INTERNATIONAL LIQUIDITY, NEGATIVE INTEREST RATE POLICY AND BANKING SUPERVISION: EVIDENCE FROM A NATURAL EXPERIMENT

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This academic research is aimed at cleanly trace the effect of an unanticipated exogenous shock to different economic components. I use the same methodology, namely a difference-in-differences estimation, in order to identify the incentive effects of an exogenous shock. The research proceeds as follows. The first article analyses the impact of the Banking Union on European bank credit risk. I find that, after a supervision reform, European banks directly supervised by the ECB reduced their riskiness. The second article analyses the impact of temporary U.S. dollar liquidity arrangements (swap lines) on international reserves. I find empirical evidences that those countries - involved in swap lines by the FED, when these temporary global financial crisis arrangements expired - started to accumulate reserves to a greater extent to the other considered EME. Finally, I study the effects of the negative interest rate policies on European competition. I find that, when entering into a negative interest rate territory, European banks increase their market power.

All empirical evidences passed a battery of robustness tests that support the reliability of my analysis. These studies are intended to contribute to the existing literature as it is sometimes scarce in these specific fields.

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CHAPTER 1

Centralised or Decentralised Banking Supervision? Evidence from European Banks

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Abstract

This paper analyses the impact of the Banking Union on European bank credit risk. Specifically, we investigate the effect that the establishment of the Single Supervisory Mechanism has had on the credit risk of the banks it supervises in comparison to financial institutions that are still supervised by National Supervisory Authorities. We analyse a sample of 746 European banks over the period 2011-2018, by means of a difference-in-differences methodology. We provide empirical evidence that Single Supervisory Mechanism supervised banks reduced credit risk exposure compared to banks supervised by National Supervisory Authorities, suggesting that the Banking Union has successfully reduced the riskiness of the European banking sector. Our results passed a battery of robustness tests that support the reliability of our analysis. Our contribution sheds light on the benefits of centralised versus decentralised supervision, on the effectiveness of the current supervisory system in Europe, and on its impact on European bank risk.

Keywords: Banking Union; Bank Credit Risk; Banking Supervision; Regulation; Difference-in-Differences

JEL Classifications: G20; G21; G28.

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1. Introduction

The role of supervisory authorities is crucial for the stability of the banking sector (Barth *et al.*, 2004; Basel Committee on Banking Supervision, 2006). Weaknesses in regulation and supervision are widely considered amongst the main determinants of the global financial crisis (GFC) (Chan-Lau, 2010; Levine, 2010; Merrouche and Neir, 2010; and Barth *et al.*, 2012). Consequently, banking regulation and supervision have been frequently revised over the last years and the Banking Union has been one of the most important institutional response to the crisis in Europe (Carboni *et al.*, 2017).

The Banking Union was officially established in November 2014 and it is organized in two pillars: (i) the Single Resolution Mechanism (SRM) and (ii) the Single Supervisory Mechanism (SSM). The main objective of the SRM is to guarantee the efficient resolution of failing financial institutions with low costs for taxpayers and for the economy as a whole. The other pillar of the Banking Union consists in the establishment of a new supervisory authority, the SSM directly led by the European Central Bank (ECB), whose main responsibility is banking supervision.[1] However, the SSM is not in charge of supervising all European banks. The Economic and Financial Affairs Council (ECOFIN, 2012) has set the framework and the criteria that the ECB should use to identify systemically important financial institutions (SIFIs) to be supervised by the SSM. The SSM framework regulation identifies four "significance criteria": size, economic importance, cross-border activities, and public financial assistance. To qualify as significant, banks must fulfil at least one of the four criteria, and therefore falling under the direct supervision of the ECB, through the SSM. There are currently 117 banks in 19 countries supervised by the SSM representing 85 percent of total assets of the whole European banking sector (Nouy, 2015).[2] The SSM directly supervises these banks, whereas national supervisory authorities (NSAs) continue to supervise the remaining part of their national banking system.[3]

There are several reasons why the ECB decided to take charge of the supervision of SIFIs. First, a centralised supervision has been considered an effective way to reduce the excessive credit risk exposure and to tackle the related issue of the outstanding amount of non-performing loans (NPLs) in banks' balance sheet (Enria, 2019). Second, the Banking Union has been a

[1] For more information see the Regulation (EU) No 806/2014, available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0806&from=EN

[2] For the full list of SSM supervised financial institutions see: https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.listofsupervisedentities201912.en.pdf

[3] A more detailed timetable of the key steps of European Banking Union is provided in Table A1 in the appendix.

way to deal with the problems related to the link between sovereign debt and banking risk (Gerlach *et al.*, 2010; Dermine, 2020). Third, a decentralised supervision may lead to regulatory and supervision arbitrage between credit institutions located in different European member states (so-called regulatory and supervision arbitrage[4]) that tend to prefer member states with lax supervision; while a centralised supervision could overcome these issues. Fourth, elevate standards are required not only in financial regulation, but also in banking supervision in order to ensure financial stability. Supervision and regulation complement each other, as without a reliable supervisory framework, financial regulation would be ineffective (De Larosière, 2009).

The literature has proposed two theoretical frameworks to analyse the effectiveness of centralised banking supervision compared to the decentralised model. First, Agarwal *et al.* (2014) remark the superior effectiveness of a central supervisor model. The authors show that local and supranational supervisors could have different aims, and the former are likely to use their supervisory power in order to protect national banks and to pursue national objectives that might have detrimental effects at systemic wide level. Hence, a supranational supervisor should be better suited to supervise large and systemically important financial institutions, as it is not subjected to this kind of conflict of interest. Second, by analysing the behaviour of a supervisory authorities in the "hub-and-spokes" regime, Carletti *et al.* (2020) provides another interesting viewpoint. The "hub-and-spokes" regime is a model where a central supervisory authority has juridical power over the decisions concerning banks, and it relies on local supervisors to collect the information necessary to perform its monitoring function. Carletti *et al.*'s (2020) theoretical model posits that the "hub-and-spokes" regime can succeed in reducing bank risk taking, if local supervisors act according to a centralised mandate.

This paper investigates whether the centralised supervisory framework introduced by the Banking Union via the implementation of the SSM has been effective in reducing credit risk of SSM supervised banks in comparison to those monitored by NSAs. To this aim, we employ a sample of 746 European banks over the period 2011-2018 and a difference-in-differences (DiD) methodology. We focus on credit risk as non-performing loans grew extraordinary following the European sovereign debt crisis[5]. This has pushed policy-makers to prioritise

[4] For more information on the concept of regulatory arbitrage, see Karolyi *et al.* (2015).
[5] The academic literature has analyzed the influence of banking supervision on credit provisioning. See for instance Fratzscher *et al.* (2016).

actions to tackle this problem (Enria, 2019) and the new supervisory framework introduced by the Banking Union has specifically targeted banks' credit risk exposure (ECB, 2016). To preview our main findings, we provide empirical evidence that the establishment of the SSM has contributed to reduce the credit risk exposure of those financial institutions directly supervised by the SSM. This result supports the idea that the central supervision model is more effective than the decentralised one. Our results stand up well to a battery of robustness checks such as different measures of credit risk and overall risk as well as placebo and sample selection bias tests. These findings suggest that the Banking Union has successfully reduced the riskiness of the European banking sector, and shed light on the effectiveness of the supervisory arrangement in Europe.

This paper contributes to the extant literature in several ways. We contribute to the empirical literature that studies the effectiveness of centralised and decentralised supervisory settings, and to the literature on bank risk, by focusing on the effects of different banking supervision regimes on credit risk. Although other papers have studied different banking supervision settings, the literature that analyses the effects of radical changes in banking supervision by focusing on bank risk is scarce. We also analyse the effects that an under-researched regulatory change (i.e. the Banking Union) has had on bank credit risk.

The paper proceeds as follows. Section 2 reviews the extant literature related to these topics and develops our research hypotheses. Section 3 describes the methodology, variables, and data. Section 4 shows the main results along with several robustness checks. Section 5 concludes.

2. Literature Review and Hypothesis tests

2.1 Literature Review

The academic debate on the benefits and drawbacks of centralised banking supervision has started well before the GFC and the problems that have induced the European System of Central Banks to establish the SSM. Peek *et al.* (1999) shed light on an important advantage of the centralised framework, suggesting that it is important to centralise supervisory responsibilities and monetary policy under a single authority, as confidential information on banks help policy makers to predict macroeconomic factors. The debate has focused in particular on whether centralised regulation and supervision lead to higher levels financial

stability than a decentralized framework (Laffont and Martimort, 1999; Martimort, 1999; Laffont and Pouyet, 2004; among others). Laffont and Pouyet (2004) propose a theoretical analysis to describe the drawbacks of decentralisation in comparison to centralisation. In a decentralised framework, each bank is supervised by a different authority in different countries. This factor generates competition between different cross-border authorities, which leads to an increase in the contractual power of banks, jeopardizing the effectiveness of banking supervision. In this regard, it is worth to mention that a centralized supervision is not optimal for any context. Dell'Ariccia and Marquez (2006a) provide a model that postulates that a centralised supervisory framework is more likely to emerge in countries characterised by a certain degree of homogeneity. Also Barth *et al.* (2001, 2004, 2008, 2012) cast doubts on the effectiveness of centralised supervision. Through the World Bank's Bank Regulation and Supervision Surveys (BRSSs), these authors study the relationship between specific regulatory and supervisory practices and banking-sector development, efficiency, and fragility. They conclude that, while many countries strengthened capital regulations and official supervisory agencies over time, these reforms are not likely to improve neither bank stability nor efficiency. Hence, there is no significant relation between official supervisory power and bank efficiency. In summary, these economic surveys provide conflicting predictions about the impact of regulatory and supervisory policies on bank performance.

The literature on these topics has gained momentum after the financial crisis. An extensive strand of literature argues that inadequate regulation and poor supervision were amongst the main causes of the GFC (Levine, 2010; Merrouche and Neir, 2010; Barth *et al.*, 2012). This has raised important questions on the effectiveness of the regulatory and supervisory framework. De Larosière (2009) has been among the first to advocate a European centralised system of regulation and supervision. According to his report, weak banking supervision was amongst the main determinants of the GFC. De Larosière (2009) stresses that supervision and regulation are interdependent, because without an adequate supervisory framework the renewed financial regulation would be ineffective. Thus, elevate standards are required in both regulation and supervision in order to ensure financial stability.

Schoenmaker (2011) and Obstfeld (2014) use the financial trilemma to highlight the benefits of a centralized supervision.[6] The financial trilemma assumes that (1) financial integration, (2)

[6] For more information on the financial trilemma see Rodrik (2000).

financial stability and (3) national financial policies are incompatible. Only two of the three objectives can be achieved. The financial trilemma suggests that the delicate role of regulation and supervision of financial institutions should be shifted at the European level (Schoenmaker, 2011). Obstfeld (2014), referring to the euro area, suggests that macro-prudential supervision and Banking Union are the solution to ensure financial stability. It is clear that a supranational central supervisory authority would have been a step ahead towards the solution of the financial trilemma. Aside from the literature that analyses the financial trilemma, other studies have supported the idea of a centralised supervision in Europe. Poghosyan and Cihak (2011) state that an important argument in favour of a more centralised banking regulation and supervision in the EU is related to the fact that European bank risks have become increasingly homogenous. In this context, a supranational supervisor would be in the position to fulfil its role more effectively.

Beck *et al.* (2013) argue that centralisation is able to offset a wide range of national effects for the sake of systemic wide financial stability. However, they also identify some weaknesses of centralised supervision. The first is related to information asymmetry. National supervisors might have a deeper knowledge of their supervised entities, in comparison to a supranational supervisor. Secondly, in case of intervention in support of troubled banks, a different legal framework can lead the supranational supervisor to a longer and more expensive resolution, in comparison to a national supervisor that may be more supportive with its supervised entities. Hence, a sufficient degree of homogeneity in banking regulation is necessary for a central supervisory arrangement to be fully effective.

The current supervisory architecture in Europe is not the only banking supervision framework that is based on both centralised and decentralised supervision. The peculiarities of the U.S. framework provide useful insights to study the effects of different supervisory settings. These aspects have been analysed by Agarwal *et al.* (2014), who exploit the exogenously predetermined alternation of state (decentralised) and federal (centralised) supervision in the U.S. to analyse the effects of a dual supervisory mechanism. Their study provides empirical evidence that local banking supervisors are more lenient than federal ones. More specifically, local supervisors may have different objectives than those of the central agency and are in general less inclined to intervene. U.S. banks anticipate the different attitude of federal and national supervisors by modifying their loan quality and leverage ratio figures. Under federal regulators, banks report higher NPLs, higher regulatory capital ratios, and lower ROA.

Furthermore, there is a greater frequency of bank failures and bank-related issues in states with more lenient supervision relative to the federal benchmark. Hence, the accommodating supervision of decentralised supervisors may have detrimental effects for the whole banking system. Overall, centralisation is likely to raise supervisory standards and deal with the perceived laxness and unwillingness to intervene that led to the recent crisis. In contrast, decentralised supervision and different national jurisdictions may create relative advantages amongst the supervisory and regulatory systems, jeopardizing the systemic-wide financial stability (Scott, 1977).

After the establishment of the banking union, some studies have focused on the analysis of its effects. However, notwithstanding the importance of the topic in question, this strand of literature is not yet well developed. Carboni *et al.* (2017), analysing daily log-returns over a 252 trading-day of 158 listed European banks, assess the impact that the announcement of the names of the banks that were going to be supervised by the SSM has had on their stock prices. Their contribution provides evidence that investors penalized the banks supervised by the SSM, because of the fear of regulatory inconsistencies. In contrast, Sahin and De Haan (2016) find that European bank stock market prices and credit default swap showed no reaction to the Banking Union. A recent paper written by Sáiz *et al.* (2019) addresses the question as to whether the Banking Union has influenced the contagion mechanism amongst financial institutions and sovereign risk, which was amongst the main goals of the ECB. These authors do not find robust evidence that the Banking Union decreased the contagion between bank stock returns and sovereign risk. Colliard (2020) focuses on bank regulation within the Banking Union, stating that the supervisory architecture may be an important determinant of the regulatory effectiveness. By analysing the short-term effect of the comprehensive assessment before the SSM launch, Fiordelisi *et al.* (2017) find that banks reduced their lending activities in order to increase their level of capitalisation. Even though there are other studies that investigate various issues related to the Banking Union (Kudrna, 2016; Hüser *et al.*, 2018), the academic literature on this topic is scant. Thus, this topic requires further investigations, as it is important to understand the various effects that the launch of the SSM and the Banking Union has had on the banking system (Colliard, 2020). Lastly, our study is also motivated by the fact that although, an ample literature analyses the impact of regulation on bank behaviour by focusing on bank risk (Fiordelisi *et al.*, 2011; Harris and Raviv, 2014; among others), only a few papers empirically examine bank reactions to changes in the way they are supervised.

2.2 Theoretical Framework

The current European supervisory system entails a close cooperation between national supervisors and the SSM. Consequently, the theories that study the effectiveness of the monitoring function in a multi-supervisor setting (Agarwal *et al.*, 2014; Carletti *et al.*, 2020), and more generally the studies that analyze the benefits of a more integrated supervisory regime (De Larosière *et al.*, 2009; Schoenmaker, 2011) represent fundamental points of reference for our analysis.

Carletti *et al.* (2020) propose a theoretical framework that is particularly useful for our research setting. They analyse the behaviour of the supervisory authorities in the "hub-and-spokes" regime. It consists in a model where a central supervisory authority has juridical power over the decisions concerning banks, even though it relies on local supervisors to collect the information necessary to perform its monitoring function. The authors themselves admit that their theoretical analysis is inspired by the European banking supervision structure. This model suggests that if the NSAs (spokes) and the SSM (hub) act jointly with the same goals, the effectiveness of the entire supervisory system would be guaranteed. Carletti *et al.* (2020, pp. 2) also argue that "internal mechanisms need to be devised to guarantee that the "spokes" act according to the centralized mandate. Various elements of the institutional design in the banking union in Europe […] go in this direction. For example, in Europe, onsite inspections at the largest banks are conducted by multicountry teams headed by European Central Bank officials in order to facilitate the exchange of information." Hence, according to this theoretical analysis, the SSM central supervision may be more effective than that of NSAs, resulting in lower levels of risk for SSM supervised banks.

Agarwal *et al.* (2014) study bank supervisors' decisions in the U.S. framework, by exploiting a legally determined rotation policy that assigns federal or state supervisors to the same bank at predetermined time intervals. Their research question is the following: "Does regulatory effectiveness depend only on written rules, or do the institutions that are entrusted with implementing those rules also matter for regulatory outcomes?". Agarwal et. al. (2014) show that different supervisory authorities implement the same rules inconsistently, as they have different objective functions. More specifically, local supervisory authorities tend to carry out a softer monitoring activity during stressed economic periods, because a tough supervision could increase the probability of bank failure. This circumstance could in turn lead to a reduction of the local lending activity and of national banking jobs (local interest hypothesis).

In contrast, central supervisors are more concerned about the overall systemic stability, rather than about the geographical distribution of bank jobs and lending supply. According to this reasoning, a central supervisor may perform better than local supervisory authorities, as the former does not have any specific interests in favouring the national banking sector. The central supervisor is focused on the stability at systemic wide level, whilst local supervisory authorities have specific interests on their respective geographic areas. Specifically, local supervisors may compete with each other, as they may want to attract financial institutions from close areas. In order to achieve this goal, they perform a softer monitoring function, giving banks the chance to exploit a regulatory arbitrage and undermining the stability of the whole banking system.

The findings of Agarwal *et al.* (2014) are fundamental to understand the trade-offs of the distribution of supervisory functions and responsibilities across different authorities. Although European local supervisors might have an advantage in terms of information, as they have been the sole supervisors for a long time, their objective functions are important in determining the outcomes of their supervisory function. For example, NSAs may be softer with distressed banks, if they are too big to fail at national level. Furthermore, NSAs may have a close relationship with their national governments. Thus, according to the local interest theory, a central supervisor should perform a more effective monitoring activity than several local supervisors, as they are focused on specific local issues and not interested in the stability of the financial sector at systemic wide level. Specifically, in our research setting, the ECB should be a better supervisor than NSAs, resulting in a more effective monitoring for SSM supervised banks in comparison to nationally supervised financial institutions. This enhanced supervisory framework should significantly impact the risk exposure level of the financial institutions directly supervised by the SSM. We support this argument in light of the vast literature which remarks that the quality of the supervisory function is an important determinant of bank risk (Barth. *et al.*, 2004; Buch and DeLong, 2008; Maddaloni and Peydró 2011; Lee & Hsieh, 2014; Shehzad and De Haan, 2015, amongst others) and based on the idea that "a supervisor's job is to collect information about banks' portfolios and, upon obtaining it, to intervene if a bank is deemed to be too risky." (Carletti *et al.*, 2020, pp.1). In particular, since credit risk has been considered an ECB supervisory priority since shortly after the establishment of the Banking Union[7] (ECB, 2016; Enria, 2019), we contend that the SSM has significantly contributed to

[7] For further information see:
https://www.bankingsupervision.europa.eu/banking/priorities/npl/html/index.en.html

lessen credit risk for SSM supervised banks. For these reasons, we develop our research hypothesis as follows:

H1: The establishment of the SSM has led to a significant reduction of the credit risk exposure level of SSM supervised financial institutions compared to nationally supervised banks.

3. Methodology & Data

3.1 Methodology

We employ a DiD approach to study the effect of the Banking Union on bank credit risk. Various banking studies employ this methodology (Morkoetter *et al.*, 2014; Becchetti *et al.*, 2016; Walker & Wu, 2019), especially when it comes to evaluate the impact of policy changes (Giannetti & Jentzsch, 2013; Argimón *et al.* 2017; Fiordelisi *et al.* 2017). This methodology has the advantage to use a panel data set up to compare a treated group of banks (those affected by the policy change) with a control group (those unaffected by the policy change). Specifically, we compare the effect of the Banking Union on credit risk for our treatment group, with a control group of European banks that are under the supervision of the SSM. The regression model takes the following form

$$Y_{i,j,t} = \alpha + \beta_1\left(Treated_{i,j} * Post_{j,t}\right) + \beta' K_{i,j} + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \quad [1]$$

Where Y_{ijt} represents our measures of credit risk for bank *i* in country *j* at time *t.* Specifically, we use loan loss reserves to gross loans (LLR_GL) and loan loss provisions to gross loan (LLP_GL). *Treated* is a binary variable equal to unity if bank *i* in country *j* is under the supervision of the SSM, 0 if it falls under the NSAs supervision. *Post* is a binary variable equal to unity in the years following the establishment of the SSM, 0 otherwise. β_1 represents the average difference in LLR_GL and LLP_GL between banks that switched to the SSM supervision and banks that did not. $K_{i,j}$ denotes our vector of control variables. Specifically, we include the logarithm of the bank total asset (Size), total customer deposits-to-total assets (Funding Structure), gross loans-to-total assets (Asset Structure), return on assets (Profitability), and equity-to-total assets (Capitalisation). As for the macroeconomic control variables, we include the economic growth (GDP), inflation and gross domestic saving-to-GDP (Saving Propensity). We include country fixed effects (γ) to control for unobservable country-specific characteristics that can affect LLR_GL and LLP_GL. We also control for time-variant

shocks over the sample period on bank credit risk with year effects (φ). All regressions are estimated with bank-level clustering, thus allowing for correlation in the error terms. We use robust standard errors to control for heteroskedasticity and dependence (Bertrand *et al.*, 2004; Donald and Lang, 2007; Petersen, 2009).

The DiD model must satisfy the parallel trend assumption to ensure suitability to analyse the effect of the SSM on bank credit risk (Bertrand *et al.*, 2004; Imbens and Wooldridge, 2009). According to the parallel trend assumption, changes in the dependent variables over time should be exactly the same in both treatment (banks supervised by SSM) and control groups (banks supervised by NSAs) in the absence of the intervention (the introduction of the Banking Union). Figure 1 shows that the main dependent variables in both treated and control groups, have a similar trend from 2011 to 2014 (pre-treatment period). The assumption holds since the trend lines move together before implementation of the Banking Union in 2014. Fig. 1 shows the level of LLR_GL and LLP_GL, from 2011 to 2014 for both Banking Union affected and non-affected banks. As displayed, LLR_GL and LLP_GL move in the same direction in the pre-treatment period (correlation among the treatment and control is 0.86 for LLR_GL and 0.90 for LLP_GL).

[Insert Figure 1 Here]

3.2 Data

We construct a dataset from several sources. Bank balance sheet information are collected from Moody's BankFocus (Bureau Van Dijk), whilst macroeconomic variables are retrieved from World Development Indicators (World Bank). The dataset consists of 19 European countries (Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain). Similarly to Fiordelisi *et al.* (2017), we focus only on credit institutions and financial holding companies (FHCs)[8] following the classification provided by BankFocus. Table 1 (Panel A) shows the sample divided by bank specialisation and country. Given that BankFocus comprises 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

[8] Similarly to Fiordelisi *et al.* (2017), we do not consider cooperative banks, investment banks, private banking, mortgage banks and savings banks because they have different business models.

subsidiary, in order to avoid the inclusion of duplicate observations. The final sample consists of 746 banks in the Euro area; 95 are supervised by the SSM (treatment group) and 651 supervised by NSAs (control group), over the 2011 – 2018 period. Table 1 (Panel B) provides a snapshot of the number of banks divided by supervisor and country. Bank balance sheets are winsorized at the 1% and 99% level to mitigate the influence of outliers.

[Insert Table 1 Here]

Descriptive statistics for the dependent variables and other balance sheet and macroeconomic variables in the treatment and control groups prior and after the establishment of the SSM are shown in Table 2. We use the ratios of loan loss reserves-to-gross loans (LLR_GL) as a first measure of bank credit risk (Barry *et al.*, 2011). Altunbas *et al.* (2007) suggest that higher levels of loan loss reserves can be interpreted as greater bank risk. Therefore, we expect – after the introduction of the new supervisory mechanism – to observe a contraction of the reserve for loan losses among SSM supervised banks in comparison to those banks supervised by NSAs. As a second measure of credit risk, we employ the ratio of loan loss provision-to-gross loans (LLP_GL), which is considered an indicator of asset quality (e.g., Williams, 2004). Previous studies have found that banks increase provisions when they expect credit risk to deteriorate (Bikker and Metzemakers, 2005). Since our expectation is to observe a significant reduction of bank credit risk, we expect to observe a reduction of loan loss provisions for those banks supervised by the SSM after its establishment.

As reported in Table 2, the average value of LLR_GL and the LLP_GL before the introduction of the European Banking Union for treatment and control groups is statistically different. Contrarily, after the introduction of the Banking Union the average value of LLR_GL and LLP_GL between the treatment and control group loses its statistical significance. This primary result indicates that the SSM appears to have reduced the difference in credit risk between SSM and NSA banks. Indeed, after the introduction of the centralised supervisory system, the treated banks have experienced a contraction of LLR_GL and LLP_GL from 5% to 4.6% and from 1.2% and 0.6%, respectively. On the contrary, the control group shows that, after 2014, a slight decrease of LLP_GL (from 1% to 0.7%) and an increase in LLR_GL (from 4.4% to 4.7%).

Balance sheet variables. Panels B and E of Table 2 display summary descriptive statistics for bank balance sheet data divided by the treatment and control group. We include total customer

deposits-to-total assets (Funding Structure) as a measure of bank funding structure. The relationship between bank funding structure and credit risk is ambiguous. On the one hand, retail deposits are considered a more stable source of funds than wholesale funding (Gatev and Strahan, 2006). Laeven *et al.* (2014) suggest that customer deposits improve bank performance, while wholesale funding is considered to be a major source of vulnerability. Similarly, Demirgüç-Kunt and Huizinga (2010) argue that an extensive use of non-deposit funding is more profitable but, at the same time, riskier. On the other hand, Bologna (2011) indicates that market funding may be relatively cheaper and it allows more flexibility for banks in financing projects.

We employ the ratio of gross loan-to-total assets (Asset Structure) to control for bank asset structure. This variable indicates whether bank business model is based on traditional lending activities. We expect a positive relationship as banks that engage more in lending activity to be more exposed to credit risk (Altunbas *et al.*, 2007). We also control for bank size (Size), computed as the logarithm of bank total assets. The too-big-too-fail hypothesis suggests a positive relationship between bank size and risk (Stern and Feldman, 2004). However, portfolio diversifications, lower funding costs and better managerial skills may lead to an inverse relationship (Bertay *et al.*, 2013).

The regressions also include a measure of profitability (Profitability). On the one hand, less profitable banks face incentives to take risks in an attempt to boost profitability (Mare, 2015; Poghosyan and Čihak, 2011). On the other hand, profitable banks could use their resources to increase risky lending. Hence, the sign of the expected relationship is unknown. Following Gambacorta and Mistrulli (2004), we employ the ratio of equity-to-total assets (Capitalisation) as a measure of bank capitalisation. While highly capitalised banks can increase their risk exposure, binding capital constraints mitigate banking risk for undercapitalised banks (Gambacorta and Shin, 2018; De Nicolò *et al.*, 2010). Hence, we may expect a positive relationship. However, we cannot exclude the possibility that banks might gamble for resurrection, or that weakly capitalised banks assume greater risks to increase earnings, which, if retained, could strengthen bank equity; thereby improving their soundness (Calem and Rob, 1999). If this is the case, a negative relationship is plausible.

Macroeconomic variables. Panels C and F of Table 2 show summary descriptive statistics for the macroeconomic variables. Uhde and Heimeshoff (2009) argue that a deterioration in the

macroeconomic environment is transmitted to banks credit quality, which in turn, can affect loan loss reserves and provisioning (Schinasi, 2005). Hence, it is of great importance to control for the macroeconomic environment when investigating changes in bank credit risk. We include GDP growth (GDP), as it is one of the main macroeconomic factors that affects credit risk (Blaschke and Jones, 2001). However, GDP growth may have opposite effects on credit risk. On the one hand, GDP growth indicates a stable macroeconomic environment, which is related to a lower probability of bank distress, therefore banks may exploit this situation by increasing risk (Marcucci and Quagliariello, 2008; Poghosyan and Cihak, 2011). On the other hand, several studies find that banks behave procyclically, therefore they increase their risk provisions when the economic environment weakens (Arpa *et al.*, 2001; Guidara *et al.*, 2013).

We also include the ratio of domestic savings to GDP (Saving Propensity). Festic *et al.* (2011) provide evidence of the relationship between savings and bank credit quality. Greater domestic savings increase bank deposits and liquidity. This, in turn, may boost bank lending and consequently loan loss provisions and reserves. Finally, we control for inflation (Inflation). Gerlach *et al.* (2005) provide evidence of an inverse relationship between credit risk and inflation. Borrowers' ability to fulfil original obligations improves as inflation erodes the real value of debt. Hence, we expect to observe a negative relationship between credit risk and inflation.[9]

[Insert Table 2 Here]

4. Empirical Results

4.1 Baseline Results

Table 3 shows the results of our empirical analysis from estimating equation [1] and it is organized in 8 columns. Column 1 and 2 include the coefficient of the interaction between the dummy *Treated* and the dummy *Post* together with country- and time-fixed effects. In columns 3 and 4, we add the bank-specific variables and keep both country- and time-fixed effects, whilst in columns 5 and 6, we substitute country- and time-fixed effects with country*time fixed effects. In columns 7 and 8, we present results with banks specific variables, macroeconomic variables and country- and time-fixed effects. Our main interest is the

[9] A more detailed explanation of the variables and expected signs are provided in Table A2 in the appendix.

magnitude, sign and statistical significance of the coefficient of β_1 that represents the average difference in LLR_GL and LLP_GL between banks that switched to the SSM supervision and those that remained under the supervision of NSAs; denoted in the table as Centralised Supervision dummy.

Our results show that the coefficient of Centralised Supervision dummy is negative and statistically significant in each specification, suggesting that SSM supervised banks (SIFIs) reduced their credit risk after the implementation of the Banking Union in comparison to banks supervised by NSAs. Specifically, SSM banks reduced LLR_GL and LLP_GL by 0.94 and 0.51 percentage points, respectively (columns 1 and 2). This result is consistent with our research hypothesis that a centralised supervisory mechanism is more effective than a decentralised one, as it is neutral from national interests aimed at protecting national banking sectors. Furthermore, these results support the idea that the centralised mandate under which the NSAs operate guarantees the effectiveness of SSM supervision and allows the ECB to achieve its policy objectives in terms of reduction in credit risk (ECB, 2016; Enria, 2019).

Our results are robust to different econometric specifications. In columns 3 and 4, we report the results from regressions augmented with bank control variables where we continue to observe a statistically significant effect of the Centralised Supervision dummy. Only few bank-specific variables are statistically significant. Specifically, we find an inverse relationship between size (Size) and bank risk (LLP_GL). This indicates that portfolio diversification and management quality permit larger banks to limit their exposure to credit risks. We also observe a negative relationship between profitability (Profitability) and both measures of bank risk. This result is in line with the idea that less profitable banks invest in risker assets to boost profits. In columns 5 and 6, we 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. As displayed, the coefficient Centralised Supervision, although slightly smaller in magnitude, keeps the significance level providing further validity of our estimation. Finally, columns 7 and 8 report the results by including additional country-specific controls. While the coefficient of the interaction dummy maintains the statistical significance level, the coefficient of inflation (Inflation) displays a negative relationship with banking risk. This suggests that very low inflation levels are usually associated to deteriorated macroeconomic condition and/or slow economies and, consequently,

to higher credit risk. Finally, we find that GDP growth (GDP) is positively related to LLR_GL but negatively to LLP_GL.

[Insert Table 3 Here]

4.3 Robustness checks

4.3.1 Non-Performing Loans and Z-Score

We test the robustness of our results to a different definition of the dependent variable, by using Non-Performing Loans (NPL Ratio) ratio as an alternative credit risk measure. Several studies have used NPL ratio as proxy for bank credit risk (Berger and De Young, 1997; Williams, 2004, among others). In addition, in order to understand whether the results of our analysis are driven solely by credit risk, we use Z-score as an alternative dependent variable[10], which represents an overall measure of banking risk (Agoraki *et al.*, 2011; Laeven and Levine, 2009; Beck *et al.* 2013; Mohsni and Otchere, 2014). The Z-score indicates the number of standard deviations that return on assets have to fall below the average for the bank to become insolvent. A high Z-score suggests a sound bank, which is unlikely to fail (Delis and Staikouras, 2011). Most credit risk proxies are affected by the problem that they assume a backward-looking approach and are procyclical (Laeven and Majnoni, 2003; Bikker and Metzemakers, 2005). In contrast, the Z-score can be interpreted as a forward-looking measure of risk, as the variance at the denominator captures potential changes in bank risk level (Delis and Staikouras, 2011).

We use the logarithmic version of both NPL ratio and Z-Score, to avoid problems owing to the skewness in the distribution (Baselga-Pascual, 2015). The two new regressions (Table 4, panel A) show that the Centralised Supervision dummy is negative and statistically significant, which indicates that the banks supervised by SSM have reduced both credit and overall risk since the introduction of the new supervisory system (columns 1, and 2). The results of this robustness check are consistent with those of our previous specification, confirming the validity of the baseline model.

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

4.3.2 Placebo test

The results of our DiD estimation might be driven by other events occurred before the sample period we are analyzing. Hence, we investigate whether there have been other factors that have influenced bank credit risk before the establishment of the SSM. To rule out this possibility we create a fictitious *post* dummy starting in 2012 and study its effect over the 2009-2018 time horizon, extending our sample period of two years. The results reported in Panel B of Table 4 show that the coefficient of the dummy variable is not statistically significant for any of the dependent variables (columns 3 and 4). This finding supports our original hypothesis that the reduction of the risk exposure level of SSM supervised financial institutions is associated to the Banking Union, rather than to other past events. Moreover, since the Banking Union has been announced in 2012, we also exclude the possibility that the results were associated to the announcement of the Banking Union, rather than its actual implementation.

4.3.3 Removing Germany and France

We also test whether our results are driven by a sample selection bias. We remove Germany and France from our sample, as they have the largest number of banks in the sample (110 and 115 banks, respectively). Firstly, we remove all German banks from our original sample. Secondly, we proceed removing all banks located in France. Panels C and D of Table 4 show that the results are qualitatively unchanged from our baseline model, confirming that our results are not affected by a sample selection bias.

[Insert Table 4 Here]

4.3.4 SSM supervision in non-GIIPS countries

The results of our analysis might be driven by the sovereign debt crisis shock that hit some European countries during the 2010-2012 period. During the sovereign debt crisis in Europe, the link between sovereign and banking risk increased considerably, and it was marked in weaker countries (De Bruyckere *et al.*, 2013). Shambaugh (2012) uses the acronym GIIPS to represent the five most troubled economies of the Eurozone[11]. Their weakness is due to the fact that access to government bond markets became difficult during the crisis (Popov and Van Horen, 2013). Several banks had an excessively large exposure in domestic bonds, and

[11] They are the following: Greece, Italy, Portugal, Spain and Ireland.

therefore the sovereign weaknesses were transmitted to the banking system (Neri, 2013; Acharya *et al.*, 2015; De Marco, 2019). By analysing Italian banking industry, Bofondi *et al.* (2018) identify a causual link between the sovereign debt crisis and bank credit supply. Specifically, this crisis resulted in a significant reduction in lending, which is in turn associated to lower levels of bank credit risk (Salas and Saurina, 2002; Dell'Ariccia and Marquez, 2006b; Foos *et al.*, 2010).

In order to rule out the hypothesis that our results might be driven by the sovereign debt crisis, we remove the GIIPS countries from our sample, as they were the most affected by this crisis. If our baseline model is robust, we should observe, ceteris paribus, a reduction in banking risk in non-GIIPS countries. In the non-GIIPS subsample (Table 5), the Centralised Supervision dummy is still statistically significant for both dependent variables, suggesting that credit risk exposure of SSM supervised banks located in non-GIIPS countries has reduced in comparison to the financial institutions monitored by NSAs. This result supports the reliability and robustness of our baseline model.

[Insert Table 5 Here]

5. Conclusion

The Banking Union has been the most transformative supervisory reform in the European banking system. The ECB, through the SSM, directly supervises 117 banks in 19 countries, whereas the NSAs continue to supervise the remaining part of their respective national banking system. By drawing on the theoretical models that analyse the benefits of centralised supervision over decentralised supervision (Agarwal *et al.*, 2014; Carletti *et al.*, 2020), and on the extensive strand of literature that has shown that the quality of the supervisory function is an important determinant of bank risk (Barth *et al.* 2004; Buch and DeLong, 2008; Maddaloni and Peydro, 2011; Shehzad and De Haan, 2015) we study the effects of the European Banking Union on bank credit risk. We analyse a sample of 746 European banks over the period 2011-2018 by means of a DiD methodology to distinguish the banks that are under the SSM central supervision from those that are still supervised by NSAs.

We provide empirical evidence that banks supervised directly by the SSM have reduced their credit risk exposures more than their nationally supervised peers after the establishment of the Banking Union and the introduction of the SSM. This finding is in line with the literature that

studies the benefits of centralized banking supervision (De Larosière, 2009; Agarwal *et al.*, 2014; Carletti *et al.*, 2020). Our results shed light on the superior effectiveness of centralised supervision compared to a decentralised model in the European context. The alignment of the policy objectives of the supervisory authorities in Europe and the centralised mandate under which the NSAs operate guarantee the effectiveness of SSM supervision and allows the ECB to achieve its policy objectives in terms of reduction in credit risk (ECB, 2016; Enria, 2019).

In light of our findings, we argue that an even more integrated banking supervision might further enhance the stability and the soundness of the European banking system, enabling the banking sector to take advantage of the benefits associated to centralised supervision.

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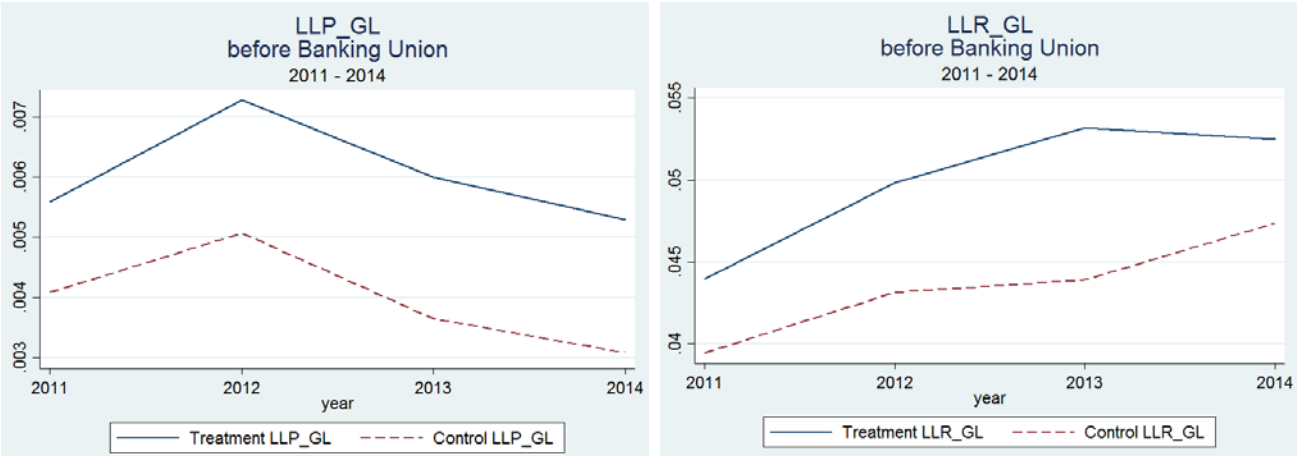

Figure 1. Figure 1 shows the average growth of Loan Loss Provisions / Gross Loans (LLP_GL) and Loan Loss Reserves / Gross Loans (LLR_GL) among treated banks (blue line) and non-treated banks (red dashed line) from 2011–14. In the pre-treatment period, correlation among the treatment and control group is: 0.9021 for LLP_GL and 0.8657 for LLR_GL, indicating that the parallel trend assumption holds.
Notes: LLP_GL is the ratio of loan loss provision-to-gross loans. LLR_GL is the ratio of loan loss reserves-to-gross loans.

Table 1
Number of banks by bank specialisation and supervisor.

Panel A
Descriptive statistics divided by specialisation and country

	Specialisation		
Country	**FHC**	**Credit Institutions**	Total
Austria	3	95	98
Belgium	4	32	36
Cyprus	1	25	26
Estonia	1	6	7
Finland	1	17	18
France	6	109	115
Germany	11	99	110
Greece	1	6	7
Ireland	1	9	10
Italy	3	96	99
Latvia	0	14	14
Lithuania	0	5	5
Luxembourg	3	60	63
Malta	1	7	8
Netherlands	9	28	37
Portugal	4	21	25
Slovakia	1	9	10
Slovenia	0	8	8
Spain	3	47	50
Overall	53	693	746

Panel B
Descriptive statistics divided by supervisor and country

	Supervisor		
Country	**NSA**	**SSM**	Total
Austria	93	5	98
Belgium	29	7	36
Cyprus	24	2	26
Estonia	4	3	7
Finland	17	1	18
France	107	8	115
Germany	98	12	110
Greece	3	4	7
Ireland	7	3	10
Italy	89	10	99
Latvia	11	3	14
Lithuania	3	2	5
Luxembourg	56	7	63
Malta	5	3	8
Netherlands	33	4	37
Portugal	22	3	25
Slovakia	7	3	10
Slovenia	5	3	8
Spain	38	12	50
	651	95	746

Note: FHC means Financial Holding Companies. NSA indicates National Supervisory Authorities. SSM is the Single Supervisory Mechanism.

Table 2

Descriptive statistics of control and treatment group prior to and after the introduction of the Banking Union.

Variables	Treatment (*SSM*)									
	Pre-Banking Union					**Banking Union Period**				
	Obs	Mean	St.Dev	min	max	Obs	Mean	St.Dev	min	max
Panel A: Bank Credit Risk and Overall Risk										
LLR_GL	323	5,00%***	4,60%	0,00%	24,72%	337	4,60%	4,90%	0,00%	24,50%
LLP_GL	345	1,20%***	2,10%	-3,20%	9,75%	356	0,60%	1,30%	-3,30%	9,80%
Z-Score	352	2,75***	1,42	-4,21	5,82	369	2,99***	1,13	0,11	6,00
NPL Ratio	74	-2,73%	0,97%	-4,88%	-0,43%	146	-3,20%	0,98%	-6,12%	-0,54%
Panel B: Bank Balance Sheet										
Funding Structure	349	50,40%***	21,10%	0,37%	91,90%	368	56,40%**	20,20%	0,40%	90,10%
Asset Structure	352	56,10%***	22,60%	0,41%	98,00%	369	54,97%*	21,10%	0,40%	93,10%
Size	352	17,48***	1,74	11,30	19,62	372	17,44***	1,68	11,31	19,59
Profitability	352	0,19%***	1,72%	-3,92%	14,80%	369	0,54%*	1,36%	-3,89%	14,55%
Capitalization	352	7,46%***	7,13%	1,59%	88,02%	369	8,89%***	7,92%	1,98%	87,62%
Panel C: Macroeconomic Variables										
GDP	380	0,72%	2,70%	-9,13%	8,56%	380	2,71%***	2,56%	-0,44%	25,16%
Saving Propensity	380	24,97%	9,10%	8,33%	52,35%	380	27,38%	10,23%	10,27%	57,08%
Inflation	372	1,78%	1,23%	-1,31%	4,98%	372	0,93%	0,97%	-1,74%	3,72%
Variables	**Control (*NSAs*)**									
	Pre-Banking Union					**Banking Union Period**				
	Obs	Mean	St.Dev	min	max	Obs	Mean	St.Dev	min	max
Panel A: Bank Credit risk and Overall Risk										
LLR_GL	1397	4,40%***	4,70%	0,00%	23,70%	1538	4,70%	5,50%	0,00%	24,50%
LLP_GL	1866	0,96%***	2,00%	-3,30%	9,86%	1972	0,70%	1,80%	-3,30%	9,80%
Z-Score	2121	3,13***	1,29	-2,72	6,21	2211	3,27***	1,23	-2,03	6,00
NPL Ratio	86	-2,80%	0,92%	-4,79%	-1,05%	182	-3,29%	1,05%	-6,22%	-1,07%
Panel E: Bank Balance Sheet										
Funding Structure	1998	56,04%***	27,00%	0,90%	92,70%	2082	59,01%**	26,30%	0,40%	91,60%
Asset Structure	2062	53,20%***	27,50%	0,40%	98,00%	2165	53,16%*	26,70%	0,75%	96,00%
Size	2158	13,95***	2,19	8,96	19,59	2412	13,99***	2,13	8,96	18,65
Profitability	2145	0,57%***	1,98%	-3,92%	14,55%	2244	0,69%*	2,00%	-3,85%	13,45%
Capitalization	2140	14,30%***	17,64%	1,59%	87,62%	2226	14,51%***	17,25%	1,43%	87,34%
Panel F: Macroeconomic Variables										
GDP	2604	0,69%	2,04%	-9,13%	8,56%	2604	2,21%***	1,64%	-0,44%	25,16%
Saving Propensity	2604	25,39%	8,94%	8,33%	52,35%	2604	27,10%	9,33%	10,27%	57,08%
Inflation	2508	1,83%	1,02%	-1,31%	4,98%	2508	0,97%	0,79%	-1,74%	3,72%

***Note**:* LLR_GL is the ratio of loan loss reserves-to-gross loans. LLP_GL is the ratio of loan loss provision-to-gross loans. NPL ratio is the natural logarithm of the ratio between non-performing loans and total gross loans. Z-Score is the number on a logarithmic scale of standard deviations that the bank's profitability (ROA) have to fall below the average for the bank to become insolvent. Funding structure is the ratio of total bank customer deposits-to-total assets. Asset structure is the ratio bank gross loans-to-total assets. Size is the natural logarithm of bank total assets. Profitability is the return on assets, which is the yearly net income-to-total assets ratio. Capitalization is the ratio of equity-to-total assets. GDP is the growth rate of the gross domestic product. Saving propensity is the ratio domestic savings-to-GDP. Inflation is the rate of increase in prices for goods and services. T-test difference in means between Mean treatment and Mean control prior and after the European Banking Union is also reported. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 3
The effect of the Banking Union on LLR_GL and LLP_GL

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	LLR_GL	**LLP_GL**	**LLR_GL**	**LLP_GL**	**LLR_GL**	**LLP_GL**	**LLR_GL**	**LLP_GL**
Centralised Supervision	**-0.0094*** **	**-0.0051*** **	**-0.0089*** **	**-0.0040** **	**-0.0057** **	**-0.0027* **	**-0.0082*** **	**-0.0032** **
	(0.0031)	**(0.0019)**	**(0.0030)**	**(0.0016)**	**(0.0027)**	**(0.0015)**	**(0.0028)**	**(0.0015)**
Funding Structure			0.0095	-0.0056*	0.0074	-0.0037	0.0074	-0.0053*
			(0.0082)	(0.0029)	(0.0084)	(0.0029)	(0.0084)	(0.0029)
Asset Structure			0.0001	-0.0028	-0.0015	-0.0036	-0.0034	-0.0031
			(0.0095)	(0.0028)	(0.0094)	(0.0028)	(0.0086)	(0.0028)
Size			-0.0009	-0.0008**	-0.0012	-0.0008**	-0.0017	-0.0009**
			(0.0012)	(0.0004)	(0.0012)	(0.0004)	(0.0012)	(0.0004)
Profitability			-0.0049***	-0.0048***	-0.0043***	-0.0042***	-0.0051***	-0.0047***
			(0.0011)	(0.0007)	(0.0011)	(0.0007)	(0.0012)	(0.0008)
Capitalization			0.0007**	-0.0001	0.0006**	-0.0000	0.0006**	-0.0001
			(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
GDP							0.0015***	-0.0008***
							(0.0006)	(0.0002)
Saving Propensity							-0.0019***	-0.0001
							(0.0007)	(0.0002)
Inflation							-0.0031**	-0.0018**
							(0.0015)	(0.0008)
Observations	3,048	3,331	2,996	3,277	2,996	3,277	2,861	3,146
R-squared	0.267	0.141	0.359	0.175	0.342	0.180	0.364	0.167
Number of banks	487	527	480	520	480	520	456	497
Country Fixed Effects	YES	YES	YES	YES	NO	NO	YES	YES
Time Fixed Effects	YES	YES	YES	YES	NO	NO	YES	YES
Country*Time Fixed Effects	NO	NO	NO	NO	YES	YES	NO	NO

Notes: This table displays difference-in-differences regression results. LLR_GL is the ratio of loan loss reserves-to-gross loans. LLP_GL is the ratio of loan loss provision-to-gross loans. The Centralised Supervision dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank i in country j has been supervised by SSM after the Banking Union implementation, 0 otherwise. Funding structure is the ratio of total bank customer deposits-to-total assets. Asset structure is the ratio bank gross loans-to-total assets. Size is the natural logarithm of bank total assets. Profitability is the return on assets, which is the yearly net income-to-total assets ratio. Capitalization is the ratio of equity-to-total assets. GDP growth is the rate of change of the gross domestic product. Saving propensity is the ratio domestic savings-to-GDP. Inflation is the rate of increase in prices for goods and services. Robust standard errors clustered at bank-level are reported in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 4

Robustness checks

	Panel A. Credit and Overall Risk		Panel B. Fictitious Banking Union	
	[1]	[2]	[3]	[4]
	NPL Ratio	**Z-Score**	**LLR_GL**	**LLP_GL**
Centralised Supervision	**-0.3111****	**0.1028*****	**-0.0026**	**-0.0008**
	(0.1564)	(0.0362)	(0.4602)	(0.0012)
Observations	452	4,044	3,655	4,077
R-squared	0.485	0.0874	0.388	0.162
Number of banks	115	658	457	498
Country Fixed Effects	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES

	Panel C. EU, no Germany		Panel D. EU, no France	
	[1]	[2]	[3]	[4]
	LLR_GL	**LLP_GL**	**LLR_GL**	**LLP_GL**
Centralised Supervision	**-0.0097*****	**-0.0032***	**-0.0093*****	**-0.0038****
	(0.0031)	(0.0017)	(0.0032)	(0.0017)
Observations	2,465	2,682	2,274	2,548
R-squared	0.314	0.146	0.464	0.188
Number of banks	384	416	363	403
Country Fixed Effects	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES

Note: **Panel A** displays difference-in-differences regression results of NPL ratio, which is the natural logarithm of the ratio between non-performing loans and total gross loans, and Z-Score, which is the number of standard deviations that the bank's profitability (ROA) have to fall below the average for the bank to become insolvent. **Panel B** displays difference-in-differences regression results of Loan Loss Reserves ratio and Loan Loss Provision ratio with "fictitious" Banking Union dummy in 2012. **Panel C** displays difference-in-differences regression results of Loan Loss Reserves ratio and Loan Loss Provision ratio for a sub-sample, which considers Euro-area banks except those located in Germany. **Panel D** displays difference-in-differences regression results of Loan Loss Reserves ratio and Loan Loss Provision ratio for a sub-sample, which considers Euro-area banks except those located in France. LLR_GL is the ratio of loan loss reserves-to-gross loans. LLP_GL is the ratio of loan loss provision-to-gross loans. The interaction dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank i in country j has been supervised by SSM after Banking Union implementation, 0 otherwise. Robust standard errors clustered by banks in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 5

The effect of the Banking Union on non-GIIPS countries

	[1]	[2]
	LLR_GL	**LLP_GL**
Centralised Supervision	**-0.0081*** **	**-0.0046** **
	(0.0025)	(0.0023)
Funding Structure	0.0006	-0.0013
	(0.0091)	(0.0041)
Asset Structure	-0.0129	-0.0053
	(0.0106)	(0.0037)
Size	-0.0020	-0.0011**
	(0.0014)	(0.0005)
Profitability	-0.0054***	-0.0035***
	(0.0019)	(0.0011)
Capitalization	0.0010***	-0.0002
	(0.0004)	(0.0002)
GDP	-0.0004	-0.0008
	(0.0010)	(0.0005)
Saving Propensity	0.0002	-0.0000
	(0.0005)	(0.0002)
Inflation	-0.0007	-0.0022**
	(0.0016)	(0.0010)
Observations	1,877	2,099
R-squared	0.348	0.091
Number of banks	305	337
Country Fixed Effects	YES	YES
Time Fixed Effects	YES	YES

Note: Table 5 displays difference-in-differences regression results of Loan Loss Reserves ratio and Loan Loss Provision ratio for CORE sub-sample, which considers Euro-area banks except GIIPS ones (Greece, Italy, Portugal, Spain, and Ireland). LLR_GL is the ratio of loan loss reserves-to-gross loans. LLP_GL is the ratio of loan loss provision-to-gross loans. The Centralised Supervision dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country j has been supervised by SSM after Banking Union implementation, 0 otherwise. Funding structure is the ratio of total bank customer deposits-to-total assets. Asset structure is the ratio bank gross loans-to-total assets. Size is the natural logarithm of bank total assets. Profitability is the return on assets, which is the yearly net income-to-total assets ratio. Capitalization is the ratio of equity-to-total assets. GDP growth is the rate of change of the gross domestic product. Saving propensity is the ratio domestic savings-to-GDP. Inflation is the rate of increase in prices for goods and services. Robust standard errors clustered by banks in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Appendix

Table A1

Timeline of the key steps of European Banking Union

Event Data			Description
25	February	2009	De Larosière propose a report that underlines the importance of a centralized system of regulation and supervision.
29	June	2012	At the Euro area summit, Governments decide to assign supervisory tasks to the European Central Bank (ECB) within a Single Supervisory Mechanism (SSM).
12	September	2012	The European Commission presents legislative proposals and formulates a road map towards a banking union.
23	October	2013	The ECB starts the comprehensive assessment.
3	November	2013	The SSM Regulation enters into force and states that the ECB assumes its full supervisory tasks on 4 November 2014.
4	September	2014	The ECB publishes the list of the significant credit institution.
4	November	2014	The SSM enters into force.

Table A2

Explanatory variables

Classification	Explanatory variables	Expected signs	Data source	References
Bank-specific variables				
Funding Structure	Total Customer Deposit / Total Assets (%)	(-)	BankFocus	Laeven *et al.* (2015)
Asset Structure	Loan / Total Assets (%)	(-)	BankFocus	Altunbas *et al.*(2007)
Size	Natural log of Total Assets	(-)	BankFocus	Baghat *et al.* (2013)
Profitability	Return on Assets (%)	(-)	BankFocus	Poghosyan and Čihak (2011)
Capitalization	Equity / Total Assets (%)	(+)	BankFocus	Gambacorta and Shin (2015)
Macroeconomic variables				
GDP	Annual real GDP growth rate (%)	(+/-)	World Bank	Poghosyan and Čihak (2011); Guidara *et al.* (2013)
Saving Propensity	Gross Domestic Savings / GDP (%)	(-)	World Bank	Festic *et al.* (2011)
Inflation	Annual average rate change in CPI (%)	(-)	World Bank	Gerlach *et al.* (2005)

CHAPTER 2

The international reserves path, evidence from the new FED swap lines era

The international reserves path, evidence from the new FED swap lines era.

Abstract

Given the importance Swap lines played during the coronavirus-induced crisis, this paper analyses the impact of temporary U.S. dollar liquidity arrangements (swap lines) on international reserves (IR). Specifically, I investigate the effect that the Federal Reserve (FED) swap lines have had on the accumulation of IR of those countries involved compared to those countries that do not have any type of liquidity arrangements with the FED. By analysing a sample of 47 countries over the period 2002-2018 and a difference-in-differences methodology, I find that, overall, there is no difference in the accumulation process of IR between those countries that were involved in the global financial crisis (GFC) swap lines and those that were not. However, on close inspection, by analysing the emerging market economies (EME) sub-sample, I find empirical evidences that these countries - involved in swap lines by FED, when these GFC arrangements expired - started to accumulate reserves to a greater extent to the other considered EME. Furthermore, when I investigate whether these divergences are due to ultra-easy monetary policies or turbulence periods, I find this greater accumulation to be a phenomenon clearly wanted by the countries involved. This result suggests that swap lines involved countries that do not believe in the benevolence of Fed operations, and being more exposed to dollar shocks than other EME, they need a higher stockpile of IR. My contribution could suggest that EME will continue to follow their precautionary patterns, also after the last coronavirus swap lines.

Keywords: International reserves; financial crises; US dollar shortage; central bank swap lines; Difference-in-Differences

JEL Classifications: E 58; F3; F31; F33; F36; F42; F55.

1. Introduction and overview

As the level of globalization has risen, numerous crises have hit emerging market economies (EMEs). Tequila Mexican crisis in 1995; East Asia in 1997; Russia in 1998; Turkey in 2001, Argentina in 2002 and 2018 are noteworthy examples. A common feature for all of them is the capital sudden stop and reserve capital flows, which have strongly affected the domestic economic and financial systems. After these first crisis episodes, several EME, particularly in the Southeast Asian region, have started to accumulate foreign exchange reserves. Figure 1 depicts the abnormal amount of international reserves (IR) accumulated after the 1990s. Specifically, the Asian crisis in late 1990s is considered the turning point of this phenomenon, thereafter several researches studied the motivations behind this buildup of IR. The latter could be considered as a defense tool against shock. They are a useful instrument against market turbulence, as also evidenced in the last global financial crisis (GFC) in 2007/2008, IR constitute the first line of defense (IMF, 2011). The reasons for the accumulation of reserves can change over time and vary from country to country (Ghosh *et al.*, 2012).

Although there are several theories considering the massive accumulation of IR by central banks in the EME, the most important explanations are only two, namely the neo-mercantilist (export-led strategy) and the precautionary (self-insurance) theories.

The IMF (2010) points out that the buildup of IR due to mercantile motives is not an objective but only a consequence of the export-led growth strategy. After the Asian financial crisis, some countries in that region began to accumulate IR in order to prevent a hypothetical appreciation of the exchange rate as an undervalued exchange rate allows them to become net exporters (Dooley *et al.*, 2004; Palley, 2007). An undervalued exchange rate can stimulate exports (Ghosh and Kim, 2009) as it helps export competitiveness (Rodrik, 2008). Since maintaining competitiveness is important, the IR accumulation process is necessary to keep both the exchange rate undervalued and an external surplus (Delatte and Fouquau, 2012). The export-led growth strategy requires a persistent surplus in the current account, and at the same time either an increase in gross capital inflows or a reduction in gross capital outflows (Bernanke, 2005). Bernanke (2005) argues that the export-led strategy is not merely the devaluation of the exchange rate, but there is a mix of factors, among which the feature that in Asia there is a constant and large "saving glut"[1]. Dooley *et al.* (2009) highlight some similarities with the Bretton Woods system in which, after WWII, some countries (Europe and Japan) pursued a development strategy based on the export-led growth. However, regarding the IR accumulation,

[1] If the high savings rate of Asian countries is spontaneous or the result of active policies remains a controversial issue.

supporting this mercantilist theory with empirical evidence is problematic, as researchers found only a little proof with respect to the mercantile motives (among others, Obstfeld *et al.*, 2010; Ghosh *et al.*, 2012).

On the other hand, several authors argue that the precautionary theory is better able to clarify a large amount of IR since the Asian crisis (Aizenman and Lee, 2007; Obstfeld *et al.*, 2010; Cheung *et al.*, 2019). The devastating Asian crises showed that EME are vulnerable and cannot trust on the support of the IMF and the other supranational institutions (Feldstein, 1999), in this perspective IR constitute a war chest of international liquidity (Bernanke, 2005). In the spirit of Diamond and Dybvig (1983), it is necessary a long-term investment that should be undertaken before a probable liquidity shock occurs. In particular, EME are characterized by the less developed financial system, weak currencies and poor financial integration, which is why they are more vulnerable to financial crises (Fischer, 2001). The EME need an adequate liquidity level to intervene in case of disorderly market conditions (IMF, 2008), since they are more exposed to capital account shocks and speculative attacks. IR could be used to prevent and mitigate a likelihood of a sudden stop (Calvo et al, 2008) and can be worthwhile to smooth financial cycles (Hofmann *et al.*, 2019), while Obstfeld et al (2010) suggest that IR should be used to protect the domestic capital markets, since residents tend to put their capital abroad in a crisis event in EME with poor IR (Alberola *et al.*, 2016). In support of precautionary motives, Aizenman and Lee (2007) underline that trade openness and external financial shocks are two factors statistically significant when they try to explain the hoarding of IR.

Analysing their composition, Aizenman *et al.* (2019) highlight how the GFC was a watershed for the IR. The GFC has strongly affected the U.S. dollar funding market both in the United States and abroad and the result was a shortage of dollar liquidity. Obstfeld *et al.* (2009) show that - owing to this lack of liquidity - EME widely used their IR and exploited IR to stabilize their weak domestic currencies (Dominguez *et al.*, 2012). Although, the GFC shows that EME are more sensitive to financial shocks (Shin and Turner, 2015), Arslan and Cantù (2019) provide evidence that EME with more IR showed lower currency depreciation during the crisis.

Since 2007, to address this issue of liquidity, the Federal Reserve (FED) established temporary U.S. dollar liquidity arrangements (swap lines) with central banks of several advanced countries. This has not been a new program, since the FED has established similar arrangements since the 1960s for foreign exchange market intervention (Hooyman, 1993), and during the terrorist attacks in 2001 (Kos, 2001). All the previous programs have been established with advanced countries[2], however, the new

[2] With some exceptions, indeed the FED established swap lines with Mexico in the 1990s.

innovative factor during the GFC was that at the end of October 2008, the Fed provided $ 30 billion swap lines to four emerging countries (Brazil, Mexico, Singapore and South Korea) (Bernanke, 2009). These new agreements could create a precedent which these countries could rely on.

Apart from a short lines window with advanced countries during the European debt crisis, swap lines appeared again in 2020, when COVID-19 (Coronavirus) pandemic triggers off a new economic and financial crisis. Since Coronavirus has spread to the United States, the domestic stock market has fallen more than 30 % while the VIX index[3] has rapidly increased (Fleming *et al.*, 2020). While the source of the crisis is different than that of the GFC, their outcomes are similar: there has been a lack of dollar liquidity at worldwide level. The Fed has used both conventional and unconventional policy tools to deal with the economic and financial disruptions caused by the pandemic. Among various measures[4], in March the FED has established temporary swap lines with all the same countries involved in the previous GFC arrangements. In this case, the provision towards EME is double, respectively each country can rely on $ 60 billion lines.

Stressing the previous key role played by the FED, for the aforementioned arrangements several authors suggest that the FED engages in swap lines as international lender of last resort (ILOLR) (Obstfeld *et al.*, 2009; McDowell, 2012; Bahaj and Reis, 2018).

Concerning the GFC swap lines, Aizenman *et al.* (2011) write an article titled "International Reserves and Swap Lines: Substitutes or Complements?". The point is that with the swap lines the FED provides the international liquidity needed in the event of crisis, therefore, centrals banks could decrease the stockpile of IR if swap lines would provide the needed liquidity in case of crisis.

The challenge is to understand if EME countries involved in swap lines trust in the FED intervention in the event of crisis. Differently to Aizenman *et al.* (2011), the aim of this paper is to address if EME actually rely on the FED intervention. Thus, the aim of this paper is not to assess if swap lines are a substitute of IR, but to identify the impact that swap lines have on them.

In order to understand the future path of IR, this research exploits the setting created by a unique natural experiment, namely the swap lines arrangements during the GFC. Although there are other examples of swap lines provided by the FED, there is a marked difference among them because the older swap lines were meant to intervene on exchange rates while those established during the GFC and Coronavirus have the sole objective of providing money market liquidity (Fleming and Klagge, 2010). These new agreements have been unprecedented and innovative. In a nutshell, taking into account the purpose of the new bilateral agreements, I would like to clearly trace the effect of

[3] It is the CBOE volatility index, also called fear gauge.

[4] For a detailed explanation of the FED measures, available from: https://www.newyorkfed.org/markets/new-york-fed-actions-related-to-covid-19

unanticipated swap lines on the IR, emphasizing that in my study swap lines constitute an external shock.

In order to identify the potential effect of the Coronavirus swap lines on IR, I use a backward-looking approach. The purpose of the 2008 and 2020 swap lines is identical, both are intended to compensate for the lack of dollar liquidity and the counterparties involved are the same. Therefore, I use a difference-in-differences (DiD) methodology applied to the GFC lines swap to understand the potential future IR movements of those EMEs involved by the Fed in the aftermath of the coronavirus liquidity arrangements. Although my analysis is aimed at EMEs, for illustrative purposes only, I also use a dataset with advanced and emerging countries. Therefore, the subsample of interest is the one relating to EMEs. I split my sample between countries involved in swap lines and not, respectively treated and control groups. To the extent that these two groups did not present systematic differences in terms of IR accumulation before 2008, I can identify the average "treatment" effect of swap lines, as an exogenous shock, on IR. To preview my main findings, the results of the whole sample indicate that overall the IR path by advanced and emerging countries does not change after the swap lines. However, additional analysis shows that the EME involved in swap lines by the FED have not decreased their trend of IR accumulation after that these programs expired, moreover, they further increase their IR level at a higher rate than other EME.

The dichotomy in the results of my entire sample and sub-sample are consistent with Aizenman *et al.* (2019), where it is shown that advanced countries and EME have a different IR accumulation behavior. In fact, the former use IR for foreign exchange interventions (Goldberg *et al.*, 2013), while the latter use IR for precautionary and mercantilist purposes (Aizenman and Marion, 2003; Aizenman and Lee, 2007). My results support the Aizenman *et al.* (2011) hypothesis, which assert that swap lines should not be considered an IR substitute, because only countries with preexisting strong financial and trade relationship can rely on some sort of dollar liquidity arrangements by the FED. However, these linkages could also constitute a source of vulnerability. As declared by the FED Chairman Greenspan in a FOMC meeting[5], the swap lines have been a necessary tool used by the FED to guarantee the safety and soundness of the domestic financial system, they thus were used for the sole purpose of preserving the stability of the United States. Therefore, the aim of this research is

[5] Meeting of the Federal Open Market Committee March 28, 1995. Available from: https://www.federalreserve.gov/monetarypolicy/files/FOMC19950328meeting.pdf

to prove that the FED is not benevolent, whereas Brazil, Mexico and South Korea are more exposed to dollar shocks than other EME.

It is also important to take into consideration the macroeconomic environment. After the GFC, central banks of advanced economies followed an unconventional monetary policy, including quantitative easing. These ultra-easy policies spilled out numerous effects on EME, such as deep capital inflows and lower international interest rates. On the one hand, the capital inflows phase could appreciate EME currencies, while the normalization phase could generate sudden outflows and speculative attacks on weak and volatile currencies. Capital flow is characterized by its skewness, where inflows are usually slow and require time, on the contrary, outflows are sudden and acute. On the other hand, these accommodative policies push huge capitals towards EME, making the IR accumulation process easier. I develop further robustness checks to underline that the highest observed accumulation rate is not a by-product of ultra-easy policies, in fact even with further explanatory variables my previous results do not change.

Although, after the GFC, all EME began to accumulate IR heavily to preserve their economies, swap lines received economies (Brazil, Mexico and South Korea) showed a more marked trend, furthermore, it is important to emphasize that the accumulation of IR in the latter countries is not only a by-product of the capital inflows.

The accumulation of IR in Brazil began before the GFC and continued thereafter. During that period, the Brazilian real continued to appreciate, as IR buying auctions had the only aim to raise the IR level (Central Bank of Brazil, 2019). The report of the Brazilian central bank (2019) highlights that EME prefer a precautionary approach as supranational institutions have demonstrated their inability to provide sufficient timely liquidity during the GFC, which is perhaps why Brazil never used its FED lines.

On the other hand, the Deputy Governor of the Bank of Mexico clearly argues that FED swap lines or other liquidity arrangements cannot be considered an IR substitute, but they could only play a complementary role (Calafell, 2019). During the GFC, the last swap lines used by Mexico expired on January 12, 2010 as the FED program was at an end, while less than one month later, in February 2010, the Mexican central bank launched monthly auctions in U.S. dollars with the aim of increase the IR as deemed insufficient. This underlines the cleared goal of Mexico to increase its IR.

Santiago (2019) asserts that: “the credibility of reserves in the eyes of financial markets is ultimately determined by the credibility of the central bank holding the reserves while the credibility of swap

lines is determined by the credibility of the central bank providing the liquidity support". In this spirit, since 2008 Korea started to disclose the currency composition and the management process of its IR (Bank of Korea, 2019). Even though, during the GFC the FED swap lines helped the Korean central bank to overcome the currency pressure and to stabilize the domestic situation (Aizenman *et al.*, 2011; Baba and Shim, 2010; Bank of Korea, 2019), as pointed out by Arslan and Cantú (2019), the swap lines are characterized by a high level of selectivity, an uncertainty linked to the times and which are not managed by the country that needs them. For the aforementioned questions, as suggested by Rossini *et al.* (2019), IR remain a mandatory tool to overcome the problem of the lack of a U.S. dollar-based lender of last resort, especially for dollarized economies.

I provide evidence that EME do not trust the Fed as an international lender of last resort. These countries do not believe in the benevolence of the Fed operations. The EME will continue to follow their precautionary patterns, and this is also owing to the characteristics of these swap lines. On the one hand, in 2013 the swap lines with 5 central banks of advanced countries[6] were converted by the FED from temporary to permanent standing arrangements, moreover, they have not any amount caps; on the other hand, some EME have been involved for a shorter period and for an exceptional lower amount. Analysing the differences among swap lines, it is understandable the reason why EME cannot rely on the FED for their dollar liquidity needs. EME involved in swap lines by the FED have only beneficed of temporary arrangement and these swap lines extended up to $ 30 billion and $ 60 billion, respectively in the 2008 and 2020 agreements. These outstanding swap amounts ranges between 4 and 10 times less the IR of the EME involved, moreover, Brazil and Singapore never used their lines. Obstfeld *et al.* (2009) argue that, in light of the IR stockpile, swap lines with EME have been largely symbolic. While the temporary nature and limited quantity of these agreements mean that they are not a valid substitute for IR, furthermore, according to Aizenman and Pasricha (2010) and Aizenman *et al.* (2011), these EME have definitively understood that they have been involved in swap lines only for their high levels of liabilities and claims in dollars, in order to avoid negative spillover in the U.S. economy. Analysing the currency composition of IR, Aizenman *et al.* (2019) provide evidence that EME central banks tend to hold a larger share of the currency of that country with which they have a stronger trade linkage and a greater amount of debt securities outstanding in that currency. In the last decade, Korea peaked 70.3% of its IR denominated in dollars, 82.3% in Brazil, while it is still predominant in Mexico. The financial and trade sectors of these EME were and continue to be heavily based on U.S. dollars, these links could be a source of vulnerability in the event of a crisis. For the aforementioned reasons when the swap lines expired in 2010, the EME concerned

[6] Bank of Canada, Bank of England, Bank of Japan, European Central Bank, and Swiss NationalBank

have started to accumulate IR again and a higher rate based on these vulnerabilities, therefore being Brazil, Mexico and Korea involved again, so it might be reasonable to expect to observe similar behavior when the Coronavirus swap lines expire.

This paper contributes to the extant literature in several ways. I contribute to the academic literature related to IR, in particular that relating to the precautionary self-insurance motives. Although, several papers analyse the change on IR accumulation before and after the GFC, the literature that has analysed the causal impact of swap lines on IR is scarce. I analyse the impact that an exogenous shock has on IR. Specifically, I analyse the impact of a temporary liquidity arrangement made by the issuer of the world key currency.

The paper proceeds as follows. Section 2 reports some historical stylized facts about the FED swap lines. Section 3 provides information related to methodology and data. The empirical results are reported in Section 4, while further robustness checks are shown in Section 5. Section 6 concludes.

2. The FED swap lines: some stylized facts

Although swap lines could appear as a modern and innovative instrument, they have almost a centenary history. The FED entered in temporary swap lines with other central banks since 1936 (Bordo *et al.* 2015). The aim of these primitive form of arrangements was a short-term instrument that anticipate a loan agreement.

However, most similar to the swap lines that the FED has entered most recently are all those arrangements established since 1961. Officially, Bordo *et al.* (2015) set the 1961 as the year of "the advent of the Federal Reserve's Swap Lines". Even though, swap lines could appear similar, in fact they have totally different aims. At that time the Bretton woods system was in force, some problems arose when the price of gold rose in the London market. By changing conditions, the other central banks had incentive to exchange unwanted dollar reserves held for gold with the U.S. Treasury (Coombs, 1976). From the U.S side, the main problem was that outstanding dollar liabilities were greater than U.S. gold stocks. With the aim to preserve the confidence in the U.S. dollar, in 1962 has been officially established a network of reciprocal swap lines. As highlighted by Bordo *et al.* (2015), the undeclared intent of the swap lines was to preserve the U.S. gold reserves. By the end of the Bretton woods era, the FED has picked up 14 counterparties: At first, Austria, Belgium, Canada, England, France, Germany, Italy, the Netherlands, and Switzerland; later, Denmark, Japan, Mexico, Norway, and Sweden. Noteworthy is the fact that the FED refused to involve Ireland because it was too slight in terms of financial and international trade relations (Reynold, 1969). As long as the

Bretton Woods system was in place, the swap lines have succeeded in their intent to preserve the US gold reserves (Makin, 1971).

With the arrival of the new era of floating exchange rates, swap lines have once again changed their main role. In this context, the swap lines acted as an IR substitute, as they became a tool for foreign exchange interventions (Hooyman, 1993). During this period, several issues related to risk sharing arose, in particular profits and losses on swap lines and the credibility of monetary policies. Despite the swap lines remained in force, after the 1981 neither the G10 central banks nor the Fed drew on these lines. They were also considered an outmoded tool (Bordo *et al.*, 2015). However, in 1994, in this spirit the FED has also established swap lines in the North American Framework Agreement (NAFA), in which are involved Canada and Mexico. Canada has never used its line of $ 2 billion, while Mexico last drew up from these lines in 1995 (FED, 2020 a). Noteworthy is the fact that Mexico was the only emerging country involved by the Fed, although, it had a $ 3 billion line, at the same time any drawing has been subject to an approval process and for any drawing above $ 1 billion have been required extra guarantees (Bordo *et al.*, 2015).

The new era of swap lines started aftermath the 11 September terroristic attack in 2001[7] (Tab 1, panel A). They differ in nature and duration than the previous arrangements. The FED entered in swap lines to ensure the functioning of the worldwide financial markets and provide liquidity in US dollars (Kos, 2001). After the terroristic attack there was a lack of dollar liquidity, for this motive the FED established swap lines with the ECB and Bank of England [8], $ 50 and $ 30 billion respectively. The highlights of these measures are the temporary nature and the aim of providing liquidity. In this case they expired after 30 days.

When the GFC spread around the world, the FED intervened to provide dollar liquidity, because it feared that instability on the foreign money market could spill out on the United States (Bordo *et al.*, 2015). Fleming and Klagge (2010) divide these new swap lines arrangements in three phases (Tab 1, panel B). The first phase, on 12 December 2007 the FED established swap lines with the European Central Bank (ECB) and Swiss National Bank (SNB), respectively $ 20 and $ 4 billion. The second phase started after the Lehman Brothers collapse in September 2008, on 18 September the FED involved Bank of Japan (BoJ), Bank of England (BoE) and Bank of Canada (BoC) in its swap lines program, while on 24 September is the turn of Reserve Bank of Australia, Sveriges Riksbank, Norges Bank, Danmarks Nationalbank. At this stage there is a huge increase in the amount of lines available,

[7] Check Table 1 for a detailed exposure of the Fed swap lines in the 21st century.
[8] The FED also increased to $ 10 billion the line in force with Canada.

which has gone from $ 24 to $ 620 billion. Finally, due to the worsening market conditions, the FED started the third and more aggressive phase, on 3 October the FED removed the swap line caps established with the ECB, BoE, SNB and BoJ. Reserves Bank of New Zealand has been involved on 28 October 2008; however, the landmark of this last stage is that the FED further extended swap lines to four EME. On 29 October 2008, the FED enter in arrangements with Banco Central do Brasil, Banco de Mexico, Bank of Korea and Monetary Authority of Singapore for respectively $ 30 billion. In December, the swap outstanding reached a peak of $ 580 billion (Fleming and Klagge, 2010). All these arrangements were definitively concluded on February 12, 2010.

The standby situation has been very short as the Fed returned from 9 May 2010 to enter in swap lines with the central banks of the five most advanced countries. The swap lines with the ECB, BoE, SNB, BoJ and BoC were set again for facing the European debt crisis (Tab 1, panel C). A limit of $ 30 billion was set for the agreement with the BoC, while the other agreements had no cap. On 31 October 2013, the FED converted the aforementioned swap lines from temporary to standing arrangements.

In March 2020, the swap lines are once again considered an innovative tool (tab 1, panel D). In early 2020, Coronavirus pandemic spreads worldwide, the Fed, among other monetary policy measures, eased the conditions of the permanent swap lines on March 15, while on 19 March it established a further nine temporary swap lines, including a six-month line of up to $60 billion to the central banks of Australia, Brazil, South Korea, Mexico, Singapore, Sweden, and of $30 billion to those of Denmark, Norway and New Zealand (FED, 2020 b).

3. Methodology & Data

3.1. Methodology

The policy implemented by the FED in 2008 regarding swap lines is an unexpected and global exogenous shock on international liquidity. This paper aims to analyse its causal effect on IR. Given the nature of the exogenous treatment, I employ a DiD approach to study the effect of the temporary U.S. swap lines on foreign exchange reserves. Various macroeconomics studies utilize this methodology (Card and Krueger, 1994, Agarwal and Qian, 2014, Koudijs and Voth, 2014), specifically Chițu (2016) develops a DiD considering the IR accumulation in the scenario of the GFC. As an alternative, Reis and Bahaj (2018) use a DiD approach to assess the impacts of swap lines evaluating several factors of central banks that have been involved in swap lines and those that have not been. This methodology has the advantage to use a panel data set up to compare a treated group of countries, those involved in swap lines, with a control group, those uninvolved by the FED.

Specifically, I compare the effect of swap lines on IR for my treatment group, with a control group of advanced and emerging countries. The regression model takes the following form:

$$Y_{j,t} = \alpha + \beta_1\left(Treated_j * Post_t\right) + \beta' K_{j,t} + D_j + \gamma_j + \varphi_t + \varepsilon_{j,t} \qquad [1]$$

Where $Y_{j,t}$ represents my measure of IR in country *j* at time *t*. Therefore, my dependent variable is IR, which is the ratio of the international reserves divided by GDP on a logarithmic scale. *Treated* is a binary variable equal to unity if country *j* has been involved in swap lines by the FED, and 0 otherwise. *Post* is a binary variable equal to unity in the years following the establishment of swap lines, 0 otherwise. β_1 is the coefficient of the so-called swap lines variable, which is the product of *Treated* and *Post* dummies, and it is the main coefficient of interest. β_1 provides the average causal treatment effect on treated countries, therefore it represents the average difference on IR between countries that can rely on swap lines for their liquidity needs and countries that cannot. K_j denotes my vector of control variables. I include five variables widely used in the literature, namely: Freedom Status (Democracy); the log ratio Broad money to GDP (Financial deepening); foreign direct investments divided by GDP (FDI), the log ratio Gross savings to GDP (Saving rate), exchange rate regime (Exchange rate). *D* is a further dummy variable (Advanced), which distinguishes between advanced and emerging countries, is equal to 1 or 0 respectively. I insert country fixed effects (γ) to control for unobservable country-specific characteristics that can affect IR. I also control for time-variant shocks over the sample period on IR with year effects (φ). All regressions are estimated with country clustering, thus allowing for correlation in the error terms. I use robust standard errors to control for heteroskedasticity and dependence (Bertrand *et al.*, 2004; Donald and Lang, 2007; Petersen, 2009). In line with Popov and Rocholl (2015), I do not insert stand-alone *Treated* and *Post* dummies in the equation [1], since their effects are already captured by γ and φ, namely country and year fixed effects.[9]

The DiD model must satisfy the parallel trend assumption to ensure suitability to analyse the effect of the swap lines on IR (Bertrand *et al.*, 2004; Imbens and Wooldridge, 2009). According to the parallel trend assumption, changes in the dependent variables over time should be exactly the same in both treatment (countries with swap lines) and control groups (countries without swap lines) in the absence of the intervention (the introduction of the FED swap lines arrangement). Figure 2 shows that the dependent variables in both treated and control groups have a similar trend from 2002 to 2008

[9] For robustness check I re-assess DiD with a more traditional approach, that is the aforementioned equation [1] plus stand-alone *Treated* and *Post* dummies (Chițu, 2016). Results appear similar and are available upon request.

(pre-treatment period). The assumption holds since the trend lines move together before implementation of the swap lines arrangement in 2008. As displayed, IR trends move in the same direction in the pre-treatment period (correlation among the treatment and control is 0.8327)[10].

3.2. Data

I construct a dataset using several sources. As gauge of the democracy, I use data from the Freedom House Political Rights Index (Freedom House, 2019). As for Macroeconomic traditional variables, I use data from International Financial Statistics (IMF). The data related to Financial and country characteristic variables are extracted from World Development Indicators (World Bank) and Statistical Data Warehouse (ECB). Exchange rate regime data are extracted from Ilzetzki, Reinhart, and Rogoff (2017)[11]. The dataset consists of 47 Countries[12]. As already mentioned, I further split the sample into 22 advanced and 25 emerging countries. Similarly to Aizenman and Pasricha (2010), I use the Morgan Stanley Emerging Market index (MSCI) criteria to classy countries[13]. I aggregate all Euro area countries of the sample into a single specification, considering that all of them are part of the Eurosystem[14]. The final sample consists in two groups, namely a treated group with 14 countries, which includes those countries that have been involved by the FED in swap lines, and a control group with 23 ones, which considers all those countries that do not receive any bilateral liquidity arrangement by the FED. The sample period ranges from 2002 to 2018[15]. All variables are winsorized at the 1% and 99% level to mitigate the influence of outliers.

Descriptive statistics for the dependent variable and all the other control variables in both treatment and control groups, prior and after the establishment of the swap lines, are shown in table 2, while table 3 reports the descriptive statistics divided by country[16]. I use the ratio total reserves[17] divided

[10] I test the parallel trend assumption on EME sub-sample, since it is my sample of interest. However, testing the full sample I obtain similar result.
[11] I suppose there are no changes in the exchange rate regime in 2017 and 2018.
[12] Appendix A shows country classification.
[13]For the full list of countries see:
https://www.msci.com/market-classification
[14] I should specify that ECB's reserves and European national central banks IR are two different and independent grosses. In this paper I only consider the IR of the whole Eurosystem. The results are similar to those with all Euro area countries no aggregated (available upon request).
[15] I decide to start from 2002 for two main reasons. On the one hand, it is in the aftermath of the 11 September terrorist attacks, in which a new era of swap lines begins. On the other hand, it is the year in which the euro was officially introduced in Europe, while previously international reserves included, among other currencies, Deutsche mark, French francs, Netherlands guilder. For further information on reserves composition see:
https://data.imf.org/?sk=E6A5F467-C14B-4AA8-9F6D-5A09EC4E62A4
[16] Although my final sample includes many advanced countries, the descriptive statistics shown are related to the EME sub-sample since it is my main sample of interest.
[17] Specifically, I use the measure total reserves minus gold (e.g., Aizenman and Lee, 2007; Aizenman *et al.*, 2019).

by gross domestic product (IR) as dependent variable. It is a classic measure of foreign exchange reserves. According to, e.g., Aizenman *et al.* (2007) and Obstfeld *et al.* (2009), I utilize the log ratio to avoid problems owing to the skewness in the distribution. All measures widely employed in the literature to assess if the reserves level is adequate or not are simply rules of thumb. Although, they are transparent and easily interpreted, with the great financial crisis they demonstrate to have a limited relevance (IMF, 2011). Nevertheless, Rodrick (2006) points out that it is necessary to find the optimal level of IR. According to Jeanne and Rancière (2006), I use the ratio reserves to GDP. Even though, the latter is not related to any risk, it is simply used as a scale factor for cross-country analysis and is useful to compare countries of different sizes (Aizenman *et al.*, 2015). Several authors employ reserves to GDP as dependent variable (e.g., Lane and Burke, 2001; Aizenman and Lee, 2007; Obstfeld *et al.*, 2009; Obstfeld *et al.*, 2010; Aizenman and Sun, 2012; Steiner, 2013; Aizenman *et al.*, 2015). Obstfeld *et al.* (2010) demonstrate that the ratio reserves to GDP is a better indicator for reserves adequacy than the traditional measures. In contrast to Guidotti (1999) and Greenspan (1999), Obstfeld *et al.* (2010) provide evidence that a "sudden stop" (Calvo, 1998) is not the unique source of financial shock, since the domestic sources of financial instability must also be taken into account. As shown by Rothenberg and Warnock (2011), many sudden stops are due only in part to a foreign reserve capital flight as they are severely affected by a national capital flight. For the aforementioned reasons, we use the ratio reserves to GDP for taking into consideration the "double- drain"[18] scenario.

As reported in Table 2 panel A and C, the average value of IR before the introduction of the swap lines for the treatment and control groups is statistically different at the level of 1%, 2.45% and 2.78% respectively. On the contrary, after the swap lines there is no difference significant, this means that the average value is almost the same, 2.88% for the treatment and 2.86% for the control group. Although both categories of countries have increased their IR levels after the swap line period, the treatment group countries have increased their IR at a faster rate. Not only Brazil, Mexico and Korea accumulate IR at a higher rate, but the average value of IR after the swap lines is higher than the control group countries.

Advanced country dummy. In line with Obstfeld *et al.* (2009) and Obstfeld *et al.* (2010), I add a dummy variable to distinguish between advanced countries and EME. Obstfeld *et al.* (2009) justify the fact that advanced countries need less IR because of their more stable banking system and also because they have better access to the financial market. Whereas Obstfeld *et al.* (2010), ceteris

[18] Internal drain and external drain, they are respectively related to capital flight and "sudden stops" in capital inflows (Calvo and Reinhart 2000).

paribus, point out that advanced countries accumulate less IR. In my full sample regression, I expect to observe a negative relation between advanced country dummy and IR.

Democracy variable. Panel B and D of table 2 report descriptive statistic for the selected democracy variable before and after the swap lines. To capture the level of democracy of a country I use the Freedom House Political Rights Index (see Freedom House, 2019), which is a measure widely used in the economic literature (Acemoglu et al, 2005). From this dataset I take into consideration the "freedom status", which ranges from 1 to 3 and distinguishes respectively among Free, Partly Free, and Not Free countries. According to the previous literature I suppose to observe a negative relationship between reserves and democracy, where autocracies have a higher incentive to accumulate reserves. Rodrick (2008) studies the opportunity cost to accumulate and hold reserves, the results are that opportunity costs could be very high especially in emerging countries and that the less democratic ones are less sensitive to this factor. Analysing the mercantilist strategy, Aizenman (2008) suggests that those countries that follow this strategy are generally less democratic than others and are better poised to accumulate reserves. Specifically, Son (2019) directly links reserves with democracy[19], he finds that those autocratic countries that rely in particular on export earnings for the national budget have greater incentives to build up IR. This result is coherent with the mercantilist strategy, according to which, in order to follow this path, it is necessary a strong political coalition.

Financial Variables. Panel B and D of table 2 report the descriptive statistics of the financial deepening before and after the swap lines, namely the ratio M2 divided by GDP. Several researchers provide evidences that development of a country's financial sector contributes to economic growth (Demirguc-Kunt and Maksimovic, 1998; Rajan and Zingales, 2003; Demirgüç-Kunt and Levine, 2008). There are different measures of financial development (Rajan and Zingales, 2003). Inspired on Levine (1997) approach, Loayza *et al.* (2000) use broad money (M2) as a share of GDP to measure the domestic financial depth. The broad money in an emerging country is considered a proxy for the potential magnitude of capital flight. Stressing that IR provide an intervention tool against abnormal market conditions (IMF, 2008), IR could be considered a buffer against the "double- drain" crisis, that is, a scenario in which there are currency and banking problems. The ratio M2 divided by GDP is widely used in the literature regarding the IR (among others, Aizenman and Lee, 2007; Obstfeld *et al.*, 2009; Aizenman *et al.*, 2015)[20]. Obstfeld *et al.* (2009) highlight the importance of considering the size of the financial system (M2) to understand the demand for IR. The latter find a positive and

[19] Using Freedom House gauge as a robustness check.
[20] Among others, Frankel and Saravelos (2010) or Rose and Spiegel (2009) provide an empirical model focused on international reserve and domestic monetary aggregates.

statistically significant relationship between M2 / GDP and IR, therefore the IR should be quite large if the financial system is highly developed. I use logarithmic version of financial deepening to avoid problems owing to the skewness in the distribution (Obstfeld *et al.*, 2009). In summary, I use this variable to assess the so-called internal drain.

Foreign direct investments to GDP (FDI)[21] is the other financial variable, the descriptive statistic of this variable is reported in Panel B and D of table 2. It is the net FDI, namely the difference between FDI inflows (liabilities) and FDI outflows (assets). FDI are widely studied in economic literature. Analysing the 1990s Asian crisis, Krugman (2000) describes the "Fire-sale FDI", namely the path of cross-border acquisition during a financial crisis. Stoddard and Noy (2015) do not find empirical evidence of Fire-sale FDI during a financial crisis in emerging countries, moreover, they find that a financial crisis affects FDI negatively. Although there could be evidence of acquisitions during a fire-sale crisis period, Alquist *et al.* (2016) find that these acquisitions may be driven by short-run and speculative intent rather than long-run investments. Although FDI is a variable widely used in studies on IR, I also stress that there is no evidence of Fire-sale FDI hypothesis, since these studies provide evidence that in the event of a financial crisis, emerging countries have to face the reverse capital flow. According to precautionary motives, for those countries that rely heavily on external financing it is important to accumulate IR to mitigate and prevent the sudden stop and reverse capital flow (Feldstein, 1999; Aizenman and Lee, 2007; Calvo *et al.*, 2008). FDI indicate a source of vulnerability, Broto et al (2011) exhibit that a greater stock of IR decreases the volatility of FDI net flows. Aizenman *et al.* (2014) find that FDI is a determinant of change on IR accumulation, particularly since when emerging countries have relaxed outflow controls (Aizenman and Pasricha, 2013). Similarly to Aizenman *et al.* (2014), I suppose to observe a negative relation between outward FDI and IR, thereby the sign of my control variable should be positive. I use this variable to assess the so-called external drain.

Macroeconomic traditional variables. Panel B and D of table 2 report the descriptive statistic before and after the swap lines of the Saving rate, that is, the gross saving divided by GDP. Saving rate is an important variable of some of the most important economic academic researches (Ramsey, 1928; Solow, 1956; Swan, 1956). Saving rate is also widely used on IR studies. Analysing IR disparities among emerging countries, Aizenman (2008) explains that the different level of IR could be owing to different cross-country saving rates and that for those countries with a higher saving rate sterilization of IR is easier. Bernanke (2005) highlights that this phenomenon of IR accumulation has

[21] Differently of the other control variables, I do not use the logarithmic form of this ratio because it could be negative. For a detailed elucidation about FDI consult Lane and Milesi-Ferretti (2007).

been widely observed in those regions with a high level of domestic saving, where governments have channeled domestic saving to build up IR. For instance, there are evidences that an EME as China has overabundance of saving (Aizenman *et al.*, 2014). Aizenman and Marion (2004) suggest that it is more difficult to accumulate IR for those countries with a low saving rate, the explanation is related to the need to use the reserve stock in the event of a fiscal crunch. A high level of savings rate leads to a higher level of IR in emerging countries, while national savings could have a negative impact on IR in advanced countries, given the best opportunities to invest in global capital market (Aizenman *et al.*, 2015). Specifically, I expect to observe a positive relationship between saving rate and IR in the EME sub-sample.

Country Characteristic Variables. I use a variable to identify the exchange rate regime, its descriptive statistic is reported in panel B and D of table n 2. Considering Ilzetzki, Reinhart, and Rogoff (2017) dataset I divide the examined countries in 5 exchange rate regime classes, namely: no separate legal tender; de factor crawling peg; managed floating, freely floating and freely falling. Each exchange rate regime represents a different level of flexibility, where a higher index represents a more flexible one. Klein and Shambaugh (2008) note that EME tend to go back and forth among different exchange rate regimes. Aizenman *et al.* (2010) suggest that, according to the mercantilist point of view, EME in Asia adopted a flexible exchange rate during the crisis of the 1990s, while they later adopted a dollar-based managed exchange rate regime again. Whereas, Dooley *et al.* (2009) underline that countries such as Brazil, Korea, Russia and Turkey during the GFC managed their exchange rate to stimulate their exports. The exchange rate regime is particular important in EME because it allows to relatively absorb market pressures (IMF, 2008). Arslan and Cantú (2019) assert that a higher level of IR is required in those countries where the exchange rate is highly managed. Numerous studies highlight the importance of considering the exchange rate regime when analysing the behavior of IR accumulation (Frenkel, 1980; Flood and Marion, 2002). Obstfeld *et al.* (2009) provide evidence that the exchange rate regime may be a determinant of IR accumulation, however, this proxy is not statistically significant when considering the EME sub-sample. Whereas, Lane and Burke (2001) point out that the exchange rate regime is not statistically significant in any sub-sample. Although, I expect to observe a negative relation where countries with a more flexible exchange rate regime need a lower level of IR, this relationship could not be statistically significant.

4. Empirical results

As specified above, advanced countries and EMEs have no similar need to hold IR, then the main results of interest are those related to EME since advanced countries have transparent, credible and certain monetary policies, and in particular they can rely on swap lines, so they need less to

accumulate IR. However, for illustrative purpose, I also report the results of the full sample, which includes advanced countries.

4.1. Full sample

[Insert Table 4 Here]

Results coming from equation n. 1 are shown in table 4. In the first column is represented only the swap lines variable, which is the interaction between dummy treated and dummy post. The coefficient is positive but not statistically significant, indicating that there is no statistically significant difference between the IR accumulation rates of those countries involved in swap lines, after that these arrangements have been set. The estimate appears substantially similar even when fixed effects by country and time have been added in the second column, aimed at considering country-specific and time-variant characteristics. Column 3 shows the result with advanced, democracy, financial, macroeconomic and country characteristic variables. At this stage, it is widely intuitive that the significance of the swap lines variable does not change, however, in this section my variable of interest is advanced country dummy. The latter splits the whole sample between advanced and emerging countries. Whereas the swap lines variable, like the previous cases, is not statistically significant, the dummy advanced is negative and statistically significant at 1 %. Namely, there is a statistically significant difference in the IR accumulation path between advanced and emerging countries, this result therefore suggests further analysis taking into account the EME subsample. The coefficient of democracy is positive and statistically significant, that means that less democratic countries have major stimulus to accumulate IR. The coefficient of FDI is positive, that is countries in which FDI inflows is bigger than FDI outflows are more exposed to external drains, according to precautionary motives those countries tend to accumulate a major stockpile of IR. Although, the sign of the other control variables is coherent with my expectation, being no statistically significant they do not represent a determinant of IR accumulation for the whole sample.

4.2. Emerging market economies – subsample

[Insert Table 5 here]

In this section, I examine the dynamics of IR accumulation in EME, which are the subjects more interested by this phenomenon. The baseline result is reported in table 5 column 1, in which there is only the swap line variable that is positive and significant. To avoid unobservable country-specific characteristics and time-variant shocks, I add country and time fixed effects to my baseline regression.

Column 2 shows that the swap lines variable is still positive and statistically significant. Finally, column 3 exhibits the result of the whole equation [1], in which democracy, financial, macroeconomic and country characteristic variables are also considered. The swap lines variable maintains the statistical significance level (albeit at the 10% level). The positivity of the swap lines variable displays that after the GFC swap lines the EME counterparts have started their IR accumulation process considerably more than other EME. Another important factor is that, with the exception of the exchange rate regime, all my control variables have a positive and significant relation regarding to IR. According to the full sample result, democracy variable is positive and significant, so this is a further validation that autocratic countries have a higher incentive to accumulate reserves. According to Obstfeld *et al.* (2009), the positive relation between IR and financial deepening is statistically significant. An EME with a quite large size of its financial system should hold a stockpile of IR to face an internal capital drain in the event of crisis, therefore a higher size of the financial system suggests a major level of IR. The relation between FDI and IR is the same of the aforesaid motives, net liabilities for FDI are positively related to IR, therefore the external drain is still considered a source of risk among those EME that accumulate IR. Saving rate variable highlights a linear relationship with IR, consistently with Bernanke (2005), for those countries with a major saving rate have been easier to channel domestic saving toward IR. According to Aizenman (2008), EME with a higher saving rate face less problems to sterilize IR.

In summary, it emerges that there are empirical evidences that those countries involved in swap lines by FED start to accumulate reserves to a greater extent to the other EME considered, when these arrangements expired. Analysing the control variables, I could highlight that motives behind the accumulation IR process differ between advanced and emerging countries. When I consider the whole sample, then advanced and emerging countries together, financial deepening and saving rate variables are not significant, by contrast the same variables are considered two important proxy in EME sub-sample. Moreover, as displayed in table 5, in EME sub-sample financial deepening and saving rate variables are significant at the 1% level. The latter finding is coherent to Aizenman *et al.* (2015), where financial deepening and saving rate show opposite paths depending if the sample involves advanced or emerging countries.

5. Robustness checks

5.1. Ultra-easy monetary policies and fear gauge

As highlighted by Aizenman *et al.* (2015), it is important to consider accommodative monetary policies in advanced countries, because after the GFC, quantitative easing (QE) and extremely low interest rate policies triggered a huge capital inflow into EME in search of yields. Whereas Aizenman

et al. (2019) highlight that it is important to distinguish between distressed and tranquil financial situation. With the aim of validating my previous results, I add some more explanatory variables. Adding GDP growth, I would evaluate whether the difference in IR accumulation between swap received countries and the other ones is due to cross-country growth rate differences. In a regression, I use the Fed's monetary policy rate[22] to take into account the accommodative monetary policies of advanced countries, in addition, with the interaction FDI * policy rate it is possible to examine whether some countries experienced a higher inflow during the QE period. Whereas, in another regression, I use VIX[23] to distinguish between turmoil and quiet times and the FDI * VIX interaction to evaluate whether some countries had higher outflow during a turbulent period.

[Insert Table 6 here]

Table 6 reports the results with the new explanatory variables. Column 1 shows that the swap lines variable is still positive and statistically significant, while among the new proxy only policy rate is statistically significant. The negative sign of the latter indicates that the EME examined tend to increase their IR during a period characterized by a low monetary policy rate. In column 2 the swap lines variable remains positive and significant, while among the added variables VIX is the only statistically significant with a positive relationship, i.e. the EME increase their IR during a turmoil period. In light of these additional tests, I can assert that the differences in the accumulation path of IR after the swap lines are not due to differences between countries, since in both regressions the new interactions, the FDI * policy rate and the FDI * VIX, are not statistically significant, while GDP growth is never significant. Therefore, these results further confirm that Brazil, Mexico and Korea have intentionally increased their IR after the GFC swap lines because they do not rely on the Fed as an international lender of last resort, and it is not a merely by-product of the differences in capital flows.

5.2. Propensity Score matching – Difference in Differences

As I mentioned before, in a DiD approach the main coefficient of interest is β_1, because it allows us to identify the average causal effect of the swap lines on IR in the treated countries after the implementation of the arrangements (relative to not being treated). What I need to evaluate is the average treatment effect on treated, which, in a DiD, is captured by the interaction variable (Angrist and Pischke, 2008). However, a prerogative is that the average treatment effect on treated can be

[22] Data are extracted from BIS statistics.
[23] Data related to volatility index, fear gauge, are extracted from Datastream.

identify only in absence of sample selection bias. For validating previous results, treatment must be assigned randomly. If the FED had involved some countries for some specific characteristics, the treatment would not have been randomly assigned, so the study would have been influenced by selection bias.

In order to assess whether my previous results were due to sample selection bias, I use a different and larger sample. Similarly to Chițu (2016), as robustness checks, I employ a sample that includes all EME among the 186 IMF member countries. It is important that control group owns similar characteristics with treatment group, so the treatment might be somewhat random. For the development of further analysis on the new sample, I use propensity score matching (PSM) to construct a control group as proposed by Rosenbaum and Rubin (1983). The predicted probability (propensity score) of swap lines to be undertaken by a country is obtained from the estimation of a Logit model. The PSM model could be depict as follow:

$$p_i = \Pr\left(D_i = 1 \middle| X_{j,t}\right) = \delta\left(\mathrm{X'}_{j,t}\,\beta + \varepsilon_i\right) \qquad [2]$$

where D_i is a dummy variable describing the treatment status. D = 1 if a country has been involved by the FED, and D = 0 otherwise. $X_{j,t}$ is a vector of democracy, financial, macroeconomic and country characteristic variables in the two years prior to GFC swap lines and δ is a standard normal cumulative distribution function. As subset of observable characteristics of PSM, I use the same variables used in the previous estimations. Specifically, to match treated and control observations, I employ the nearest neighbor(s)[24] algorithm (Forbes *et al.*, 2013). The PSM model checks for systematic differences between treated and control group that affect outcomes, namely the sample selection bias is removed. These further tests are important to support the hypothesis that the previous results are driven by the effect of the treatment, and therefore there are not systematic differences between the two groups before the swap lines.

I divided this analysis in two steps. Firstly, by using the logit regression, I estimate the propensity scores based on neighbor algorithm. Secondly, I construct a new sub-sample consisting of the treated and control countries, in which the latter are those countries considered as close as possible to the treated on the basis of a series of observable characteristics.

[Insert Table 7 here]

[24] It captures those countries that have the closest propensity score.

Table 7 reports the average treatment effect on the treated, the treatment is positive and statistically significant. This result is a proof that all my previous estimations are not driven by systematic differences, but the highlighted differences in the IR accumulation behavior are due to the FED swap lines.

[Insert Table 8 here]

The estimate from the DiD-PSM results is shown in Panel A of table 8. The new sample consists of 102 countries and even with a larger sample the estimates rare broadly similar. Although, the magnitude of the swap lines variable is smaller, it is still positive and statistically significant.

5.3. Panel average

In the spirit of Obstfeld *et al.* (2010), I remove all time series identifications, that is I summarize all the information available in only two time periods: pre and post. On the one hand, “pre” assembles the averages of the pre-swap lines variables for each country, on the other hand, “post” puts together the averages of the variables in the after-swap lines period for the same countries. Substantially, I have only two observations for all variables for each country. In summary, in panel B of table 8 I perform my DID through the pre and post averages of the panel for each country.

[Insert Table 8 here]

My results are still strikingly similar, since the swap lines variable is statistically significant at 5 % level.

5.4. Placebo test

For further validate the DiD estimation, I carry out a specific test on swap lines variable. The aim of this further test is to assess whether there have been other exogenous factors that have influenced IR accumulation path before the establishment of the GFC swap lines. To perform this experiment, I create a fictitious *post* dummy starting in 2007.

[Insert Table 8 here]

The results are reported in panel C of table 8, in which the swap lines variable is not statistically significant while the control variables, with the exception of the exchange rate regime, are still positive and statistically significant. Based on this result, I can assert that the new IR accumulation phenomenon of EME involved by the FED is associated to GFC swap lines rather than other past

events. Furthermore, since the GFC began in 2007, with this further test I can rule out that the starting point of this trend was implemented before the swap lines.

6. Conclusions

Considering the changing nature of the accumulation of international reserves, an extensive strand of literature has shown that the global financial crisis was a watershed for the IR (Aizenman *et al.*, 2015; Aizenman *et al.*, 2019). Noticeably, FED swap lines have been among the most important intervention tools during the GFC. Stressing the key role played by the FED, for the aforementioned arrangements several authors suggest that the FED engages in swap lines as international lender of last resort (Obstfeld *et al.*, 2009; McDowell, 2012; Bahaj and Reis, 2018). It is important to emphasize that the swap lines, in providing dollar liquidity, play a complementary role of IR. In this research, by using a sample of 47 countries over the period 2002-2018 and a DiD methodology, I investigate the impact of FED swap lines on IR accumulation.

I provide empirical evidence that advanced and emerging countries follow different patterns in the accumulation of IR. My results, with respect to emerging market economies subsample, empirically confirmed that have been structural change in IR accumulation, moreover, I find that those countries involved in swap lines by FED, when these GFC arrangements expired, started to accumulate reserves to a greater extent to the other EME.

According to previous literature, I discover a statistically significant relationship with democracy, financial deepening, FDI and savings rate. Where less democratic countries tend to accumulate more IR, whereas EME with a fairly large size of their financial system hold a greater stockpile of IR. Net FDI liabilities are positively related to IR, while countries with a major saving rate hold more IR.

Owing to the global macroeconomic scenario, EME tend to increase their IR during a period characterized by a low US monetary policy rate and a turmoil period.

My analysis has important policy implications. I provide evidence that, notwithstanding the recent liquidity arrangements, further efforts are still required for the sake of the global economic architecture. Although, the FED swap lines are a useful and essential tool, the credibility of swap lines is determined by the credibility of the central bank providing the liquidity support, and the EME involved in these arrangements do not believe in the benevolence of these supports.

In the recent Coronavirus crisis, similar arrangements have been set again with the same counterparties, however, until a credible ILLR is found, there is no reason to expect future stability in the IR accumulation path and in line with the above results, I expect that when these agreements expire, the countries involved might accumulate reserves to a greater extent than the other EME.

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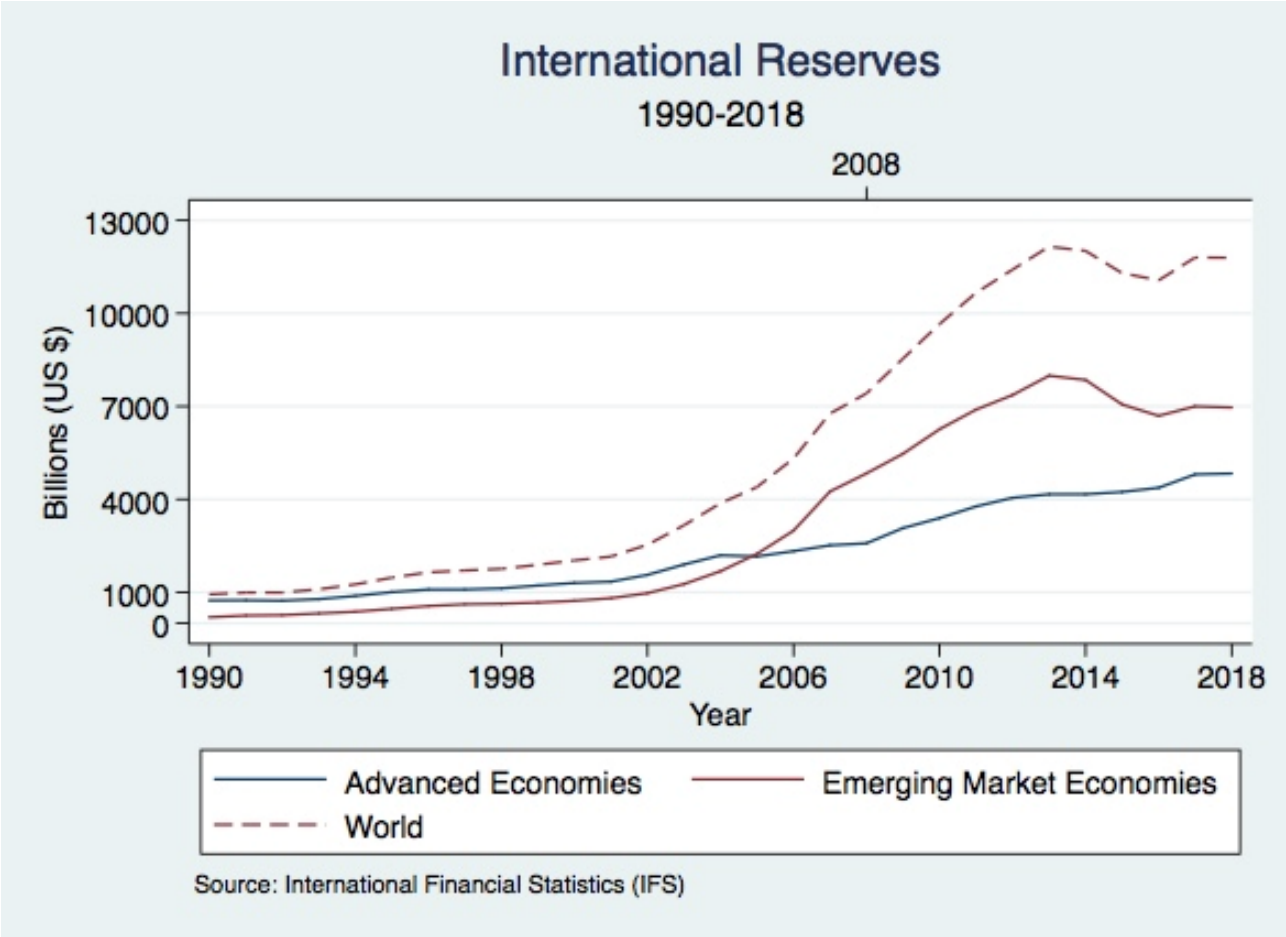

Figure 1. Figure 1 depicts the amount of international reserves (IR) accumulated after the 1990s. I split my sample among advanced economies (blue line), emerging market economies (red line), and world (red dashed line) from 1990 to 2018.

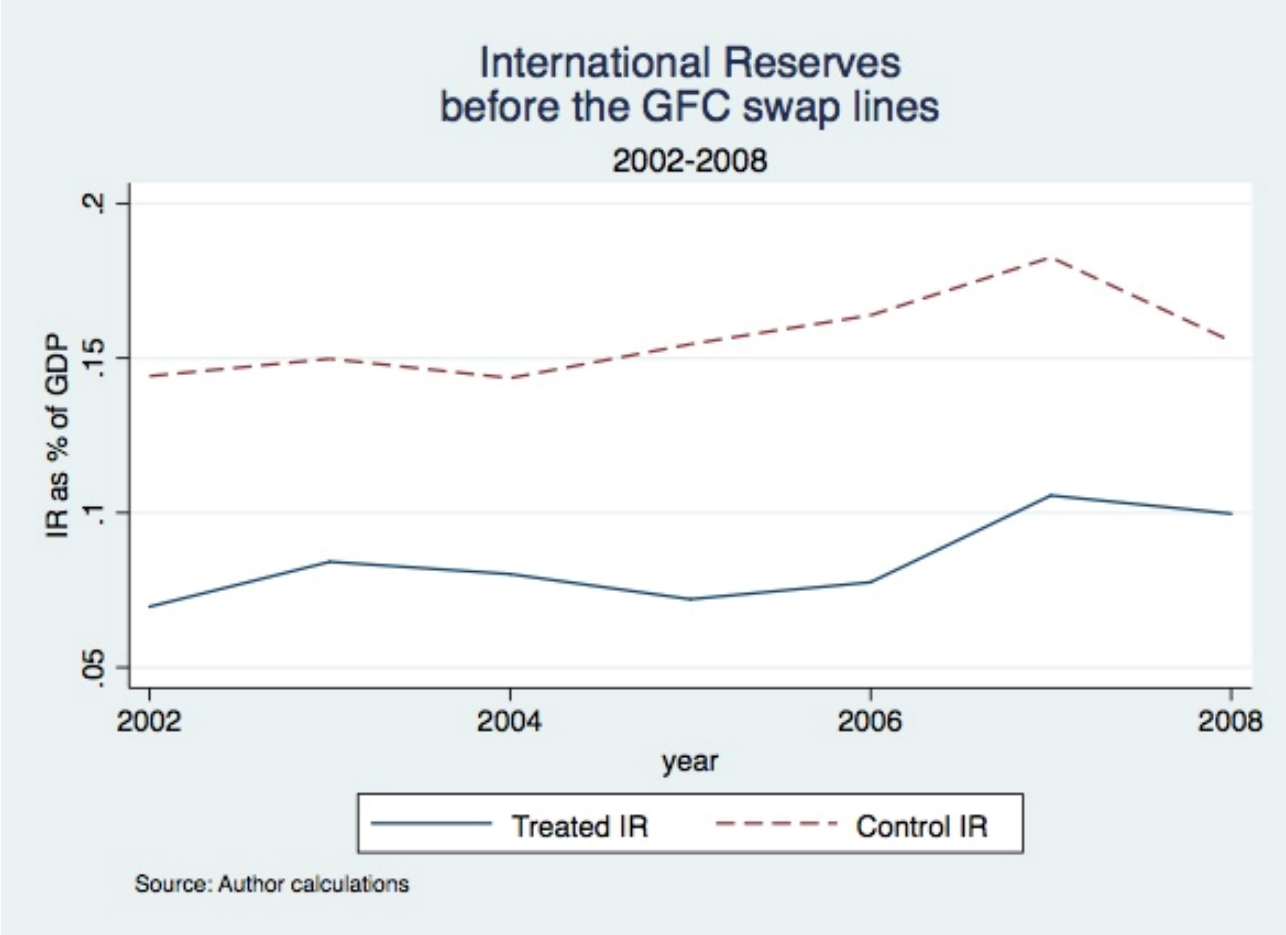

Figure 2. Figure 2 shows the average growth of the International Reserves ratio between the treated countries (blue line) and the untreated countries (red dashed line) from 2002 to 2008, relative to the sub-sample of emerging market economies. In the pre-treatment period, correlation among the treatment and control is 0.8327 for IR, indicating that the parallel trend assumption holds.

Notes: IR is the ratio of international reserves as % of GDP.

Table 1

FED swap lines opened with Central Banks

	Date			Central bank and authorized swaps lines (billion)
Panel A : ***11 September Terroristic attack***				
Phase 1	12	September	2001	European Central Bank (ECB) $ 50
	13	September	2001	Bank of Canada (BoC) $ 10
	14	September	2001	Bank of England (BoE) $ 30
Phase 2	13	October	2001	All swap lines expired
Panel B : ***Global Financial Crisis***				
Phase 1	12	December	2007	ECB $20 , Swiss National Bank (SNB) $ 4
	11	March	2008	ECB $ 30 , SNB $ 6
	2	May	2008	ECB $ 50 , SNB $ 12
	30	July	2008	ECB $ 55
Phase 2	18	September	2008	ECB $ 110 , SNB $ 27, Bank of Japan (BoJ) $ 60, BoE $ 40, BoC $ 10
	24	September	2008	Reserve Bank of Australia $ 10, Danmarks Nationalbank $ 5, Sveriges Riksbank $ 10, Norges Bank $ 5
	26	September	2008	ECB $120 , SNB $ 30
	29	September	2008	ECB $240 , SNB $ 60, BoJ $120, BoE $ 80, BoC $ 30, Reserve Bank of Australia $ 30, Danmarks Nationalbank $ 15, Sveriges Riksbank $ 30, Norges Bank $ 15
Phase 3	13	October	2008	ECB, SNB, BOE without cap
	14	October	2008	BoJ without cap
	28	October	2008	Reserve Bank of New Zealand $ 15
	29	October	2008	Banco Central do Brasil $ 30, Banco de Mexico $ 30, Bank of Korea $ 30, Monetary Authority of Singapore $ 30
	1	February	2010	All swap lines expired
Panel C : ***European debt crisis***				
Phase 1	9	May	2010	ECB, SNB, BoJ, BoE without cap; BoC $ 30
Phase 2	31	October	2013	ECB, SNB, BoJ, BoE, BoC converted to standing
Panel D : ***Coronavirus***				
	15	March	2020	ECB, SNB, BoJ, BoE, BoC new terms and conditions
	19	March	2020	Reserve Bank of Australia $ 60, Danmarks Nationalbank $ 30, Sveriges Riksbank $ 60, Norges Bank $ 30, Reserve Bank of New Zealand $ 30, Banco Central do Brasil $ 60, Banco de Mexico $ 60, Bank of Korea $ 60, Monetary Authority of Singapore $ 60

Source: Federal Reserve System

Table 2
Descriptive statistics of treatment and control group prior and after the introduction of the Global Financial Crisis Swap lines

Variables	Treatment									
	Pre- swap lines					After- swap lines				
	Obs.	Mean	S.D.	Min	Max	Obs.	Mean	S.D.	Min	Max
Panel A: Dependent variable										
IR	21	2,45%***	0,51	1,79%	3,26%	30	2,88%	0,31	2,40%	3,40%
Panel B: Independent variables										
Democracy	21	1,00***	0,00	1,00	1,00	30	1,30***	0,47	1,00	2,00
Financial deepening	21	4,04%	0,63	3,22%	4,86%	30	4,30%	0,60	3,40%	5,02%
FDI	21	1,24%**	1,28	-1,16%	3,00%	30	1,12%	1,98	-1,73%	4,08%
Saving rate	21	3,15%	0,27	2,74%	3,56%	30	3,15%	0,33	2,60%	3,59%
Exchange rate	21	3,24***	0,70	2,00	5,00	30	3,13***	0,35	3,00	4,00
GDP	21	3,64%***	1,89	-0,04%	7,43%	30	2,16%***	2,66	-5,29%	7,53%
Policy rate	21	2,76%	1,60	1,10%	5,02%	30	0,41%	0,55	0,13%	1,83%
VIX	21	19,76	6,87	12,55	31,59	30	18,74	5,84	11,05	31,79
Variables	Control									
	Pre- swap lines					After- swap lines				
	Obs.	Mean	S.D.	Min	Max	Obs.	Mean	S.D.	Min	Max
Panel C: Dependent variable										
IR	147	2,78%***	0,53	1,31%	4%	210	2,86%	0,71	0,80%	4,58%
Panel D: Independent variables										
Democracy	147	1,88***	0,87	1,00	3,00	210	1,92***	0,84	1,00	3,00
Financial deepening	147	4,02%	0,46	3,16%	5,06%	210	4,21%	0,43	3,19%	5,31%
FDI	133	2,23%**	2,18	-3,39%	10,12%	198	1,08%	1,83	-5,47%	7,99%
Saving rate	133	3,23%	0,35	2,62%	3,97%	198	3,23%	0,38	2,26%	4,10%
Exchange rate	147	2,31***	1,10	1,00	5,00	210	2,46***	0,84	1,00	4,00
GDP	147	5,90%***	3,37	-10%	17%	210	3,85%***	3,35	-7,80%	17%
Policy rate	147	2,76%	1,56	1,10%	5,02%	210	0,41%	0,54	0,13%	1,83%
VIX	147	19,76	6,73	12,55	31,59	210	18,74	5,76	11,05	31,79

Note: IR are International reserves, which is the ratio of the international reserves divided by GDP on a logarithmic scale. Democracy means the cross-country Freedom Status. Financial deepening is the log ratio Broad money to GDP. FDI means foreign direct investments divided by GDP. Saving rate is the log ratio Gross savings to GDP. Exchange rate depicts the different exchange rate regimes. GDP is the annual growth of the gross domestic product. Policy rate is the official Fed's monetary policy rate. VIX is the CBOE volatility index. T-test difference in means between Mean treatment and Mean control prior and after the FED swap lines is also reported. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 3
Descriptive statistics of treatment and control group divided by country

Country	IR	Democracy	Financial deepening	FDI	Saving rate	Exchange rate	GDP
Treatment group							
Brazil	2,517	1	4,297	2,338	2,821	3,412	2,378
	(0,38)	(0,00)	(0,18)	(1,16)	(0,12)	(0,71)	(3,04)
Korea, Rep.	3,205	1	4,862	-0,829	3,528	3,118	3,737
	(0,10)	(0,00)	(0,11)	(0,84)	(0,04)	(0,49)	(1,67)
Mexico	2,386	1,529	3,413	1,992	3,100	3	2,195
	(0,29)	(0,51)	(0,16)	(0,82)	(0,07)	(0,00)	(2,33)
Control group							
Argentina	2,239	1,059	3,366	1,686	2,834	1,941	2,821
	(0,40)	(0,24)	(0,29)	(0,72)	(0,18)	(0,90)	(5,98)
Chile	2,699	1	4,355	3,225	3,100	3	3,865
	(0,19)	(0,00)	(0,07)	(1,37)	(0,08)	(0,00)	(2,26)
China	2,521	3	5,148	2,239	3,861	1,529	9,221
	(0,62)	(0,00)	(0,13)	(1,32)	(0,07)	(0,51)	(2,21)
Colombia	2,436	2	3,641	2,555	2,845	3	4,025
	(0,18)	(0,00)	(0,21)	(1,09)	(0,08)	(0,00)	(1,85)
Czech Republic	3,270	1	4,217	2,744	3,233	2,882	2,799
	(0,42)	(0,00)	(0,16)	(2,88)	(0,06)	(0,33)	(2,92)
Egypt, Arab Rep.	2,420	2,941	4,454	2,904	2,777	1,706	4,257
	(0,68)	(0,24)	(0,11)	(2,71)	(0,32)	(0,47)	(1,70)
Hungary	3,122	1,059	4,017	2,042	3,023	2,588	2,303
	(0,33)	(0,24)	(0,11)	(1,57)	(0,18)	(0,51)	(3,00)
India	2,788	1	4,289	1,063	3,514	2,235	6,901
	(0,14)	(0,00)	(0,08)	(0,48)	(0,08)	(0,44)	(1,60)
Indonesia	2,499	1,529	3,702	0,981	3,329	2,647	5,390
	(0,12)	(0,51)	(0,08)	(0,74)	(0,16)	(0,79)	(0,60)
Malaysia	3,684	2	4,872	-0,454	3,482	2,235	5,142
	(0,20)	(0,00)	(0,05)	(1,68)	(0,13)	(1,09)	(1,88)
Pakistan	1,863	2,353	3,961	1,320	3,099	2	4,543
	(0,47)	(0,49)	(0,08)	(1,01)	(0,13)	(0,00)	(1,77)
Peru	3,221	1	3,626	3,898	3,027	2,529	5,286
	(0,24)	(0,00)	(0,20)	(1,31)	(0,11)	(0,51)	(2,31)

Philippines	3,069	1,824	4,163	0,395	3,796	2,706	5,548
	(0,24)	(0,39)	(0,13)	(1,09)	(0,03)	(0,47)	(1,66)
Poland	2,816	1	3,976	2,208	2,861	3	3,909
	(0,20)	(0,00)	(0,18)	(1,00)	(0,09)	(0,00)	(1,54)
Qatar	2,610	3	4,115	-2,925	3,962	1	8,960
	(0,40)	(0,00)	(0,25)	(1,85)	(0,13)	(0,00)	(6,42)
Russian Federation	3,132	2,882	3,796	-0,236	3,319	2,824	3,330
	(0,26)	(0,33)	(0,27)	(0,81)	(0,11)	(1,13)	(4,16)
Saudi Arabia	4,010	3	4,045	2,018	3,670	1	3,826
	(0,81)	(0,00)	(0,19)	(3,06)	(0,24)	(0,00)	(3,84)
South Africa	2,257	1	4,265	0,491	2,804	3,882	2,692
	(0,38)	(0,00)	(0,09)	(1,54)	(0,06)	(0,33)	(1,92)
Thailand	3,595	2,176	4,742	1,001	3,386	3	4,069
	(0,20)	(0,73)	(0,09)	(2,11)	(0,06)	(0,00)	(2,44)
Turkey	2,348	2,118	3,841	1,381	3,142	3,647	5,682
	(0,09)	(0,33)	(0,17)	(0,86)	(0,08)	(0,70)	(3,75)
United Arab Emirates	2,744	3	4,162	.	.	1	4,080
	(0,38)	(0,00)	(0,28)	.	.	(0,00)	(3,65)

Note: IR is the International reserves ratio, which is the ratio of the international reserves divided by GDP on a logarithmic scale. Democracy means the cross-country Freedom Status. Financial deepening is the log ratio Broad money to GDP. FDI means foreign direct investments divided by GDP. Saving rate is the log ratio Gross savings to GDP. Exchange rate depicts the different exchange rate regimes. GDP is the annual growth of the gross domestic product. Robust standard errors in parenthesis.

Table 4
The effect of swap lines on IR

	(1) IR	(2) IR	(3) IR
Swap lines	**0.2289**	**0.2289**	**0.2571**
	(0.1701)	(0.1773)	(0.1792)
Advanced country			-1.1914***
			(0.2433)
Democracy			0.1753*
			(0.0931)
Financial deepening			0.3104
			(0.2026)
FDI			0.0215**
			(0.0097)
Saving rate			0.5520*
			(0.2945)
Exchange rate			-0.0699
			(0.0760)
Observations	629	629	569
R-squared	0.107	0.854	0.835
Number of Countries	37	37	34
Time Fixed Effects	NO	YES	YES
Country Fixed Effects	NO	YES	YES
Cluster (Country)	YES	YES	YES

Note: This table displays difference-in-differences regression results of IR. IR is the International reserves ratio, namely the ratio of the international reserves divided by GDP on a logarithmic scale. The Swap lines dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if country j has been involved in swap lines by the FED after the global financial crisis, 0 otherwise. Advanced country is a dummy variable that distinguishes between advanced countries and Emerging Market Economies. Democracy means the cross-country Freedom Status. Financial deepening is the log ratio Broad money to GDP. FDI means foreign direct investments divided by GDP. Saving rate is the log ratio Gross savings to GDP. Exchange rate depicts the different exchange rate regimes. Robust standard errors clustered by Country in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 5
The effect of swap lines on IR in Emerging Market Economies

	(1) IR	(2) IR	(3) IR
Swap lines	**0.4116*** **	**0.3787** **	**0.3480***
	(0.0863)	(0.1531)	(0.1952)
Democracy			0.1475*
			(0.0796)
Financial deepening			0.9823***
			(0.2386)
FDI			0.0362*
			(0.0205)
Saving rate			0.8400***
			(0.1896)
Exchange rate			-0.0364
			(0.0539)
Observations	425	425	399
R-squared	0.0434	0.819	0.867
Number of Countries	25	25	24
Time Fixed Effects	NO	YES	YES
Country Fixed Effects	NO	YES	YES
Cluster(Country)	YES	YES	YES

Note: This table displays difference-in-differences regression results of IR.IR is the International reserves ratio, namely the ratio of the international reserves divided by GDP on a logarithmic scale. The Swap lines dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if country j has been involved in swap lines by the FED after the global financial crisis, 0 otherwise. Democracy means the cross-country Freedom Status. Financial deepening is the log ratio Broad money to GDP. FDI means foreign direct investments divided by GDP. Saving rate is the log ratio Gross savings to GDP. Exchange rate depicts the different exchange rate regimes. Robust standard errors clustered by Country in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 6
The effect of swap lines on IR in Emerging Market Economies considering ultra-easy monetary policies and global fear gauge.

	(1) IR	(2) IR
Swap lines	**0.3313***	**0.3443***
	(0.1864)	(0.1907)
Democracy	0.1493*	0.1520*
	(0.0811)	(0.0804)
Financial deepening	1.0267***	1.0181***
	(0.2413)	(0.2369)
FDI	0.0270	0.0398
	(0.0228)	(0.0377)
Saving rate	0.7707***	0.7795***
	(0.1922)	(0.1945)
Exchange rate	-0.0443	-0.0420
	(0.0568)	(0.0560)
Gdp	0.0109	0.0105
	(0.0132)	(0.0130)
Policy rate	-0.2078***	
	(0.0726)	
FDI * Policy rate	0.0043	
	(0.0067)	
VIX		0.0234**
		(0.0095)
FDI * VIX		-0.0002
		(0.0016)
Observations	399	399
R-squared	0.868	0.868
Number of Countries	24	24
Time Fixed Effects	YES	YES
Country Fixed Effects	YES	YES
Cluster(Country)	YES	YES

Note: This table displays difference-in-differences regression results of IR. IR is the International reserves ratio, namely the ratio of the international reserves divided by GDP on a logarithmic scale. The Swap lines dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if country j has been involved in swap lines by the FED after the global financial crisis, 0 otherwise. Democracy means the cross-country Freedom Status. Financial deepening is the log ratio Broad money to GDP. FDI means foreign direct investments divided by GDP. Saving rate is the log ratio Gross savings to GDP. Exchange rate depicts the different exchange rate regimes. GDP is the annual growth of the gross domestic product. Policy rate is the official Fed's monetary policy rate. VIX is the CBOE volatility index. Robust standard errors clustered by Country in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 7

Propensity Score matching estimates - Average treatment effect on the treated

Estimator: *propensity-score matching* Number of Countries = 108
Matches: *Nearest neighbour* Outcome model : *matching*
Treatment model: *logit*

IR	Coef.	Rob. Std. Err.	z	P>|z|	[95% Conf. Interal]	
ATET						
dummy						
Treated						
(1 vs 0)	0,72794	0,35056	2,08	0,038	0,04085	1,41503

Note: The table reports the average treatment effect on the treated obtained from the propensity score matching estimates calculated as the difference in International reserves ratio between the treated and the matched control groups according to the nearest neighbour algorithm. IR is the International reserves ratio, namely the ratio of the international reserves divided by GDP on a logarithmic scale. Treated is a binary variable equal to unity if country j has been involved in swap lines by the FED, 0 otherwise.

Table 8

Robustness Checks

	Panel A. Propensity score matching	Panel B. Panel average	Panel C. Fictitious Swap lines
	IR	**IR**	**IR**
Swap lines	**0.1944***	**0.3494****	**0.1729**
	(0.1175)	(0.1473)	(0.1426)
Observations	1,626	47	399
R-squared	0.205	0.401	0.864
Number of Countries	102	24	24

Note: **Panel A** displays difference-in-differences regression results of IR for Propensity score matching subsample. **Panel B** displays difference-in-differences regression results of IR through the pre and post averages of the panel for each country. **Panel C** displays difference-in-differences regression results of IR with "fictitious" swap lines dummy in 2007. IR is the International reserves ratio, namely the ratio of the international reserves divided by GDP on a logarithmic scale. The Swap lines dummy is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if country j has been involved in swap lines by the FED after the global financial crisis, 0 otherwise. Robust standard errors clustered by Country in parenthesis. Significance levels: ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Appendix A: **Country samples**

Advanced countries: Australia; Canada; Denmark; Euro countries; Hong Kong SAR, China; Israel; Japan; New Zealand; Norway; Singapore; Sweden; Switzerland; United Kingdom.

Emerging Market Economies: Argentina; Brazil; Chile; China; Colombia; Czech Republic; Egypt, Arab Rep.; Hungary; India; Indonesia; Korea, Rep.; Malaysia; Mexico; Pakistan; Peru; Philippines; Poland; Qatar; Russian Federation; Saudi Arabia; South Africa; Thailand; Turkey; United Arab Emirates.

Euro countries: Austria; Belgium; Cyprus; Finland; France; Germany; Greece; Ireland; Italy; Luxembourg; Malta; Netherlands; Portugal; Spain.

CHAPTER 3

Banks' Market Power, Monetary Policy Transmission and Financial Stability Risks:
The effects of negative policy rates on euro area banks

Banks' Market Power, Monetary Policy Transmission and Financial Stability Risks: The effects of negative policy rates on euro area banks

Abstract

This paper investigates to what extent the introduction of negative monetary policy rates altered competitive conditions 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, increased market power hindered the transmission of monetary policy and discouraged banks from taking excessive risks.

Keywords: NIRP, Banks' market power, Bank lending channel, Financial Stability, DiD

JEL Classifications: E44, E52, E58, G20, G21

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1. Introduction

To counter the severe recession and the deflationary pressures arose during the Global Financial Crisis (GFC) and the sovereign debt crisis, policymakers launched an unprecedented accommodative monetary policy cycle.[36] During this period, which has been now lasting for about ten years, monetary policy rates reached the zero-lower bound (ZLB). In the euro area the low interest rate environment reached its watershed in 2014 when the ECB was the first major central bank to lead its main policy rate into negative territory[37] 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 and their customers in comparison to a positive interest rate environment. Such behavioural changes could affect the market power of banks, which in turn may have monetary policy and financial stability implications. For example, a stream of literature shows that banks reshape their asset side flexibly when their margins are compressed by Negative Interest Rate Policies (NIRP). Specifically, in response to NIRP, banks adjust their sources of income (Altavilla et al., 2018), investment choices (Bubeck et al., 2020) and lending decisions (Heider et al., 2019).

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. Secondly, 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,

[36] Available from: https://www.ecb.europa.eu/pub/economic-bulletin/articles/2020/html/ecb.ebart202003_02~4768be84e7.en.html#toc1

[37] 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.

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 with respect to banks which are located in countries that did not adopt the NIRP. We also 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.

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 et al. (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 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 and investment decisions (Bubeck et al., 2020, Heider et al., 2019)), tend to enhance fee-based services and start charging higher fees (Bottero et al., 2019; IMF, 2017; Kok et al., 2016; Lopez et al., 2018) offsetting to some extent the negative impact of the low interest rates on the net interest income (Altavilla et al., 2018; Molyneux et al., 2019, Basten and Mariathasan, 2018; Cœuré, 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 cost of non-deposit funding (Heider et al., 2019). Overall several studies show a significant decrease in banks' overall funding costs after 2014 (IMF, 2021; ECB, 2020) and an increase in banks' efficiency accompanied with a general reduction in costs

(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 monetary policy transmission and financial stability in the euro area after the introduction of the NIRP. More specifically, we tack two further research questions. We study 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 financial 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 financial stability. We compare the lending behaviour and financial stability of euro area banks with different levels of market power before and after the ECB sets 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 hinders monetary-policy transmission. On the other hand, we find that after setting negative rates, banks with higher market power reduce their overall risk. This latter result is confirmatory of the "competition-fragility" view, which suggests that an erosion (increase) of market power and a decrease (increase) in mark-up would encourage banks to take excessive (less) risks.

The many empirical works which study the NIRP effects cover different fields, i.e. the NIRP effects on bank profitability (Altavilla et al., 2018; Molyneux et al., 2019), on systemic risk (Nucera et al., 2017), on lending channel (Eggertsson et al., 2019, Heider et al., 2019), on investment choices (Bubeck et al., 2020), however, 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 et at., 2017) and the impact of competition on the bank lending channel (Fungácová et al.,2014; Leroy, 2014). We also contribute to the literature that analyses financial stability by focusing on competition (Allen and Gale, 2004; De Jonghe et al.,2016; Jiménez et al., 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 financial 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 2 reviews the existing academic literature relevant for this study. Section 3 depicts the evolution of competition in the Eurozone. Section 4 sheds light on the tripod estimation methodology applied in this study and Section 5 describes the adopted empirical models, estimation strategy and data. Section 6 reports the empirical results and Section 7 reports a battery of robustness checks which confirm the baseline findings. Finally, section 8 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 by 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, as a result banks can generate high returns. However, Berger et al (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, so higher market concentration could not generate higher profits (SCP paradigm).

Due to the aforementioned weaknesses, a more recent strand of literature employs a non-structural approach[38] for studying the dynamic 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.

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

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 bank lending channel

As banking competition may influence how monetary policy is transmitted to bank lending, it is essential to take into consideration bank market power for an exhaustive assessment of the pass-through mechanism of the NIRP. In this context, it is key to capture the possible way NIRP may affect banks' market power.

Recent researches 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., Drechsler et al., 2017; Scharfstein and Sunderam 2016). Fungácová 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 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, Fungácová et al. (2014) and Leroy (2014) obtain different results as regards the role of competition in distressed periods. Fungácová et al. (2014) find no evidence on the role of bank competition in the transmission of monetary policy during the crisis.[39] 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 financial stability

The literature provides many insights concerning the nature of the relationship between bank competition and financial 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

[39] Altunbas et al. (2012) also find no impact of competition on bank behaviour in crisis times, i.e. competition does not seem to influence bank risk.

thereby would encourage banks to take excessive risks. On the other hand, Boyd and De Nicoló (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 et al. (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 Detriagiache (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 et al. (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 Eurozone

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, the empirical evidences have shown mixed results for the EU banking markets. Casu and Girardone (2009), 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 evidences 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 et al. (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. 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 report (2017) 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.[40]

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 financial stability in the NIRP period.

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

Market power

In this study, we gauge 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:

$$Lerner_{it} = \left(P_{TA_{it}} - MC_{TA_{it}}\right)/P_{TA_{it}} \quad [1]$$

where $P_{TA_{it}}$ 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 $MC_{TA_{it}}$ is the marginal cost of total assets for bank *i* at time *t*. $MC_{TA_{it}}$ 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 $MC_{TA_{it}}$, 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:

[40] 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.

$$\log(C_{it}) = \alpha + \beta_1 \times \log(Q_{it}) + \beta_2 \times (\log(Q_{it}))^2 + \beta_3 \times \log(W_{1,it}) + \beta_4 \times \log(W_{2,it}) + \beta_5 \times \log(W_{3,it}) + \beta_6 \times \log(Q_{it}) \times \log(W_{1,it}) + \beta_7 \times \log(Q_{it}) \times \log(W_{2,it}) + \beta_8 \times \log(Q_{it}) \times \log(W_{3,it}) + \beta_9 \times (\log(W_{1,it}))^2 + \beta_{10} \times (\log(W_{2,it}))^2 + \beta_{11} \times (\log(W_{3,it}))^2 + \beta_{12} \times \log(W_{1,it}) \times \log(W_{2,it}) + \beta_{13} \times \log(W_{1,it}) \times \log(W_{3,it}) + \beta_{14} \times \log(W_{2,it}) \times \log(W_{3,it}) + \theta \times Year\ Dummies + \gamma \times Bank\ Specialization\ Dummies + \varepsilon_{it} \quad [2]$$

where bank costs (C_{it}) are a function of output (Q_{it} for the total asset), three input prices (i.e. the price of borrowed funds $(W_{1,it})$, the price of labour ($W_{2,it}$), and the price of physical capital $(W_{3,it})$)[41], 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:

$$\beta_3 + \beta_4 + \beta_5 = 1\ ;\ \beta_6 + \beta_7 + \beta_8 = 0\ ;\ \beta_9 + \beta_{12} + \beta_{13} = 0\ ;\ \beta_{10} + \beta_{12} + \beta_{14} = 0\ ;\ \beta_{11} + \beta_{13} + \beta_{14} = 0 \quad [3]$$

Exploiting the estimated coefficients from Eq. [2] we compute the marginal cost $MC_{TA_{it}}$:

$$MC_{TA_{it}} = C_{it}/Q_{it} \times [\beta_1 + 2 \times \beta_2 \times \log(Q_{it}) + \beta_6 \times \log(W_{1,it}) + \beta_7 \times \log(W_{2,it}) + \beta_8 \times \log(W_{3,it})] \quad [4]$$

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).

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 and Gertler, 1995). In this study, we use the annual growth rate

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

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, $\Delta(Loans)_{i,t}$ 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 supports the idea that it is important to normalize the measure of lending, in our analysis, we also use a different specification of our dependent variable. More precisely, we use $\Delta(Loans)_{i,t\,\mathrm{NORM}}$ 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.

$$\Delta(Loans)_{i,t\,\mathrm{NORM}} = \Delta(Loans)_{i,t} - \frac{1}{4}\sum_i \Delta(Loans)_{i,T} \qquad [5]$$

where *T*=2011, 2012, 2013, 2014 is the time period (year).
A higher level of $\Delta(Loans)_{i,t}$ or $\Delta(Loans)_{i,t\,\mathrm{NORM}}$ 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 et al., 2006; Berger et al., 2009; Beck et al., 2013; De Jonghe et al., 2016). The Z-score, $Z_{i,t}$, 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:

$$Z_{i,t} = \frac{ROA_{i,t} + EA_{i,t}}{\sigma(ROA)_{j,t}} \qquad [6]$$

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 σ(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 et al., 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 et al. (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.

$$ROR_{ROA} = \frac{ROA_{i,t}}{\sigma(ROA)_{i,t}} \quad [7]$$

where ROR_{ROA} indicates the risk-adjusted ROA, that is ROA divided by its volatility. However, in this case the volatility of the ROA, σ(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.

5. Empirical model, estimation strategy and data

5.1 Empirical Model and Estimation Strategy

Market power

We adopt a DiD approach to examine the impact of NIRP on market power, on bank lending and bank stability. 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:

$$Y_{i,j,t} = \alpha + \beta_1\left(Treated_{i,j} * Post_{j,t}\right) + \beta' K_{i,j,t} + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \quad [8]$$

Where $Y_{i,j,t}$ represents the Lerner index for bank *i* in country *j* at time *t*. However, we also develop two further econometric specifications in which $Y_{i,j,t}$ represents the logarithm of the Lerner index's components $P_{TA_{it}}$ and $MC_{TA_{it}}$, i.e. respectively output prices and marginal costs. $Treated_{i,j}$ is a dummy variable that takes the value 1 if bank *i* in country *j* has been affected by NIRP and 0 otherwise. $Post_{j,t}$ 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.[42] 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. $K_{i,j}$ 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)[43], and Chinn-Ito index of capital account openness (Financial openness). Finally, we also include banks fixed effects (γ) and time fixed effects (φ)[44]. We use robust standard errors to control for heteroskedasticity and cross-sectional dependence (Bertrand et al., 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- 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

[42] The treated countries in our sample introduced the NIRP on 5 June 2014, so the dummy $Post_{j,t}$ 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 $Post_{j,t}$ takes value 1 in 2014 instead of 2015.

[43] 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.

[44] 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.

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 evidences 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.

Bank lending channel

The changes in euro area banks' market power over time suggest the need of a detailed analysis of the effects of this evolution on the monetary policy transmission mechanism. In this context, 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.[45] Relying on the following specification we study the impact of bank competition on the transmission of monetary policy via the lending channel:

$$Y_{i,j,t} = \alpha + \beta_1\left(Lerner_{i,j,t} * MP_{j,t} * Post_{j,t}\right) + \beta_2\left(Lerner_{i,j,t} * MP_{j,t}\right) + \beta_3\left(Lerner_{i,j,t} * Post_{j,t}\right) + \beta_4\, Lerner_{i,j,t} + \beta_5\, MP_{j,t} + \beta_6\, Post_{j,t} + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \qquad [9]$$

$Y_{i,j,t}$ denotes our measues of lending, specifically, it is $\Delta(Loans)_{i,t}$ or $\Delta(Loans)_{i,t\,\mathrm{NORM}}$ 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. [9] 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 that banks with a higher level of market power are less sensitive to changes

[45] 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.

in the monetary policy rate during the NIRP period. β_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.

Bank stability

It is also important to shed light on the potential effects of the increase in market power during the NIRP period on financial stability. Accordingly, using the sample of euro area banks, we estimate a further specification[46] with the aim of investigating the link between bank market power and bank stability:

$$Y_{i,j,t} = \alpha + \beta_1\left(Lerner_{i,j,t} * Post_{j,t}\right) + \beta' K_{i,j,t} + \gamma_j + \varphi_t + \varepsilon_{i,j,t} \quad [10]$$

$Y_{i,j,t}$ denotes banks' soundness 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.

5.2 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 (S&P 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)[47]. 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

[46] 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.

[47] 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.

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 1,347extra-euro area banks (control group). All bank specific characteristics are winsorized at the 1% and 99% level to smooth the influence of outliers. The cross-correlation matrix, which shows that our control variables are not highly correlated[48] 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 trendof 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

[48] We also develop the Hausman test for endogeneity, which tells us that there is not reverse causality among dependent and control variables (results not reported but available upon request).

dynamics are consistent with the higher level of market power of euro area banks in the aftermath of the NIRP.

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 et al, 2005).

We employ the variable liquid asset to total assets to control for bank liquidity. Liquidity generates lower margins, as higher liquidity results into lower returns. Fernández de Guevara and Maudos (2007) provide empirical evidences 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 leverage leads to lower funding costs (Arnould et al., 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 leverage 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. [8] 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. Athanasouglu et al. (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[49]. 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. Therefore, total lending shrinks and banks optimally 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) 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 et al., 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). Therefore, we expect to observe a positive relationship between the Chinn-Ito index and competition in the banking sector.

6. 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 monetary policy transmission during the NIRP period and finally iii) estimate the relationship between banks' market power and banks' financial stability during the NIRP period.

[49] 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 Bank' s deposits has had greater influence on money market rates, effectively making the DFR rate the main policy rate. Noteworthy that DFR was the only official rate that went into negative territory.

Baseline results

By employing the Lerner index as dependent variable, Table 2 shows the empirical results obtained from the estimation of Eq. [8] 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 of 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.

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. Differently, liquidity is negatively correlated to market power. In fact, a 10 percentage points increase in liquidity decreases the Lerner index by about 0.6 bps. This confirms our expectations, as higher liquidity results into lower remuneration which translates into lower market power. Leverage have the greatest impact on market power. Specifically, we find that an increase in banks' leverage 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 a 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, therefore, the advantages due to banks' size decrease as bank total assets increase. Finally, column 5 reports the result by including 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 are a threat to banks' mark-up. The estimate coefficient of the monetary policy rate is negative and significant confirming our hypothesis. A monetary policy tightening of 100 bps decreases 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.

Table 3 shows the empirical findings obtained from the estimation of Eq. [8] 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.

Monetary policy transmission mechanism

Table 4 reports the results obtained from the estimation of Eq. [9] 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 providing empirical evidence of the existence of a bank lending channel in the euro area and proving that a decrease (increase) in the monetary policy rate leads to an increase (decrease) in loan growth rate. Furthermore, we find that our coefficient of 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 hindered 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 Fungácová 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 loan growth rate and loan growth rate normalised.

Financial stability

Table 5 reports the results obtained from the estimation of Eq. [10] 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. This result is validated by the similar results reported in column (2) 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 et al. (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 financial stability of the euro area.

7. Robustness checks

In this section we provide evidence that our results stand up a battery of robustness checks.

7.1 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:

$$Q_Y\left(\tau\middle|K_{i,j,t}\right) = (\alpha_i + \delta_i\, q(\tau)\,) + \beta_1\left(Treated_{i,j} * Post_{j,t}\right) + K'_{i,j,t}\beta + K'_{i,j,t}\,\gamma\, q(\tau) \quad [11]$$

The variable $Y_{i,j,t}$ is the Lerner index, while τ is the τ-th quantile of $Y_{i,j,t}$ and $(\alpha_i + \delta_i\, q(\tau)\,)$ are the quantile-τ fixed effect for bank i. $K_{i,j}$ denotes our vector of bank and country characteristics. $\beta_1\left(Treated_{i,j} * Post_{j,t}\right)$ 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. [11] and is structured in 5 columns. The columns contain the estimate results for the median, 10th, 30th, 70th and 90th 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 10th and 90th, are relatively less significant[50]. Also the impact of NIRP decreases to some extent as the level of the Lerner index increases indicating indeed 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

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

significant at 5% level on the median; while Asset structure has only a significant impact on the 70th 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. By observing 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.
In summary, NIRP has increased the market power of European banks regardless of their original level of market power.

7.2 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 authors' 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 and rejects the possibility that results are driven by the authors' decision.

7.3 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 are due to the NIRP introduction.

7.4 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 reports the result of our DiD baseline estimation calculated in a narrower time period. Keeping

the sample symmetry, we shrink the time period of four years, therefore the new sample period goes from 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.

7.5 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 [8]. 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).

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:

$$\log(P_i) = \alpha + \beta_1 \times \log(W_{1,i}) + \beta_2 \times \log(W_{2,i}) + \beta_3 \times \log(W_{3,i}) + \gamma_1 \times \log(Y_{1,i}) + \gamma_2 \times \log(Y_{2,i}) + \gamma_3 \times \log(Y_{3,i}) + \Omega \times Bank\ Specialization\ Dummies + \varepsilon_{it} \quad [12]$$

where the output price of loans (P_i) is a function of three input prices ($W_{1,it}$ for the price of borrowed funds, $W_{2,it}$ for the price of labour, and $W_{3,it}$ for the price of physical capital), three control variables ($Y_{1,i}$ for the banks' total assets, $Y_{2,i}$ for the ratio of net loans to total assets, and $Y_{3,i}$ for the ratio of equity to total assets) and a vector of bank specialization dummies. We estimate Eq. [12] 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:

$$\text{H} - \text{statistic} = \beta_1 + \beta_2 + \beta_3 \quad [13]$$

We use the opposite sign of the H-statistic[51] 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 [8]. 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.

7.6 Propensity Score Matching

However, 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 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 et al., 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. Therefore, increases in the banks' market power in the Eurozone are directly attributable to NIRP.

8. Conclusion

In the last decade, central banks launched an unprecedented accommodative monetary policy cycle. Moreover, several central banks located in advanced countries led their policy rates into negative territory. The effects of this new policy aroused interest in central banking circles and academia. 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 and their customers will change in comparison to a positive interest rate environment.

[51] Noteworthy is the fact that the reliability of the H-statistic depends on the long-run equilibrium, that is, return on bank assets must be not related to input prices. We test the E-statistic, which shows that the long-run equilibrium condition is satisfied (results not reported but available upon request).

We support the idea that behavioural changes affect the market power of banks, which in turn has monetary policy and financial 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 evidences that NIRP increased market power of the affected banks. Furthermore, we find that, in a negative rates context, bank competition has implications for monetary policy transmission and financial stability. In the euro area, during the NIRP period, the increased market power hindered the transmission of monetary policy and at the same time the higher level of market power discourages banks from taking excessive risks.

In light of our findings, we argue that although negative rates have become a standard instrument in the ECB's toolkit, their overall effects could remain controversial.

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

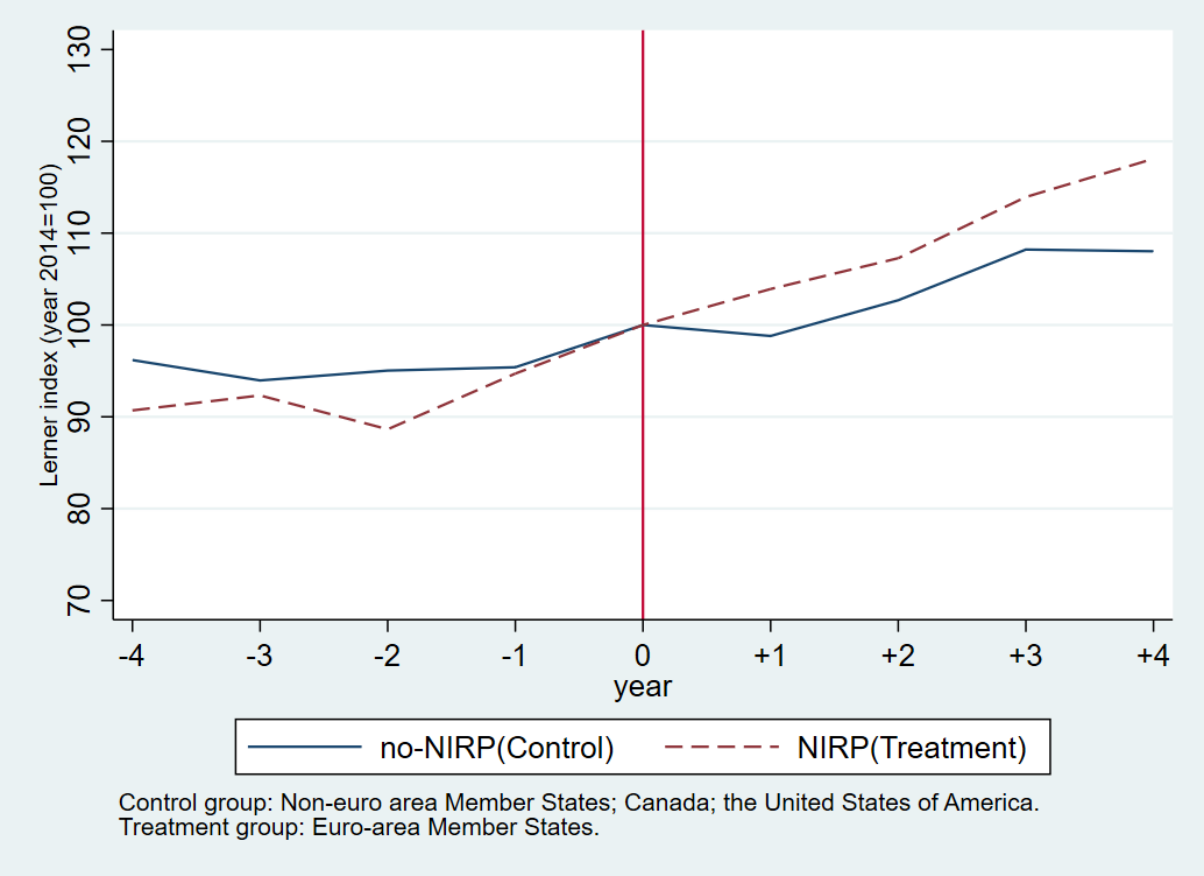
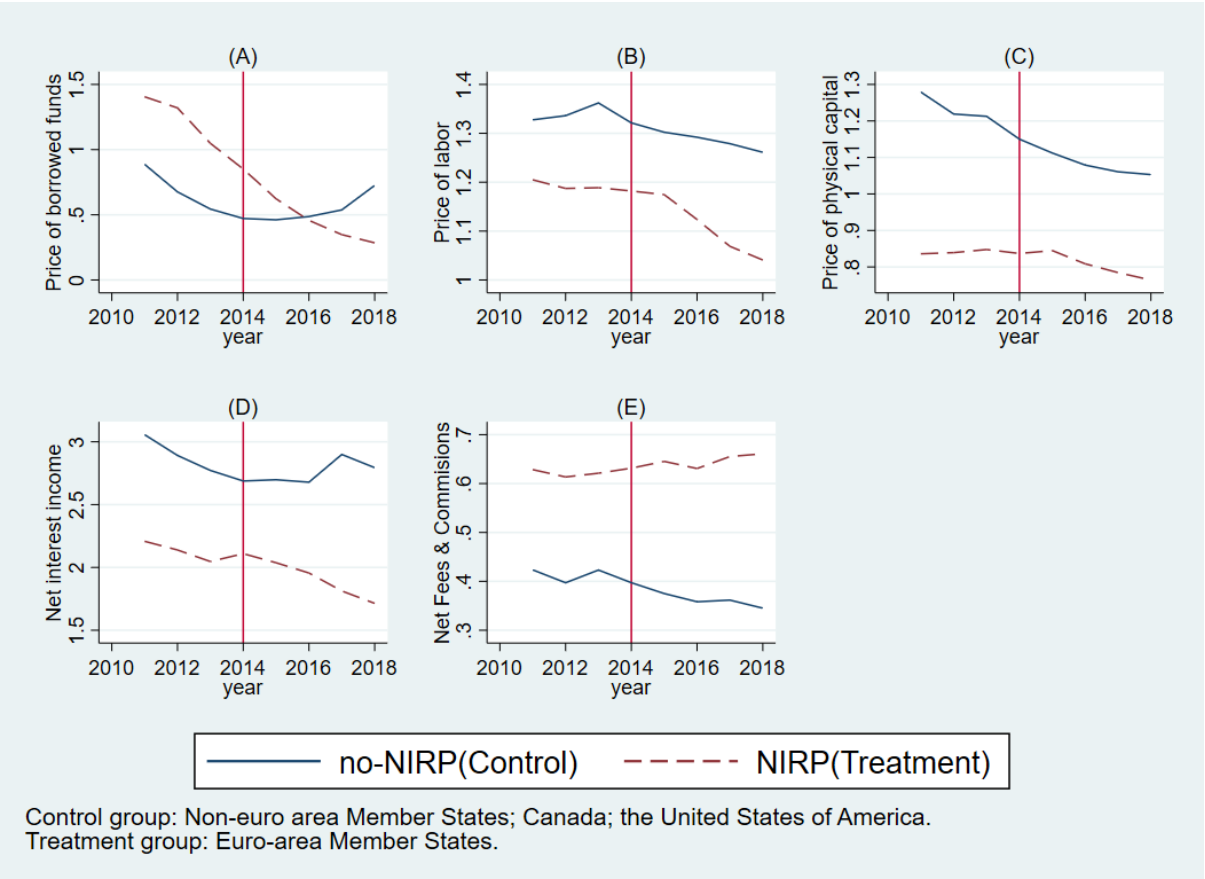


Figure 1 shows the yearly evolution of Lerner index (year 2014 = 100) for the treated banks (red dashed line) and non-treated banks (blue line). We calculate an index for each bank and plot the mean index for NIRP and no-NIRP affected banks. The vertical red line indicates the introduction of NIRP (year 0 = 2014).

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



Control group: Non-euro area Member States; Canada; the United States of America.
Treatment group: Euro-area Member States.

Figure 2 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)

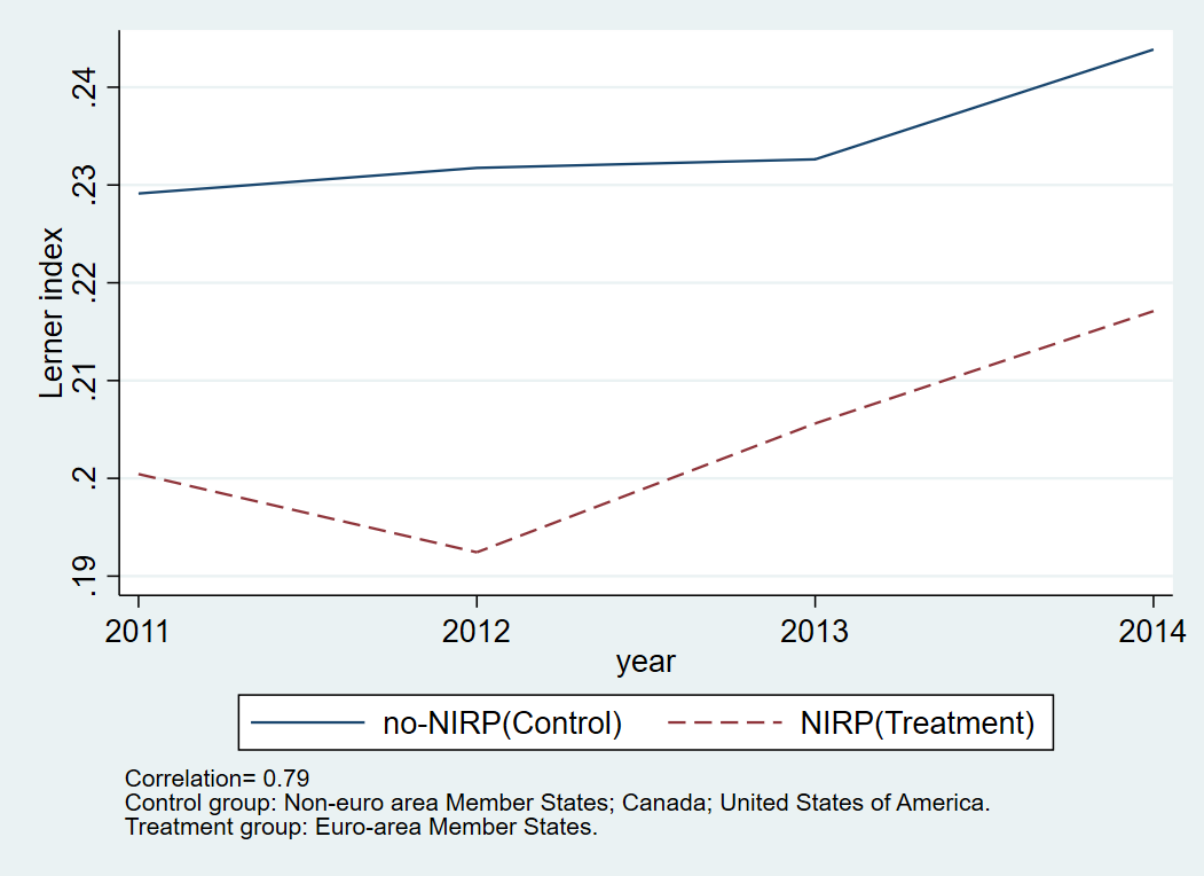


Figure 3 shows the yearly mean of Lerner index for the treated banks (red dashed line) and non-treated banks (blue line) from 2011 to 2014. In the pre-treatment period, correlation among the treatment and control group is 0.84, indicating that the parallel trend assumption holds.

Table 1. T-test for differences in means

Variable: Lerner index	Level			First Difference		
	[1]	[2]	[3]	[4]	[5]	[6]
	Control	**Treatment**	**Diff (T-C)**	**Control**	**Treatment**	**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: The first two rows of columns [1], [2], [4] and [5] show the means of the Lerner index for the control group and treatment group before and after the NIRP, specifically [1] and [2] for the levels whereas [4] and [5] for the first differences. The bottom row of columns [1], [2], [4] and [5] 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 and differences in differences. The bottom row in columns [3] and [6] show the difference in differences and t-test. Standard deviations are reported in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 2. The effect of NIRP on Lerner index

	(1)	(2)	(3)	(4)	(5)
	Baseline	+Fixed Effects	+Bank specific variables		+Macroeconomic variables
Variables	Lerner index	Lerner index	Lerner index	Lerner index	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. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

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

	[1]	[2]	[3]	[4]	[5]	[6]
	Baseline+FE		+Bank specific variables		+Macroeconomic variables	
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 banks' output prices while Ln(MC) is the logarithm of the banks' marginal costs. NIRP-effect is the interaction dummy Treated*Post, 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, *** p<0.01, ** p<0.05, * p<0.1

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

Variables	(1) $\Delta(Loans)_{i,t}$	(2) $\Delta(Loans)_{i,t\ \mathrm{NORM}}$
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*. $\Delta(Loans)_{i,t\ \mathrm{NORM}}$ 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. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 5. The impact of bank competition on financial stability

Variables	(1) Z-score	(2) ROR_{ROA}
Lerner index*NIRP	**0.1467*** **	**0.0735** **
	(0.0241)	(0.0292)
Funding Structure	0.0001	0.0011
	(0.0005)	(0.0007)
Asset structure	0.0000	-0.0011**
	(0.0004)	(0.0005)
Liquidity	-0.0003	-0.0004
	(0.0004)	(0.0005)
Leverage	0.0566***	0.0170***
	(0.0046)	(0.0031)
Size	-0.0888***	0.0146
	(0.0217)	(0.0208)
Observations	17,755	17,745
R-squared	0.5853	0.0495
Number of Banks	2,744	2,744
Bank Fixed Effects	YES	YES
Time Fixed Effects	YES	YES
Cluster(id)	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. Standard errors adjusted for both within correlation clustered at the bank level and heteroskedasticity are in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

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. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

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); We use the opposite sign of the H-statistic aimed at improving the readability of the result. NIRP-effect is the interaction dummy $Treated_{ij}$ * Postjt; 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. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. 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). Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Appendix A

Figure A1. Market power distribution at the bank level.

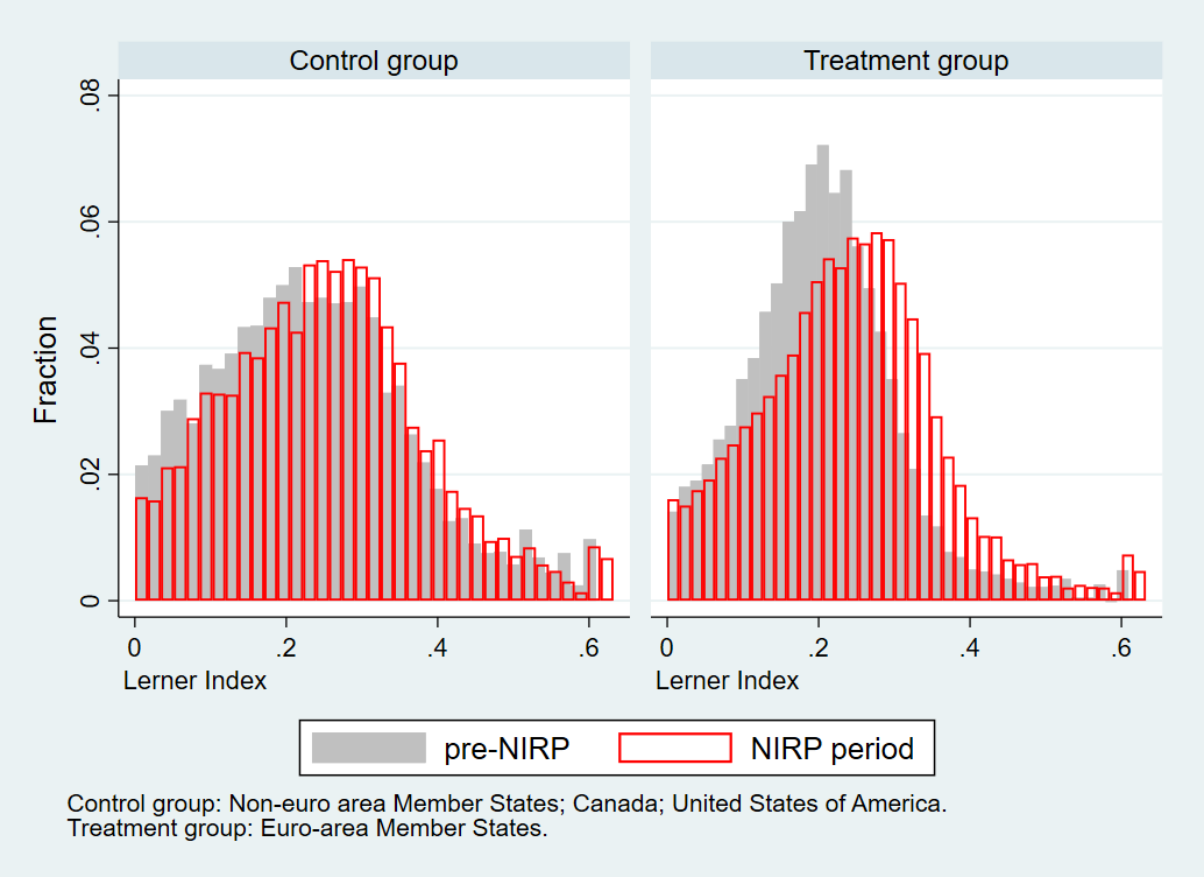


Figure A1 shows the market power distribution. For the Control group, even though there is a small shift, it appears similar for both pre-NIRP and NIRP period. Differently, for the Treatment group, we can observe a marked shift toward the right side, which means that market power is increased after the 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 A.1 shows that our control variables are not highly correlated.

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	Lerner index is 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	Loans growth rate is 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	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. We use the logarithmic version of Z-Score.	Author calculation, data BankFocus & SNL Financial
ROR_{ROA}	ratio	ROR_{ROA} is the 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	Asset structure is widely considered an indicator of banking specialization. It is the ratio gross loans to total assets.	BankFocus & SNL Financial
Liquidity	ratio	Liquidity considers the liquidity of the bank's asset side. It is the ratio liquid asset to total assets.	BankFocus & SNL Financial
Leverage	ratio	Leverage measures the bank's level capitalization. It is the ratio equity to total assets.	BankFocus & SNL Financial
Size	logarithm	Size 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	GDP is used as a proxy of market expansion. It is the real Gross Domestic Product growth rate.	WDI & SDW
Inflation	percentage	Inflation is the Consumer Price Index. It is used to assess the presernce of an inflationary environment.	WDI & SDW
Central bank assets	ratio	Central bank assets is a proxy of unconventional monetary policies. It is the central bank assets to GDP.	WDI & SDW
MP(Deposit Facility)	percentage	MP is one of the main monetary policy rate, namely the official Deposit Facility rate.	WDI & SDW
Chinn-Ito index	index	Chinn-Ito is an index that measures the 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

Tab 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 - normalized	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 - normalized	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.