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**Did Negative Interest Rates Impact Bank Lending?**

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## Abstract

Since 2012 several central banks have introduced a negative interest rate policy (NIRP) aimed at boosting real spending by facilitating an increase in the supply and demand for bank loans. We employ a bank-level dataset comprising 16,675 banks from 33 OECD member countries over 2012-2016 and a difference-in-differences methodology to analyze whether NIRP resulted in a change in bank lending in NIRP-adopter countries compared to those that did not adopt the policy. Our results suggest that following the introduction of negative interest rates, bank lending was weaker in NIRP-adopter countries than in countries that did not adopt the policy. The result is robust to a wide range of checks. This adverse NIRP effect appears to have been stronger for banks that were smaller, more dependent on retail deposit funding, less well capitalized, had business models reliant on interest income, and operate in more competitive markets. NIRP also appears to have canceled out the stimulus impact of other forms of unconventional monetary policy.



JEL: E43, E44, E52, G21, F34

Keywords: Negative interest rates, monetary policy transmission, bank lending, difference in differences estimation

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## 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 experimented with a range of unconventional monetary policies (UMP) 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, and forward guidance to communicate about future policy rate paths. The effectiveness of these policies in raising nominal spending has been at the center of a vigorous policy and academic debate with no clear consensus emerging. Nonetheless, since 2012 six European economies (Denmark, the Euro area, Hungary, Norway, Sweden and Switzerland) and Japan have taken unconventional monetary policy a step further by introducing a negative interest rate policy (NIRP) aimed at additional monetary accommodation.[1] The primary objective of NIRP in adopter countries is to stabilize inflation expectations and support economic growth, and in Denmark and Switzerland the policy was also aimed 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 fueled 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 relate to NIRPs efficacy and limitation in stimulating economic growth and inflation, as well as how the policy influences bank profitability, financial stability, and exchange rates. Skeptics of NIRP (for example, McAndrews, 2015) point to several possible complications, including a limited pass-through to lending rates as banks may hold deposit rates steady to maintain the deposit funding base. Such behavior has an adverse influence on bank profitability, which can limit credit growth if banks charge higher lending rates or fees to cover losses, or if a diminished capital base makes banks more reluctant to lend. Other associated distortions in asset valuations can create asset price bubbles threatening financial stability. The empirical literature on NIRP and its effects is small and generally comprises overviews of developments in key banking and other financial aggregates in the immediate pre- and post-NIRP periods rather than rigorous econometric analysis (see Section 2). Our paper contributes to the literature by examining how NIRP has performed with respect to a key policy objective--achieving an increase in bank lending to support economic growth. To examine this issue, we employ a bank-level dataset comprising 16,675 banks from 33 OECD member countries over the period 2012-2016 and use a difference-in-differences methodology. The methodology provides a sound basis for drawing conclusions as to whether NIRP resulted in a change in bank lending in NIRP-adopter countries compared to countries that did not adopt the policy. It also allows us to examine factors that might have been influential in the

[1] See Bech and Malkhozov (2015) for a discussion of the implementation mechanisms of NIRP in adopting countries. The time of introduction of NIRP is noted in Table 2.

effectiveness of NIRP compared to other monetary policy frameworks. In contrast to the conclusions of most of the recent research in the area, we find that banks in NIRP-adopter countries reduce lending significantly compared to those in countries that do not adopt the policy. This adverse NIRP effect is stronger for banks that were smaller, more dependent on retail deposits , less well capitalized, had business models reliant on net interest margins, and operated in more competitive market environments.

The paper proceeds as follows. Section 2 reviews the related academic literature on NIRP. Section 3 introduces our data and methodology. Section 4 presents our results along with several robustness checks to address threats to validity and a final section concludes.

**2. Related literature**

Until the global financial crisis, the benchmark monetary theory for many macroeconomists drew upon Wallace (1981) and Eggertsson and Woodford (2003) who viewed liquidity as having no further role once nominal policy rates reached their lower bound. After the crisis, various studies highlight mechanisms through which UMP (policy guidance, LSAPs and NIRP) can have an impact. Curdia and Woodford (2011) provide a model with heterogeneous agents and imperfections in private financial intermediation to demonstrate that UMP will affect the economy provided either an increase in banks' reserves boosts lending to the private sector, or that UMP changes expectations about future interest-rate policy. Brunnermeier and Sannikov (2016) show that UMP can work against adverse feedback loops that precipitate crises by affecting the prices of assets held by constrained agents. Drechsler et al. (2016) point out the role played by LSAPs, equity injections, and asset guarantees in supporting risky asset prices. Del Negro et al. (2011) investigate the effects of interventions in which the government provides liquidity in exchange for illiquid private paper once nominal interest rates reach the zero bound. Similarly, Brunnermeier and Koby (2016) present a "reversal interest rate" hypothesis according to which there is a rate of interest at which accommodative monetary policy "reverses" its effect and becomes contractionary. The reversal interest rate depends on such factors as the composition of banks' asset holdings, the degree of interest rate pass-through to loan and deposit rates, and banks funding structures - they argue that quantitative easing increases the reversal rate and should only be employed after interest rates cuts have been exhausted.[2]

UMP relates to policies that guide longer term interest rate expectations and expand and change the composition of central bank's balance sheets (Bernanke and Reinhart, 2004). It is aimed at facilitating credit expansion in order to boost economic growth. However, little is known about the effectiveness and pass-through of unconventional policy to bank lending. Focusing on the effect of UMP on bank lending in the U.S, Rodnyansky and Darmouni (2016) confirm that quantitative easing and mortgage backed securities purchases facilitated an increase in mortgage lending. However, Chakraborty et al. (2017) show that increased mortgage lending may crowd-out commercial lending at the same time. Bowman et al. (2011) examine the effectiveness of the Bank of Japan's injections of liquidity into the

[2] Our later empirical analysis test dimensions of the Brunnermeier and Koby (2016) hypothesis.

interbank market in promoting bank lending (using bank-level data from 2000 to 2009). They report a robust, positive, and statistically significant effect of bank liquidity positions on lending suggesting that the expansion of reserves associated with UMP likely boosted the flow of credit (although the overall increase was modest). Butt et al. (2015) report no evidence of a traditional bank lending channel associated with LSAPs in the UK and suggest that this was because it gave rise to deposits that were likely to quickly leave banks.[3]

The effect of NIRP is expected to be transmitted via lower money market and bank lending rates to households and corporates (Jobst and Lin, 2016). These lower rates impact both sides of bank's balance sheets. When lower policy rates are transmitted to bank loan rates, they reduce the value of bank assets. Conversely, lower policy rates also reduce the cost of bank liabilities, namely, lower funding expenses. Heider et al. (2016) find that when policy rates remain positive, deposit rates closely track policy rates. However, when policy rates turn negative, banks that rely on deposit funding are reluctant to reduce deposit rates fearing a loss of their funding base. In cases where sticky deposit rates compress lending margins, banks tend to shift activities toward fee-based services. Ball et al. (2016) survey recent developments in the monetary policy transmission mechanism in NIRP-adopter countries. They argue that policy rate cuts below zero are generally transmitted to bank lending rates, although sluggishly. They also conclude that there's no clear relationship between NIRP and bank credit expansion. Arteta et al. (2016) suggest that lending rates generally decline under NIRP, particularly in countries with greater bank competition, but pass-through is only partial due to downward rigidities in retail deposit rates (reflecting the importance of retail deposits as a source of bank funding). In two recent studies that focus on NIRP in the Euro area Bräuning and Wu (2017) suggest that negative rate policy reduces loan rates and boosts lending to businesses and households. In a similar study using bank level data, Demiralp et al. (2017) also find that banks increase lending as a reaction to NIRP. However, the latter studies may provide misleading inferences as the authors do not compare the differential effects of policy rates on bank lending behaviour in NIRP adopter and non-adopter countries.

Empirical analysis of the impact of NIRP is also linked to the bank lending channel literature. Kashyap and Stein (2000) and Altunbas et al. (2017) provide evidence of the bank lending channel for the transmission of conventional monetary policy. Maddaloni and Peydro (2011) find that low short-term interest rates for an extended period soften lending standards for household and corporate loans. Jimenez et al. (2014) show that lower overnight interest rates induce less capitalized banks to lend to riskier firms and Jimenez et al. (2012) illustrate that tighter monetary policy and deteriorating economic conditions substantially reduce lending by distressed banks. Agarwal et al. (2017) estimate banks' marginal propensity to lend out of a decrease in their cost of funds to show that banks were reluctant to lend to riskier borrowers in the aftermath of the global financial crisis. This paper makes a significant contribution to the empirical literature on the impact of UMP on bank lending by focusing specifically on the effectiveness of the most recent UMP innovation: the adoption of negative central bank policy rates.

[3] A related literature focuses on the broader macroeconomic effects of LSAPs (e.g., Lenza et al. 2010; Baumeister and Benati, 2010; Fujiwara, 2004; Berkmen, 2012; Schenkelberg and Watzka, 2011; Kapetanios et al., 2012) and generally finds a positive—albeit often small—impact of LSAPs on output and inflation.

## 3. Methodology and data

### *3.1 Methodology*

We examine two periods and two monetary policy regimes; NIRP and traditional monetary policy, using a difference-in-differences methodology. Our baseline specification takes the following form:

$$\Delta L_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 \left(Treated_{ij} * Post_{jt}\right) + \varphi_t + \varepsilon_{ijt} \quad (1)$$

where $\Delta L_{ijt}$ is the growth rate of lending of bank $i$ in country $j$ at time $t$, $Treated_{ij}$ is a dummy variable that takes the value 1 if bank $i$ in country $j$ has been affected by NIRP and 0 otherwise, and $Post_{jt}$ is a dummy variable that takes the value 1 after the period that country $j$ at time $t$ decided to implement NIRP and 0 before that period, and $\beta_3$ represents the average difference in the change in bank lending between countries that switched to NIRP and countries that continued with traditional monetary policy. We also include $\gamma_i$, and $\varphi_t$, to capture, respectively, bank and year fixed effects and limit the potential for bias in estimates of $\beta_3$.

We introduce bank- and country-specific controls in a second specification that takes the form:

$$\Delta L_{ijt} = \alpha + \beta_1 Treated_{ij} + \beta_2 Post_{jt} + \beta_3 \left(Treated_{ij} * Post_{jt}\right) + \beta_4 X_i + \varphi_t + \varepsilon_{ijt} \quad (2)$$

where $X_i$ is a vector of bank- and county-specific characteristics to capture cross-bank and cross-country heterogeneity over time that can affect bank lending. Bank-specific variables are a combination of balance sheet and performance measures and include total assets, the ratio of equity to total assets, return on average equity, and the liquidity ratio. Country-specific variables are key measures of economic performance and include real GDP growth, consumer price inflation, and the rate of unemployment.

The difference-in-differences estimation requires that a parallel trend assumption is met. Figure 1 depicts the average growth rate of gross loan from 2012 to 2016 for both NIRP adopter and non-adopter countries. The difference in the average growth rate of gross loan was constant in the pre-treatment period, indicating that the parallel trend assumption holds. Since June 2014, when policy rates in most of the NIRP adopter countries turned negative, an increasing gap developed for gross loan growth rates in the treated and untreated countries. Overall, Figure 1 suggests that banks in NIRP adopter countries reduced their lending after the treatment period compared with NIRP non-adopter countries.

### *3.2 Data*

We rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information from two main sources. The macroeconomic series are from Thompson DataStream, and the bank balance

and performance data are from Orbis Bank Focus. Our sample covers 16,675 financial institutions (commercial banks, savings banks, cooperative banks and bank holding companies) from 33 OECD countries over 2012 - 2016, giving us a total of 66,700 observations. The number of banks is 5,114 and 11,561 for treated and non-treated countries, respectively. The treated countries include those of the Euro Area, Hungary, Sweden and Switzerland.[4] Descriptive statistics for the bank lending series, other bank balance sheet variables, and the macroeconomic series in the treatment and control groups of countries are shown in Table 1.[5]

Panel A of Table 1 presents summary statistics for bank lending. In a recent study on monetary stimulus and bank lending, Chakraborty et al. (2017) find that in response to the Federal Reserve's asset purchases, banks shift resources away from C&I lending into mortgage origination. To take this potential crowding-out effect between bank lending activities into consideration, we group bank lending behaviour into three types: gross loans, mortgage loans and C&I loans. We use the log growth rate of gross loans; mortgage loans and commercial and industrial (C&I) loans as our measures of interest.

Panel B of Table 1 presents summary statistics on other bank balance sheet data, including bank size (log(TA)), equity ratio (E/TA), profitability (ROE), liquidity ratio (liquidity), total capital ratio (capital), funding structure (funding_structure), and income structure (income_structure). Bank size is defined as the natural logarithm of total assets and is used to control for different characteristics across relatively large and small banks. Bank lending may also be driven by other bank level characteristics including equity strength, profitability and liquidity condition. Accordingly, we control for bank equity, profitability and liquidity ratios in the regression models. In a recent theoretical study, Brunnermeier and Koby (2016) suggest that monetary policy may have unintended contractionary effects on lending due to bank capital constraints, bank business models and market competition. To empirically test the hypothesis of Brunnermeier and Koby (2016), we also include variables that account for bank funding and income structures and the Hirshman Herfindahl market structure index (HHI) to proxy the impact of bank competition.

Furthermore, we include country GDP growth, inflation and the unemployment rate to account for macroeconomic heterogeneity across countries. Earlier literature also highlighted the major transmission channels of other UMP policies including central banks' asset purchase programs (Di Maggio et. al, 2016; Rodnyanski and Darmouni, 2016; Kandrac and Schulsche, 2016; Chakraborty et. al, 2017). In line with Gambacorta et al. (2014), we employ the log growth rate of a country's central bank balance sheet and the log growth rate of the monetary base (M0) as further controls to isolate the impact of other UMP's on bank lending behavior.

[4] We exclude Japan in our sample as the country only adopted NIRP in early 2016, which provides too short a period to examine the impact of NIRP on bank lending.

[5] We also estimate Pearson correlation coefficients for the macroeconomic variables in the treatment and control groups. The coefficients (not reported) suggest that the countries in the two groups experienced a similar macroeconomic environment. This finding, together with the parallel trend assumption that we report in Figure 1, further supports our decision to choose a difference-in-differences methodology in our analysis.

A further issue is that bank lending may be driven by loan demand from households and corporates. To address this concern, we construct loan demand indices based on data from the ECB and FED bank lending surveys. Both of these surveys identify loan demand as the need of enterprises and households for bank loan financing, irrespective of whether a loan is granted or not.[6] Based on data from these two surveys, we construct loan demand indices for the Euro area and US, focusing on increases or decreases in loan demand. Panel C of Table 1 presents summary statistics of macroeconomic conditions, monetary policy and loan demand indices.

## 4 Empirical results

### *4.1 Baseline results*

The results from estimating equations (1) and (2) are presented in tables 3 to 5. All the estimates include fixed bank and time effects. Table 3 reports results for estimates where the dependent variable is the (natural logarithm) growth rate of gross loans with control variables added sequentially. Our main interest is the size, sign and statistical significance of the coefficient on $\beta_3$, which is the average difference in the change in bank lending between countries that adopted NIRP and countries that did not, and which in the table we denote as the *NIRP-effect*. The baseline result reported in column 1 of Table 3 excludes all control variables. The coefficient on NIRP is sizeable, negative and statistically significant at the 1% level, indicating that countries in which central banks implemented NIRP experienced a decline in total bank lending of around 7.4% relative to those countries in which central banks did not follow this policy. The remaining columns of the table present the results from adding bank- and country- specific controls sequentially. The baseline regression result holds up well in the face of all controls—though the size of the coefficient is diminished somewhat (with the marginal effect on total loans falling to between 6.6% to 7.3%), the coefficient on *NIRP-effect* remains negative and significant at the 1% level in all estimates. Of the bank-specific control variables, bank size and profitability appear to be the major factors driving lending, though the results in column 7 indicate that bank-specific effects do not hold-up well when macroeconomic performance is considered. In Tables 4 and 5 we report results from estimates for mortgage loans and C&I loans, respectively. As is the case for gross loans, the coefficients on *NIRP-effect* are all sizeable, negative and statistically significant, including the presence of all control variables. Countries where central banks implemented NIRP experienced a decline in mortgage loans of between 1.8% to 3.8% relative to countries that pursued other monetary policies; the decline in C&I loans was more marked, however, falling by 13.2% to 15.4%. Once again, size is the main bank-specific factor driving lending but these factors seem to be less important than the general macroeconomic environment.

### *4.2 Robustness tests*

[6] The bank lending surveys from ECB and FED are available at:
1) https://www.federalreserve.gov/boarddocs/snloansurvey/
2) https://www.ecb.europa.eu/stats/money/surveys/lend/html/index.en.html

In this section, we report results from a wide range of robustness checks that offer variations from our choice of controls used in the baseline model. NIRP was brought into the UMP mix by central banks several years after the adoption of other unconventional monetary policies, most particularly extensive outright asset purchases, and it is important to disentangle the effects of NIRP on lending from the effects of these policies. Outright asset purchases were aimed at expanding the central bank's balance sheet to increase the level of the monetary base in order to boost nominal spending (Bernanke and Reinhart 2004). Accordingly, we proxy for the use of other UMPs by including, alternatively, variables that take account of central bank balance sheet size and (alternatively) the size of the monetary base. Results reported in panel A of Table 6 are for each of the three categories of bank lending. The results including the log growth rate of the size of central bank balance sheets are reported in columns 1, 3 and 5 and suggest that NIRP and central bank assets purchases had the opposite (almost offsetting) impact on bank lending. The impact of NIRP seems to have been to cancel out a substantial amount of the stimulus impact of central bank balance sheet expansion—about 60% of it in the case of gross loans and 28% in the case of mortgage lending, while the negative impact of NIRP on C&I lending is substantially larger than the positive impact of central bank balance sheet expansion. Thus, estimates suggest that central banks that introduced NIRP to boost lending undermined other aspects of UMP that had the same objective. Results where growth in the monetary base are used as a second proxy for UMPs are reported in columns 2, 4 and 6 of panel A. In this case, NIRP and the monetary base had the same negative impact on the different types of bank lending, though the coefficients on the monetary base variable are small. These results are somewhat at odds with those obtained using central bank asset size and would suggest that the impact of asset purchases on bank lending was mainly through other means than encouraging banks to lend accumulated reserves.

Our second robustness check aims to control for the effect of credit demand on bank lending behavior. To this end, we make use of indications of loan demand from the US Federal Reserve Board's Senior Loan Officer Opinion Survey on Bank Lending Practices and the ECB's Euro Area Bank Lending Survey both of which have elements focused on the need of firms and households for bank loan financing irrespective of whether the loan is granted. We construct monthly credit demand indices from the aforementioned ECB and Federal Reserve surveys. These results are reported in columns 1, 3 and 5 of panel B where the coefficient on NIRP remain negative and statistically significant even in the case of (relatively) strong loan demand. The results demonstrate that the negative relationship between NIRP and bank lending is not driven by loan demand.

If one impact of NIRP is to force down bank deposit rates, then banks in NIRP-adopter countries might face greater difficulties in raising deposits to fund lending. For a third robustness test, we control for this possibility by introducing bank deposit interest rates into our estimates. These results are reported in columns 2, 4 and 6 of panel B. The coefficient on NIRP generally remain negative and statistically significant; the coefficient on the deposit rate is positive and statistically significant suggesting that the ability to attract deposits is an important factor in supporting bank lending and banks in non-NIRP countries had funding advantages through their ability to offer higher rates.

For a fourth robustness check, we alter our country sample and focus only on European countries where the treatment group includes only European country NIRP adopters and the control group includes only European non-NIRP adopters. These results are reported in panel C of the table. The coefficients on NIRP in the cases of gross loans and mortgage loans remain negative and statistically significant, though somewhat smaller than in the baseline case, but for C&I lending the coefficient is no longer significant.

As a final robustness test, we try to eliminate the possibility that bank behavior in the treatment group may have altered prior to the introduction of NIRP—for example, in anticipation of adverse effects of NIRP, or for some bank-specific reason—thereby invalidating our choice of difference-in-differences estimation. If the estimated coefficients on the 'false' NIRP coefficient are not statistically significant, we can be more confident that our baseline coefficient is capturing a genuine monetary policy shock. In panel D of the table we report results from estimates in which we extend our sample to the period from 2008 – 2012. The coefficients on the NIRP variable are positive but not statistically significant in the cases of total loans and C&I loans, and positive and significant in the case of mortgage loans adding further support to the validity of our baseline results. The results also reaffirm the parallel trend assumption further lending support to the conclusion that differential bank lending behavior is driven by NIRP.

*4.3 NIRP and the reverse interest rate hypothesis*

In this section, we report results from a test of aspects of the Brunnemeier and Koby (2016) 'reverse interest rate hypothesis' within a difference-in-differences framework by creating NIRP-adopter treatment groups and non-adopter control groups according to whether banks meet representations of bank-specific factors that these authors suggest might reduce bank lending in a low interest rate setting. Specifically, we focus on banks' capitalization, funding structure, business model, interest rate exposure, and competitive conditions in the banking market. First, we examine the impact of bank capital on lending by grouping banks in the treatment and control groups according to whether they have total capital ratios above or below the median for banks in our sample, labelling banks with higher than median capital ratios as 'well-capitalized' and those below the median as 'under-capitalized. The results for the different categories of loans are reported in panels A and B of Table 7. The coefficients on NIRP are negative and statistically significant in both sets of estimates but suggest a substantially larger decline in lending by under-capitalized banks after the introduction of NIRP. Specifically, banks with capital below the median reduced gross loans, mortgage, and business loans by 8.3%, 1.9% and 4% more in comparison to banks with above median capital. This is consistent with the Brunnemeier and Koby (2016) assertion that suggests that in situations of economic uncertainty and changing regulation, binding capital requirements can limit the pass-through of accommodative monetary policies to bank lending. Second, we consider how NIRP interacts with bank funding structure. We distinguish between retail deposit-based and wholesale deposit-based banks on the assumption that if interest rates on retail deposits are more downwards sticky then the introduction of NIRP would likely pose greater limitations on retail deposit-based banks to increase lending.[7] This is confirmed by the results reported in panels C and D of table 7, where

[7] For this exercise, we consider as retail deposit banks those with retail deposits greater that 50% of total liabilities.

the coefficients on NIRP are highly significant in both sets of estimates but indicate that NIRP resulted in a markedly larger decline in lending by retail deposit-based banks. The result is consistent with the argument of Dell'Ariccia et al. (2010) that NIRP enabled wholesale-funded banks to take greater advantage of the decline in funding costs and provide more loans.

We assess the impact of banks' business models on lending in a NIRP context by distinguishing between traditional interest-dependent banks from those that have a more fee-dependent business model. For our purposes, a bank is defined as interest-dependent if the interest earnings share of total earnings is above the median for banks in our sample; banks are deemed to be fee-based if their interest earnings share is below the median. If interest rates on retail deposits are sticky downwards then the introduction of NIRP would likely pose more constraints for banks with interest-dependent than fee-dependent business models. The results from these estimates are reported in panels E and F of the table and show that banks whose business model is mainly interest-based reduced their lending by more than banks whose business model was more fees orientated. In the case of gross lending, for example, the effect of NIRP in reducing lending by interest-dependent banks was about twice that compared to fee-based banks.

Our final test of the Brunnemeier and Koby (2016) hypothesis is to assess the impact of NIRP on lending in the context of competitive conditions in banking markets. In this case, we proxy market competition by focusing on market concentration in each country as indicated by the Herfindahl-Hirschman Index (HHI). Sørensen and Werner (2006), for example, use the concentration ratio as a proxy for competition and conclude that banks operating in a less competitive environment make slower adjustments to interest rates (and therefore to net interest margins), which slows the transmission of monetary policy changes to bank lending.[8] We define markets as competitive with a HHI value below 1000 (the median value in our sample) and split the sample for the treatment and control groups. According to Brunnemeier and Koby (2016) low interest policy is likely to have a more limiting effect on bank lending in competitive markets because of the associated pressure on net interest margins. The results reported in panels G and H of table 7 support this view: the impact of NIRP on bank lending in competitive markets is negative and statistically significant for each category of lending, suggesting that banks in these markets have little option but to generate alternative income from other sources to maintain profitability. In more concentrated markets in contrast, the impact of NIRP is positive and statistically significant in the case of gross loans suggesting that banks in these markets are better able to maintain profitability and interest margins.

## 5. Conclusions

[8] We recognize that there are shortcomings with using the HHI as a proxy for competitive conditions. There are different views about competition and concentration in the literature, Claessens and Laeven (2003), for example, point out that there are some countries, such as USA, that show levels of monopolistic competition in banking despite the large number of banks, while countries like Canada are highly competitive, although the number of banks is relatively small. The US Department of Justice 'generally consider markets in which the HHI is between 1,500 and 2,500 points to be moderately concentrated, and consider markets in which the HHI is in excess of 2,500 points to be highly concentrated'. https://www.justice.gov/atr/herfindahl-hirschman-index .

Since 2012, several central banks have adopted NIRP aimed at boosting real spending by facilitating an increase in the supply and demand for loans. The policy has generated controversy with skeptics pointing to several factors that might complicate the transmission from negative policy rates to higher bank lending. Empirical evidence on the impact of the policy is scant. However, in this paper, we provide new evidence that bank lending fared worse in NIRP-adopter countries than it did in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in total bank lending relative to those countries in which central banks did not follow this policy. This result holds for gross bank lending and separately for mortgage and C&I lending, the key categories of bank lending, and is robust to the inclusion of several bank-specific control variables. It also stands up in the face of a wide array of robustness checks, including controlling for the effects of other aspects of UMP, developments in loan demand across countries, for possible bank funding constraints, , and to (possibile) changes in bank behavior prior to the introduction of NIRP. Finally, our results are relevant to the validity of the 'reverse interest rate hypothesis' developed recently by Brunnemeier and Koby (2016) in that bank-specific factors (capitalization, funding structure, business model, interest rate exposure, competitive conditions) appear to reduce banks' willingness to lend in a negative interest rate setting.

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Figure 1. Average logarithm growth of gross loans among treated banks (blue line) and non-treated banks (red line) from 2012 – 2016.

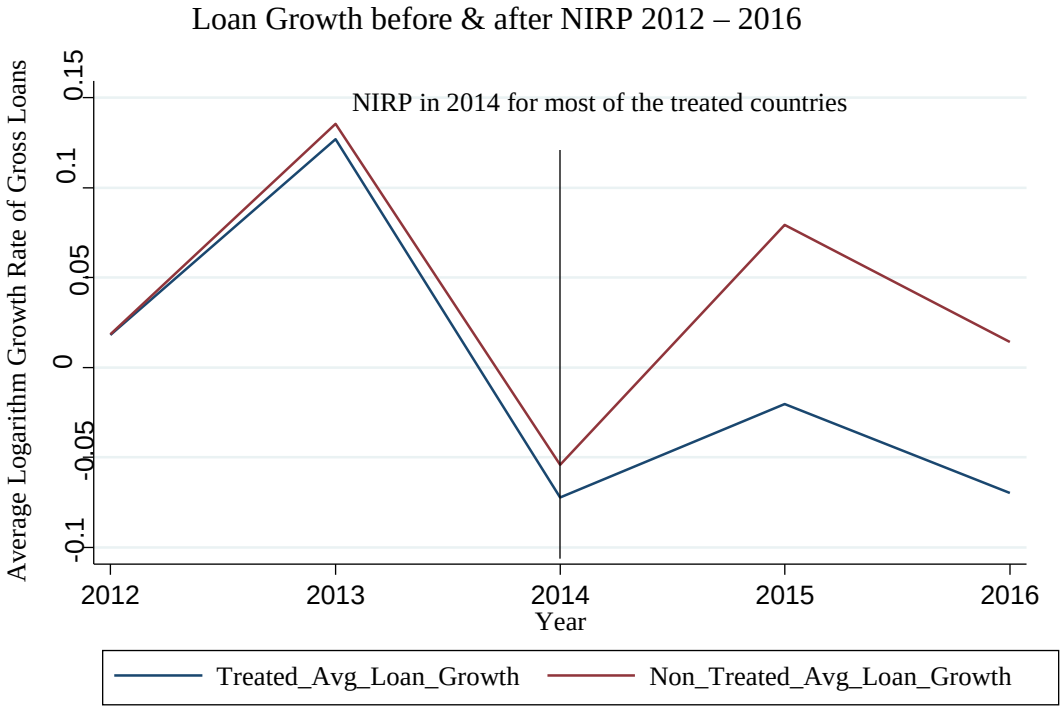

Table 1. Descriptive statistics: treatment and control groups

| | I. Treatment group: | | | | | II. Control group | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Obs.** | **Mean** | **Std. Dev.** | **Min** | **Max** | **Obs.** | **Mean** | **Std. Dev** | **Min** | **Max** |
| **Panel A: Bank Lending** | | | | | | | | | | |
| GL_GR | 7543 | -0.04 | 0.41 | -9.73 | 8.54 | 15704 | 0.03 | 0.45 | -10.17 | 7.31 |
| MORT_GR | 3795 | -0.03 | 0.39 | -7.00 | 7.90 | 5938 | 0.02 | 0.50 | -9.13 | 7.71 |
| CL_GR | 3259 | -0.11 | 0.54 | -6.96 | 4.83 | 8018 | 0.02 | 0.61 | -8.25 | 6.76 |
| **Panel B: Bank Balance Sheet Data** | | | | | | | | | | |
| Log(TA) | 8138 | 13.77 | 2.12 | 3.94 | 21.72 | 18700 | 14.07 | 2.38 | 2.95 | 21.90 |
| E/TA | 8136 | 10.48% | 5.71% | 3.83% | 24.93% | 17703 | 11.74% | 6.56% | 3.83% | 24.93% |
| ROE | 8099 | 4.56% | 4.40% | 0.00% | 16.83% | 18261 | 6.27% | 5.18% | 0.00% | 16.83% |
| Liquidity | 7895 | 21.76% | 15.12% | 0.90% | 46.94% | 17264 | 20.67% | 15.44% | 0.90% | 46.94% |
| Capital | 5700 | 18.38% | 4.57% | 11.00% | 26.30% | 11302 | 17.40% | 4.59% | 11.00% | 26.30% |
| Income_Structure | 7881 | 6.67% | 5.69% | 0.00% | 16.99% | 18261 | 4.97% | 5.05% | 0.00% | 16.99% |
| Funding_Structure | 7465 | 64.61% | 20.30% | 20.40% | 85.32% | 14752 | 65.06% | 20.98% | 20.40% | 85.32% |
| HHI | 10092 | 855 | 536 | 453 | 3777 | 56608 | 446 | 397 | 249 | 4237 |
| **Panel C: Macroeconomic Conditions and Monetary Policy** | | | | | | | | | | |
| GDP growth | 10092 | 0.41% | 0.66% | -0.19% | 6.62% | 56604 | 0.44% | 0.28% | -1.13% | 1.89% |
| Inflation | 10092 | 0.43% | 0.77% | -1.73% | 4.39% | 56608 | 1.51% | 1.14% | -1.73% | 8.93% |
| Unemployment | 4978 | 7.91% | 4.71% | 4.50% | 26.30% | 45047 | 7.34% | 2.51% | 3.1% | 27.20% |
| CB_GR | 5700 | -0.02 | 0.15 | -0.41 | 0.35 | 46991 | 0.09 | 0.16 | -0.66 | 0.45 |
| M0_GR | 6588 | 8.07 | 10.17 | -4.55 | 20.12 | 51648 | 9.51 | 9.22 | -26.63 | 51.56 |
| Deposit Rate | 1962 | 0.5% | 0.57% | -0.18% | 1.41% | 5512 | 3.38% | 4.83% | 0.03% | 16.77% |
| Loan Demand | 8360 | 15.74 | 13.85 | -22.92 | 48.33 | 46772 | 10.40 | 16.00 | -68.33 | 23.10 |

Note: GL_GR is the yearly logarithm growth rate of loans plus loan-loss reserves; MORT_GR is the yearly logarithm growth rate of mortgage loans; CL_GR is the yearly logarithm growth rate of commercial and industrial loans; Log(TA) is the natural logarithm of bank total asset; E/TA is the ratio of bank equity to total assets; ROE is the ratio of bank pre-tax profits to total equity; Liquidity is the ratio of bank liquid asset to total assets; Capital is bank's total capital ratio; Income_Structure is the ratio of bank interest income to total income; Funding_Structure is the ratio of bank deposit funding to total liabilities; HHI is the Herfindahl-Hirschman index; GDP_GR is the yearly growth rate of real GDP; Inflation is the yearly Consumer Price Index in percentage; Unemployment is the rate of yearly unemployment in percentage; CB_GR is the monthly logarithm growth rate of central bank balance sheet size; M0_GR is the logarithm growth rate of the money supply M0; Deposit Rate is the country level aggregate deposit rate in percentage; Loan Demand is the monthly credit demand indices constructed from data from ECB and Federal Reserve loan demand surveys.

Table 2. 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 3: Baseline regressions: NIRP and total gross lending

All regressions include fixed bank and time effects. Standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *NIRP-effect* | -0.0738*** | -0.0677*** | -0.0675*** | -0.0728*** | -0.0664*** | -0.0695*** | -0.0692*** | -0.0726*** |
| | (0.0034) | (0.0034) | (0.0034) | (0.0033) | (0.0034) | (0.0035) | (0.0064) | (0.0068) |
| Log(TA) | | 0.0571*** | 0.0624*** | -0.0000 | 0.0632*** | 0.06683*** | | 0.0076 |
| | | (0.0082) | (0.0085) | (0.0004) | (0.0089) | (0.0093) | | (0.0146) |
| E/TA | | | 0.0014 | -0.0000 | 0.0010 | 0.0015* | | 0.0024* |
| | | | (0.0009) | (0.0001) | (0.0009) | (0.0009) | | (0.0013) |
| Funding_Structure | | | | -0.0007*** | 0.0000 | 0.0001 | | 0.0001 |
| | | | | (0.0001) | (0.0003) | (0.0003) | | (0.0005) |
| ROE | | | | | 0.0016*** | 0.0016*** | | 0.0012*** |
| | | | | | (0.0004) | (0.0004) | | (0.0006) |
| Liquidity | | | | | | 0.0004 | | 0.0011*** |
| | | | | | | (0.0003) | | (0.0004) |
| GDP_GR | | | | | | | -0.0269*** | -0.0378*** |
| | | | | | | | (0.0104) | (0.1072) |
| Inflation | | | | | | | -0.0007 | -0.0023 |
| | | | | | | | (00021.) | (0.0021) |
| Unemployment | | | | | | | -0.0206*** | -0.0229*** |
| | | | | | | | (0.0037) | (0.0038) |
| Adjusted $R^2$ | 0.267 | 0.270 | 0.271 | 0.201 | 0.282 | 0.294 | 0.273 | 0.302 |
| No. of banks | 6558 | 6552 | 6551 | 6426 | 6423 | 6260 | 6130 | 5582 |
| No. of observations | 23247 | 23237 | 23233 | 22577 | 22556 | 21881 | 17749 | 16666 |

Table 4. Baseline Regression: NIRP and total mortgage loans

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *NIRP-effect* | -0.0376*** | -0.0264*** | -0.0262*** | -0.0335*** | -0.0270*** | -0.0256*** | -0.0182* | -0.0186* |
| | (0.0068) | (0.0067) | (0.0067) | (0.064) | (0.0067) | (0.0069) | (0.010) | (0.0112) |
| Log(TA) | | 0.0955*** | 0.0911*** | -0.0002 | 0.0911*** | 0.1063*** | | -0.0078 |
| | | (0.0150) | (0.0153) | (0.0007) | (0.0158) | (0.0166) | | (0.0283) |
| E/TA | | | -0.0020 | -0.0015*** | -0.0024 | -0.0014 | | -0.0018 |
| | | | (0.0019) | (0.0003) | (0.0019) | (0.0019) | | (0.0033) |
| Funding_Structure | | | | -0.0007*** | 0.0008 | 0.0008 | | 0.0008 |
| | | | | (0.0002) | (0.0007) | (0.0007) | | (0.0010) |
| ROE | | | | | 0.0014 | 0.0013 | | 0.0001 |
| | | | | | (0.0009) | (0.0009) | | (0.0013) |
| Liquidity | | | | | | 0.0003 | | 0.0006 |
| | | | | | | (0.0005) | | (0.0007) |
| GDP_GR | | | | | | | 0.0904*** | 0.0936)*** |
| | | | | | | | (0.0208) | (0.0215) |
| Inflation | | | | | | | 0.0023 | 0.0034 |
| | | | | | | | (0.0047) | (0.0048) |
| Unemployment | | | | | | | -0.0260*** | -0.0281*** |
| | | | | | | | (0.0073) | (0.0075) |
| Adjusted $R^2$ | 0.285 | 0.290 | 0.290 | 0.186 | 0.292 | 0.290 | 0.290 | 0.295 |
| No. of banks | 2740 | 2740 | 2740 | 2703 | 2703 | 2689 | 2556 | 2506 |
| No. of observa6ions | 9732 | 9732 | 9730 | 9535 | 9533 | 9468 | 7364 | 7160 |

All regressions include fixed bank and time effects. Standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 5. Baseline Regressions: NIRP and C&I loans

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *NIRP-effect* | -0.1535*** | -0.1343*** | -0.1349*** | -0.1494*** | -0.1317*** | -0.1324*** | -0.1474*** | -0.1400*** |
| | (0.0084) | (0.0092) | (0.0093) | (0.0083) | (0.0095) | (0.0096) | (0.0185) | (0.0198) |
| Log(TA) | | 0.1362*** | 0.1534*** | 0.0047*** | 0.1560*** | 0.1626*** | | 0.0561 |
| | | (0.0273) | (0.0272) | (0.0012) | (0.0276) | (0.0273) | | (0.0447) |
| E/TA | | | 0.0060*** | 0.0009* | 0.0058** | 0.0050* | | 0.0047 |
| | | | (0.0026) | (0.0005) | (0.0027) | (0.0028) | | (0.0041) |
| Funding_Structure | | | | -0.0007 | -0.0012 | -0.0009 | | -0.0007 |
| | | | | (0.0004) | (0.0014) | (0.0014) | | (0.0018) |
| ROE | | | | | 0.0024* | 0.0029** | | 0.0031 |
| | | | | | (0.0014) | (0.0014) | | (0.0019) |
| Liquidity | | | | | | 0.0018** | | 0.0025** |
| | | | | | | (0.0009) | | (0.0013) |
| GDP_GR | | | | | | | 0.0816*** | 0.1042*** |
| | | | | | | | (0.0363) | (0.0376) |
| Inflation | | | | | | | 0.0084 | 0.0149 |
| | | | | | | | (0.0128) | (0.0137) |
| Unemployment | | | | | | | -0.0259*** | -0.0246*** |
| | | | | | | | (0.0098) | (0.0103) |
| Adjusted $R^2$ | 0.072 | 0.076 | 0.0764 | 0.215 | 0.078 | 0.079 | 0.067 | 0.070 |
| No. of banks | 3220 | 3220 | 3220 | 3170 | 3169 | 3142 | 2999 | 2924 |
| No. of observations | 11277 | 11277 | 11275 | 11006 | 10999 | 10886 | 8547 | 8245 |

All regressions include fixed bank and time effects. Standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 6. Robustness checks

| | GL_GR | | ML_GR | | CL_GR | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *A. Monetary Policy* | | | | | | |
| NIRP-effect | -0.0721*** | -0.0655*** | -0.0382*** | -0.0252*** | -0.153*** | -0.1275*** |
| | (0.0037) | (0.0035) | (0.007) | (0.0075) | (0.0088) | (0.0093) |
| CB_GR | | 0.1074*** | | 0.0867*** | | 0.0406* |
| | | (0.0085) | | (0.0084) | | (0.2225) |
| M0_GR | 0.0005*** | | -0.0005*** | | -0.0006** | |
| | (0.0000) | | (0.0002) | | (0.0003) | |
| Adjusted $R^2$ | 0.283 | 0.284 | 0.298 | 0.286 | 0.0782 | 0.0734 |
| No. of banks | 6530 | 4874 | 2723 | 2583 | 3201 | 2913 |
| No. of observations | 22505 | 17565 | 9539 | 9268 | 10659 | 10335 |
| *B. Credit demand and the deposit rate* | | | | | | |
| NIRP-effect | -4.1836*** | -0.0158** | -3.2117*** | 0.0467*** | -1.9212*** | 0.0251 |
| | (0.0723) | (0.0069) | (0.0953) | (0.0113) | (0.2280) | (0.0316) |
| Loan_Demand | -5.4329*** | | -4.1674*** | | -2.3529*** | |
| | (0.0957) | | (0.1252) | | (0.3022) | |
| Deposit_Rate | | 0.0196*** | | 0.0291*** | | 0.0244*** |
| | | (0.0058) | | (0.0106) | | (0.0178) |
| Adjusted $R^2$ | 0.498 | 0.0742 | 0.314 | 0.0503 | 0.0423 | 0.034 |
| No. of banks | 7006 | 1501 | 4942 | 692 | 5546 | 1509 |
| No. of observations | 2695 | 4782 | 1752 | 2094 | 2147 | 529 |
| *C. NIRP and the EU* | | | | | | |
| NIRP-effect | -0.0267*** | | -0.0562*** | | 0.0268 | |
| | (0.0057) | | (0.0100) | | (0.0164) | |
| Adjusted $R^2$ | 0.31 | | 0.34 | | 0.07 | |
| No. of banks | 5008 | | 2282 | | 2122 | |
| No. of observations | 17978 | | 8264 | | 7558 | |
| *D. The counterfactual or "fake" NIRP* | | | | | | |
| NIRP-effect | 0.0205 | | 0.0628* | | -0.0335 | |
| | (0.0127) | | (0.0277) | | (0.0223) | |
| Adjusted $R^2$ | 0.01 | | 0.02 | | 0.01 | |
| No. of banks | 6204 | | 2520 | | 3423 | |
| No. of observations | 21425 | | 8925 | | 11289 | |

All regressions include fixed bank and time effects. Robust standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 7. NIRP and bank lending, bank capitalization, funding structure and business model

| | GL_GR | ML_GR | CL_GR |
|---|---|---|---|
| *A. Undercapitalized* | | | |
| NIRP-effect | -0.1444*** | -0.0483*** | -0.1817*** |
| | (0.0109) | (0.0215) | (0.0325) |
| Adjusted $R^2$ | 0.35 | 0.21 | 0.09 |
| No. of banks | 1291 | 499 | 677 |
| No. of observations | 2754 | 1057 | 1414 |
| *B. Well-capitalized* | | | |
| NIRP-effect | -0.0635*** | -0.0362*** | -0.1425*** |
| | (0.0038) | (0.0075) | (0.0096) |
| Adjusted $R^2$ | 0.33 | 0.32 | 0.24 |
| No. of banks | 6230 | 8676 | 3063 |
| No. of observations | 20493 | 2626 | 9863 |
| *C. Wholesale deposit-based* | | | |
| NIRP-effect | -0.0569*** | -0.0196 | -0.1069*** |
| | (0.0079) | (0.0152) | (0.0204) |
| Adjusted $R^2$ | 0.16 | 0.22 | 0.06 |
| No. of banks | 2148 | 534 | 704 |
| No. of observations | 6689 | 1482 | 1954 |
| *D. Retail deposit-based* | | | |
| NIRP-effect | -0.0763*** | -0.0467*** | -0.1684*** |
| | (0.0039) | (0.0081) | (0.0095) |
| Adjusted $R^2$ | 0.33 | 0.30 | 0.08 |
| No. of banks | 4999 | 2386 | 2728 |
| No. of observations | 16558 | 8251 | 9323 |
| *E. Fee-based* | | | |
| NIRP-effect | -0.0381*** | -0.0082 | -0.1577*** |
| | (0.0117) | (0.0337) | (0.0364) |
| Adjusted $R^2$ | 0.04 | 0.06 | 0.03 |
| No. of banks | 2063 | 327 | 582 |
| No. of observations | 4590 | 626 | 1178 |
| *F. Interest earnings-based* | | | |
| NIRP-effect | -0.0833*** | -0.4466*** | -0.1559*** |
| | (0.0037) | (0.0072) | (0.0089) |
| Adjusted $R^2$ | 0.40 | 0.32 | 0.09 |
| No. of banks | 5766 | 2624 | 3003 |
| No. of observations | 18657 | 9107 | 10099 |
| *G. Competitive markets* | | | |
| NIRP-effect | -0.9985*** | -0.0534*** | -0.1844** |
| | (0.0037) | (0.0079) | (0.0089) |
| Adjusted $R^2$ | 0.31 | 0.29 | 0.08 |
| No. of banks | 5191 | 2302 | 2716 |
| No. of observations | 17644 | 7837 | 9777 |
| *H. Concentrated markets* | | | |
| NIRP-effect | 0.02134*** | -0.0048 | 0.0239 |
| | (0.0070) | (0.0012) | (0.0234) |
| Adjusted $R^2$ | 0.19 | 0.31 | 0.08 |
| No. of banks | 1728 | 673 | 515 |
| No. of observations | 5603 | 1896 | 1500 |

All regressions include fixed bank and time effects. Robust standard errors in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.