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Euro area banks' market power, lending channel and stability: the effects of negative policy rates

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Abstract

This paper investigates to what extent the introduction of negative monetary policy rates altered the competitive behaviour in the euro area banking sector. Specifically, it analyses the effect that negative policy rates had on euro area banks' market power in comparison to banks that have not been subject to negative rates. The analysis, considering a sample of 4,223 banks over the period 2011–2018 and relying on a difference-in-differences methodology, finds that negative monetary policy rates led to an increase in euro area banks' market power. Furthermore, it shows that, during the negative interest rate policy period, change in banks' competitive behaviour affected the bank lending channel and discouraged banks from taking excessive risks.

KEYWORDS: NIRP, Lerner index, Bank lending channel, Bank Stability, DiD
JEL CLASSIFICATION: E44, E52, E58, G20, G21

Non-Technical Summary

In the euro area the low interest rate environment reached a watershed in 2014 when the ECB was the first major central bank to take its main policy rate into negative territory and set, after several reductions, the Deposit Facility rate (DF) at -0.50% in September 2019. Negative interest rate policies (NIRP) could lead to changes in the behaviour of banks in comparison to a positive interest rate environment.

In this paper, we investigate to what extent negative interest rates altered competitive conditions in the euro area banking sector. With this purpose, using a panel dataset of 4,223 banks from 28 countries for the period between 2011 and 2018 and employing a difference-in-differences (DiD) estimator, we examine the effects of NIRP on banks' market power. First, we study the impact of the introduction of the NIRP on the market power of banks incorporated in the euro area countries with respect to the market power of banks incorporated in countries that have not been subject to negative monetary policy rates. Second, we investigate the banks' features which influence how NIRP affects banks' market power. In addressing these questions, we use a sample of euro area banks, our treatment group, and non-euro area banks, our control group, and control for bank-specific and country characteristics. The analysis finds that NIRP led to an increase in the market power of euro area banks in comparison to banks which are located in countries that did not adopt the NIRP.

Furthermore, we also investigate how changes in market power affected lending behaviour and bank stability in the euro area after the introduction of the NIRP. More specifically, we explore two additional research questions, namely how the NIRP affects the relationship between banks' market power and the monetary policy transmission mechanism and how the NIRP affects the relationship between banks' market power and bank stability. We here employ a DiD approach on a sample of euro area banks to analyse the effect of NIRP on banks' lending behaviour and bank stability. We compare the lending behaviour and bank stability of euro area banks with different levels of market power before and after the ECB introduced its NIRP in 2014. On the one hand, we find evidence of the existence of the bank lending channel but also that increased market power during the NIRP period dampened monetary policy transmission. On the other hand, we find that after negative interest rates were introduced, banks with higher market power reduced their overall risk.

1 Introduction

To counter the severe recession and the deflationary pressures that arose during the Global Financial Crisis (GFC) and the sovereign debt crisis, policymakers launched an unprecedented accommodative monetary policy cycle (Boucinha and Burlon 2020). During this period, which lasted for about ten years, monetary policy rates reached the zero-lower bound (ZLB). In the euro area the low interest rate environment reached a watershed in 2014 when the ECB was the first major central bank to take its main policy rate into negative territory[1] and set, after several reductions, the Deposit Facility rate (DF) at -0.50% in September 2019.

It can be argued that negative interest rates can lead to changes in the behaviour of banks in comparison to a positive interest rate environment. A stream of literature shows that banks reshape their asset side flexibly when their margins are compressed by the negative interest rate policy (NIRP). In response to NIRP, banks adjust their sources of income (Altavilla, Boucinha and Peydro 2018), investment choices (Bubeck, Maddaloni and Peydro 2020) and lending decisions (Heider, Saidi and Schepens 2019). Behavioural changes could also affect the market power of banks, which in turn may have monetary policy and stability implications. For example, leveraging on the Rotemberg and Saloner (1986) model[2], Bagliano, Dalmazzo and Marini (2000) theoretically demonstrate how monetary policy tends to affect the competitive environment of the banking sector. When a monetary policy decision threatens banks' margins and accordingly their current and future profitability, banks tend to behave less aggressively as they have less to gain from undercutting their competitors. By contrast, banks tend to compete more aggressively when the loan market is buoyant. Therefore, Bagliano et al. (2000) argue that monetary policy can foster implicit collusion between banks. However, this is only an "implicit collusion" with no overt cooperation between the banks.

In this study, we investigate to what extent negative interest rates altered competitive conditions in the euro area banking sector. With this purpose, using a panel dataset of 4,223 banks from 28 countries for the period between 2011 and 2018 and employing a difference-in-differences (DiD) estimator, we examine the effects of NIRP on banks' market power. By using the Lerner index, which is considered a direct measure of market power and is defined as the difference between banks' marginal returns and marginal costs, the DiD approach allows to examine whether the NIRP led to a decline in competition in the euro area banking sector. In this context, we particularly investigate two research questions. First, we study the impact of the introduction of the NIRP on the market power of banks incorporated in the euro area countries with respect to the market power of banks incorporated in countries that have not been subject to negative monetary policy rates. Second, we investigate the banks' features which influence how NIRP affects banks' market power. In addressing these questions, we use a sample of euro

[1] On 5 June 2014, the ECB lowered the Main Refinancing Operation rate to 0.15% and the Deposit Facility rate to -0.10%. The latter is widely considered the main policy rate.

[2] Rotemberg and Saloner (1986) argue that implicitly colluding oligopolies tend to behave in a more competitive manner during times of high demand (economic boom), while periods of recession tend to generate greater microeconomic distortions.

area banks, our treatment group, and non-euro area banks, our control group, and control for bank-specific characteristics and macroeconomic variables that, in previous studies, were shown to have an impact on market power.

In the analysis, we find that NIRP led to an increase in the market power of euro area banks in comparison to banks which are located in countries that did not adopt the NIRP. This result is consistent with the findings of Bagliano et al. (2000). As the NIRP threatens banks' margins, euro area banks would indeed have an incentive to increase their market power by implicitly colluding and, thus, reducing competition in the banking sector[3].

Furthermore, we find that NIRP had a significant negative effect on both banks' marginal returns and marginal costs. However, the effect on marginal costs was more material leading to an increase in banks' mark-ups. This finding is consistent with empirical results of Gropp, Kok and Lichtenberger (2014) and Levieuge and Sahuc (2021) who provide evidence of the downward rigidity of bank lending rates. They argue that banks tend to adjust their lending rates more slowly and less completely to decreases in short-term market rates than to increases. This rigidity is amplified when policy rates are close to their effective lower bound or if banks' profitability deteriorates[4].

These results are coherent with a part of the literature which argues that banks featuring a "nonstandard profit function" are price-setters in the output market and price-takers in the input market and accordingly their interest rates on liabilities follow the policy rates closer than their interest rates on the assets. For example, Humphrey and Pulley (1997) assert that banks exploit their market power to choose output prices, so that they can differentiate output prices over time, across markets and customer groups; while recently Martinez-Miera and Repullo (2020) theoretically demonstrate that the intensity of the pass-through of policy rates to loan rates depends on the market power of banks. Moreover, Eggertsson, Juelsrud and Wold (2017) highlight a limited pass-through of changes in monetary policy rates to lending rates in a low interest rate environment and also assert that lending rates seem less sensitive to changes in monetary policy rates once the latter become negative. Furthermore, our result is also consistent with the recent literature which assesses the effects of the NIRP on banks' profitability. Indeed, looking at the output market, where banks are likely to be price setters, and, thus, focusing on the marginal returns' side, several studies provide evidence that when NIRP comes into effect banks tend to shift activities toward riskier lending Heider et al. (2019) and investment decisions[5] (Bubeck et al. 2020), tend to enhance fee-based services and start charging higher fees (Bottero, Minoiu, Peydro, Presbitero and Sette (2019); IMF (2017); Kok, Mirza, Móré and Pancaro (2016); Lopez, Rose and Spiegel (2020)) offsetting to some extent the negative impact of the low interest rates on the net interest income (Altavilla et al. (2018);

[3]However, the empirical analysis in this work does not investigate the transmission channel through which NIRP leads to a higher bank mark-up.

[4]The empirical literature (e.g. Bubeck et al. (2020) and Heider et al. (2019)) also advocates the hypothesis that there may be a zero-lower bound on deposit rates. See also Brunnermeier and Koby (2018).

[5]Bubeck et al. (2020) empirically demonstrate that when NIRP comes into force, the most affected banks tend to invest more in securities, especially in those yielding higher returns.

Molyneux, Reghezza and Xie (2019); Basten and Mariathasan (2018); Coeuré (2016)). Conversely, looking at the input market, where banks are price-takers, and, thus, focusing on the marginal costs' side, low interest rates were shown to lower funding costs for financial intermediaries (Martinez-Miera and Repullo 2020), and the NIRP was found to lower the cost of non-deposit funding (Heider et al. 2019). Overall, several studies show a significant decrease in banks' overall funding costs after 2014 (Brandão-Marques, Casiraghi, Gelos, Kamber and Meeks (2021); ECB (2020)) and an increase in banks' efficiency accompanied with a general reduction in costs (Avignone, Girardone, Pancaro, Pancotto and Reghezza (2022); ECB (2017)). This overall evidence is consistent with an increase in banks' mark-ups led by a more material decline in marginal costs than in marginal returns.

In this paper, we also investigate how changes in market power affected lending behaviour and bank stability in the euro area after the introduction of the NIRP. More specifically, we explore two additional research questions, namely how the NIRP affects the relationship between banks' market power and the monetary policy transmission mechanism and how the NIRP affects the relationship between banks' market power and bank stability. We here employ a DiD approach on a sample of euro area banks to analyse the effect of NIRP on banks' lending behaviour and bank stability. We compare the lending behaviour and bank stability of euro area banks with different levels of market power before and after the ECB introduced its NIRP in 2014. On the one hand, we find evidence of the existence of the bank lending channel but also that increased market power during the NIRP period dampened monetary policy transmission. On the other hand, we find that after negative interest rates were introduced, banks with higher market power reduced their overall risk. This latter result is in consistent with the "competition-fragility" view, which suggests that an increase (erosion) of market power and an increase (decrease) in mark-up would encourage banks to take less (excessive) risks.

To our knowledge, this work is the first paper to analyse how NIRP affects banks' market power. Furthermore, by analysing empirically in a novel way the influence of banks' market power on monetary policy transmission in a negative interest rate environment, we contribute to the existing literature studying the influence of monetary policy on the bank-lending channel (Borio and Gambacorta (2017); Salachas, Laopodis and Kouretas (2017)) and the impact of competition on the bank lending channel (Fungacova, Solanko and Weill (2014);Leroy (2014)). We also contribute to the literature that analyses bank stability by focusing on competition (Allen and Gale (2004); De Jonghe and Schepens (2016); Jimenez, Lopez and Saurina (2013)) and negative interest rates (Bubeck et al. (2020); Heider et al. (2019); IMF (2015)). More specifically, we contribute to this literature by studying the link between bank stability and competition in a context of negative interest rates. Our research differs from the existing studies in terms of methodology and sample coverage.

The article continues with the following structure. Section section 2 reviews the existing academic literature relevant for this study. Section section 3 depicts the evolution of competition in the euro area. Section section 4 describes the adopted empirical models, estimation strategy

and data. Section section 5 reports the empirical results and Section section 6 reports a range of robustness checks which confirm the baseline findings. Finally, Section section 7 concludes.

2 Literature review

2.1 Banking competition

The study of competitive conditions in the financial sector is of considerable interest to academics and policy makers owing to the presence of significant links between competition, credit behaviour and the soundness of the financial system.

The academic literature on banking competition is divided in two main strands, namely structural and non-structural. The first strand draws inspiration from Bain (1956), which was the developer of the Structure-Conduct-Performance (SCP) model. The SCP approach employs concentration measures to determine the competitive conduct, thus the market structure would provide information relating to banks' pricing power. The underlying idea is that in a more concentrated environment it is easier to collude, and as a result banks can generate high returns. However, Berger, Demirgüç-Kunt, Levine and Haubrich (2004) point out that researchers found several weaknesses in the SCP approach. For example, Demsetz (1973) and Peltzman (1977) argue that a higher market share may not be due to a greater market power, but it could rather be a by-product of greater efficiency, leading to higher profits and consequently to a higher market share (Efficient Structure paradigm). Furthermore, Hannan (1991) and Berger and Hannan (1998) argue that banks in a highly concentrated market follow a "quiet life", accordingly they can charge higher prices but have no incentive to minimize costs. In other words, in contrast to the SCP paradigm, higher market concentration does not necessarily generate higher profits.

Due to the aforementioned weaknesses, a more recent strand of literature employs a non-structural approach[6] for studying the dynamics of banking competition. By analysing the pricing behaviour of banks, this approach seeks to directly detect bank conduct. Measures such as Lerner index (Lerner 1934), the H-statistc (Panzar and Rosse 1987) or the more recent Boone indicator (Boone 2008), allow direct measurement of bank competition.

In this analysis, we rely on the Lerner index as our benchmark yardstick to measure banks' market power. The Lerner index can be estimated at bank level and is not influenced by the composition of the considered banks' sample (Bikker and Spierdijk 2017)[7]. However, in the

[6] It is also known as the New Empirical Industrial Organization (NEIO).

[7] It is worth noting that competition varies by market segment and country, and the mix of lending and non-traditional activities is particularly heterogeneous among the banks in the sample. Different products are very likely to have a different elasticity of demand, and banks might face a very heterogeneous competitive pressure across different markets. To address these weaknesses, in spirit of Anginer, Demirgüç-Kunt and Zhu (2014), the standard translog function used to compute the Lerner index is calculated separately for each country in order to capture the heterogeneity between markets, moreover, the function includes a banking specialization dummy that captures the effects induced by non-traditional activities and heterogeneous business lines. A detailed explanation of the calculation and components of the Lerner index can be found in Appendix B.

analysis, we also check the robustness of our results employing the H-statistic which measures the elasticity of banks revenues relative to input prices. Finally, the Boone indicator, which also measures the degree of market competition, is calculated as the elasticity of banks' profits with respect to their marginal costs. The rationale behind the indicator is that higher profits are achieved by more-efficient banks.

We rely mainly on the Lerner index as the existing literature highlights several weaknesses related to the other two indicators. The H-statistic is influenced by the composition of the considered sample and would need auxiliary information, such as the market concentration index (Bikker, Shaffer and Spierdijk (2012); Shaffer and Spierdijk (2015)), for a more accurate calculation. The Boone indicator cannot be interpreted correctly if we do not control for economies / diseconomies of scale[8] and its value is also affected by the composition of the banks in the sample (Van Leuvensteijn, Kok Sørensen, Bikker and van Rixtel 2013).

Against this backdrop, our article intends to contribute to the non-structural approach literature assessing the impact of NIRP on banks' market power.

2.2 Banking competition and the bank lending channel

As banking competition may influence how monetary policy is transmitted to bank lending, it is essential to take bank market power into consideration for an exhaustive assessment of the bank lending channel during the NIRP period.

A stream of literature provides evidence of the existence of the bank lending channel and that the latter can be affected by bank specific characteristics and bank market structure (e.g., Bernanke and Blinder (1988); Bernanke (1995); Kashyap and Stein (2000); Ehrmann, Gambacorta, Martinez-Pages, Sevestre and Worms (2003); Gambacorta (2005); Kishan and Opiela (2006); Altunbas, Gambacorta and Marques-Ibanez (2009); Boivin, Kiley and Mishkin (2010); Disyatat (2011). Moreover, a rich literature study the relationship between banking competition and the transmission of monetary policy through the bank lending channel (Kashyap and Stein (1997); Hellmann, Murdock and Stiglitz (2000); Repullo (2004); Adams and Amel (2005); Yang and Shao (2016)).

Recent studies provide evidence that bank market power is an important element that affects the pass-through of monetary policy through the banking system to the supply of loans (e.g. Payne and Waters (2008); Van Leuvensteijn et al. (2013) focusing on the pricing of loans (i.e. interest rate pass-through); and Scharfstein and Sunderam (2016); Drechsler, Savov and Schnabl (2017) focusing on the volume of loans). Fungacova et al. (2014), using a large panel of banks from 12 eurozone countries over the period 2002–2010, analyse the reaction of loan supply to monetary policy actions depending on the degree of bank competition. They find that greater bank competition fosters the transmission of monetary policy via the bank lending channel. Therefore, wide variations in the level of bank market power may lead to asymmetric effects

[8] Indeed, a change in the Boone indicator may not be related to a change in the level of competition but to a shift in the cost function due to technological change.

of the single monetary policy. Leroy (2014) obtains similar results by analysing the entire euro area as he points out that market power reduces the effectiveness of monetary policy. However, Fungacova et al. (2014) and Leroy (2014) obtain different results as regards the role of competition in distressed periods. Fungacova et al. (2014) find no evidence on the role of bank competition in the transmission of monetary policy during the crisis[9]. By contrast, Leroy (2014) suggests that during the GFC the negative effect of market power on monetary effectiveness has remained. Also, in light of the aforementioned dichotomy related to the crisis period, we deem necessary to investigate the transmission of monetary policy via the lending channel during the negative policy rate period.

2.3 Banking competition and bank stability

The literature provides many insights concerning the nature of the relationship between bank competition and bank stability, however, the evidence remains mixed. On the one hand, Allen and Gale (2004) support the "competition-fragility" view, which suggests that more competition would lead to an erosion of market power and decreased profit margins, and thereby would encourage banks to take excessive risks. On the other hand, Boyd and De Nicolo (2005) support the "competition-stability" view, which implies that more intense competition leads to lower interest rates for borrowers, thus reducing borrowers' defaults and asset portfolio risk. This would suggest that banks become riskier as competition decreases. However, Berger, Klapper and Turk-Ariss (2009) show that the two views could coexist because banks' overall risks can be kept in check if banks protect their charter-value through risk-mitigating measures, while Demirgüç-Kunt and Detragiache (1998) sustain that increasing bank competition erodes charter-value and reduces this incentive towards prudence, therefore lower franchise values and lower market power are likely to lead to increased fragility. Using a widely used measure of bank soundness (Z-score) and market power (Lerner index), De Jonghe and Schepens (2016) provide evidence that bank market power and bank stability are positively correlated in the European banking sector over the period 2000–2014. In the light of this latest study, it is important to investigate whether the positive relationship between bank soundness and market power persists in a context of negative rates.

3 Evolution of competition in the euro area

There is a rich literature, which has analysed the evolution of competition in the European banking sector, providing a comprehensive picture of its dynamics before and after the GFC. Although, a number of studies argue that the deregulation process, coupled with the strengthening of European banking integration, should lead to a marked increase in competition, empirical studies have shown mixed results for the EU banking markets. Casu and Girardone (2009),

[9] Altunbas, Gambacorta and Marques-Ibanez (2012) also find no impact of competition on bank behaviour in crisis times, i.e. competition does not seem to influence bank risk.

analysing the effect of EU deregulation and competition policies on the competitive conditions of the main European banking markets over the period 2000-2005, find important differences across countries, suggesting that significant barriers to the integration of the EU retail banking markets may exist. On the contrary, Weill (2013) finds some evidence of banking integration taking place across EU countries and the convergence of the levels of banking competition in the period 2002-2010. Specifically, Weill (2013), using the Lerner index, finds that the Lerner index increased before the financial crisis (2002-2006) while it decreased during the crisis (2006-2010) though still hovering above the 2002 average level. De Jonghe and Schepens (2016), consistently with Weill (2013), find a decrease in competition in the period 2000-14 for a broad sample of EU banks. However, they find that the financial crisis had a deep detrimental effect on competition, with market power increasing sharply between 2008 and 2014 reaching the highest value of the period in 2014. This development likely reflected, among other things, the significant consolidation of banking sectors in jurisdictions particularly affected by the euro area sovereign debt crisis (such as Spain, Italy, Ireland, Greece and Portugal). Fernández de Guevara and Maudos (2017) further validate the previous results, since they find that overall competition has deteriorated over the period 2002-13. Also, a recent ECB (2017) report suggests that banks' market power has increased in comparison with the crisis and pre-crisis periods for the euro area as a whole and in most Member States.[10]

However, all the most recent papers analysed the evolution of competition in the European banking sector in the pre-NIRP period. Thus, our paper intends to contribute to the literature that studies the evolution of competitive conditions in the banking sector in the euro area in light of the introduction of negative monetary policy rates. Furthermore, intends to assess how this evolution affected the lending channel and bank stability in the NIRP period.

4 Empirical model, estimation strategy and data

4.1 Empirical Model and Estimation Strategy

4.1.1 Market power

We adopt a DiD approach to examine the impact of NIRP on market power. Several studies use this approach to study the effects of NIRP (Eggertsson et al. (2017);Heider et al. (2019);Bubeck et al. (2020)). This approach (see for example Molyneux et al. (2019) and Lopez et al. (2020)) allows us to use a panel data set up for comparing a treated group of banks (NIRP-affected) with a control group (NIRP-unaffected).

Our baseline specification is the following:

[10]This report suggests that this evolution has been driven mainly by a fall in the marginal costs of providing banking services, due to efficiency gains and lower costs of bank funding. By contrast, prices have remained broadly unchanged resulting in a somewhat reduced banking competition.

$$Y_{i,j,t} = \alpha + \beta_1 \ (\text{Treated}_{i,j} * Post_{j,t}) + \beta' \ \text{K}_{i,j,t} + \gamma_i + \phi_t + \epsilon_{i,j,t} \quad (1)$$

Where $\text{Y}_{\text{i,j,t}}$ represents the Lerner index[11] for bank i in country j at time t. However, we also develop two further econometric specifications in which $\text{Y}_{\text{i,j,t}}$ represents the logarithm of the Lerner index's components $P_{\text{TAi,t}}$ and $MC_{\text{TAi,t}}$, i.e. respectively output prices and marginal costs. $\text{Treated}_{\text{i,j}}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise. $\text{Post}_{\text{j,t}}$ 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.[12]. β_1 is our coefficient of interest, which represents the average difference in the Lerner index between banks that have been affected by NIRP and banks that have been not. $\text{K}_{\text{i,j}}$ denotes our vector of control variables, namely bank specific characteristics and macroeconomic variables. More specifically, as bank specific variables we include total customer deposits-to-total assets (Funding Structure), gross loans-to-total assets (Asset Structure), liquid asset to total assets (Liquidity), equity-to-total assets (Leverage) and the logarithm of the bank total asset (Size). As macroeconomic control variables, we include real GDP growth rate (GDP), CPI inflation rate (Inflation), the ratio central bank assets to GDP (Central bank assets), the Deposit Facility rate (Monetary Policy) [13], and Chinn-Ito index of capital account openness (Financial openness) [14]. Finally, we also include banks fixed effects (γ) and time fixed effects (ϕ)[15]. We use robust standard errors to control for heteroskedasticity and cross-sectional dependence (Bertrand, Duflo and Mullainathan (2004);Donald and Lang (2007);Petersen (2009)).

Using a DiD approach, our dependent variable, the Lerner index, must satisfy the parallel trend assumption, which is crucial to identify the causal effect of the treatment (Bertrand et al. (2004);Imbens and Wooldridge (2009)). Figure 3 shows the mean of the Lerner index for both the treated and control banks for the period between 2011 to 2014. In this pre-treatment period, correlation among the euro area and non-euro area group is 0.84, indicating that, before the treatment, changes over time in banking competition were nearly similar in the treatment and control group, providing evidence that the parallel trend assumption holds.

Table 1 corroborates the finding of Figure 3. The first two rows of columns [1] – [2] of table 1 show the average level of the Lerner index for the control and treatment groups in the pre-

[11] A detailed explanation of the calculation and components of the Lerner index can be found in Appendix B.

[12] The treated countries in our sample introduced the NIRP on 5 June 2014, so the dummy $\text{Post}_{\text{j,t}}$ takes the value 1 from 2015 onward. For robustness, we re-estimate the model with the treatment timing redefined, to see how the estimation changes if the dummy $\text{Post}_{\text{j,t}}$ takes value 1 in 2014 instead of 2015.

[13] We also estimate a different specification (available upon request) with main refinancing operations (MRO) rate rates instead of DF rates to account for central bank monetary policies. The findings are consistent with the baseline results obtained in the paper.

[14] A detailed explanation of bank and country specific characteristics can be found in Appendix B.

[15] Moreover, in an additional specification (available upon request) we further tighten our econometric specification replacing year and country fixed effects by including country*time fixed effects to account for time varying country-level unobservable heterogeneity. The results obtained relying on this specification are consistent with the main results reported in the paper.

and post-NIRP period. The last row of columns [1] and [2] highlights that in the NIRP period both groups experienced a statistically significant increase in their market power, however, the increase in market power was larger for the treatment group. The bottom row of column [3] shows the unconditional difference in differences effect, which is positive and statistically significant. The magnitude and significance of the latter coefficient shows that banks that have been affected by NIRP on average increased their market power more than banks located in countries which did not adopt the NIRP. In summary, table 1 finds preliminary evidence for our hypothesis that the NIRP led to an increase in euro area banks' market power.

Columns [4] and [5] of table 1 further document that the Lerner index has been on average increasing both in the pre- and in the post- NIRP periods for both the treatment and control group. Moreover, column [6] of table 1 shows that the difference between the treatment and control group in the growth of the Lerner index in the pre-NIRP period is not significantly different from zero. We take this as further evidence that the parallel trend assumption holds. As mentioned above, it also shows that the growth in market power significantly steepened its slope for NIRP affected banks after the introduction of the negative interest rate policy.

4.1.2 Bank lending channel

In order to assess whether changes in banks' competitive behaviour when entering a NIRP environment has implications for the monetary policy transmission mechanism, we adopt a different identification strategy, which exploits only euro area banks and compares the lending behaviour of high-market power and low-market power banks in the pre- and post-NIRP periods.[16] Relying on the following specification we study the impact of bank competition on the transmission of monetary policy via the lending channel:

$$Y_{i,j,t} = \alpha + \beta_1(Lerner_{i,j,t} * MP_{j,t} * Post_{j,t}) + \beta_2(Lerner_{i,j,t} * MP_{j,t}) + \beta_3(Lerner_{i,j,t} * Post_{j,t}) + \beta_4 Lerner_{i,j,t} + \beta_5 MP_{j,t} + \beta_6 Post_{j,t} + \gamma_i + \phi_t + \epsilon_{i,j,t} \quad (2)$$

$Y_{i,j,t}$ denotes our measure of lending[17], specifically, it is $\Delta(\text{Loans})_{i,t}$ or $\Delta(\text{Loans})_{i,t\ \text{NORM}}$ of bank i in country j at time t. MP is the Deposit Facility rate in country j at time t. The specification of Eq. 2 is in line with the one used by Heider et al. (2019) and Bubeck et al. (2020), in which the variable of interest is the triple interaction. Our coefficient of interest is thus β_1, as it allows to test whether the impact of the policy rate in the NIRP period was significantly different for banks with a greater market power. A statistically significant positive coefficient would provide evidence of the impact of bank competition on the bank lending channel and show

[16] We carry out a correlation analysis and a visual inspection as well as we perform the T-test for differences in means of the slope of high-market power and low-market power banks in the pre-NIRP period. All these tests (available on request) validate the parallel test assumption. Therefore, the lending behaviour of high-market and low-market power banks followed a similar trend in the pre-NIRP period.

[17] A detailed explanation of the calculation of our measures of lending can be found in Appendix B.

that banks with a higher level of market power are less sensitive to changes in the monetary policy rate during the NIRP period. $\beta_5$tests the presence of the bank lending channel and β_2 allows to examine the role of bank competition in affecting the bank lending channel.

4.1.3 Bank stability

It is also important to shed light on the potential effects of the increase in market power during the NIRP period on bank stability. Accordingly, using the sample of euro area banks, we estimate a further specification[18] with the aim of investigating the link between bank market power and bank stability:

$$Y_{i,j,t} = \alpha + \beta_1(Lerner_{i,j,t} \times Post_{j,t}) + \beta' K_{i,j,t} + \gamma_i + \phi_t + \epsilon_{i,j,t} \quad (3)$$

$Y_{i,j,t}$ denotes banks' soundness[19] measured by the Z-score and ROR_{ROA} of bank i in country j at time t. $K_{i,j}$ denotes our vector of bank specific characteristics. β_1 is our coefficient of interest, which represents the average impact of banks' market power on banks' soundness for NIRP-affected banks.

4.2 Data

In this analysis, we rely on yearly data for the period between 2011 and 2018 extracted from several sources. Bank balance sheet information is sourced from Moody's BankFocus (Bureau Van Dijk) and SNL Financial (SP Global Market Intelligence), whilst macroeconomic variables are retrieved from World Development Indicators (World Bank) and Statistical Data Warehouse (European Central Bank). The dataset consists of 19 euro area countries (Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain) and 9 non-euro area countries (Bulgaria, Canada, Croatia, the Czech Republic, Iceland, Poland, Romania, the United Kingdom and the United States of America).[20] Given that BankFocus and SNL comprise financial statement data that can either be consolidated or unconsolidated, we include in our dataset the data that are either unconsolidated or consolidated but without an unconsolidated subsidiary, in order to avoid the inclusion of duplicate observations. The final sample consists of 2,876 banks in the euro area (treatment group) and 1,347 non-euro area banks (control group). All bank-specific characteristics are winsorized at the 1% and 99% level to smooth the influence

[18] As in the previous section, we also here perform the T-test for differences in means of the slope of high-market power and low-market power banks in the pre-NIRP period, as well as carry out correlation and a visual inspection. All these tests (available on request) validate the parallel test assumption. Therefore, the bank stability of high-market and low-market power banks followed a similar trend in the pre-NIRP period.

[19] A detailed explanation of our measures of bank stability can be found in Appendix B.

[20] Investigating the effect of NIRP on bank margins and profitability in Europe, Molyneux et al. (2019) use a similar DiD control group. Lopez et al. (2020) also use a similar sample to investigate the effects of the NIRP on bank performance.

of outliers. The cross-correlation matrix, which shows that our control variables are not highly correlated can be found in Table A.1. Table A.2 provides a detailed description of the used variables and their sources. Descriptive statistics are displayed in Table A.3, where we can observe that euro area banks increased their market power by 20 percent after the introduction of NIRP, as the Lerner index reached 0.24 from 0.20, while in the meantime no-NIRP affected banks increased their Lerner index by about 8 percent, from 0.24 to 0.26. Furthermore Figure A.1, which depicts the Lerner index distributions for the treatment and control groups in the pre-NIRP and NIRP periods, confirms the descriptive evidence exhibited in Table A1 and shows a more marked increase in market power after the introduction of the NIRP for euro area banks than for banks which were not subject to this policy. This result suggests that the euro area banking sectors featured a more significant decline in competition than the non-euro area banking sectors considered in this analysis.

Furthermore Figure 1 shows the evolution of bank market power for the treatment and control group, as measured by the indexed version of the average Lerner index, over the sample period. Figure 1 shows that banks' market power has been generally increasing for both groups during the sample period. However, after the introduction of the NIRP in 2014 the evolution of banks' market power trend of the treatment and the control group has significantly decoupled as market power increased at a faster pace for banks established in countries which adopted the NIRP. Figure 2 shows the evolution of the determinants of the Lerner Index over the sample period for both the treatment and the control groups. As regards the costs, it can be observed that the price of borrowed funds (Chart A), the price of labour (Chart B) and the price of physical capital (Chart C) are generally declining for both groups of banks. Relevant exception is the price of borrowed funds for the control group which after 2014 is increasing. As regards the revenues, Figure 2 shows a decrease in banks' net interest income (Chart D) in NIRP countries which is to some extent compensated by an increase in euro area banks' net fees and commissions (Chart E). Overall, in the aftermath of 2014 euro area banks showed less pronounced reduction in revenues than in costs relative to non-euro area banks. These dynamics are consistent with the higher level of market power of euro area banks in the aftermath of the NIRP.

5 Empirical results

In this section, we report the results of our regression analysis that i) evaluates the impact of NIRP and bank specific characteristics on euro area banks' market power, ii) assesses the impact of competition on euro area banks' lending channel during the NIRP period and finally iii) estimates the relationship between banks' market power and banks' financial stability during the NIRP period.

5.1 Baseline results

By employing the Lerner index as dependent variable, Table 2 shows the empirical results obtained from the estimation of Eq. 1 which allows to assess the effect of NIRP on banks' market power. The table is structured in 5 columns. Column 1 contains the results for the regression including only the interaction between the post dummy and the treated dummy, while column 2 reports the results for the regression including the interaction, bank and time fixed effects. In columns 3 and 4, we add bank-specific variables while keeping both fixed effects. Column 5 shows the results of the regression which includes bank specific variables, macroeconomic variables, bank and time fixed effects. To answer our question, we are particularly interested in the magnitude, sign and statistical significance of the estimated coefficient (β_1) of the interaction term which represents the average difference between the Lerner index of banks located in countries whose policy rate has ventured into negative territory and those located in countries which have not adopted NIRP. This effect is indicated in Table 2 as "NIRP-effect".

Our results, as expected, show that the coefficient on the NIRP-effect is positive and statistically significant in every specification, suggesting that euro area banks increased their mark-up after the implementation of the NIRP in comparison to banks located in countries which did not adopt the NIRP. More specifically, according to our baseline regression in column 5, the adoption of the NIRP led to an increase in the Lerner index by 1.6 bps. This implies that the introduction of the NIRP led to an increase in the average banks' market power of about 8%. This effect is rather significant also when put in light of the overall 20% increase recorded by the Lerner index between the pre-NIRP and the post-NIRP period.

Our results are robust to different specifications, the NIRP-effect is positive and statistically significant in all estimated models reported in Table 2. In columns 3, 4 and 5, we can observe that several bank specific characteristics are statistically significant. We find a positive relationship between banks' asset structure and Lerner index, in particular, an increase in the share of customer loans by 10 percentage points leads on average to an increase in the Lerner index of about 0.5 bps. This result means that banks with a larger exposure to the retail market have a higher market power. The liquid asset ratio is negatively correlated with market power. A 10 percentage points increase in liquidity reduces the Lerner index by about 0.6 bps. This confirms our expectations, as banks would typically be price takers in the markets for liquid assets and hence banks with a relatively higher concentration of liquid assets on their balance sheet overall has lower market power. Bank capitalisation is found to have a significant impact on market power. Specifically, we find that an increase in banks' equity-to-total asset ratio of 10 percentage points induces an increase in the Lerner index by about 1.3 bps on average. There is also a positive link between size and market power, a 100 bps increase in size generates an increase in the Lerner index of around 2.7 percentage , indicating that bank size is an important source of market power. Column 4 reports the results by adding the size-squared variable. The coefficient of the latter is negative and statistically significant, which means that the positive relationship between market power and bank size is not linear. In other words, there seems to

be declining marginal market power returns for increasing bank size. Finally, column 5 reports the results when we include macroeconomic control variables. The NIRP-effect is still positive and significant, while the bank-specific variables confirm previous results. Inflation is positively related to the Lerner index, i.e. an increase in inflation of 1 percentage point leads to an increase in the Lerner index of about 0.5 bps. The size of the central bank's balance sheet is negative related to banks' market power. An increase in the size of the central bank's balance sheet by 10 percentage points causes the Lerner index to decrease by about 2 bps. Therefore, central banks' asset purchases, via their effect on the yield curve, tend to compress banks' mark-up. The estimated coefficient of the monetary policy rate is negative and significant confirming our hypothesis. A monetary policy tightening of 100 bps is associated with a decrease in the Lerner index by 1.9 bps. An increase in the policy rates makes bank loans less attractive to firms. Therefore, total lending shrinks and banks optimally lower the mark-ups they apply on loans to mitigate the effect of lower loan demand (Scharfstein and Sunderam 2016). Finally, the negative coefficient of the Chinn-Ito index suggests that financial barriers favour the market power of banks.

Although the empirical analysis does not investigate the transmission channel through which NIRP leads to a higher bank mark-up, a possible interpretation could be that when interest rates enter into a negative territory and banks' margins are threatened, euro area banks change their behaviour by implicitly colluding and thereby increasing their market power[21].
Moreover, Table 3 shows the empirical findings obtained from the estimation of Eq. 1 in which the dependent variables are the logarithm of the output prices (columns [1], [3] and [5]) and the logarithm of the marginal costs (columns [2], [4] and [6]). The results show that output prices and marginal costs of euro area banks decreased after the introduction of the NIRP in comparison to no-NIRP affected banks. However, Table 3 depicts that this percentage reduction is deeper for marginal costs than output prices. In particular this difference is more marked when we control for bank and country-specific characteristics. In summary, the latter finding suggests that the recent increase in market power is driven by a more marked reduction in costs than in returns for euro area banks.

5.2 Bank lending channel

Table 4 reports the results obtained from the estimation of Eq. 2 which allows to assess the impact of bank competition on the transmission of monetary policy via the lending channel.

Our results show that the estimated coefficient of the monetary policy rate (β_5) is negative and statistically significant suggesting that a decrease (increase) in the monetary policy rate leads to an increase (decrease) in loan growth. Furthermore, we find that our coefficient of

[21] Banks' implementations of negative rates on deposits differed across countries. In some countries, negative rates were charged on retail deposits more easily, whereas in others this was more cumbersome due to explicit or implicit country-specific legal constraints. In this context, it is worth acknowledging that the NIRP might have exerted more pressure on the margins of the banks whose deposit rates have been floored at ZLB. Therefore, such banks may have had greater incentives to increase their market power.

interest, β_1, which is the coefficient of the triple interaction between the Lerner index, the monetary policy rate and the dummy variable NIRP, is positive and significant. The significance of the estimated coefficient of the interaction term shows that the impact of a monetary policy easing (tightening) on loan growth in the NIRP period was significantly different for banks with a different level of market power. The positive sign of the coefficient, which is the opposite of the sign of the estimated coefficient of the monetary policy rate, indicates that a higher market power during the NIRP period had a somewhat dampening effect on the transmission of monetary policy. The coefficient of the interaction term between the deposit facility rate and the Lerner index, (β_2), which allows us to examine the role of bank competition in affecting the bank lending channel the overall sample period, is not statistically significant. This result is in line with Fungacova et al. (2014), who find that bank competition does not significantly affect the transmission of monetary policy after the GFC. Borio and Gambacorta (2017) also find no evidence of the existence of the bank lending channel in a low interest rate environment by considering the period 2009-14. In summary, our result for β_2 is consistent with the existing literature on the role of banks' market power in affecting monetary transmission via the lending channel in the pre-NIRP period. However, our result for β_1 provides new insights on the role on competition in affecting monetary policy transmission via the lending channel during the NIRP period.

The aforementioned results hold for two different specifications of the dependent variable, i.e. both when we use the loan growth rate and the normalised loan growth rate.

5.3 Bank stability

Table 5 reports the results obtained from the estimation of Eq. 3 which allows to assess the effects of competition on bank stability.

The estimated coefficient of the interaction term between the Lerner index and the dummy variable NIRP, (β_1), is positive and significant. This indicates that banks with a higher level of Lerner index have reduced their overall risks after 2014 as a higher Z-score implies that a bank is more distant from default. The estimated coefficient of the interaction term shows that in the aftermath of the introduction of a NIRP an increase in the in the Lerner index of 10 bps led to 1.5 percentage increase in the Z-score (column [1]). This result is validated by the similar results reported in columns 2 and 4 where the dependent variable of the regression is the ROR_{ROA}.

Our results are in line with the "competition-fragility" view (Allen and Gale 2004), which suggests that a higher level of market power discourage banks to take excessive risks. Similarly to De Jonghe and Schepens (2016), who find a positive relationship between bank market power and bank stability over the period 2000–2014, we provide empirical evidence that European banks with a higher level of market power decreased their overall risk in the aftermath of the introduction of the NIRP, thus promoting the overall stability of the euro area banking system.

6 Robustness checks

In this section, we provide evidence that our results hold for a range of robustness checks.

6.1 Quantile regression

Studies using standard panel data techniques may fail to capture the potential non-linear effects of bank-specific characteristics. Therefore, we estimate a quantile panel model to examine the non-linear effects of bank specific variables on market power. We follow the approach proposed by Machado and Santos Silva (2019), whose set up also allows quantile-variant fixed effects:

$$Q_{\mathrm{Y}}(\tau|K_{\mathrm{I,j,t}}) = (\alpha(i) + \delta_{\mathrm{i}} q(\tau)) + \beta_1(Treated_{\mathrm{i,j}} \times Post_{\mathrm{j,t}}) + K_{\mathrm{i,j,t}}{}'\beta + K_{\mathrm{i,j,t}}{}'\gamma q(\tau) \qquad (4)$$

The variable $\mathrm{Y_{i,j,t}}$ is the Lerner index, while τ is the τ^{th} quantile of $\mathrm{Y_{i,j,t}}$ and $\alpha(i)+\delta_{\mathrm{i}} q(\tau)$ are the quantile-τ fixed effect for bank i. $\mathrm{K_{i,j,t}}$ denotes our vector of bank and country characteristics. $\beta_1(\mathrm{Treated_{i,j}} \times Post_{\mathrm{j,t}})$ is the interaction term between the NIRP dummy, which takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, and the Post dummy which takes the value 1 after the period that country j at time t decided to implement NIRP and 0 before that period.

Table 6 reports the results of the quantile regression aimed at capturing the potential non-linear effects of bank-specific and country characteristics on market power. It shows the empirical results obtained from Eq. 4 and is structured in 5 columns. The columns contain the estimated results for the median, 10^{th}, 30^{th}, 70^{th} and 90^{th} percentiles, respectively. Our results show that the coefficient of NIRP effect is positive and statistically significant in each specification, suggesting that the increase in the Lerner index of European banks after the implementation of the NIRP is not a phenomenon linked to a specific level of market power. However, in term of significance levels the extreme deciles, namely 10^{th} and 90^{th}, are relatively less significant. [22] Also the impact of NIRP decreases to some extent as the level of the Lerner index increases indicating some negligible non-linearity in the relation between the Lerner index and the NIRP. By analysing the bank-specific variables, funding structure is only statistically significant at 5% level on the median; while Asset structure has only a significant impact on the 70^{th} percentile and the median. Liquidity is less significant in the lowest decile while it is insignificant in the highest decile. Size is the only bank-specific variable statistically significant for each percentile. For what concerns the macroeconomic variables a difference in terms of significance level is found only for some variables in the lower deciles and for Chinn-Ito index. Although the impact of some variables is not statistically significant in the lower deciles and the interaction term shows differences in terms of magnitude, the results of quantile regressions confirm the previous results and exclude too marked non-linear effects.

[22] Albeit they are statistically significant at 10% level.

In summary, NIRP has increased the market power of European banks regardless of their original level of market power.

6.2 Redefine dummy post

Highlighting that treated countries in our sample introduced NIRP on 5 June 2014 and that we assume the dummy Post j,t to take the value 1 from 2015 onward, in Table 7 we re-estimate the model with the treatment timing redefined to see how the estimation changes if the dummy Post j,t takes value 1 in 2014 instead of 2015. This further test is needed to investigate whether the empirical results are influenced by the assumption on the timing of the treatment. Panel A (column 1) shows that the interaction dummy (NIRP-effect) is still positive and statistically significant, which is confirmatory of the previous results.

6.3 Placebo test

In Table 7 we also want to test if the results of our DiD estimation might be driven by other events occurred before our sample period. Specifically, we investigate whether similar results can be observed in 2012, year in which the Deposit Facility rate reached 0.00%. To rule out this hypothesis we create a fictitious post dummy starting in 2012. The interaction term is not statistically significant; therefore Panel B (Column 2) rejects this hypothesis and confirms that the market power increments in the euro area only tend to kick in with the NIRP introduction.

6.4 Window period

Furthermore, we want to rule out the hypothesis that the results of our DiD estimation might be driven by the selected sample period or that it is purely a long-term phenomenon. Table 7 (Panel C) reports the result of our DiD baseline estimation calculated in a narrower time period. Keeping the sample symmetry, we shrink the time period to four years, with the new sample period covering 2013 to 2016. The interaction variable is still significant, then Panel C (Column 3) rejects the time period bias and the long-term phenomenon hypothesis. This test is confirmatory of the NIRP effect, which also holds in the short-term period.

6.5 H-statistic

We test the robustness of our results employing a different definition of the dependent variable, by using the H-statistic ratio as an alternative market power measure in the baseline equation [1]. The H-statistic is a widely used measure of competition; it is based on the Panzar and Rosse (1987) methodology. It belongs to that strain of literature attributable to the non-structural approach. It is a direct measure of bank competition, which captures the elasticity of bank interest revenues to input prices. The economic insight is that in a perfect competitive environment, an increase in input prices will be followed by an increase in both marginal costs and total revenues by the same extent, therefore the H-statistic will be equal to 1. Differently,

in a monopolistic context, an increase in input prices will be followed by an increase in marginal costs, then the decision to decrease the output followed by a decline in total revenues, therefore the H-statistic will be equal to or less than 0. In the middle, monopolistic competition varies between 0 and 1. In summary, the H-statistic ranges between ∞ (monopoly) and 1 (perfect competition).

We use the opposite sign of the H-statistic aimed at improving the readability of the results, therefore, similarly to the Lerner index, a higher value denotes a greater bank mark-up.

Table 7 outlines the result of the new regression, which uses the negative H-statistic as dependent variable in Eq 1. Panel D (column 4) shows that the interaction dummy "NIRP-effect" is positive and statistically significant, which means that euro-area banks increased their market power when official rates went into negative territory. This result is confirmatory of our previous results, confirming the validity of the baseline model.

6.6 Propensity Score Matching

One concern with our baseline estimates could be that the results are not driven by the effect of the treatment itself but by systematic differences between banks in the control and treated groups. We address this concern by obtaining propensity score matching (PSM) estimates (Rosenbaum and Rubin (1983)), which addresses the possible sample selection bias and takes into consideration time constant unobserved effects. We select a subsample of control (non-treated) banks that are as close as possible a match for the sample of treated countries based on a set of observable characteristics. Specifically, among various algorithms that can be used to match treated and non-treated observations, we implement nearest neighbour(s), 5-nearest neighbours and kernel matching (Heckman, Ichimura and Todd (1998)).

Outcomes are confirmatory of the previous results, as Table 8 shows that the Average Treatment Effect on the Treated (ATT) is positive and statistically significant for Lerner index.

6.7 Excluding CEE banks

It could be argued that the competitive behaviour of banks located in the Central and Eastern European (CEE) countries could be affected by the behaviour of the several euro area banking groups which own subsidiaries and branches in these countries and whose response to NIRP may spillover to pricing policies at the group level. Also, it can also not be excluded that the monetary policy decisions of the CEE central banks could be influenced by the monetary policy decisions of the ECB. To rule out possible concerns of this type, we assess the impact of the NIRP on euro area banks' market power as we do in our baseline analysis but excluding CEE banks from the control group. Therefore, in this robustness test the treatment group is made up of euro area banks while the control group is made up of banks established in Canada, the United Kingdom and the United States of America. Table 9 (Panel A) shows the result of this new DiD estimation. The interaction term is statistically significant and the estimated coefficient is positive as in the baseline analysis. Therefore, the results reported in Table 9

(Panel A) further reject possible concerns about sample selection and confirm that the increase in the market power of euro area banks with respect to the market power of banks in the control group is related to the NIRP introduction.

6.8 A widely used identification strategy

To further avoid other concerns related to the selection of the control group and further validate our results, we assess the impact of NIRP on euro area banks' market power exploiting an identification strategy similar to the one introduced by Heider et al. (2019). More specifically, we scrutinise if NIRP led to a higher market power for high-deposit banks than for low-deposit banks. The rationale of the identification introduced by Heider et al. (2019) is that high-deposit banks have been more affected by the NIRP than low-deposit ones. Indeed, as banks are generally reluctant to pass on negative rates to depositors, high-deposit banks experienced higher funding costs relative to low-deposit banks since the NIRP was introduced as the former have a larger deposit base.

Using a sample composed of euro area banks only, the new econometric specification differs from our baseline specification reported in Eq. 1 for the definition of the interaction dummy "NIRP-effect". The new NIRP-effect variable is the interaction between the dummy Deposit ratio and the dummy Post. Deposit ratio_i is a dummy variable that takes the value 1 if the average ratio of deposits over total assets in 2013 of bank i was above the median and 0 otherwise, while Post_t is a dummy variable that takes the value 1 after the introduction of the NIRP and 0 before. The results of this DiD estimation are reported in Table 9 (Panel B). The results show that the interaction variable is positive and statistically significant suggesting that euro area high-deposit banks, i.e. the banks which were more significantly affected by NIRP, adapted their pricing behaviour in a way that led to an increase of their market power more than low-deposit banks as policy rates fell into negative territory.

6.9 Efficiency

To assess if the increase in bank market power is due to an increase in bank efficiency rather than to the NIRP effect we augment our baseline regression by including a widely used measure of bank efficiency, namely the cost to income ratio which is defined as bank operating cost divided by operating income. As reported in Table 10 (panel A), the estimated coefficient of the cost to income ratio is negative and statistically significant indicating that a higher level of efficiency increases banks' mark-up. However, despite this finding, our NIRP interaction dummy is still positive and statistically significant indicating that the increase in the market power of the banks in our treatment group is related to the introduction of NIRP.

6.10 State aid

To assess whether the substantial state aids granted to the banking sector in Europe after the European sovereign crisis had a significant impact on banking competition, we include in our benchmark regression, as an additional control, a country-level variable, defined as approved state aids to the financial sector over GDP. This variable is sourced from the European Commission's database and considers both state aids provided both for banks' recapitalizations and guarantees. As this variable is available only for member states of the European Union, we perform the regression on a sub-sample of countries. In this context, euro area banks are the treatment group while the banks from other European countries are the control group.

The estimated results, reported in Table 10 in panel B, show that our variable for state aid to the financial sector is negative and significant (albeit at 10% level). Therefore, the substantial state aids granted to the banking sector have not increased market power of European banks. This result is coherent with Laser (2021) who advocates the hypothesis that euro area competition policy has succeeded in preventing rescued banks from abusing public funds to distort competition in their favour. However, our variable of interest, the interaction between the Lerner index and the NIRP dummy, is still positive and statistically significant, demonstrating that the increased market power of our treatment group is not due to confounding effects stemming from the provision of state aid to the financial sector after the sovereign crisis.

6.11 Credit demand

It could be argued that the findings regarding bank market power could be driven by differences in credit demand across countries. However, in line with the existing literature, in our baseline regression we control for demand by including country specific controls, such as GDP and inflation, which reflect economic conditions and are highly related to credit demand (Borio and Gambacorta (2017); Carlson, Shan and Warusawitharana (2013). However, to rule out any concern related to the possible role of credit demand, we follow a similar approach of Altavilla, Boucinha, Holton and Ongena (2021). More specifically, we exploit the ECB and FED bank lending surveys, which provide information on credit supply and demand, to identify country level credit demand. The variable credit demand is defined as the net percentage of credit demand, which is given by the difference between the share of banks reporting an increase in loan demand and the share of banks reporting a decline. We include the aforementioned variable in our baseline regression and estimate this extended specification for a sub-sample of countries. In this context, euro area banks are the treatment group and US banks are the control group. As reported in Table 10, the NIRP interaction dummy is still positive and significant indicating that our model is correctly specified, and that higher banks' market power is related to the introduction of NIRP. It is noteworthy that the estimated coefficient of the credit demand variable is negative and statistically significant. This result is coherent with Rotemberg and Saloner (1986) who argue that implicitly colluding oligopolies tend to behave in a more competitive manner during times of high demand, so market power and credit demand

are negatively correlated.

7 Conclusions

In the last decade, central banks launched an unprecedentedly accommodative monetary policy cycle. In this context, several central banks located in advanced countries led their policy rates into negative territory. In this study, we contribute to the ongoing literature on this topic addressing the impact that NIRP has on banking competition in the euro area.

When entering into a negative interest rate territory, it can be argued that the behaviour of banks will change in comparison to a positive interest rate environment. The results of this work support the idea that behavioural changes due to the negative interest rate environment affect the market power of banks, which in turn has monetary policy and bank stability implications.

By analysing a sample of 4,223 banks over the period 2011–2018 and adopting a difference-in-differences methodology, we provide empirical evidence that NIRP increased market power of the affected banks. Even if our empirical analysis does not shed light on the specific mechanisms by which NIRP leads to this outcome, one possibility is that, as the NIRP threatens banks' margins, euro area banks react by increasing their market power by implicitly colluding and, thus, reducing competition in the banking sector.

Existing studies provide empirical evidence that the global financial crisis had a deep detrimental effect on competition, with worsening banking competition peaking in 2014. A stream of literature argues that the lowest level of competition was a consequence of a consolidation of the banking sectors in jurisdictions particularly affected by the global financial crisis and the euro area sovereign debt crisis. However, our analysis shows that this trend has still persisted in the post-NIRP period, as we observe that euro area banks have increased their market power by 20 percent since the introduction of NIRP. Our analysis also shows that about 40% of this increase is due to the introduction of the NIRP.

Furthermore, we find that, in a negative rate environment, bank competition has implications for monetary policy transmission and bank stability. In the euro area, during the NIRP period, the increased market power dampened the transmission of monetary policy and at the same time the higher level of market power discouraged banks from taking excessive risks.

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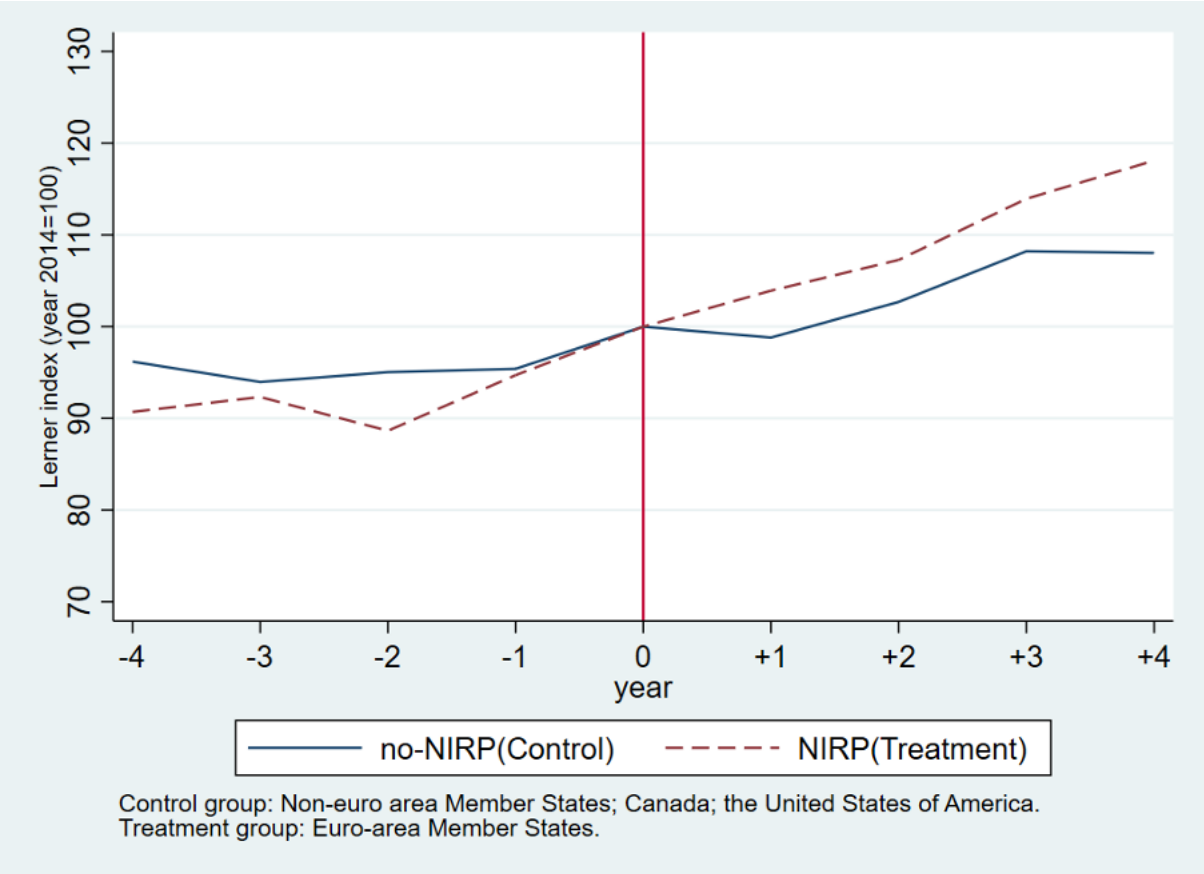
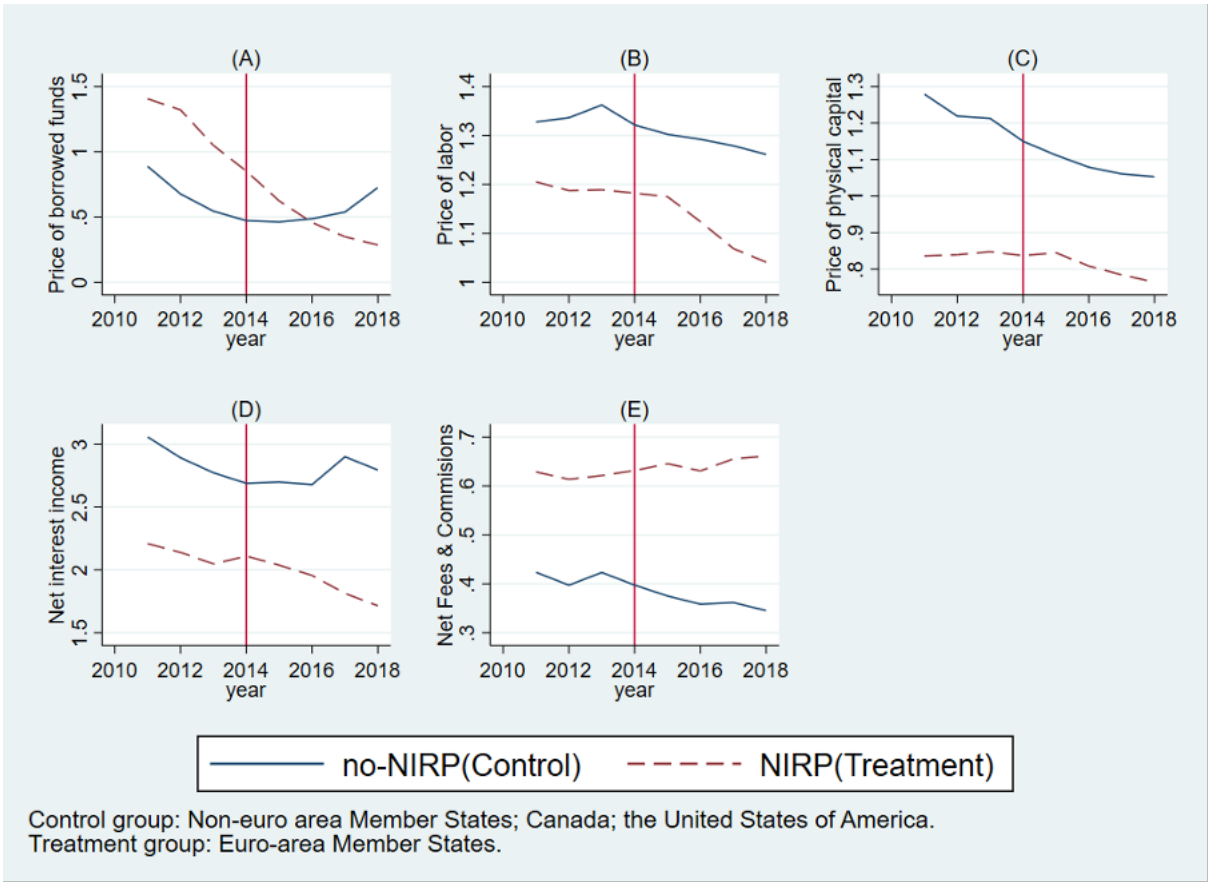
Results

Figure 1. Lerner index evolution pre- and post-NIRP period.



This figure shows the yearly evolution of Lerner index (year 2014 = 100) for the treated banks (red dashed line) and non-treated banks (blue line). We calculate an index for each bank and plot the mean index for NIRP and no-NIRP affected banks. The vertical red line indicates the introduction of NIRP (year 0 = 2014).

Figure 2. Lerner index determinants pre- (2011-2014) and post- NIRP period (2015-2018).



This figure shows the average variable value for the treated banks (red dashed line) and non-treated banks (blue line) from 2011 to 2018. Variables represent bank revenues and costs, specifically three banking input prices, i.e. the price of borrowed funds (A), the price of labour (B), and the price of physical capital (C), and interest (D) and non-interest income (E).

Figure 3. Parallel trend assumption pre-NIRP period (2011-2014).

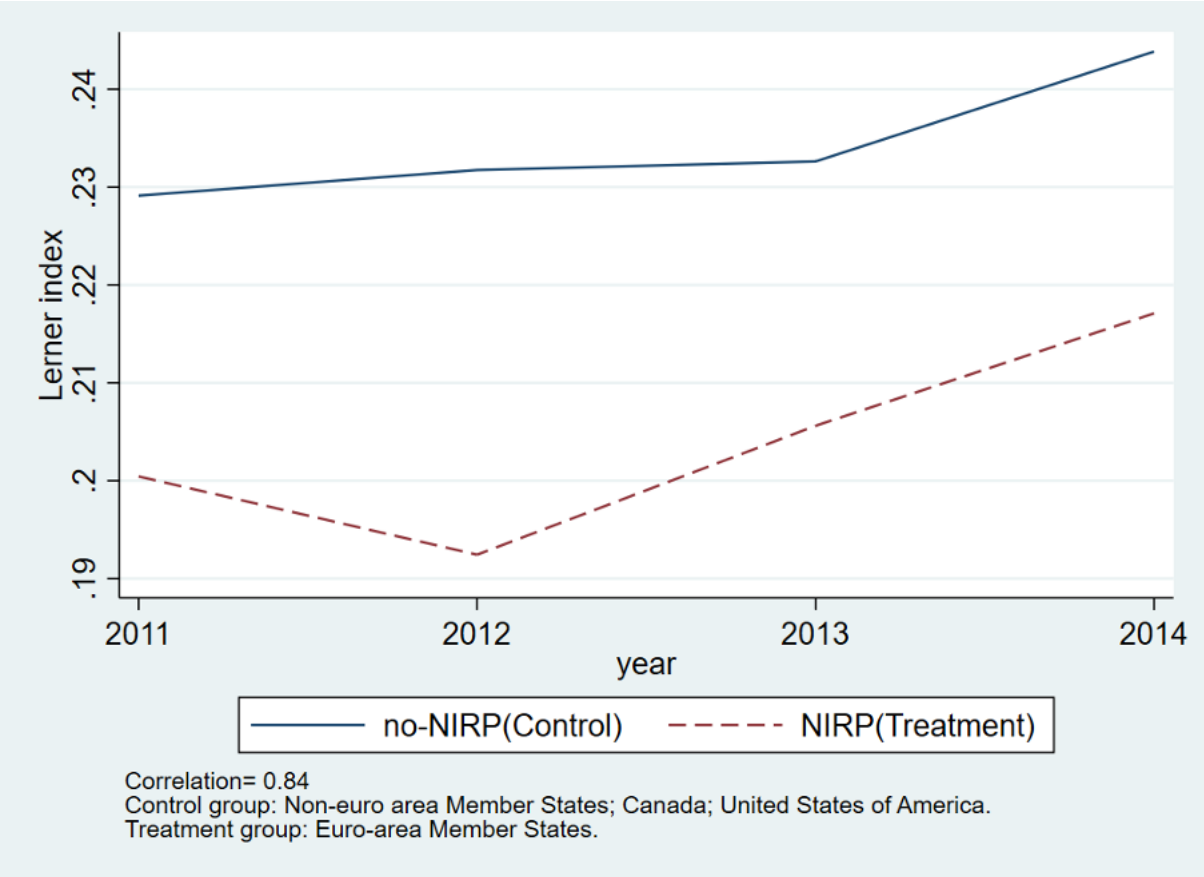


Figure 3 shows the yearly mean of Lerner index for the treated banks (red dashed line) and non-treated banks (blue line) from 2011 to 2014. In the pre-treatment period, correlation among the treatment and control group is 0.84, indicating that the parallel trend assumption holds.

Table 1: T-test for differences in means

Variable: Lerner index	Level			First Difference		
	[1] **Control**	[2] **Treatment**	[3] **Diff (T-C)**	[4] **Control**	[5] **Treatment**	[6] **Diff (T-C)**
Pre-NIRP	0.235	0.204	-0.030***	0.005	0.005	0.000
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Post-NIRP	0.255	0.24	-0.014***	0.006	0.009	0.003***
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Diff (Post-Pre)	0.020***	0.036***	0.016***	0.001	0.004***	0.003*
	(0.003)	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)

Notes: Columns [1],[2],[4], and [5] show means of Lerner index for the control group and treatment group before and after the NIRP, specifically [1] and [2] for the level whereas [4] and [5] for the first difference. The bottom row shows the difference in means between the pre and post NIRP period and stars indicate the t-test for differences in means. Columns [3] and [6] show the difference in means between the two groups within the pre or post NIRP period and stars the t-test for differences in means. The bottom row in columns [3] and [6] show the difference in differences and t-test. Standard deviations are reported in parentheses. Stars indicate significance level: *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 2: The effect of NIRP on Lerner index

Variables	(1) Baseline Lerner index	(2) +Fixed Effects Lerner index	(3) +Bank specific Var Lerner index	(4) +Bank specific Var Lerner index	(5) +Macro Var Lerner index
NIRP-effect	0.0344***	0.0140***	0.0180***	0.0153***	0.0159***
	(0.0014)	(0.0025)	(0.0030)	(0.0035)	(0.0033)
Funding Structure			-0.0002	-0.0002	-0.0005***
			(0.0002)	(0.0002)	(0.0002)
Asset structure			0.0005***	0.0005***	0.0006***
			(0.0001)	(0.0001)	(0.0002)
Liquidity			-0.0006***	-0.0006***	-0.0008***
			(0.0002)	(0.0001)	(0.0002)
Leverage			0.0013***	0.0015***	0.0011**
			(0.0005)	(0.0005)	(0.0005)
Size			0.0266***	0.0780***	0.0374***
			(0.0055)	(0.0229)	(0.0057)
Size-squared				-0.0034**	
				(0.0016)	
GDP					0.0012
					(0.0008)
Inflation					0.0054***
					(0.0016)
Central bank assets					-0.0023***
					(0.0003)
MP(Deposit Facility)					-0.0188***
					(0.0033)
Chinn-Ito index					-0.0677**
					(0.0291)
Observations	29,789	29,789	27,160	27,160	23,220
R-squared	0.00452	0.1023	0.1016	0.1035	0.1051
Number of Banks	4,101	4,101	4,011	4,011	3,933
Bank Fixed Effects	NO	YES	YES	YES	YES
Time Fixed Effects	NO	YES	YES	YES	YES
Cluster(id)	YES	YES	YES	YES	YES

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness. Robust standard errors in parentheses, *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 3: The effect of NIRP on output prices and marginal costs

	[1]	[2]	[3]	[4]	[5]	[6]
	Baseline+FE		+Bank specific Var		+Macro Var	
Variables	ln(P)	ln(Mc)	ln(P)	ln(Mc)	ln(P)	ln(Mc)
NIRP-effect	**-0.1455*** **	**-0.1564*** **	**-0.1652*** **	**-0.2049*** **	**-0.0831*** **	**-0.1135*** **
	(0.0051)	(0.0061)	(0.0068)	(0.0092)	(0.0081)	(0.0102)
Funding Structure			0.0010**	0.0017***	0.0015***	0.0020***
			(0.0004)	(0.0005)	(0.0004)	(0.0005)
Asset structure			0.0018**	0.0005	0.0015**	0.0001
			(0.0008)	(0.0004)	(0.0007)	(0.0003)
Liquidity			-0.0030***	-0.0018***	-0.0025***	-0.0012**
			(0.0007)	(0.0006)	(0.0006)	(0.0005)
Leverage			0.0081***	0.0076***	0.0079***	0.0073***
			(0.0019)	(0.0023)	(0.0019)	(0.0023)
Size			-0.1028***	-0.1739***	-0.1199***	-0.2035***
			(0.0153)	(0.0221)	(0.0161)	(0.0231)
GDP					-0.0113***	-0.0137***
					(0.0017)	(0.0026)
Inflation					-0.0026	-0.0088*
					(0.0031)	(0.0045)
Central bank assets					-0.0035***	0.0007
					(0.0007)	(0.0009)
MP(Deposit Facility)					0.1142***	0.1509***
					(0.0097)	(0.0096)
Chinn-Ito index					-0.0523***	-0.0183
					(0.0197)	(0.0240)
Observations	23,220	23,220	23,220	23,220	23,220	23,220
R-squared	0.5229	0.4959	0.5810	0.5402	0.6178	0.5730
Number of Banks	3,933	3,933	3,933	3,933	3,933	3,933
Bank Fixed Effects	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES
Cluster(id)	YES	YES	YES	YES	YES	YES

Note: Ln(P) is the logarithm of the output prices while Ln(MC) is the logarithm of the marginal costs. NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness. Robust standard errors in parentheses, *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 4: The impact of bank competition on the transmission of monetary policy

Variables	(1) $\Delta(Loans)_{i,t}$	(2) $\Delta(Loans)_{i,tNORM}$
Lerner index*MP*NIRP	**0.4353*** **	**0.4742*** **
	(0.1682)	(0.1635)
Lerner index*MP	0.0776	0.0779
	(0.0939)	(0.0939)
Lerner index*NIRP	0.1633***	0.1753***
	(0.0604)	(0.0592)
NIRP*MP	-0.9838***	-1.0515***
	(0.1814)	(0.1775)
NIRP	-0.3808***	-0.4061***
	(0.0677)	(0.0663)
Lerner index	0.0344	0.0322
	(0.0298)	(0.0297)
MP(Deposit Facility)	-0.0825**	-0.0829**
	(0.0387)	(0.0387)
Observations	18,694	18,406
R-squared	0.0125	0.0135
Number of Banks	2,778	2,697
Bank Fixed Effects	YES	YES
Time Fixed Effects	YES	YES
Cluster(id)	YES	YES

Note: $\Delta(Loans)_{i,t}$ is the annual growth rate of loans in period t of bank i. $\Delta(Loans)_{i,tNORM}$ is the annual growth rate of loans in period t of bank i normalized by the average annual growth rate of the same bank during the four years prior to the NIRP. Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP 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. MP is the Deposit Facility rate. Robust standard errors in parentheses, *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 5: The impact of bank competition on financial stability

Variables	(1) Z-score	(2) ROR_{ROA}	(3) Z-score	(4) ROR_{ROA}
Lerner index*NIRP	**0.1467*** **	**0.2699*** **	**0.1195*** **	**0.2218*** **
	(0.0241)	(0.0678)	(0.0255)	(0.0729)
Funding Structure	0.0001	0.0024	0.0004	-0.0007
	(0.0005)	(0.0017)	(0.0006)	(0.0020)
Asset structure	0.0000	-0.0027**	0.0001	-0.0032*
	(0.0004)	(0.0013)	(0.0005)	(0.0018)
Liquidity	-0.0003	-0.0010	-0.0012**	-0.0008
	(0.0004)	(0.0012)	(0.0005)	(0.0015)
Leverage	0.0566***	0.0398***	0.0556***	0.0488***
	(0.0046)	(0.0073)	(0.0053)	(0.0104)
Size	-0.0888***	0.0496	-0.0847***	0.1253**
	(0.0217)	(0.0489)	(0.0244)	(0.0603)
GDP			0.0026	0.0431***
			(0.0024)	(0.0115)
Inflation			0.0027	0.0368
			(0.0054)	(0.0227)
Central bank assets to GDP (%)			-0.0069***	-0.0010
			(0.0019)	(0.0090)
Chinn-Ito index			0.1103***	0.1545
			(0.0375)	(0.1825)
Observations	17,755	17,745	15,063	15,054
R-squared	0.5853	0.0447	0.5783	0.0651
Number of Banks	2,744	2,744	2,688	2,688
Bank Fixed Effects	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES
Cluster(id)	YES	YES	YES	YES

Note: Z-score indicates the distance from insolvency of bank i in country j at time t. ROR_{ROA} indicates the risk-adjusted ROA, that is ROA divided by its volatility. Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP 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. Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness. Robust standard errors in parentheses, *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 6: The effect of NIRP on Lerner index using quantile regression method

Variables	(1) Median Lerner index	(2) 10th Lerner index	(3) 30th Lerner index	(4) 70th Lerner index	(5) 90th Lerner index
NIRP-effect	**0.0157*** **	**0.0197***	**0.0176** **	**0.0140*** **	**0.0123***
	(0.0050)	(0.0118)	(0.0077)	(0.0050)	(0.0073)
Funding Structure	-0.0005*	-0.0006	-0.0005	-0.0004	-0.0004
	(0.0003)	(0.0006)	(0.0004)	(0.0003)	(0.0004)
Asset structure	0.0006**	0.0007	0.0006	0.0006**	0.0005
	(0.0003)	(0.0006)	(0.0004)	(0.0003)	(0.0004)
Liquidity	-0.0008***	-0.0009	-0.0009**	-0.0008***	-0.0008*
	(0.0003)	(0.0007)	(0.0004)	(0.0003)	(0.0004)
Leverage	0.0011	0.0010	0.0011	0.0011	0.0012
	(0.0008)	(0.0020)	(0.0013)	(0.0008)	(0.0012)
Size	0.0371***	0.0439**	0.0403***	0.0343***	0.0314***
	(0.0077)	(0.0180)	(0.0117)	(0.0076)	(0.0112)
GDP	0.0013	0.0004	0.0008	0.0016	0.0020
	(0.0015)	(0.0035)	(0.0023)	(0.0015)	(0.0022)
Inflation	0.0056*	0.0027	0.0042	0.0068**	0.0080*
	(0.0031)	(0.0072)	(0.0047)	(0.0031)	(0.0045)
Central bank assets	-0.0024***	-0.0022*	-0.0023***	-0.0024***	-0.0025***
	(0.0005)	(0.0012)	(0.0008)	(0.0005)	(0.0008)
MP(Deposit Facility)	-0.0190***	-0.0140	-0.0166**	-0.0211***	-0.0232***
	(0.0051)	(0.0120)	(0.0078)	(0.0051)	(0.0075)
Chinn-Ito index	-0.0676	-0.0695	-0.0685	-0.0668	-0.0659
	(0.0501)	(0.1175)	(0.0766)	(0.0497)	(0.0730)
Observations	23,220	23,220	23,220	23,220	23,220
Bank Fixed Effects	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness. Robust standard errors in parentheses, *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 7: Robustness checks

	Panel A. Dummy 2014	Panel B. Fictitious NIRP
	(1)	(2)
Variables	Lerner index	Lerner index
NIRP-effect	**0.0084****	**0.0004**
	(0.0033)	(0.0033)
Observations	23,220	27,160
R-squared	0.1034	0.0970
Number of Banks	3,933	4,011
Banks Fixed Effects	YES	YES
Time Fixed Effects	YES	YES
Cluster(id)	YES	YES
	Panel C. Shorter window period	Panel D. Competition
	(3)	(4)
Variables	Lerner index	Negative H-statistic
NIRP-effect	**0.0164*****	**0.1527*****
	(0.0036)	(0.0054)
Observations	14,685	26,016
R-squared	0.0738	0.2382
Number of Banks	3,845	4,223
Banks Fixed Effects	YES	YES
Time Fixed Effects	YES	YES
Cluster(id)	YES	YES

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). The H-statistic is a measure of competition, which ranges between ∞ (monopoly) and 1 (perfect competition). NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Panel A displays difference-in-differences regression results of Lerner index in which post dummy is set in 2014. Panel B displays difference-in-differences regression results of Lerner index with "fictitious" NIRP dummy in 2012. Panel C displays difference-in-differences regression results of Lerner index within a shorter window period, that is from 2013 to 2016. Panel D displays difference-in-differences regression results of the negative H-statistic. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.
The coefficients for control variables are suppressed for brevity.

Table 8: PSM estimates - Average treatment effect on the treated

Variable: Lerner index					
Sample	Treated	Control	Difference	S.E.	T-stat
Nearest neighbour	0.022328	0.007097	**0.01523****	0.006236	2.44
On support obs.	1461	986			
5-Nearest neighbour	0.022328	0.005295	**0.017032*****	0.005348	3.18
On support obs.	1461	986			
Kernel	0.022328	0.006346	**0.015982*****	0.005096	3.14
On support obs.	1461	986			

Note: The table reports the average treatment effect on the treated obtained from the propensity score matching estimates calculated as the difference in Lerner index between the treated and the matched control groups according to three different matching algorithms. Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.

Table 9: Sample robustness checks

	Panel A. Full sample except CEE banks	Panel B. High vs Low-deposit EA banks
	(1)	(2)
Variables	Lerner index	Lerner index
NIRP-effect	**0.0229*** **	**0.0088*** **
	(0.0035)	(0.0028)
Observations	22,501	15,526
R-squared	0.1016	0.1175
Number of Banks	3,807	2,720
Banks Fixed Effects	YES	YES
Time Fixed Effects	YES	YES
Cluster(id)	YES	YES

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP-effect is an interaction variable, which differs between Panel A and Panel B. Panel A displays difference-in-differences regression results of Lerner index whose control group is made up of Canada, the United Kingdom and the United States of America. NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Panel B displays difference-in-differences regression results of Lerner index of euro area banks. NIRP-effect is the interaction dummy Deposit ratio*Post, $Depositratio_{ij}$ is a dummy variable that takes the value 1 if the average ratio of deposits over total assets in 2013 of bank i has been above the median and 0 otherwise, while $Post_{jt}$ 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. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. Significance levels: *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.
The coefficients for control variables are suppressed for brevity.

Table 10: Market robustness checks

	Panel A. Efficiency	Panel B. State Aid	Panel C. Loan Demand
	(1)	(2)	(3)
Variables	Lerner index	Lerner index	Lerner index
NIRP-effect	0.0155***	0.0179**	0.0180***
	(0.0031)	(0.0072)	(0.0039)
Cost to income	-0.0033***		
	(0.0002)		
State Aid		-0.0003*	
		(0.0002)	
Loan demand			-0.0001***
			(0.0001)
Observations	23.22	16.798	19.758
R-squared	0.1034	0.1215	0.1161
Number of Banks	3.933	2.952	3.332
Banks Fixed Effects	YES	YES	YES
Time Fixed Effects	YES	YES	YES
Cluster(id)	YES	YES	YES

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). NIRP-effect is an interaction variable, which differs between Panel A and Panel B. Panel A displays difference-in-differences regression results of Lerner index whose control group is made up of Canada, the United Kingdom and the United States of America. NIRP-effect is the interaction dummy $Treated_{ij}$ * $Post_{jt}$; where $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise, while $Post_{jt}$ 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. Panel B displays difference-in-differences regression results of Lerner index of euro area banks. NIRP-effect is the interaction dummy Deposit ratio*Post, Deposit ratio_{ij} is a dummy variable that takes the value 1 if the average ratio of deposits over total assets in 2013 of bank i has been above the median and 0 otherwise, while $Post_{jt}$ 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. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. Significance levels: *, **, *** indicate statistical significance of 1%, 5% and 10% respectively.
The coefficients for control variables are suppressed for brevity.

Appendix A

Figure A1. Market power distribution at the bank level.

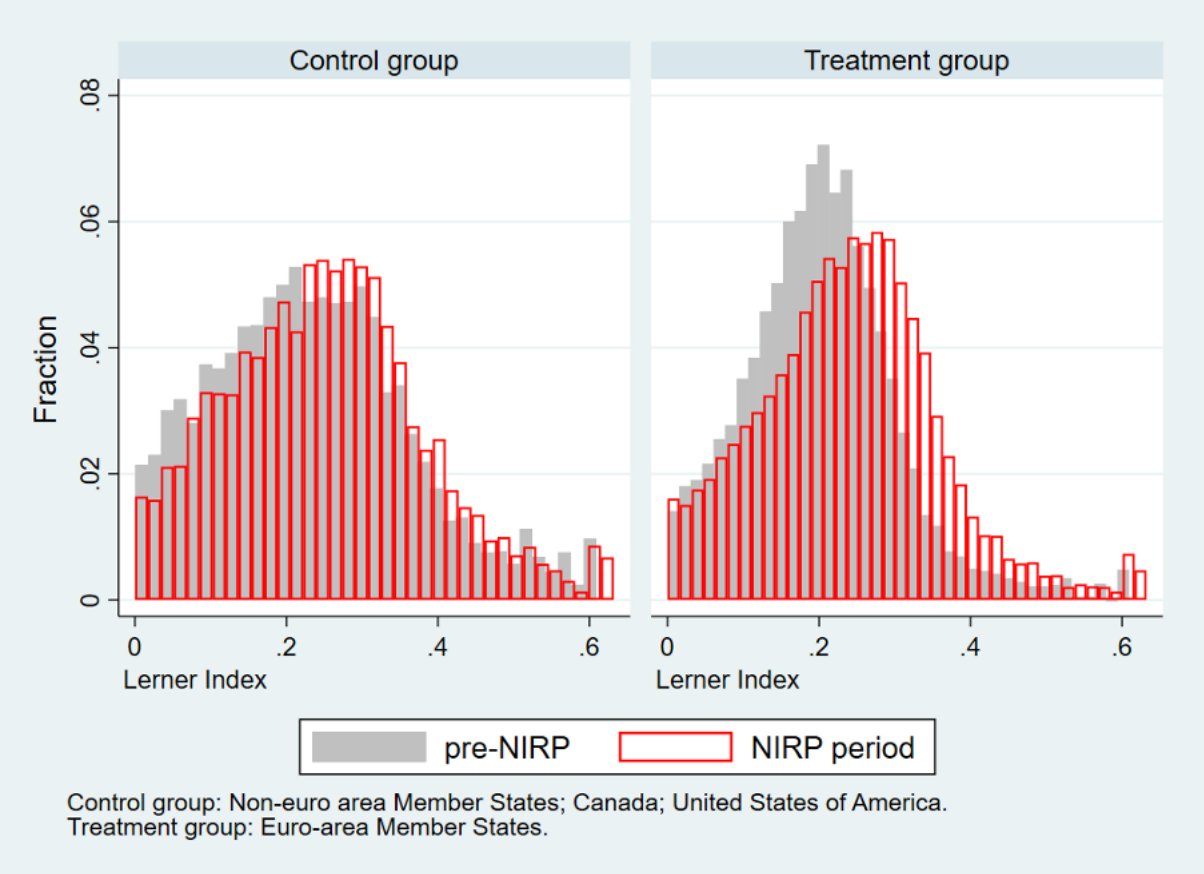


Figure A1 shows the market power distribution. For the Control group, even though there is a small shift, it appears similar for both pre-NIRP and NIRP period. Differently, for the Treatment group, we can observe a marked shift toward the right side, which means that market power is increased after the introduction of the NIRP.

Table A1: Cross-correlation matrix of control variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Funding Structure	1									
(2) Asset structure	0.22	1								
(3) Liquidity	-0.055	-0.338	1							
(4) Leverage	-0.186	-0.018	0.134	1						
(5) Size	-0.172	0.033	-0.013	-0.221	1					
(6) GDP	0.096	0.004	-0.066	0.021	0.102	1				
(7) Inflation	0.022	0.007	0.047	-0.02	0.017	-0.18	1			
(8) Central bank assets	0.025	0.051	0.055	0.045	0.261	0.231	0.007	1		
(9) MP(Deposit Facility)	0.003	0.045	0.041	0.008	0.165	0.027	0.418	0.191	1	
(10) Chinn-Ito index	-0.009	-0.015	-0.013	-0.003	0.046	-0.069	0.047	0.152	-0.35	1

Note: Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness.

Table A2: This table displays variables, units, description and source of the variables used in the sample

Variables	Units	Description	Source
Bank market power	(Bank level)		
Lerner index	index	A measure of banks' market power, which captures the extent to which banks can increase the marginal returns beyond the marginal costs. It ranges between 1 (monopoly) and 0 (perfect competition).	Author calculation, data BankFocus & SNL Financial
Bank lending channel	(Bank level)		
Loans growth	percentage	Widely used to assess the bank lending channel. It is the annual growth rate of the gross loans.	BankFocus & SNL Financial
Loans growth - normalized	percentage	The normalized loans growth rate is the annual growth rate of loans normalized by the average annual growth rate during the four years prior to the NIRP introduction.	BankFocus & SNL Financial
Bank stability	(Bank level)		
Z-score	ratio	A measure of banks' soundness. It is the sum of ROA plus the ratio of equity-to-total assets, all divided by the standard deviation of ROA at country level. A high Z-score represents a greater level of bank stability.	Author calculation, data BankFocus & SNL Financial
ROR_{ROA}	ratio	Risk-adjusted profitability, that is ROA divided by its volatility. A higher value of the ROR represents more bank stability.	Author calculation, data BankFocus & SNL Financial
Bank balance sheet	(Bank level)		
Funding Structure	ratio	It gauges the bank dependence on deposit funding. It is the ratio total customer deposits-to-total assets.	BankFocus & SNL Financial
Asset structure	ratio	Widely considered an indicator of banking specialization. It is the ratio gross loans to total assets.	BankFocus & SNL Financial
Liquidity	ratio	Considers the liquidity of the bank's asset side. It is the ratio liquid asset to total assets.	BankFocus & SNL Financial
Leverage	ratio	It measures the bank's level capitalization. It is the ratio equity to total assets.	BankFocus & SNL Financial
Size	logarithm	It takes into account potential advantages due to cost benefits and better managerial skills. It is the logarithm of the bank total asset.	BankFocus & SNL Financial
Macroeconomics	(Country level)		
GDP	percentage	A proxy of market expansion. It is the real Gross Domestic Product growth rate.	WDI & SDW
Inflation	percentage	Consumer Price Index. It is used to assess the presernce of an inflationary environment.	WDI & SDW
Central bank assets	ratio	A proxy of unconventional monetary policies. It is the central bank assets to GDP.	WDI & SDW
MP(Deposit Facility)	percentage	One of the main monetary policy rate, namely the official Deposit Facility rate.	WDI & SDW
Chinn-Ito index	index	A measure of financial openness. It evaluates the presence of barriers to entry in the domestic bank system. It ranges between 1 (the highest openness) and 0 (completely restricted).	Chinn-Ito

Table A3: Descriptive statistics of control and treatment group prior to and after the introduction of NIRP

Variables	Treatment (NIRP affected)											
	Pre-NIRP (2011-2014)						NIRP period (2015-2018)					
	N.Obs	Mean	Std.Dev.	p25	Median	p75	N.Obs	Mean	Std.Dev.	p25	Median	p75
Panel A : Bank market power												
Lerner index	10149	0.20	0.10	0.14	0.20	0.26	10322	0.24	0.12	0.16	0.24	0.31
Panel B : Bank lending chanel and bank stability												
Loans growth	9354	3.14	13.47	-0.35	2.98	6.54	11854	4.55	15.62	0.93	4.31	8.18
Loans growth NOR	9354	0.00	9.75	-2.17	0.00	2.10	11467	1.20	17.51	-2.79	0.91	5.01
Z-score	10939	1.25	0.60	1.01	1.25	1.52	12115	1.38	0.64	1.15	1.36	1.61
ROR	10950	0.15	0.38	0.06	0.12	0.21	12138	0.15	0.39	0.04	0.09	0.17
Panel C : Bank balance sheet and macroeconomic variables												
Funding Structure	11107	64.40	22.61	55.34	72.25	80.00	11575	67.15	22.21	61.97	74.75	81.56
Asset structure	10631	58.82	20.30	48.84	61.04	72.04	11877	59.72	20.60	49.88	62.72	73.48
Liquidity	9420	24.92	20.83	9.24	19.34	34.33	12131	23.26	20.82	7.69	16.81	32.30
Profitability	10950	0.40	1.01	0.15	0.30	0.53	12138	0.51	1.32	0.14	0.29	0.57
Leverage	11566	10.93	10.89	6.81	8.61	11.24	12168	12.34	12.20	7.82	9.58	12.13
Size	11592	6.60	2.04	5.19	6.41	7.68	12213	6.70	2.02	5.31	6.54	7.82
GDP	12272	0.94	1.89	0.42	0.58	2.23	12272	2.06	1.29	1.53	2.02	2.47
Inflation	12272	1.77	0.89	1.11	2.00	2.11	12272	1.00	0.72	0.49	0.90	1.70
Central bank assets	12159	1.46	2.15	0.16	0.23	1.61	9204	7.46	5.05	2.87	6.49	9.84
MP(Deposit Facility)	12272	0.14	0.22	-0.04	0.07	0.32	12272	-0.35	0.08	-0.40	-0.39	-0.29
Chinn-Ito index	12028	1.00	0.04	1.00	1.00	1.00	12028	1.00	0.03	1.00	1.00	1.00
Variables	Control (no-NIRP affected)											
	Pre-NIRP (2011-2014)						NIRP period (2015-2018)					
	N.Obs	Mean	Std.Dev.	p25	Median	p75	N.Obs	Mean	Std.Dev.	p25	Median	p75
Panel D : Bank market power												
Lerner index	4525	0.24	0.13	0.14	0.23	0.31	4793	0.26	0.13	0.16	0.25	0.33
Panel E : Bank lending chanel and bank stability												
Loans growth	4902	8.29	17.53	-0.01	7.19	17.53	5590	8.54	16.96	0.20	9.79	17.06
Loans growth NOR	4902	0.00	13.09	-6.75	-1.20	7.11	5510	-0.13	18.52	-9.21	0.97	8.61
Z-score	5075	1.49	0.77	1.40	1.69	1.89	5805	1.55	0.76	1.44	1.72	1.92
ROR	5078	0.36	0.53	0.19	0.33	0.47	5804	0.31	0.41	0.17	0.27	0.38
Panel F : Bank balance sheet and macroeconomic variables												
Funding Structure	5183	68.35	39.04	55.87	77.72	84.30	5439	68.90	38.80	59.28	77.40	84.14
Asset structure	5349	63.41	19.66	54.45	67.15	76.25	5627	66.55	20.25	59.29	71.47	79.58
Liquidity	5414	27.01	18.40	14.81	23.25	34.75	5805	24.20	18.63	12.63	19.15	30.17
Profitability	5078	0.95	1.40	0.49	0.86	1.23	5804	1.05	1.39	0.56	0.93	1.29
Leverage	5497	12.19	10.46	8.38	10.23	12.53	5818	12.90	11.73	8.63	10.55	12.83
Size	5506	7.82	1.89	6.90	7.55	8.65	5819	8.17	1.91	7.35	8.01	9.05
GDP	5860	2.01	0.75	1.55	2.08	2.45	5860	2.46	0.90	1.89	2.36	2.93
Inflation	5860	2.14	0.90	1.47	2.07	3.16	5860	1.43	0.99	0.37	1.43	2.29
Central bank assets	5776	12.60	8.43	3.43	15.89	18.87	4332	15.65	10.06	4.63	21.75	22.62
MP(Deposit Facility)	5860	0.40	0.61	0.25	0.25	0.25	5860	0.75	0.66	0.26	0.51	1.10
Chinn-Ito index	5860	0.97	0.13	1.00	1.00	1.00	5860	0.98	0.08	1.00	1.00	1.00

Note: Lerner index is a measure of banks' market power, which ranges between 1 (monopoly) and 0 (perfect competition). Loans growth is the annual growth rate of the gross loans. The normalized loans growth rate is the annual growth rate of loans normalized by the average annual growth rate during the four years prior to the NIRP (2011-2014). Z-Score is the number of standard deviations that the bank's profitability (ROA) have to fall below the average for the bank to become insolvent. Z-score is a measure of banks' soundness. It is the sum of ROA plus the ratio of equity-to-total assets, all divided by the standard deviation of ROA at country level. A high Z-score represents a greater level of bank stability. ROR_{ROA} is the risk-adjusted profitability, that is ROA divided by its volatility. Funding Structure is the ratio total customer deposits-to-total assets. Asset structure is the ratio gross loans to total assets. Liquidity is the ratio liquid asset to total assets. Leverage is the ratio equity to total assets. Size is the logarithm of the bank total asset. GDP is the real Gross Domestic Product growth rate. Inflation is the Consumer Price Index. Central bank assets is the ratio central bank assets to GDP. MP is the Deposit Facility rate. Chinn-Ito is an index that measures the financial openness.

Appendix B

Tripod estimation methodology: market power, bank lending channel and bank stability

Market power

In this study, we estimate banks' market power mainly using the Lerner index, which relies on individual bank-level data. The Lerner index (Lerner 1934) measures the bank mark-up, that is the difference between output prices and marginal costs, and it is defined as:

$$Lerner_{\mathrm{i,t}} = (P_{\mathrm{TAi,t}} - MC_{\mathrm{TAi,t}})/P_{\mathrm{TAi,t}} \tag{5}$$

Where $P_{\mathrm{TAi,t}}$ is the price of total assets computed as the ratio of total (interest and non interest) income to total assets for bank i at time t and $MC_{\mathrm{TAi,t}}$ is the marginal cost of total assets for bank i at time t. $MC_{\mathrm{TAi,t}}$ is computed relying on a standard translog function with a single output (total assets) and three input prices for deposits, labour and physical capital. To generate $MC_{\mathrm{TAi,t}}$, we use the same methodology used by Demirgüç-Kunt and Martinez-Peria (2010) and Anginer et al. (2014), in which the log cost function is calculated separately for each country:

$$\begin{aligned} log(C_{\mathrm{i,t}}) = \alpha + \beta_1 \times log(_{\mathrm{i,t}}) + \beta_2 \times log(_{\mathrm{i,t}})^2 + \beta_3 \times log(_{1,\ \mathrm{i,t}}) + \beta_4 \times log(_{2,\ \mathrm{i,t}}) + \beta_5 \times log(_{3,\ \mathrm{i,t}}) \\ + \beta_6 \times log(_{\mathrm{i,t}}) \times log(_{1,\ \mathrm{i,t}}) + \beta_7 \times log(_{\mathrm{i,t}}) \times log(_{2,\ \mathrm{i,t}}) + \beta_8 \times log(_{\mathrm{i,t}}) \times log(_{3,\ \mathrm{i,t}}) \\ + \beta_9 \times log(_{1,\ \mathrm{i,t}})^2 + \beta_{10} \times log(_{2,\ \mathrm{i,t}})^2 + \beta_{11} \times log(_{3,\ \mathrm{i,t}})^2 + \beta_{12} \times log(_{1,\ \mathrm{i,t}}) \times log(_{2,\ \mathrm{i,t}}) \\ + \beta_{13} \times log(_{1,\ \mathrm{i,t}}) \times log(_{3,\ \mathrm{i,t}}) + \beta_{14} \times log(_{2,\ \mathrm{i,t}}) \times log(_{3,\ \mathrm{i,t}}) + \theta \times YearDummies \\ + \gamma \times \text{Bank Specialization Dummies} + + \epsilon_{\mathrm{i,t}} \end{aligned} \tag{6}$$

where bank costs ($\mathrm{C_{i,t}}$) are a function of output ($\mathrm{Q_{i,t}}$ for the total asset), three input prices (i.e. the price of borrowed funds ($\mathrm{W_{1i,t}}$), the price of labour ($\mathrm{W_{2i,t}}$), and the price of physical capital ($\mathrm{W_{3i,t}}$)) [23], and a vector of year and bank specialization dummies.

We estimate Eq. 2 by using pooled ordinary least squares (OLS) and setting five restrictions aimed at ensuring homogeneity of degree one in input prices:

[23] The price of borrowed funds ($\mathrm{W_{1i,t}}$) is defined as total interest expenses over total assets, the price of labour ($\mathrm{W_{2i,t}}$) is defined as staff expenses over total assets, and finally the price of physical capital ($\mathrm{W_{3i,t}}$) is defined as overhead expenses net of personnel expenses over total assets.

$$\begin{aligned}
\beta_3 + \beta_4 + \beta_5 &= 1 \\
\beta_6 + \beta_7 + \beta_8 &= 1 \\
\beta_9 + \beta_{12} + \beta_{13} &= 1 \\
\beta_{10} + \beta_{12} + \beta_{14} &= 1 \\
\beta_{11} + \beta_{13} + \beta_{14} &= 1
\end{aligned} \tag{7}$$

Exploiting the estimated coefficients from Eq. 2 we compute the marginal cost $\mathrm{MC_{TAi,t}}$:

$$MC_{\mathrm{TAi,t}} = \frac{C_{\mathrm{i,t}}}{Q_{\mathrm{i,t}}} + [\beta_1 + 2 \times \beta_2 \times log(_{\mathrm{i,t}}) + \beta_6 \times log(_{1,\ \mathrm{i,t}}) + \beta_7 \times log(_{2,\ \mathrm{i,t}}) + \beta_8 \times log(_{3,\ \mathrm{i,t}})] \tag{8}$$

The Lerner index ranges between zero and one, where a higher index means a greater market power and thus a lower competition. The antipodes of the Lerner index represent a perfectly competitive bank (index equals 0) and a monopolistic bank (index equals 1).

As robustness check, we adopt a different measure of market power, namely the H-statistic. By following the same approach used in Claessens and Laeven (2004) and Anginer et al. (2014), we calculate the reduced-form revenue regression for each country in each calendar year:

$$\begin{aligned}
Log(\mathrm{P_{i,t}}) = &\alpha + \beta_1 \times log(\mathrm{W_{1,\ i,t}}) + \beta_2 \times log(\mathrm{W_{2,\ i,t}}) + \beta_3 \times log(\mathrm{W_{3,\ i,t}}) + \gamma_1 \times log(\mathrm{Y_{1,i}}) \\
&+ \gamma_2 \times log(\mathrm{Y_{2,i}}) + \gamma_3 \times log(\mathrm{Y_{3,i}}) + \Omega + \text{Bank Specialization Dummies} + \epsilon_{\mathrm{i,t}}
\end{aligned} \tag{9}$$

where the output price of loans ($\mathrm{P_i}$) is a function of three input prices ($\mathrm{W_{1i,t}}$ for the price of borrowed funds, $\mathrm{W_{2i,t}}$ for the price of labour, and $\mathrm{W_{3i,t}}$ for the price of physical capital), three control variables ($\mathrm{Y_{1i}}$ for the banks' total assets, $\mathrm{Y_{2i}}$ for the ratio of net loans to total assets, and $\mathrm{Y_{3i}}$ for the ratio of equity to total assets) and a vector of bank specialization dummies. We estimate Eq. 9 by pooled ordinary least squares (OLS). The H-statistic is the sum of the elasticities of revenue with respect to the three input prices, it is thus defined as:

$$H - statistic = \beta_1 + \beta_2 + \beta_3 \tag{10}$$

The H-statistic ranges between ∞ (zero or less than zero) and one, where a higher index means a lower market power and thus a higher competition. In a nutshell, the H-statistic ranges between ∞ (monopoly) and 1 (perfect competition).

Bank lending channel

Banks' behaviour is crucial to ensure an effective transmission of monetary policy to the real economy. The literature on the bank lending channel investigates the effects of monetary policy on banks' behaviour (Bernanke 1995). In this study, we use the annual growth rate of bank loans as dependent variable in the regression analysis that assesses the influence of the NIRP and more broadly of monetary policy on credit growth (Leroy (2014); Borio and Gambacorta (2017); Salachas et al. (2017)). Specifically, $\Delta(Loans)_{\mathrm{i,t}}$ is the annual growth rate of loans in period t of bank i and it is calculated as the growth rate of bank loans between t and t-1. In the spirit of Gan (2007), who argues for the importance of normalizing the measure of lending, in our analysis we also use a different specification of our dependent variable. More precisely, we use $\Delta(Loans)_{\mathrm{i,t\ NORM}}$ which is the annual growth rate of loans in period t of bank i normalized by the average annual growth rate of the same bank during the four years prior to the NIRP.

$$\Delta(Loans)_{\mathrm{i,t\ NORM}} = \Delta(Loans)_{\mathrm{i,t}} - \frac{1}{4}\Delta(Loans)_{\mathrm{i,t}} \tag{11}$$

where T=2011, 2012, 2013, 2014 is the time period (year). A higher level of $\Delta(Loans)_{\mathrm{i,t}}$ or $\Delta(Loans)_{\mathrm{i,t\ NORM}}$ represents a more marked increase in bank lending, with non-trivial effects for the real economy.

Bank stability

We use the Z-score as a measure of bank soundness. This yardstick is widely used to assess the overall stability of banks at individual level (Boyd, De Nicoló and Jalal (2006); Berger et al. (2009); Beck, De Jonghe and Schepens (2013); De Jonghe and Schepens (2016)). The Z-score, $Z_{\mathrm{i,t}}$, indicates the distance from insolvency of bank i in country j at time t. More specifically, it indicates the number of standard deviations that bank profitability has to fall below the average for the bank to become insolvent. The Z-score is defined as follows:

$$Z_{\mathrm{i,t}} = \frac{ROA_{\mathrm{i,t}} + EA_{\mathrm{i,t}}}{\sigma(ROA)_{\mathrm{i,t}}} \tag{12}$$

where ROA is a measure of profitability, i.e. the return on assets for bank i at time t, EA is a measure of capitalisation, namely the ratio of equity-to-total assets, and $\sigma(ROA)$ is the standard deviation of the ROA in country j at time t. The Z-score increases with a higher level of profitability and capitalization, while it decreases with greater volatility of bank returns. We use the logarithmic version of Z-Score to avoid problems owed to the skewness in the distribution of the variable (Avignone, Altunbas, Polizzi and Reghezza 2021). A high Z-score represents a greater level of bank stability. Therefore, a Z-score decrease (increase) indicates a decrease (increase) in the bank stability.

In the spirit of Mercieca, Schaeck and Wolfe (2007) and Turk-Ariss (2010), we also use

another measure of bank soundness for checking the robustness of the results. We use a risk-adjusted measures of profitability.

$$ROR_{\text{ROA}} = \frac{ROA_{\text{i,t}}}{\sigma(ROA)_{\text{i,t}}} \tag{13}$$

where ROR_{ROA} indicates the risk-adjusted ROA, that is ROA divided by its volatility. However, in this case the volatility of the ROA, $\sigma(ROA)$, is measured as the standard deviation of ROA for bank i at time t. Coherently, a higher value of ROR_{ROA} indicates more bank stability.

Bank balance sheet variables

In our regression analyses we include the variable total customer deposits-to-total assets to control for banks' funding structure. The NIRP highlighted that banks are reluctant to pass negative rates on to depositors. Accordingly, banks with a greater dependence on deposit funding have exhibited higher funding costs and experienced a larger reduction in their net interest margins (Heider et al. 2019). Hence, we expect to observe a negative relationship between our variable for the funding structure and the Lerner index since lower margins are associated with a lower market power. Furthermore, we include in our regressions among the bank-specific controls, the ratio of gross loans-to-total assets to capture banks' asset structure which is a proxy for banks' business model and specialization. Banks with a higher share of loans over total assets carry out more traditional lending activities and are more concentrated in the retail market and, thus, should exhibit a higher market power as this market features a lower degree of integration and competition than wholesale and trading markets amid greater barriers to entry (Fernández de Guevara, Maudos and Pérez 2005).

We employ the variable liquid asset to total assets to control for bank liquidity. Liquidity generates lower margins, as higher liquidity results in lower returns. Fernández de Guevara and Maudos (2007) provide empirical evidence that the banks that maintain a higher level of liquidity have a lower market power. Moreover, in our regressions, we use the variable equity-to-total assets to account for bank leverage. A higher level of bank capitalisation leads to lower funding costs (Arnould, Avignone, Pancaro and Żochowski 2021) and better performance (Demirgüç-Kunt and Huizinga 1999). Accordingly, Efthyvoulou and Yildirim (2014) find a positive relationship between the ratio equity-to-total assets and the Lerner index, highlighting that higher capitalisation could be positively associated with market power. We include the logarithm of banks' total assets to measure bank size. Size may have an impact on market power for two reasons: (i) it leads to cost benefits (economies of scale) and better managerial skills and (ii) it confers market power by itself. To capture a possible nonlinear relationship between size and market power, we also insert in Eq. 1 the quadratic term of the size variable. Fernández de Guevara et al. (2005) find a positive relationship between the Lerner index and size, however, using the quadratic term they find that this relationship is not linear since market

power increases with size but at a decreasing rate.

Macroeconomic variables

In our regressions, we employ the real GDP growth rate as a proxy of economic activity as the Lerner index could be impacted by business cycle dynamics. Athanasoglou, Brissimis and Delis (2008) find a positive relationship between the business cycle and banking performance, as an economic boom should lead to larger margins associated with increased demand for credit and stock market transactions. We also control for inflation by including the CPI inflation rate as for example Demirgüç-Kunt and Huizinga (1999) assert that banks could claim higher risk premium on their loans in an inflationary environment.

We exploit the Deposit Facility rate to account for conventional monetary policy[24]. Scharfstein and Sunderam (2016) suggest the existence of a negative relationship between the main policy rate and bank market power. An increase in monetary policy rates makes bank loans less attractive to firms as borrowing costs increase. Therefore, total lending shrinks and banks will have an incentive to lower their mark-ups on loans to mitigate the effect of lower credit demand. We also employ central bank assets to GDP to capture the possible effects of unconventional monetary policy. Alessandri and Nelson (2015) and Darracq Pariès, Halaj and Kok (2016) provide evidence that unconventional monetary policy depresses income margins, moreover, Lambert and Ueda (2014) find that the size of the central bank balance sheet is negatively related to banks' interest and non-interest income. Accordingly, unconventional monetary policies should decrease bank mark-ups. Finally, we use the Chinn-Ito index to measure financial openness. Favouring foreign capital flows and easing barriers to entry stimulate domestic bank competition (Luo, Tanna and De Vita 2016). Furthermore, financial openness leads to improving the quality and availability of financial services fostering a higher level of banking competition (Calderón and Kubota (2009); and Gropp et al. (2014)). Therefore, we expect to observe a positive relationship between the Chinn-Ito index and competition in the banking sector.

[24]Prior to the GFC, the main policy rate was the MRO. In the wake of the crisis, however, demand for central bank loans has been limited. On the contrary, banks have increased their deposits with central banks. As a result, since 2009 the interest rate on the central bank's deposits has had greater influence on money market rates, effectively making the DFR rate the main policy rate. In the euro area the DFR is also the only official rate that went into negative territory.

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