise, liabilities become more expensive inducing banks to deleverage and reducing the size of their risky assets. Therefore, raising rates seems to lower risk-taking. Delis and Kouretas (2011) use a large dataset of actives banks of the euro-area during the period 2001-2008. Using NPL ratio and Risky Assets[3] as measures of banks' riskiness, they find evidence of strong negative relation between risk-taking and interest rates. Altunbas et al. (2014) utilizing the expected default frequency (EDF)[4] of listed banks from 16 OECD countries (1998-2008), observe an increase of banks' default probability during long period of low interest rates. Iannidou et al. (2008), employing Bolivian banks data during the period 1999-2003, shows that, in a low interest rate environment, the average default rate of existing loans drops while, at the same time, the risk associated with new loans increases. Using a unique database of 23 million loans from Spain (2008-2012), Jimenez et al. (2014) register a similar impact in loans credit rating granted before and after cut in ECB overnight rates. While all banks concede more loans when the policy rates are low, empirical results seems to show a "skin-in-the-game-effect"[5], where less capitalized banks push to grant riskier loans, probably because they have less to lose in case of failure[6]. De Niccolò et al. (2010) observed that bank with a high franchise value could be discouraged in gamble for resurrection, even when interest rates drop.

In this regard, different authors highlight the role of regulation in preventing excessive risk-taking by imposing capital standards to intermediaries. By employing US Banks quarterly data from quarterly Call Reports and Federal Reserve Bank Lending Survey (2006-2008), De Niccolo et al. (2014) find that when the real funds rate[7] drops, average internal credit risk rating and bank's RWA-density[8]

[2] Generally, in economic theory is considered very difficult for banks to apply negative rates on customers' deposit. furthermore, in some country liabilities are linked to a legal guaranteed minimum nominal return, (see Gambacorta; 2009).

[3] They defined risky assets as the assets subject to change in value due to changes in market conditions or changes in credit quality at various re-pricing opportunities (total assets less cash, government securities and balances due from other banks).

[4] Expected default frequency captures the probability of a firm to default in the next 12 months. EDFs are provided by Moodys.

[5] See Keeley, 1990.

[6] This is caused by asymmetric compensation structure of bank managers. Top-managers take part to profits through bonus but do not participate to losses.

[7] Defined as effective federal funds rate less the consumer price index inflation rate.

[8] The ratio of bank's risk-weighted assets to total assets.

raises. However, the authors also appointed that the effect is more complex, impacting banks that are more capitalised. In-line with the previous study, Dell'Ariccia et al. (2011) observe that, when the money conditions get eased by the central bank, well capitalized banks increase leverage and reduce credit risk monitoring. Agur and Demertzis (2010) confirm this substitution effect on banks' debt caused by monetary policy decisions. Nonetheless, they underline the role of the regulator in preventing friction during protracted periods of low rates. Maddaloni and Peydro (2011) employ confidential Bank Lending Survey (BLS) for the Euro area countries (2004-2008) and of the Senior Loan Officer (SLO) Survey for the U.S (1991-2008) find strong evidence that low short-term rates soften lending standards producing a raise in credit risk. This effect is stronger with lacking supervision.

Other studies focus on bank characteristics that can affect bank risk-taking. Buch et al. (2011) using prices, volume and riskiness of new loans for US Banks (1997-2008), find no evidence of increased risk-taking when Fed rates decrease and houses price raise for large domestic banks. However, foreign banks lower their risk exposure while domestic banks grant riskier loans. Baghat et al. (2013) employ annual accounting data on all U.S. commercial banks, investment banks and life insurance companies over the decade 2002-2012, observe that big financial institutions are less risk adverse than small banks.

In the last few years, the negative consequences of the GFC and its international spill overs gave impulse to policy-makers to intervene on market conditions and structures in order to restore confidence and provide the optimal conditions for a prompt and sustained economic recovery. Financial authorities were pushed to upgrade regulation framework (Basel 3, 2010) reducing bankers' moral hazard and raising up financial soundness of intermediaries. At the same time, policy-makers were motivated to employ tools never used previously in the form of Unconventional Monetary Policies (UMP) such as: quantitative easing (QE)[9], forward guidance and negative interest rate policy (NIRP) to provide further stimulus to constantly weak economies[10]. NIRP, in particular, has been often implemented by CBs in recent years to improve the effect of others (current or past) expansive policies charging banks for holding excesses reserves at the central banks.

The aim of such unconventional tools is to lower long-term interest rate expectations. However, academic discussions outline that, when interest rates go toward/below zero, they can affect bank's balance sheet profitability and risk.

[9] Generally, in the form of Asset Purchase Programme like those carried out by Fed, ECB in the last few years.
[10] About UMP effectiveness see Joyce et al. (2012), Gambacorta et al. (2014).

Analysing QEs experiences in the US, UK & Japan, Clayes and Darvas (2015) do not verify big changes in credit standards applied to banks[11] suggesting that a correct and balanced regulation can limit excessive recourse to leverage in the financial sector. On the other hand, using loans data from US syndicated loan market, Aramonte et al. (2015) show that, when longer-term interest rates are exceptionally low and investors expect to stay low for long, financial institutions concede loans to riskier borrowers. This effect can lead to growth in the credit risk level of the financial system and appears to be stronger with non-bank intermediaries (see also Chodorow-Reich, 2014). Same conclusion is reached by Kandrak and Schlusche (2017). Following the extra-liquidity provided by the Fed Asset Purchase Program (APP), the authors observe a general increase in loan supply with riskier loans growing quicker. Baldo et al. (2017) analysed the APP of ECB showing that the money injection resulted in a high rate of liquidity retention by banks. The authors appoint that the risk-based capital requirements could constrain banks to avoid lending on the inter-bank market preferring to hold reserves at the CB[12]. Finally, Nakashima et al. (2017), investigating Japanese bank loans during the period 1998-2015, find that UMPs stimulate lending to riskier firms from banks with a high leverage.

While studies demonstrate that monetary policy is not neutral from a stability prospective, there are also a limited number of studies that focus specifically on banks' riskiness in a very low interest rate environment[13]. Recently, Heider et al (2017) certified an increase of riskiness of syndicated loans in Europe (2013-2015) after NIRP introduction by the ECB in 2014, where the effect is stronger for high-deposit banks. Nucera et al (2017) use SRisk[14] to determine whether the ECB deposit facility rate cuts into negative territory interacted with banks soundness. Panel regressions of European banks show an improvement in large banks risk position, while small banks funding principally with customer deposits are perceived as riskier. Hence, both studies evidence that bank's characteristics are important variables of bank behaviour and NIRP transmission. Arteta et al (2018), use CDS of listed banks as variable of riskiness to observe changing after Central Banks announced NIRP-

[11] Banking surveys conducted by central banks include an indicator, namely the change in credit standards, which shows the share of banks that tighten/ease credit standards.

[12] "The investment of excess liquidity might be constrained also by risk-based capital requirements for secured and unsecured funding, since, whenever a bank lends money on the interbank market, it builds up an exposure towards its counterparty, which is subject to a capital charge with varying degrees of risk weights, while excess liquidity is not. Following this rationale, capital requirements might also be a reason for the concentration of excess liquidity at a country level as the environment of low interest rates makes the expected return from some kinds of investments (e.g. unsecured overnight lending) not worth the capital cost attached".

[13] Part of the literature focused on NIRP effect on Net Interest Margin (NIM). Borio et al. (2017) employ data from international banks over a 1995-2012 period, discovering an erosion of profitability caused by unusual periods of low rates: in the long run this suggests possible difficulties for banks to raise capital and remunerate shareholders (see also Molyneux et al. (2017); Jobst and Lin (2016)).

[14] See Brownlees, C. T. and R. Engle (2017).

introduction in different economies. The authors agree that NIRP could affect financial stability reducing banks' profits but found inconclusive evidences on bank excessive risk-taking.

There are general concerns on low interest rates that has been going on for some time. Moreover, NIRP, with its capacity of pushing real interest rates below zero, is a fully-new event that deserve further studies. We contribute to existing literature in three main ways.

First, we deepen the risk-taking channel theory from a financial stability prospective participating to a wide academic debate and, at the same time, we propose a first assessment of the impact of negative interest rates on banks risk propensity. The meaningful of our results approach to a scientific production about UMP and, in particularly, NIRP, that is still small and generally concentrated only on financial intermediaries' performance. Moreover, the reduction of risk assumed by banks showed in our results seems to contradict the mainstream thought that sees a direct link that bind accommodative monetary policies and increase bank risk.

Second, we make a cross-country comparison employing a large number of banks from advanced-economies and using a diff–in-diff methodology comparing with countries that did not adopt NIRP. This allows us to observe NIRP effect highlighting differences with financial intermediaries operating with different interest rate environment from others economies.

Third, we improved our work by looking for other factors that could explain why the risk-taking channel is not confirmed by our data. We perform various additional tests to validate our results. These provide more information on specific banks' characteristics and country financial features that influence the impact of NIRP. In particular, highlighting the importance of capital level on risk decision, our work aspires to participate to the large debate on implications between monetary policy and regulation[15]. Based on our evidences, the imposition of risk-weighted standard seems to prevent excessively leveraged banks to gamble for resurrection, conceding only well-capitalized banks to search-for-yield. This suggests (once again) a needed integrated work among regulators and policy-makers. At the same time, our sample includes financial systems with different degree of develop. We intensify our analysis taking care of a further factor that can interact with risk diffusion: the level of competition. Finally, we find that the amount of bank risky assets contract after the implementation of NIRP and this effect appears to be stronger for banks that are large, not strongly capitalised and operating in competitive markets. Our data seems to indicate, symmetrically, that risk increases only when banks have high capital buffer and operate in non-competitive environment.

[15] In 2016, in fact, Basel Committee on Banking Supervision issued standards for Interest Rate Risk in the Banking Book (IRRBB) expected to be fully implemented by banks in 2018.

3. Methodology

In order to assess the effect of negative interest rate policy on bank risk-taking, we use a differences-in-differences methodology, widely employed to evaluate policy changes (Yang 2017, Argimón et al. 2017, Cerqueiro et al. 2016, Fiordelisi et al. 2016). This method allows to compare the effect on risk taking in a treated group of banks, i.e. the ones based in countries where negative interest rates have been introduced, with a control group that has not been affected by this policy. Our baseline model can be summarized as follows:

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

Where $Y_{i,j,t}$ is the growth of risky assets for bank i in the country j at the time t, Treated is a dummy variable equal to 1 if the bank i in country j has been affected by NIRP or 0 otherwise; Post is a dummy variable that takes value 1 in the years following the adoption of the NIRP and 0 otherwise. Since most of the countries have adopted NIRP in 2014, for them the dummy variable Post takes value 1 starting from 2014[16].

Our main coefficient of interest is β_3, which measures the difference in bank growth rate of risky assets between countries that have adopted the NIRP and the ones that have maintained positive interest rates. We also add γ_i and φ_t in order to take into account, respectively, unobserved time-invariant country-specific characteristics and time-varying shocks that can affect bank risk-taking.

Following Delis and Kouretas (2011), we compute our variable of interest (risky assets) as bank total assets minus cash, government securities and due to banks. The decision to use this variable relies upon two main reasons. First, by looking at all bank assets subjected to change in value due to changes in market conditions and/or in credit quality, we can capture bank portfolio rebalancing behaviours towards riskier assets. When this variable exhibits positive growth, it means that the amount of risky assets grows at a faster rate than the safe assets (cash, government securities and due to other banks), vice versa for the negative. Second, the growing debate about the reliability of risk weighted adjusted assets as a measure of risk seems to advise against their use to assess risk-taking. The numerous evidences provided by both supervisory authorities and academics[17] have documented a regulatory arbitrage mechanism through which banks tend to handle their risk-weighted measures to lower their

[16] Only Sweden, Switzerland and Norway have introduced negative interest rates in 2015. For more details see (Jobst and Lin, 2016)

[17] See, among others, BCBS (2013); Bank of England (2011) for the point of view expressed by regulators and central banks and Ferri and Pesic (2017); Arroyo *et al.*, (2012); Beltratti and Paladino (2016).

capital requirements and show a greater capital adequacy, especially when they use internal-rating based models to assess credit risk (Mariathasan and Merrouche, 2014). Moreover, since the degree of internal rating adoption varies across countries according to the specific regulation and banking systems features, as shown by Bruno et al. (2015), the use of a risk-weighted variable may introduce a meaningful bias, further suggesting its inadequacy in assessing bank risk preference.

To control for heterogeneity among bank, we run a second econometric specification with the introduction of a set of bank-specific control variables to take in account some specific bank features that can directly influence risk-taking. The second econometric framework is specified as follow:

$$Y_{i,j,t} = \alpha + \beta_1 treated_{i,j} + \beta_2 Post_{j,t} + \beta_3\left(treated_{i,j} * Post_{j,t}\right) + \beta_4 X_i + \gamma_i + \varphi_t + \varepsilon_{i,j,t} \qquad [2]$$

Where X is a vector of bank-specific control variables. Following the mainstream literature on the topic, we expressly take in account several bank-specific determinants of risk-taking as control variables. Our first covariate is size (size), expressed as the natural logarithm of total assets. Although the "Too big to fail" hypothesis suggests a positive relation between size and risk-taking, several studies argue that broader possibility for portfolio diversification, along with better managerial skills and easier funding conditions can lead an opposite effect on the risk-taking (Bertay et al., 2013) In-line with the mainstream literature, we control for banks' capitalization, measured as the ratio of equity on total assets (E/TA). As pointed out by the "capital channel of monetary policy" (Van den Heuvel, 2002; Gambacorta and Mistrulli, 2004), the response to monetary policy impulses varies significantly across banks, according to their different capitalization. Poorly capitalized banks face constraints in the capital requirements that do not allow them to increase risk-taking, as opposed to well-capitalized, that can shift their portfolio toward riskier assets (De Nicolò et al., 2010) . However, since previous literature points out a non-clear effect of capitalization on risk-taking, a "gamble for resurrection" mechanism cannot be excluded *a priori*. Undercapitalized banks that face constraints in raising equity can be willing to take greater risks in order to increase earnings that, if retained, could boost the banks capitalization in attempting to increase their soundness (Calem and Rob, 1999). Banks funding structure (funding str.) can also influence in a significant way the banks' sensitivity to changes in interest rates. Since retail deposits are more stable and the interest rate (of deposits) stickier around the zero-lower bound, the decrease in the interest margin due to low and negative interest rates can lead banks to increase risk-taking in order to keep an adequate level of profitability. Deposit based banks should then be more exposed to changes in monetary policy compared to wholesale banks which, on the contrary, can manage the price of their liabilities more dynamically (Demirgüç-Kunt and Huizinga, 2010).

Following, among others Beck et al. (2013), Borio and Gambacorta (2017), we control for the share of non-interest income on total income (business model) to take in account the potential different effect of changes in interest rates depending on the different income structure. As pointed out by Altunbas et al. (2012), a broader income diversification, corresponding to a higher relevance of fees and commissions, can enhance bank stability as banks have lower incentives to take more risk compared to interest income based banks, that could be forced to increase risky assets to compensate the losses, in terms of profitability, caused by lower interest rates.

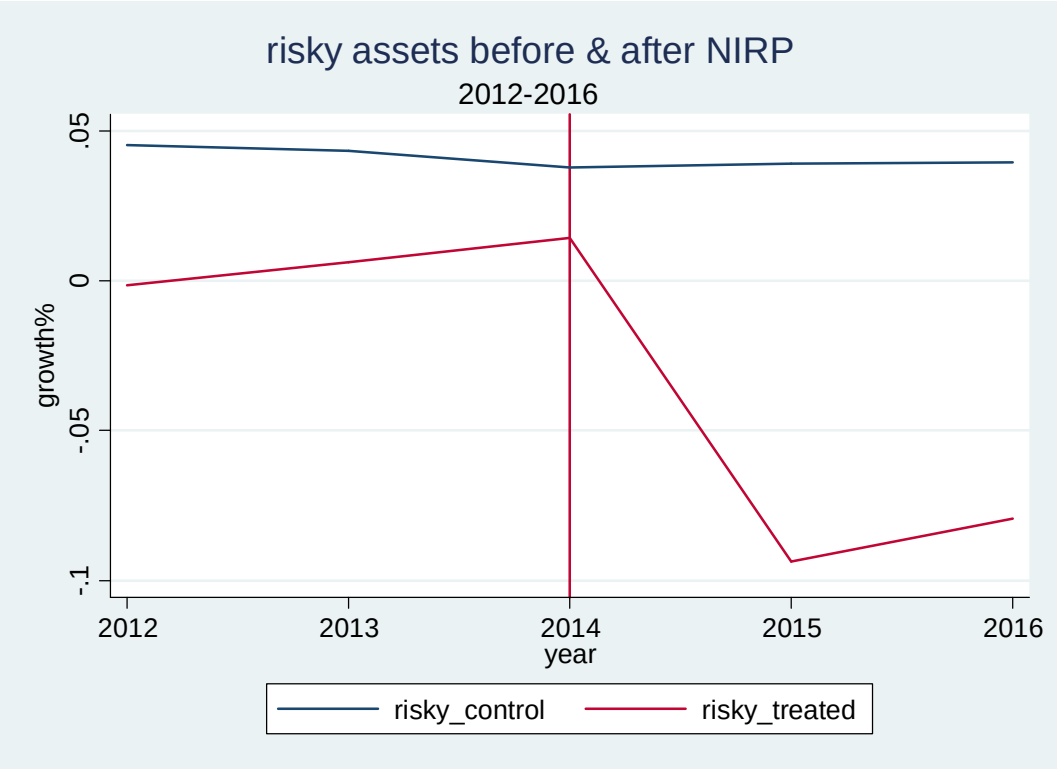
We also use liquidity (liquidity), proxied by the ratio of liquid assets to retail deposits and short terms funding, and profitability (RoA) as further control variables. For the latter, we expressly take into account the return on asset, computed as the ratio of bank net income to total assets. According to Delis and Kouretas (2011), the relation between profitability and risk taking is not clear-cut. Although a stream of the literature shows greater incentives for less profitable banks to take more risks in attempting to boost their profitability (Poghosyan and Čihak, 2011), banks with higher profitability can benefit from additional resources to increase risky lending. Moreover, previous studies provide evidence of a positive relation between liquidity and the growth of risky assets (Acharya and Naqvi, 2012). A grater amount of liquid assets can indeed be crucial in giving banks more leeway on the portfolio rebalancing decisions, allowing them to transfer resources to more profitable assets. It must be emphasised, however, that in a period of very low profitability or characterized by a lack of favourable investment opportunities, for instance due to the high riskiness of the potential borrowers, as well as by tightened capital requirement, even an adequate amount of liquid assets can be associated to a risk-averse behaviour.

In order to check the suitability of difference-in-differences methodology[18] to analyse the effect of negative interest rate policies on bank risk-taking, the compliance of two requirements needs to be checked: the parallel trend assumption and the comparability of treatment and control groups (Bertrand et al., 2004). While for the latter we provide further evidences in the next section, Figure 1 shows the growth rate of risky assets in both treated and control group over the period 2012-2016[19]. In the years prior the introduction of the negative interest rate policy, the parallel trend assumption holds. Interestingly, after the policy introduction, banks in NIRP adopter countries have faced a remarkable reduction in risky assets unlike the non-adopter countries, whose banks have instead maintained a quite stable growth rate of risky assets.

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

[19] The sample period is intentionally short. According to Roberts and Whited (2013) and Bertrand et al. (2004) the change in the treatment group should be concentrated around the onset of the treatment. Moving away leads to unobservable and other factors that affect the treatment outcome leading to omitted variable bias threatening the validity of the model.

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



4 Data

Our study is based on a sample of 2731 banks from 33 OECD countries over the period 2012-2016[20], resulting in an unbalanced panel composed of 6,312 observations. More in detail, 3,576 are the observations of banks belonging to the treatment group, i.e. based in countries where negative interest rate policies have been applied, while 2,736 obs. are referred to banks make up the control group. All the bank-level variables are obtained from Orbis and are winsorized at 1% level referring separately to the different two groups distributions. Since Orbis comprises cross-country banks that operate in more than one country, balance sheet data can be either consolidated or unconsolidated. To avoid concerns regarding banks that operate in more than one country in both treated and not treated groups, we use bank account data that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but not with an unconsolidated subsidiary.

[20] Table A.1 in the Appendix shows the dates of NIRP introductions in the different countries. We leave out from our sample Japan, since the NIRP was introduced only in 2016.

Table 1 reports the descriptive statistics for both treated and control groups. Panel A shows the risk measures used to assess the change in banks' risk aversion. As previously outlined, in addition to the yearly growth rate of risky assets, we also employ the log-transformation of Z-score[21] . Descriptive statistics regarding bank-level information as well as banking industry variables are reported in Panel B.

Moreover, in-line with previous studies that extensively point out a different effect on bank risk-taking according the structure of the financial system[22], in a further robustness check we expressly take into account the degree of market competition in each country. Following Schaeck and Cihak (2014), we use the Boone indicator, definable as the sensitivity of profits to change in marginal costs, in order to distinguish between competitive and non-competitive banking systems[23]. Furthermore, since the relation between concentration and competition is ambiguous, as suggested by Claessens and Laeven (2004), we also take into account the concentration of the banking system among different countries through the use of the Herfindahl–Hirschman index[24].

[Insert Table 1 here]

5. Empirical Results

The results from estimating [1] and [2] are presented in Table 2. All the estimates include country and year fixed effects. Our main interest is the size, sign and statistical significance of the coefficient of β_3 that represents the average difference in the change in bank risk-taking between countries that adopted NIRP and countries that did not (denoted in the table as NIRP-effect). For our variable of interest, we incrementally introduce a set of control variables in order to capture heterogeneity among banks.

[Insert Table 2 here]

The baseline result of column 1 of Table 2 excludes all the control variables. The coefficient of NIRP is sizeable, negative and statistically significant at 1% level, indicating that countries in which central bank implemented NIRP experience a decline in the amount of risky assets on their balance sheets of around 10% in comparison with countries where central banks did not follow this policy. The

[21] Z-score can be summarized by the following equation: $Z_{i,t} = \frac{ROA_{I,t}+EA_{I,t}}{\sigma(ROA)_{I,t}}$; where ROA is the return on assets for the bank i at the time t, EA is the ratio of equity to total assets and σ(ROA) is the standard deviation of return on assets.

[22] Among others, Boyd and De Nicolò (2005); Jiménez et al. (2013); Kick and Prieto (2015) analyze in deep the effect of competition on bank risk-taking.

[23] With the same purpose, we also use as additional test the well know Lerner Index. For both indicators, data are obtained from the World Bank Global Financial Development Database.

[24]Data for HHI Index are obtained from authors' calculation

interpretation of this result can be twofold. First, by increasing the supply of excess reserves, unconventional monetary policies such as QE (started in 2015 in Europe) provide banks with excess liquidity. Thus, as captured by our dependent variable[25], the excess liquidity has been used to buy safe rather than risky assets. Second, the main aim of NIRP, is to provide further stimulus to a constantly weak economy (in Europe) raising inflation expectations and boosting credit demand and supply (Jobst and Lin, 2016). However, deteriorated macroeconomic as well as bank balance sheet conditions can have limited the potential benefits from exceptionally favourable financing condition in NIRP countries. Hence, in a period with slow economic recovery, high firms' mortality rates as well as negative (or low) interest rates banks might prefer to invest in safe assets such as government bonds (excluded in the computation of the risky assets measure)[26]. Furthermore, the preferred regulatory environment of government bonds[27] could have strengthened this behaviour allowing banks to treat sovereign bonds as "risk-free" for capital requirements purposes.

The baseline result holds-up well in the face of all control, with the coefficient (NIRP-effect) strengthening when we introduce the control variables[28]. The control variables are mostly statistically significant at the conventional level and with sign in-line with the literature on bank risk-taking. *Size* is negatively related with the amount of risky assets in banks' balance sheet suggesting that larger banks have better diversified portfolio, managerial skills and lessen funding condition that reduces risk-taking. *E/TA* enters in the regression with negative sign and mostly statistically significant. Leveraged banks act as risk-loving agents as they prefer risky investments carrying a higher private payoff in case of positive outcome but large losses in case of failure. Furthermore, leveraged banks have less "skin-in-the game" and can be motivated to gamble for resurrection when the level of capital is low leading to stronger risk-taking incentives. Return on assets (*ROA*) is positive and statistically significant at the conventional level suggesting that more profitable banks are the ones that take higher risks. As expected liquidity (*liquidity*) shows negative sign indicating that less liquid banks take greater risks than liquid banks. Arguably, liquid assets are the ones carrying lower level of risk and returns as they can easily be liquidated when needed. Hence, risk adverse banks hold a substantial amount of liquid assets in their balance sheets. Finally, while the funding structure is negative but not

[25] Our dependent variable is intentionally computed to look at the relative composition of risk assets and safe assets (cash, government securities and due to banks).

[26] To gain further insight into this possible banking behaviour, we run a difference-in-differences to test whether in the years after NIRP there has been an increase in the purchase of government bonds for the treated banks in comparison with the control group. For this exercise, the ratio of government bonds on total assets is our variable of interest. The result shows that NIRP-affected banks experienced an increase in the purchase of government bonds in comparison to those banks not affected by the policy. This is in-line with the study of Altavilla et al (2016) suggesting a very high degree of substitutability between lending and sovereign during ditressed period and weak economic prospects.

[27] The Basel framework assigns zero risk weights for sovereign exposures within the EU.

[28] As suggested by Roberts and Whited (2013), a large discrepancy of the treatment coefficient with and without controls should raise a "red flag".

statistically significant, business model shows positive sign suggesting that bank privileging non-core activities such as investment banking, venture capital, trading activities and securitization have higher amount of risky assets.

5.1 Capitalisation, size and competition

In order to corroborate our baseline results, we run a set of additional tests in a difference-in-difference framework to specifically take in account some banks-specific features whose impact can be meaningful in assessing the risk-taking incentives in a negative interest rates environment. According to the capital channel model proposed by Van den Heuvel (2002), we first check the possible different response to the adoption of negative interest rates assessing separately weakly and strongly capitalized banks. Following Borio and Gambacorta (2016), we define as low and high-capitalized respectively the banks whose total capital ratio is in the bottom and in the top 10th percentiles of the capitalization distribution. According to this view, the results presented in Panel A and B of Table 2 show a non-linear effect of NIRP on bank behaviour. In-line with our baseline findings, the NIRP coefficient for under-capitalized banks is negative and statistically significant. Its magnitude, however, suggests a sensible larger effect for low-capitalized banks, characterized by a decrease in risky assets that is more than double the reduction previously documented for the whole sample. Our findings appear to contradict the "skin-in-the game" effect, proposed by De Nicolò *et al.* (2010), suggesting that weakly capitalized banks can greatly hamper the monetary stimulus since they face greater impediments to increase risky assets because of the difficulties in meeting the capital requirements. In periods characterized by severe difficulties to boost capitalization via both equity issues or retained earnings, poor capitalized banks can be indeed encouraged to improve their soundness by reducing their risk-weighted exposure through a deleveraging process in order to improve the corresponding capital ratios (Jiménez *et al.*, 2010), further amplifying the pro-cyclical effects of the credit supply.

Conversely, over-capitalized banks show a strong increase of risky assets after the adoption of negative interest rates as they have large capital buffers to do so (Gambacorta and Shin, 2015). Hence, well-capitalised banks are better able to reallocate their resources toward riskier and more profitable investments in order to compensate the negative effect of NIRP on profits [29].

[29] We have already mentioned the negative impact of low/negative interest rates on bank profits. Overall, our results are in-line with the strand of the literature the deals with the relation between capitalization and risk-taking. Among others, Gambacorta and Mistrulli (2004), EBA (2015), Kim and Sohn (2017), widely prove that over-capitalized banks are more willing to increase risk-taking thanks to their larger capital buffers that allow them to bear losses and keeping high levels of capital at the same time.

This result has also important policy implications as it highlights the key role played by bank capital in the transmission mechanism of monetary policy. In an environment characterized by difficult macroeconomic conditions and by negative interest rates, which exacerbates the pressure on banks profitability, only well-capitalized banks can increase risk-taking. The impact of buffers above the minimum capital requirements is then twofold. First, under-capitalized banks experience a direct impact due to the considerable difficulties in attempting to issue new equity, both in terms of available amount and cost of equity. Second, as argued by Iyer *et al.* (2014), poorly-capitalized banks face, especially in crisis phases, severe constraints in terms of wholesale funding due to the greater request of capital by wholesale depositors that, in turns, favor mostly capitalized banks, which can then benefit from a more stable source of funding.

Panel D shows that the contradictory effect of the NIRP is more pronounced for larger banks, i.e. banks with an amount of total assets above the median. According to the large literature that deals with income structure and diversification opportunities (see, among others, Altunbas et al., 2018), larger banks are characterized by wider opportunities to support profitability, which allow them to easily switch from the traditional granting of loans to cross-selling activities in attempting to boost fee and commission incomes. Furthermore, the higher efficiency gained thanks to the greater economies of scale and scope and the lower dependence on retail deposits, which allow them to benefit from a lower cost of wholesale funding (Salas and Saurina, 2002), further limit their incentives to shift to riskier assets in a negative interest.

Following previous studies that broadly show the meaningful effect of the market structure on the transmission speed of monetary policy (Sorensen and Werner, 2006) and on the corresponding bank risk-taking (Boyd and De Nicolò, 2005), we expressively assess the impact of NIRP according to the different competitive conditions in each banking system. Through using Boone indicator, we distinguish between competitive (below the median) and non-competitive markets (above the median), splitting the sample for both treatment and control groups. The results reported in panel E and F further confirm the discordant effect caused by the NIRP adoption according to the different market conditions. As suggested by the model proposed by Brunnermeier and Koby (2017), our findings indicate that the greater market power enjoyed by the banks in non-competitive markets limits the conflicting effects caused by negative interest rates. The lower pressure on interest margin due to the lower competitiveness and the ability to charge higher rates over the marginal costs (Turk Ariss, 2010), along with the opportunity to better assess the borrowers' creditworthiness and keep higher credit standards can indeed trigger a portfolio rebalancing towards risky assets, such as to support banks' profitability. Although not statistically significant, the impossibility to increase the mark-ups on the interest rates seems to penalize banks operating in more competitive markets, since

unable to offset the effects caused by negative interest rates, partially stifling the monetary policy transmission mechanism.

Conclusion

After the global financial crisis, a new era in Central Banking has started: a wide range of so-called unconventional tools have been implemented in the last few years. Growing attention has been paid to the implications between financial stability and strong accommodative monetary policies. In this paper, we proposed a first assessment of the impact of negative interest rate policies adopted by Denmark, Hungary, Japan, Norway, Sweden, Switzerland and the Euro-area on bank risk-taking.

By observing the change in the amount of risky assets retained by banks, our diff-in-diff methodology shows that banks seem not increase the risk of their portfolio after NIRP started. On the contrary, our variable points out a reduction of risky assets of around 10%. According to this result, it seems that monetary policy alone is not enough to change bank behaviours.

It is important to mention that, while interest rates approached zero (and beyond), at the same time big changes happened in banking regulation after Basel 3 introduction. New and higher capital standards were emanated binding banks strategies to a capital conservation prospective while liquidity ratios were adopted imposing banks to always retain an amount of high quality liquidity assets. As shown by Table 3, only banks well capitalized increased their risky assets demonstrating that a tight regulation could preserve financial stability, but, at the same time, could damage economic recovery preventing banks to concede more loans to real economy. This suggests (once again) a needed integrated work among regulators and policy-makers.

Moreover, it is more likely that banks increase risk-taking in a non-competitive environment, where the financial institution can more easily acquire market share and generate extra-profits. At the same time, larger banks seem to reduce their risky assets more than others, probably due to their lower dependence on retail deposits and because their size allow them to diversify their business towards fee-generator financial services.

In conclusion, we tried to contribute to a great debate arguing that, based on our work, NIRP does not affect bank risk taking positively but rather it seems to have an opposite effect: the health of banking system (as appointed, among the others, by De Niccolò et al. 2010) as well of the macroeconomic environment appear to have a stronger effect on banks' attitude.

References

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

Acharya, V. & Plantin, G. (2016). Monetary Easing and Financial Instability. NYU Working Paper, 1–38.

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.

Aizenman, J., & Chantapacdepong, Y. C. P. (2018). Special issue: Implications of ultra-low and negative interest rates, (December 2016), 3–7. https://doi.org/10.1111/1468-0106.12248

Allen, F., Gale, D., Journal, S., February, N., Allen, F., & Gale, D. (2016). Financial Contagion. Journal of Political Economy, 108(1), 1–33.

Altunbas, Y., Gambacorta, L., & Marqués-Ibáñez, D. (2010). Does monetary policy affect bank risk-taking? ECB Working Paper Series, N°1166(March 2010).

Altunbas, Y., Gambacorta, L., & Marques-Ibanez, D. (2012). Do bank characteristics influence the effect of monetary policy on bank risk? Economics Letters, 117(1), 220–222. https://doi.org/10.1016/j.econlet.2012.04.106

Altunbas, Y., Marqués-Ibáñez, D., & Manganelli, S. (2011). Bank risk during the financial crisis: do business models matter? Working Paper Series, 1–53. Retrieved from http://ideas.repec.org/p/ecb/ecbwps/20111394.html

Aluntabs, Yener; Gambacorta, Leonardo; Marquez-Ibanez, D. (2014). Does monetary policy affect bank credit standards. Internetional Journal of Central Banking, 10 (March).

Angeloni, I., & Ehrmann, M. (2003). Monetary Policy Transmission in the Euro Area: Any Changes after EMU ? European Central Bank Working Paper Series, (240).

Angeloni, I., & Faia, E. (2013). Capital regulation and monetary policy with fragile banks. Journal of Monetary Economics, 60(3), 311–324. https://doi.org/10.1016/j.jmoneco.2013.01.003

Anginer, D., Demirguc-Kunt, A., & Zhu, M. (2014). How does competition affect bank systemic risk? Journal of Financial Intermediation, 23(1), 1–26. https://doi.org/10.1016/j.jfi.2013.11.001

Aramonte, S., Lee, L., and 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. 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

Arroyo, J. M., Colomer, I., Garc\'ia-Baena, R., & González-Mosquera, L. (2012). Comparing risk-weighted assets: The importance of supervisory validation processes. Estabilidad Financiera, 22, 9–29.

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

Baldo, L., Bucalossi, A., & Scalia, A. (2018). Leverage Ratio and Central Bank Operations in the Euro Area. Economic Notes, 47(1), 21–68. https://doi.org/10.1111/ecno.12105

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).

Baselga-Pascual, L., Trujillo-Ponce, A., & Cardone-Riportella, C. (2015). Factors influencing bank risk in Europe: Evidence from the financial crisis. North American Journal of Economics and Finance, 34, 138–166. https://doi.org/10.1016/j.najef.2015.08.004

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., & Gertler, M. (1995). Inside the Black Box : The Credit Channel of Monetary Policy Transmission. The Journal of Economic Perspectives, 9(4), 27–48.

Bernanke, B. S., Gertler, M., & Gilchrist, S. (1996). The Financial Accelerator and the Flight to Quality. The Review of Economics and Statistics, 78(1), 1. https://doi.org/10.2307/2109844

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.

Berriel, T., & Guardado, F. (2017). How Low Can Central Banks Go ? The Banking Threshold to Negative Interest Rates, Working Paper, pp 1-34, http://dx.doi.org/10.2139/ssrn.3160982

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

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

Boone, J. (2008). A New Way to Measure Competition. The Economic Journal, 118(531), 1245–1261. https://doi.org/10.1111/j.1468-0297.2008.02168.x

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

Borio, C., & Zhu, H. (2008). Capital Regulation, Risk-taking and Monetary Policy: a Missing Link in the Transmission Mechanism?, December 2008. BIS Working Papers, 8(268), 1–45.

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

Brickley, J. A., Linck, J. S., & Smith, C. W. (2003). Boundaries of the firm: Evidence from the banking industry. Journal of Financial Economics, 70(3), 351–383. https://doi.org/10.1016/S0304-405X(03)00170-3

Brissimis, S., Delis, M., & Iosifidi, M. (2014). Bank market power and monetary policy transmission. International Journal of Central Banking, 10(4), 173–214.

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. Asset pricing under asymmetric information: bubbles, crashes, technical analysis, and herding. Oxford University Press, 2001. Print.

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, Deutesche Bundesbank

Caballero, R. J., Hoshi, T., & Kashyap, A. K. (2008). Zombie lending and depressed restructuring in Japan. American Economic Review, 98(5), 1943–1977. https://doi.org/10.1257/aer.98.5.1943

Calem, P., & Rob, R. (1999). The Impact of Capital-Based Regulation. Journal of Financial Intermediation, 8, 317–352.

Chan, K. K., & Milne, A. (2014). Bank competition, fire-sales and financial stability. European Journal of Finance, 20(10), 874–891. https://doi.org/10.1080/1351847X.2013.836552

Chan, S. G., Karim, M. Z. A., Burton, B., & Aktan, B. (2014). Efficiency and risk in commercial banking: empirical evidence from East Asian countries. European Journal of Finance, 20(12), 1114–1132. https://doi.org/10.1080/1351847X.2012.745008

Chen, M., Wu, J., Jeon, B. N., & Wang, R. (2017). Monetary policy and bank risk-taking: Evidence from emerging economies. Emerging Markets Review, 31, 116–140. https://doi.org/10.1016/j.ememar.2017.04.001

Chodorow-Reich, G. (2014). Effects of Unconventional Monetary Policy on Financial Institutions. Brookings Papers on Economic Activity, 2014(1), 155–227. https://doi.org/10.1353/eca.2014.0003

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

Claessens, S., Coleman, N., & Donnelly, M. (2017). "Low-For-Long" interest rates and banks' interest margins and profitability: Cross-country evidence. Journal of Financial Intermediation, 0, 1–16. https://doi.org/10.1016/j.jfi.2017.05.004

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

Cohen, B. H., & Scatigna, M. (2016). Banks and capital requirements: Channels of adjustment. Journal of Banking and Finance, 69, S56–S69. https://doi.org/10.1016/j.jbankfin.2015.09.022

Cordella, T., Dell'Ariccia, G., & Marquez, R. (2017). Government Guarantees, Transparency and Bank Risk-Taking. World Bank Group, Policy Research Working Paper, 7971(February).

Correa, R., Sapriza, H., & Zlate, A. (2016). Liquidity Shocks, Dollar Funding Costs, and the Bank Lending Channel During the European Sovereign Crisis. Federal Reserve, Bank of Boston, Risk and Policy Unit, Working Pa(RPA 16-4). https://doi.org/10.2139/ssrn.2178022

De Jonghe, O., Diepstraten, M. & Schepens, G. (2015). Banks' size, scope and systemic risk: What role for conflicts of interest? Journal of Banking and Finance, 61, S3–S13. https://doi.org/10.1016/j.jbankfin.2014.12.024

De Niccoló, G., Bartholomew, P., Zaman, J., & Zephirin, M. (2004). Bank Cosolidation, Internationalization and Conglomeration: Trends and Implications for Financial Risk. Financial Markets, Institutions & Instruments, 13(4), 174–217.

De Niccolò, 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

Delis, M. D., Hasan, I., & Mylonidis, N. (2012). The Risk-Taking Channel of Monetary Policy in USA: Evidence from Micro-Level Data. SSRN Electronic Journal, 1–46. https://doi.org/10.2139/ssrn.2013787

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

Dell'Ariccia, G., Laeven, L., & Suarez, G. A. (2017). Bank Leverage and Monetary Policy's Risk-Taking Channel: Evidence from the United States. Journal of Finance, 72(2), 613–654. https://doi.org/10.1111/jofi.12467

Demiralp, S., Eisenschmidt, J., & Vlassopoulos, T. (2017). Negative interest rates, excess liquidity and bank business models: Banks' reaction to unconventional monetary policy in the euro area. Koç University-TUSIAD Economic Research Forum Working Papers, 1708(March).

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

Ferri, G., & Pesic, V. (2017). Bank regulatory arbitrage via risk weighted assets dispersion. Journal of Financial Stability, 33, 331–345. https://doi.org/10.1016/j.jfs.2016.10.006

Flannery. M., (1981). American Finance Association Market Interest Rates and Commercial Bank Profitability: An Empirical Investigation, The Journal of Finance, Vol. 36, No. 5 (Dec ., 1981), pp. 1085-1101

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

Fosu, S., Ntim, C. G., Coffie, W., & Murinde, V. (2017). Bank opacity and risk-taking: Evidence from analysts' forecasts. Journal of Financial Stability. https://doi.org/10.1016/j.jfs.2017.10.009

Fu, X. (Maggie), Lin, Y. (Rebecca), & Molyneux, P. (2014). Bank competition and financial stability in Asia Pacific. Journal of Banking and Finance, 38(1), 64–77. https://doi.org/10.1016/j.jbankfin.2013.09.012

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

Gambacorta, L., Hofmann, B., & Peersman, G. (2014). The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis. Journal of Money, Credit and Banking, 46(4), 615–642. https://doi.org/10.1111/jmcb.12119

Guofeng, S., & Xiaobei, H. (2018). Zero Lower Bound on Deposit Rates and Transmission Mechanism of the Negative Interest Rate Policy, 1–19.

Hakenes, H., & Schnabel, I. (2011). Bank size and risk-taking under Basel II. Journal of Banking and Finance, 35(6), 1436–1449. https://doi.org/10.1016/j.jbankfin.2010.10.031

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

Henning, C. R. (2015). The ECB as a Strategic Actor : Central Banking in a Politically Fragmented Monetary Union. Working Papers Series, 2015(1), 1–32.

Heuvel, S. J. Van Den. (2002). The Bank Capital Channel of Monetary Policy. Finance. Retrieved from http://www3.hi.is/~ajonsson/kennsla2005/Bank_channel.pdf

Horvath, R., Kotlebova, J., & Siranova, M. (2018). Interest rate pass-through in the euro area: Financial fragmentation, balance sheet policies and negative rates. Journal of Financial Stability, 36, 12–21. https://doi.org/10.1016/j.jfs.2018.02.003

Iannotta, G., Nucera, G., & Sironi, A. (2007). Ownership structure, risk and performance in the European banking industry. Journal of Banking and Finance, 31(7), 2127–2149. https://doi.org/10.1016/j.jbankfin.2006.07.013

Ioannidou, V., Ongena, S., & Peydró, J. L. (2015). Monetary policy, risk-taking, and pricing: Evidence from a quasi-natural experiment. Review of Finance, 19(1), 95–144. https://doi.org/10.1093/rof/rfu035

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. Retrieved from https://www.imf.org/external/pubs/ft/scr/2016/cr16220.pdf

Jobst, A., & Weber, A. (2016). Profitability and Balance Sheet Repair of Italian Banks. IMF Working Paper, WP/16/175.

Kandrac, J., & Schlusche, B. (2017). Quantitative easing and bank risk taking : evidence from lending Quantitative easing and bank risk taking : evidence from lending. Federal Reserve Board - Divisions of Research & Statistics and Monetary Affairs, Washington, D.C.

Kandrac, John, and Bernd Schlusche (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

Kashyap, A. K. & Stein, J. (2000). What Do a Million Observations on Banks Say about the Transmission of Monetary Policy, The American Economic Review.

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

Kirti, D. (2017). When Gambling for Resurrection is Too Risky. IMF Working Paper, 17(180).

Kishan, R. P. & Opiela, T. P. (2000). Bank Size, Bank Capital, and the Bank Lending Channel. Journal of Money, Credit and Banking, Vol. 32, No. 1 (Feb. 2000), pp. 121-141 Published by: Ohio State University Press Stable.

Klomp, J., & Haan, J. de. (2012). Banking risk and regulation: Does one size fit all? Journal of Banking and Finance, 36(12), 3197–3212. https://doi.org/10.1016/j.jbankfin.2011.10.006

Köhler, M. (2014). Does non-interest income make banks more risky? Retail- versus investment-oriented banks. Review of Financial Economics, 23(4), 182–193. https://doi.org/10.1016/j.rfe.2014.08.001

Köhler, M. (2015). Which banks are more risky? The impact of business models on bank stability. Journal of Financial Stability, 16, 195–212. https://doi.org/10.1016/j.jfs.2014.02.005

Laeven, L., & Levine, R. (2009). Bank governance, regulation and risk taking. Journal of Financial Economics, 93(2), 259–275. https://doi.org/10.1016/j.jfineco.2008.09.003

Le Leslé, V., & Avramova, S. Y. (2012). Revisiting Risk-Weighted Assets. IMF Working Paper, March(WP/12/90), 50.

Leuvensteijn, M. (2008). The Boone-indicator: Identifying different regimes of competition for the American Sugar Refining Company 1890-1914, 8–37. Retrieved from http://www.koopmansinstitute.uu.nl

Lopes, S., Consequences, T. U., Launch, S. M., & Analysis, Q. (2016). The Unintended Consequences of the Launch of the Single Supervisory Mechanism in Europe.

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. The Review of Financial Studies, 24(6), 2121–2165. https://doi.org/10.1093/rfs/hhr015

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

Martinez-Miera, D., & Repullo, R. (2010). Does competition reduce the risk of bank failure? Review of Financial Studies, 23(10), 3638–3664. https://doi.org/10.1093/rfs/hhq057

Meeks, R. (2017). Capital regulation and the macroeconomy: Empirical evidence and macroprudential policy. European Economic Review, 95, 125–141. https://doi.org/10.1016/j.euroecorev.2017.03.010

Mergaerts, F., & Vander Vennet, R. (2016). Business models and bank performance: A long-term perspective. Journal of Financial Stability, 22, 57–75. https://doi.org/10.1016/j.jfs.2015.12.002

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

Molyneux, P., Reghezza, A., & Xie, R. (2018). Bank Profits and Margins in a World of Negative Rate. Bangor Business School Working Paper, BBSWP/18/0. https://doi.org/10.1002/ir.37019906803

Morris, S., & Shin, H. S. (2014). Risk-Taking Channel of Monetary Policy: A Global Game Approach. Working Paper Series, I(February), 1–22.

Nucera, F., Lucas, A., Schaumburg, J. & Schwaab, B. (2017). Do negative interest rate makes banks less safe? Economics Letters, 159 (2098), 112-115.

Okamura, K. (2011). “Zombie ” banks make “Zombie ” firms. SSRN Electronic Journal, (March). https://doi.org/10.2139/ssrn.1786496

Ongena, S., Popov, A., & Udell, G. F. (2013). “When the cat’s away the mice will play”: Does regulation at home affect bank risk-taking abroad? Journal of Financial Economics, 108(3), 727–750. https://doi.org/10.1016/j.jfineco.2013.01.006

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

Palley, T. I. (2016). Why ZLB economicas and Negative Interest Rate Policy (NIRP) are wrong: a theoretical critique. IMK Working Paper, 172.

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. (2005). Has financial development made the world riskier? NBER Working Paper Series, 11728, 42. https://doi.org/10.3386/w11728

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

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.

Schwaab, B., Andrè, L., & Schaumburg, J. (2017). Bank business models at negative interest rates. Journal of Businnes & Economic Statistics, 0015. https://doi.org/10.1080/07350015.2017.1386567

Shiller, R. J., Campbell, J. Y., Schoenholtz, K. L., & Weiss, L. (1983). Forward Rates and Future Policy : Interpreting the Term Structure of Interest Rates. Brookings Papers on Economic Activity, 1983(1), 173–223.

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

Tabak, B. M., Fazio, D. M., & Cajueiro, D. O. (2012). The relationship between banking market competition and risk-taking: Do size and capitalization matter? Journal of Banking and Finance, 36(12), 3366–3381. https://doi.org/10.1016/j.jbankfin.2012.07.022

Tabak, B. M., Gomes, G. M. R., & Da Silva Medeiros, M. (2014). The impact of market power at bank level in risk-taking: The Brazilian case. International Review of Financial Analysis, 40, 154–165. https://doi.org/10.1016/j.irfa.2015.05.014

Tajaddini, R., & Gholipour, H. F. (2017). National Culture and Default on Mortgages. International Review of Finance, 17(1), 107–133. https://doi.org/10.1111/irfi.12113

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

Vallascas, F., & Hagendorff, J. (2013). The risk sensitivity of capital requirements: Evidence from an international sample of large banks. Review of Finance, 17(6), 1947–1988. https://doi.org/10.1093/rof/rfs042

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

Varotto, S., & Zhao, L. (2018). Systemic risk and bank size. Journal of International Money and Finance, 82, 45–70. https://doi.org/10.1016/j.jimonfin.2017.12.002

Vazquez, F., & Federico, P. (2015). Bank funding structures and risk: Evidence from the global financial crisis. Journal of Banking and Finance, 61, 1–14. https://doi.org/10.1016/j.jbankfin.2015.08.023

Yang, K. Y. (2017). The effect of TARP on the propagation of real estate shocks: Evidence from geographically diversified banks. Journal of Banking and Finance, 83, 173–192. https://doi.org/10.1016/j.jbankfin.2016.12.009

Table 1. Descriptive statistics

	TREATMENT									
	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Bank Risk Measures										
Δ Risky assets	355	-0,01	0,23	-2,22	1,01	3221	-0,09	0,16	-0,22	4,08
Z-score	8990	54,91	47,76	6,88	147,11	8040	58,85	48,97	6,88	147,11
Bank Balance Sheet and Banking Industry Data										
Size	9048	13,76	1,55	11,51	16,32	8138	13,74	1,54	11,51	16,32
Equity	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%
Income structure	8725	6,92%	6,32%	0,15%	20,17%	7881	7,02%	6,31%	0,15%	20,17%
Lerner	10364	0,15	0,92	0,0	0,43	10092	0,17	0,08	0,67	0,41
Boone	10364	-0,03	0,91	-0,55	0,14	10092	-0,04	0,10	-0,64	0,14
HHI	10364	890,51	564,84	464,33	4237,49	10092	855,80	536,49	453,24	3777,27

	CONTROL									
	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Bank Risk Measures										
Δ Risky assets	1147	0,04	0,19	-1,93	1,25	1589	0,04	0,24	-1,85	2,82
Z-score	4795	30,54	22,62	3,87	69,50	4422	32,41	23,26	3,86	69,50
Bank Balance Sheet and Banking Industry Data										
Size	5008	14,38	0,93	11,60	17,63	4650	14,42	2,00	11,60	17,63
Equity	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%
Income structure	4662	2,74%	2,31%	-0,40%	7,02%	4316	2,91%	2,32%	-0,40%	7,02%
Lerner	22878	0,32	0,47	0,1	0,44	22522	0,33	0,03	0,16	0,42
Boone	23300	-0,39	0,04	-0,44	0,22	22944	-0,04	0,04	-0,41	0,21
HHI	23300	359,10	275,87	254,84	2166,44	22944	334,27	241,79	249,63	2174,46

Where: Δ Risky assets 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; Equity is the ratio of bank equity to total assets; Tot. Capital Ratio is the of Total Capital (Tier 1 + Tier 2) to risk-weighted assets; ROA is the yearly 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 deposit funding to total liabilities; Income structure is the ratio of non-interest income to total income; HHI is the Herfindahl-Hirschman index at country level; Lerner is the Lerner index at country level; Boone is the Boone indicator at country level.

Table 2. NIRP and risky assets

	Grisky(1)	Grisky(2)	Grisky(3)	Grisky(4)	Grisky(5)	Grisky(6)	Grisky(7)
NIRP-effect	-0.0981***	-0.101***	-0.0990***	-0.113***	-0.117***	-0.120***	-0.119***
	(0.0144)	(0.0145)	(0.0146)	(0.0144)	(0.0143)	(0.0144)	(0.0144)
Size		-0.00351	-0.00824***	-0.00789***	-0.00842***	-0.00951***	-0.00949***
		(0.00220)	(0.00222)	(0.00218)	(0.00214)	(0.00231)	(0.00235)
E/TA			-0.00457***	-0.00683***	-0.00722***	-0.00631***	-0.00651***
			(0.00114)	(0.00125)	(0.00149)	(0.00147)	(0.00147)
ROA				0.0463***	0.0456***	0.0453***	0.0494***
				(0.00865)	(0.00889)	(0.00912)	(0.00967)
Liquidity					-0.000357	-0.000694**	-0.000660*
					(0.000310)	(0.000350)	(0.000350)
Funding str.						-0.0257	-0.0286
						(0.0297)	(0.0304)
Business mod.							0.00127*
							(0.000706)
Country-FE	Y	Y	Y	Y	Y	Y	Y
Year-FE	Y	Y	Y	Y	Y	Y	Y
N.banks	2731	2731	2731	2701	2683	2601	2579
N.Obs	6312	6312	6311	6206	6173	5991	5945

Table 3. Risky assets, capitalisation, size and competition before and after NIRP

	Griskyass (1)
Panel A. Undercapitalised banks (<10th percentile)	
Nirp-Effect	-0.2180***
	(0.0632)
N.banks	41
N.Obs	60
Panel B. Overcapitalised banks (>90th percentile)	
Nirp-Effect	0.5440***
	(0.1140)
N.banks	67
N.Obs	104
Panel C. Small Banks (under median)	
Nirp-Effect	-0.1060
	(0.0967)
N.banks	991
N.Obs	1710
Panel D. Large banks (over median)	
Nirp-Effect	-0.1150***
	(0.0180)
N.banks	1770
N.Obs	3941
Panel E. Non-Competitive markets	
Nirp-Effect	0.0858**
	(0.0345)
N.banks	1985
N.Obs	3734
Panel F. Competitive markets	
Nirp-Effect	-0.0312
	(0.0313)
N.banks	729
N.Obs	1844

APPENDIX

Table A1. Time of Adoption of NIRP.

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

Table A2. NIRP and Sovereign Bond Holding

	Gov.Bond
NIRP-Effect	0.00620***
	(0.00106)
Year-Fe	Y
Country-FE	Y
N.Banks	3368
N.Obs	9303