Is bank resilience affected by unconventional monetary policy in the Euro area? ☆

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ABSTRACT

This paper examines whether euro area unconventional monetary policies have influenced the overall resilience of the banking industry. We proxy bank resilience with a Z-score measure that reflects the size of banks' loss-absorbing buffers. We employ two alternative strategies to construct instruments that allow us to identify the effect of monetary policy in this context. First, within a two-stage least squares framework, we rely on ECB balance sheet data to capture the effect of the broad array of programmes used by the ECB to implement quantitative easing, while we control for the effect of conventional and negative, or very low, interest rate policy. Second, relying on high-frequency identification methods on narrow time windows around ECB policy announcements, we compute three factors reflecting different types of monetary policy surprises and examine their impact on bank resilience. With both methodologies we find that loosening the monetary policy stance through UMPs had an overall positive impact on euro-area banks' shock absorbing buffers. The first approach, the only one that allows us to consider the level of interest rates, suggests that such effect is moderated when policy rates approach and breach the nominal zero-lower bound. The second strategy, which allows us to analyse forward guidance surprises, indicates that looser forward guidance has a positive impact on resilience. Balance sheet easing policies also seem to enhance resilience in the full sample, according to both strategies. The results are heterogeneous across subsamples, with contrasts between banks headquartered in core countries of the euro area vis-à-vis banks in the periphery of the euro-area. The contours of this heterogeneity differ in both methodologies and shows that balance sheet easing policies is detrimental for euro-area periphery banks. We also study the differential impact of monetary policy tools on banks, depending on their specific business model and their strength (i.e., their position within the distribution of loss-absorbing buffers); and the timing and persistence of monetary policy effects, which also varies with policy tools and jurisdictions.

1. Introduction

Unconventional monetary policies (UMPs thereafter) gained prominence in the wake of the global financial crisis (GFC), as traditional monetary policy tools proved less effective in tackling the financial crisis and providing the required support. There exists a plethora of channels through which UMPs affect the economy and the banking industry, such as portfolio rebalancing, liquidity, search-for-yield, and signalling channels, among others. Some of those channels may also have a feed-back effect from the banking sector towards UMPs. Moreover, many aspects of banks' risk-taking and behaviour can be affected by UMPs and be the focus of study by researchers. Not surprisingly, the literature on the matter is large.

We build on existing literature and offer new evidence and insights into the effect of UMPs on bank level resilience across the euro area. This jurisdiction is of particular interest as it has been less studied, whereas it has experimented with a wide variety of forms of UMPs. The complexity of the ECB's unconventional strategy introduces some non-trivial measurement issues that we endeavour to tackle herein. In fact, measuring bank resilience ex-ante is not straightforward either and we focus on a measure of the size of banks' loss-absorbing buffers. To the best of our knowledge, this study is the first to investigate the impact of ECB's UMPs on the bank resilience of the 19 Euro area Member States using bank-level data.

The origins of UMPs can be traced to the quantitative easing actions of the Bank of Japan (BoJ) in March 2001. To tackle economic stagnation and combat deflation, the BoJ flooded commercial banks with excess reserves by increasing its purchases of government bonds, asset-backed securities, and commercial paper. Since those initial steps, UMPs have evolved and taken various forms: forward guidance (FG), negative interest rate policy (NIRP), and a variety of policies that exploit the balance sheets of central banks, such as the large-scale asset purchasing programmes implemented initially by the Federal Reserve and the Bank of England as a response to the financial meltdown in 2008. We refer to the latter generally as quantitative easing (QE), although they may involve other closely related operations, including the provision of long-term liquidity.

The ECB has been experimenting with a considerable variety of UMPs. FG and NIRP have been part of the policy mix, as well as several measures aimed at providing long-term liquidity or implementing different versions of QE and/or enhancing its effects. Those include longer-term refinancing operations (LTROs), fixed-rate full allotment operations (FRFA), the securities market programme (SMP), the outright monetary transactions (OMT), various vintages of asset purchase programmes (APPs), and new collateral rules and reserve requirements. In other words, QE in the euro area comprised multiple layers of open market operations that also had some qualitative characteristics.

This diversity in QE programmes responded to a crucial distinction in the challenges faced by the ECB. The Federal Reserve and the Bank of England were trying to encourage real expenditure by boosting liquidity and reducing long-term interest rates in the aftermath of the financial crisis. Joyce et al. (2012) argue that although the ECB's QE programmes aimed at the same goal (lifting real expenditure), they achieved that primarily by shoring up the banking system and stopping the momentum of a process that resembled a bank run, as bank deposits from the euro area periphery shifted to the core (see also Sinn and Wollmershauser, 2011). This was particularly relevant for the euro zone, whose financial system is much more bank-based than the United States, or even the United Kingdom. That said, once the ECB began implementing its asset purchase programmes, that distinction was no longer meaningful. In any case, there have been remarkable differences in the perceived confidence on banks across the euro area. Such differences could have been reflected in a heterogeneous bank-level impact of the ECB's policies. However, few papers address the question of whether the bank-level effects of UMPs differed across Member States. In this study, we explore asymmetries in the impact of different monetary policy tools and strategies on bank resilience across the euro area.

The contributions of this study to the literature cover several areas. First, we provide evidence on the impact of unconventional monetary policy tools (negative interest rates, FG, QE) on European banks' shock absorbing buffers, which has not been studied in detail in the literature. To address the endogeneity issues that arise in this context, we rely on two independent strategies: (i) a generalised two-stage least squares estimation, and (ii) an estimation of monetary policy surprises based on the high-frequency identification (HFI) method of Altavilla et al (2019). The findings of both strategies delivered complementary insights: in the full sample the results for interest rate policy and QE are similar, while negative interest rate policy can only be assessed with the first strategy, and forward guidance only with the second strategy. Second, we investigate how the relationship between the studied policy tools and banks' buffers varies across sub-samples of Member States. We compare the experience of banks headquartered at the financial core of the currency area, and banks domiciled in the euro area countries more stressed during the sovereign debt crisis of 2011, or simply outside of the core. This investigation show variability in results across subsamples, i.e., core of the euro-area vis-à-vis the periphery of the euro-area. Third, we also investigate whether the banks' business models have a bearing on how different policies affect their resilience and discuss the possible implications for the asymmetric impact of policies across jurisdictions. Fourth, we ask whether the impact of ECB policies varies across quantiles of our chosen gauge of bank specific resilience, i.e., whether the banks that benefited the most of ECB UMPs had stronger or weaker buffers at the outset of the crisis. Lastly, recognizing that monetary policy usually works with long and variable lags, we conduct a panel VAR analysis to compute impulse response functions that allows us to trace the dynamic effects of the different types of monetary policy HFI surprises.

Our main findings suggest that loosening the monetary policy stance through UMPs had an overall positive impact on European banks' shock absorbing buffers. Reducing policy rates generally has a detrimental effect on both the level and the rate of change of bank resilience. But when policy rates approach or breach the zero-lower bound, the policy rate elasticities of our measure of bank resilience shift towards zero, pointing towards a much more muted impact. A loosening for-

ward guidance shock also tend to improve the rate of change of bank resilience. We also find that monetary policy easing through QE improve bank resilience, both in levels and rate of change.

Nevertheless, the effects are heterogeneous across subsamples, and varied depending on the specific policy tool being considered. There are material contrasts in the impact of monetary policy in the resilience of banks headquartered in the so-called euro area periphery, also with high nonperforming loan ratios and sovereign debt holdings, vis-à-vis those head-quartered in the financial core of the euro area. The results based on ECB balance sheet data points to an effect on resilience that is enhancing for core euro area banks, and detrimental for periphery banks. In contrast with results in the full sample and the core of the euro area, negative interest rate policy does not mute the negative impact of lower interest rates in the resilience of periphery's banks. On the other hand, the full enhancing effect of forward guidance on our measure of bank resilience rests on the impact on periphery's banks, because such effect is not statistically significant for banks in the core. Finally, our strategies differ in the regional assessment of QE policy effectiveness: monetary policy surprises suggest that QE policy supports periphery banks while having a non-statistically significant effect on banks in the core.

In addition, balance sheet policies seem to have enhanced more the resilience of banks that were relatively stronger, that is, banks that were in the higher deciles of the distribution of loss-absorbing buffers. Banks specialised in different business lines also were affected differently. For instance, easing of policy rates seems detrimental for the resilience of commercial banks, while QE stimulus strengthened mainly real estate and mortgage banks. FG helped commercial and real estate banks, while becoming detrimental for the sturdiness of savings banks. Finally, the impulse response analysis revealed substantial lags and persistence in the effects of monetary policy, with sometimes remarkable differences between the short- and longer-term sign of the responses.

The rest of the paper is organised as follows. Section 2 reviews the related literature regarding UMPs and their impact on bank risk and the economy. Section 3 introduces the main dataset and empirical model. Section 4 presents and discusses the results based on the generalised two-stage least squares estimations. Section 5 presents the results based on HFI monetary policy surprises, whose computation requires a brief introduction of an additional dataset. Finally, section 6 concludes and offers some reflections on policy implementation.

2. Related literature: UMPs, banking and the economy

There is an extensive literature that examines the impact of UMPs on the macroeconomy of the countries involved, and the microeconomics of their banks. Since both dimensions are relevant to the ultimate financial stability considerations of our paper, in this section we briefly review the pertinent part of that literature.

At the macroeconomic level, previous studies have focused mainly on the effectiveness of UMPs, underlying transmission mechanisms, and international spill overs. The result is a well-documented body of evidence on the impact of UMP on economic growth, aggregate demand, prices and financial conditions (e.g. Ugai, 2007; Lenza, Pill and Reichlin, 2010; Gagnon et al., 2011; Girardin and Moussa, 2011; Krishnamurthy and Vissing-Jorgensen, 2011; D'Amico et al., 2012; Lyonnet and Werner, 2012; Ueda, 2012; Bauer and Neely, 2014; Gambacorta et al., 2014; Altavilla et al. 2016b; Altavilla et al. 2017; Bernhard and Ebner, 2017; Michaelis and Watzka, 2017; Abidi and Miquel). There is some variability in the findings, though a moderate demand boost in the wake of UMP easing is often reported. Most studies of the ECB's UMPs also report some evidence about its effectiveness in stimulating economic activity, improving liquidity conditions, and reducing funding risk (Giannone et al., 2012; Darracq-Paries and De Santis, 2015; Eser and Schwaab, 2016).

The subject of whether UMPs enhance, or hinder, bank stability is at the centre of a lively debate. Researchers have attempted to assess UMP effects by considering the response of the quantity and quality of bank lending, the credit protections that banks procure for their loans, and the overall profitability of their lending activity, among others. Carpenter et al. (2014) model bank loan supply and demand, and report that relaxed conditions in money markets – because of non-standard measures – led to an increase in bank lending via a reduction in bank funding volatility. They studied the impact of the term auction facility (TAF) and the troubled asset relief programme (TARP) in the United States, and the fixed-rate tender with full allotment (FRFA) and the securities markets programmes (SMP) in the Euro area. For the three Covered Bond Purchase Programmes (CBPPs), evidence from Markmann and Zietz (2017) shows that the first one was the most effective in terms of lowering yields and thus increasing the supply of credit.

It is worth noting that UMPs could be accompanied by lax lending standards as banks expand their lending in response to loose monetary policy. Ciccarelli et al. (2013) show that the ECB's non-standard measures of liquidity provision, LTROs and FRFA, have eased credit frictions in bank lending and softened lending conditions. Using the 3-year LTROs, Darracq-Paries and De Santis (2015) reach a similar conclusion: ECB non-standard measures resulted in relaxed lending standards through the alleviation of liquidity and funding risks.

The relaxation of lending standards in turn could increase the number of risky borrowers receiving new loans (Ioannidou et al., 2015; Maddaloni and Peydró, 2011; Heider et al., 2018), hence raising credit risk.[1] Examining the United States and the

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[1] Banks reallocate their portfolio due to the scarcity of safe assets, which central banks have purchased, leading to high demand for other and riskier assets, consequently raising their prices and lowering their yields. Borrowers, subsequently, benefit from the reduction in borrowing costs thanks to lower yields. APPs inject liquidity to the banking system, allowing banks to expand their supply of credit, by making them less dependent on very short-term financing, and to reduce uncertainty regarding liquidity positions. LSAPs also signal to the market the state of the economy and the path of future short-term interest rates. A longer period of low interest rates reduces bank risk measurements. Yet, it may lead to greater bank risk-taking, and deteriorating credit quality.

Euro area, Maddaloni and Peydró (2011) find a significant positive impact of low short-term interest rates on the net percentage of banks in each country reporting a softening of credit standards. The results for low long-term interest rates, arguably targeted by QE and FG, suggest that lending standards are not affected, but the results are not robust.

Low interest rates can also induce banks to increase their risk-taking by affecting their risk perception, thus encouraging '*search for yield*' (Altunbas et al., 2014; Gambacorta, 2009; Sahuc, 2016). Banks may reduce their risk measures in a low interest rate environment with accelerating asset prices because expected volatility declines while the value of equity relative to debt increases (also reducing leverage). Therefore, the perceived risk of holding risky assets is lower, which in turn liberates risk budget and encourages banks to engage in riskier activities. Therefore, banks seem to respond to '*search for yield*' incentives in a similar way as asset managers, which on the face of lower interest rates take more risks in order to achieve the higher expected returns previously available with higher interest rates (Rajan, 2005).

Higher asset prices may also result in loan sizes representing a larger proportion of pledged assets' fair value (Ioannidou et al., 2015). Consequently, there exist effectively lower credit risk protection, and a balance sheet fragility that remains shrouded: the rise in asset and collateral values may subsequently compromise risk-absorbing capacity when and if prices eventually fall (Borio and Zhu, 2012). Relatedly, De Nicolò et al. (2010) find evidence that monetary easing increases more the risk-taking of well-capitalised banks compared to their less-capitalised peers.

The impact of UMPs on bank resilience can also be indirectly gleaned from profitability, or other measures of bank performance. Mamatzakis and Bermpei (2016) find that bank performance in the United States is generally hampered by UMPs, in part due to banks' reluctance to pass lower interest rates on to their depositors. Relatedly, Heider et al. (2018) argue that negative rates could hamper the financial stability of the euro area if lending is done mostly by high-deposit banks instead of low-deposit banks. In contrast, using a highly heterogeneous sample of banks in 28 European countries and Japan, Lopez, et al. (2018) argue that the nominal negative interest rates have little effect on bank profitability. Moreover, studies such as Lambert and Ueda (2014) find that UMPs do not seem to affect bank profitability much in the United States either, but risk-weighted assets increase with respect to total assets, and loss provisioning is delayed.

The use of HFI shocks to assess the impact of monetary policy on banks is less prevalent. Jung and Uhlig (2019) conduct such an exercise for the euro area. They find that shocks that tend to steepen the yield curve have a large beneficial impact on banks' health. Their measures of banks' health are of higher frequency than ours, mostly market based, and aggregated (as opposed to our bank-level dataset). A concern with market-based measures of banks' (or any other firms') conditions is that it is not possible to disentangle the actual change in the firms' conditions from investors' views about the expected change, or from changes in risk premia embedded in asset prices and not necessarily connected with banks' resilience. Moreover, it is only possible to assess the impact on listed banks. We try to address that concern by relying on low-frequency accounting data at the bank-level, as explained below.

3. Empirical approach and data

3.1. The empirical model and estimation

The starting point of our analysis is to define a measure of bank resilience. We choose an augmented bank-specific Z-score that incorporates bank-level loss-absorbing buffers. This dependent variable is computed as: $Z_{ijt} = \frac{(ROA_{ijt} + CR_{ijt})}{\sigma_{ijt}^{ROA}}$, where ROA_{ijt} is the return-on-assets of bank i headquartered in country j in year t, CR_{ijt} is the capital ratio of bank i headquartered in country j at the close of year t, and the denominator is the standard deviation of $ROAijt$ of bank i headquartered in country j in year t, calculated over a rolling window.[2] In turn, ROA is defined as the ratio of bank's net income to total risk assets; the CR is the bank-level ratio of regulatory capital to total risk assets.[3]

Intuitively, this measure captures bank resilience as it is the size (in standard deviations of each bank's ROA) of the loss that would result in insolvency by depleting the capital of the bank. In other words, the measure represents a gauge of "distance to insolvency": such a loss will make bank assets less than its liabilities. The main advantages of this measure is its simplicity, and its broad availability. This is of particular importance for banks that are not listed, and for which it is not possible to obtain distance-to-insolvency measures using market data. Our sample includes all banks available in the database, which implies that the majority are not listed. As stated before, studies that employ market based default probabilities restrict their scope of study only to listed banks (Anginer, et al. 2014; Koutsomanoli-Filippaki and Mamatzakis 2009). Finally, Z-scores have been widely employed in the banking literature (Mamatzakis and Bermpei, 2016; Fiordelisi and Mare 2014; Fu et al. 2014; Beck, et al. 2013; Altunbas et al. 2007; Allen and Gale 2004).

The main empirical model is linear, and regress the ln(Z-score) of bank i, in country j, during period t, on a collection of bank-level, country-level and monetary policy covariates:

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[2] The rolling window starts with the 3 years preceding 2007, and thereafter adds one observation per year till we reach the end of the sample. We also test the Altman's Z-score as an alternative measure of resilience. The Alman's Z-score relies on the difference between current assets and current liabilities and specific coefficient weights. However, this measure introduces some strong assumptions that potentially create model dependence in the measure, so we preferred to report herein the results from the simpler version of Z-score. Results using the Altman's Z-score are available upon request.

[3] ROA is an appropriate measure of performance given that banking is a service type of industry. It basically quantifies the earnings generated from invested assets. Also note that in some studies (Fu et al. 2014) the capital ratio is approximated by the ratio of equity to total assets.

$$\ln Z_{ijt} = f\left(X_{ijt}, M_{jt}^i, CIRP_t, UMP_t\right) + \varepsilon_{ijt} \tag{1}$$

where UMP_t is the proxy of unconventional monetary policies, while $CIRP_t$ captures the stance of conventional interest rate policy. X_{ijt} is a vector of bank-specific control variables for bank i in country j and period t, and the M_{jt}^i vector includes macroeconomic control variables of country j in period t, where the bank i is headquartered.

There are several sources of endogeneity which could hamper the identification of monetary policy effects. First, in a period of financial dominance, ECB policies may be at least in part spurred by the weakness of banks in the euro area, and reverse causality would explain part of the correlations measured by the coefficients in model (1). That could also arise because of heterogeneity across member states of the euro area. For example, rather than causing a differential effect on the loss-absorbing buffers of banks headquartered in different member states, ECB policy may be merely accommodating a market driven reallocation of resources towards banks or Member States that are ex-ante perceived as more resilient or safer. Similarly, common shocks that hamper (improve) banks' health and decrease (increase) GDP growth and/or inflation will tend to elicit fully expected ECB responses that will be captured by the respective linear coefficient. Such coefficients would reveal a positive correlation with policy rates and negative coefficient with QE actions, as lower (higher) ln(Z-scores) would be associated with looser (tighter) monetary policy. Those correlations, however, would not imply a causal relationship from monetary policy to bank resilience, at least not from the fully anticipated monetary policy reaction. The identification problem created by endogeneity, as usual, can only be resolved by constructing proper instruments.

In the quantitative analysis of section 4, we start with a simple maximum likelihood estimation of the unbalanced panel model for the whole sample, while considering heterogeneity across countries, banks and over time. Then, we go a step further in addressing endogeneity by employing a generalised two-stage least squares estimator (G2SLS) following Balestra and Varadharajan-Krishnakumar (1987), which provides a strong computational power. We test for robustness the validity of our results on sub-samples of Member States of the Euro-area. We also conduct quantile regressions on the whole sample to ascertain the differential impact of UMPs on banks' resilience across the distribution of bank specific ln(Z-scores). Finally, in section 5, we implement a variation of those experiments by introducing the HFI monetary policy surprises of Altavilla et al (2019) and replacing the variables in levels for changes. In this section we also explore the impact of policy surprises on the resilience of banks specialised in different business lines, and the dynamic response of resilience to the surprises, both in the full sample and subsamples of interest.

3.2. Bank-level and macroeconomic data

We collected a comprehensive data set that includes balance-sheet information for banks in 19 countries of the euro area for the period 2007-2018. We start the sample with the beginning of the global financial crisis, as the ECB began to increasingly ease its policy stance, while gradually beginning to deploy UMPs. All bank-specific variables are obtained from BankScope before 2015, and we merge this dataset with additional information from Moody's Analytics BankFocus for the rest of our sample period. The frequency is annual, and all variables are in thousand euros. There are 31,601 observations, and the panel data set is unbalanced. The number of banks varies year to year from a minimum of 2,691 to a maximum of 3,220. Banks are categorised by BankScope and BankFocus as commercial, cooperative, investment, real estate and saving banks. All our data come from the secondary sources of BankScope and BankFocus, which are available by subscription and have been employed by a plethora of banking studies in the past, such as Anginer et al. (2014), Fu et al. (2014), Fiordelisi and Mare (2014), Beck et al. (2013), Koutsomanoli and Mamatzakis (2009), Lebetit et al. (2008), and Altunbas et al. (2007), to name a few.

We include several bank specific control variables that are common in the literature, including size, asset diversification, efficiency, profitability, revenue diversification and liquidity.[4] Size is the natural logarithm of total assets (Beck et al., 2013). Thus, its coefficient computes the elasticity of Z-scores to percent changes in total assets. The remaining controls are ratios, and their coefficients compute the respective semi-elasticities of the Z-scores. Asset diversification is represented by the ratio of securities holdings to total assets (Ioannidou et al., 2015; Anginer, et al. 2014; Fiordelisi and Mare 2014; Fu et al. 2014; Beck et al. 2013; Koutsomanoli-Filippaki and Mamatzakis 2009; Altunbas et al. 2007), and efficiency is quantified as the ratio of operating costs to total operating income, with a higher ratio indicating lower efficiency.[5] Profitability is measured through the return on average assets (ROAA) of the banks in our sample over the corresponding calendar year (see Fiordelisi and Mare 2014; Fu et al. 2014; Beck et al. 2013; Altunbas et al. 2007). Revenue diversification is measured by the ratio of non-interest income to total operating income, and liquidity is measured as the ratio of liquid assets to total assets (Ioannidou et al., 2015; Beck et al., 2013; Jeon, et al., 2011; Altunbas et al., 2007).

Table 1 presents the summary statistics of the bank level data. The mean of the ln(Z-score) indicates that, on average, the shock absorbing buffers of European banks were more than 1.8 times the standard deviation of their ROA during the sample period. That is, more than 6 times larger in euro terms. The dispersion of the ln(Z-score) has been moderate at 0.742. On

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[4] The capital to asset ratio is usually among the control variables as bank capitalisation affects bank risk. However, we do not include it as a regressor because the augmented Z-score already includes the capital to asset ratio.

[5] On the measurement of efficiency, and as part of a sensitivity analysis, we also employ stochastic frontier analysis (SFA) of a translog cost function to derive efficiency scores from the residuals. Herein we opt for a simple definition of efficiency based on operating costs that does not depend on the underlying hypotheses of the distribution of errors of a typical stochastic frontier model. Results using an efficiency measure based on SFA are available upon request.

average during the period 2007-2018, banks in the euro area held 22% of their assets in securities, and almost 16% were highly liquid assets. Also, non-interest income represented around 19% of total operating income, and costs represented 79% of such income. The variable ROAA, as measure of performance, shows that invested assets have generated on average a return of 0.36% during the sample period. This is a relatively moderate performance, and the standard deviation of 0.28% indicates that bank performance has seen ample variability in our sample.

Finally, we also include country-specific macroeconomic controls, in particular annual GDP growth and inflation of the country j where each bank i in our sample is headquartered, to reflect the influence of the macroeconomic environment on banks' buffers. Data for GDP growth and inflation are available from the Eurostat national statistics. Growth is rather anaemic over the period 2007-2018, with an average of 0.95%, while inflation stayed subdued at an average of 1.5%. Both statistics are consistent with the challenging economic conditions prevalent in the euro area during our sample period.

3.3. Measures of conventional and unconventional monetary policy

To estimate the results presented in section 4, we employ alternatively five proxies of UMPs (including two QE proxies and three proxies of very low or negative interest rate policy, NIRP) and three proxies of CIRP.

As indicated above, in our taxonomy QE comprises an assortment of measures that are ultimately anchored by the ECB balance sheet, including extended liquidity provision, targeted asset purchases and large asset purchases. Asset purchases and liquidity provision operations have different objectives, and a different impact on the ECB balance sheet. The former aim at immediately increasing bank reserves, and by that means reducing the level and volatility of funding costs for banks. As a result, a fall in the funding cost for the non-financial private sectors is expected. Moreover, as asset purchases are skewed towards long maturity fixed income assets, it removes duration from the market and encourages a compression of term premia. Thus, the drop in private sector funding costs should extend to the long term as well, eventually leading to an increase in borrowing demand. On the other hand, liquidity operations such as the Long-Term Refinancing Operations (LTROs) or the Targeted LTROs (TLTROs) aim to directly increase the supply of lending to the private sector, not only reducing its cost. They provide incentives for banks to proactively seek an expansion of their loan portfolios. Their impact on the ECB balance sheet is less immediate, and contrary to asset purchases programmes, such impact is by design limited in time to the tenor of the liquidity provision operations. For instance, the initial LTRO operations matured within six months of their auctioning.

Long term liquidity provision programmes comprised the three-year LTROs, announced on 20/12/2011 and 28/02/2012, and carried out as fixed rate tender procedures with full allotment. Previously, six-month LTROs were announced on 28/03/2008 and 04/09/2008 with variable rate tender procedures and pre-set amounts. The one-year LTROs were subsequently announced on 23/06/2009, 29/09/2009, and 15/12/2009.

The asset purchases programmes included in the time span of our dataset comprise the Securities Market Programme (SMP, effective from 05/2010 to 09/2012), the Covered Bond Purchase Programmes 1 and 2 (CBPP 1, CBPP 2, both terminated), and the Asset Purchase Programme (APP). CBPP 1 was in effect from 06/2009 to 06/2010, while the second one was carried out between 11/2011 and 10/2012. The APP was initiated in 2014 and consisted of purchases of public and private sector securities. The original APP was subsequently extended, adding several programmes: the CBPP 3 (since 20/10/2014), the Asset-backed Securities Purchase Programme (ABSPP, started on 21/11/2014), the Public Sector Purchase Programme (PSPP, started 09/03/2015), and the Corporate Sector Purchase Programme (CSPP, since 08/06/2016). Figure 1 depicts the expansion of the ECB's balance sheet because of the subsequent rounds of asset purchases and liquidity operations.

Following the literature, we include in our estimations two proxies for QE: the amount of ECB's total assets, and the excess reserves of the banking system, both in natural logarithms so that their coefficients will represent Z-score elasticities. The data for these proxies is available from the ECB Statistical Data Warehouse.[6] As Lyonnet and Werner (2012) argue, central banks can use both sides of their balance sheet to shape the impact of asset purchases. The asset side provides an alternative source for private financing through outright purchase of credit products. For instance, Gambacorta et al. (2014) use central bank assets to represent the QE instrument in a cross-country study of UMPs effectiveness. The liability side of a central bank's balance sheet expansion captures the cushion created by reserve accumulation to mitigate bank funding risk. In fact, the increase in bank excess reserves reflects the liquidity buffer built up by the euro area banking system as a by-product of the initial liquidity injection created by the APP and LTRO programmes. These conventions allow us to overcome the discontinuity of the different QE programmes. Notice that these gauges emphasise a '*flow-effect*' of QE (D'Amico and King, 2011; De Santis and Holm-Hadulla, 2017) because they measure the quantum of policy stimulus by the effect on the ECB balance sheet as purchases are implemented over time, not upon their announcement.[7]

To account for conventional interest rate policy (CIRP), we alternatively use the level of the marginal lending facility rate (MLF), the main refinancing operation rate (MRO), and the deposit facility rate (DF). These variables are also available from

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[6] More precisely, excess reserves encompass the total excess reserves of credit institutions subject to minimum reserve requirement in the euro area.

[7] As defined by D'Amico and King (2011), the stock effects of QE are persistent changes in the price of government securities as changes in their expected net supply bring about movements along their demand curve. They are usually measured upon announcement, as we do with the monetary policy surprises of section 5. In contrast, 'flow effects' emerge as purchases are implemented, and they are understood as the result of portfolio rebalancing or changes in the liquidity or functioning of government security markets triggered by the purchases.

Table 1
Summary Statistics of Bank and Country Level Data

Variable	Mean	S.D.	Min	Max
ln(Z-score)	1.830	0.742	0.812	3.108
SIZE	13.854	1.477	11.781	16.445
ROAA	0.356	0.280	0.030	0.920
ASSETDIV	0.220	0.121	0.039	0.421
LIQRAT	0.157	0.105	0.041	0.375
REVDIV	0.188	0.077	0.081	0.340
COST2INC	0.790	0.078	0.664	0.911
INFLATION	1.502	1.083	-0.6	4.1
GDP	0.954	2.120	-5.7	3.5

Notes: This table reports the descriptive statistics for the key variables employed. The ln(Z-score) is defined in the main text. SIZE = ln(total assets) by bank; ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: return on average weekly assets over a calendar year; INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth (%); N: the number of observations; standard errors are in parentheses. The sample includes banks in 19 countries of the Euro-area. The sample period is 2007-2018.
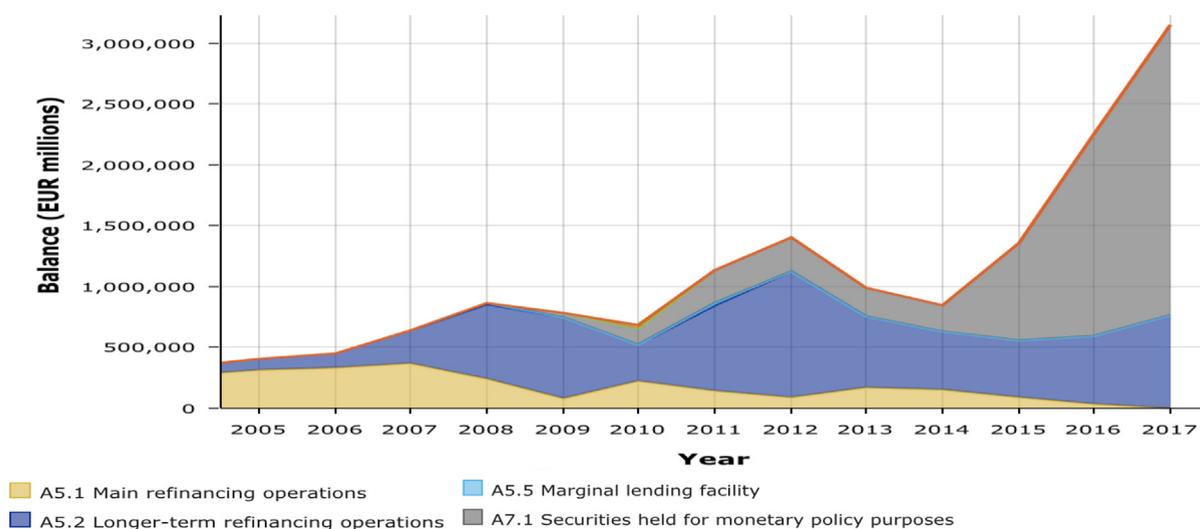
Figure 1. The footprint of QE in the ECB's balance sheet (€ trillions). Source: ECB.

the ECB's website. Cour-Thimann and Winkler (2012) emphasise that ECB's non-standard measures complement key interest rate decisions rather than acting as a substitute.

Table 2 presents the summary statistics of the euro area monetary policy measures. The data show that only the DF rate became negative during the sample period, but the MRO rate also dropped below our NIRP threshold, which we set at 0.25%. To capture potential non-linear effects created by very low and/or negative interest rates, we also include a dummy variable (NIRP), which is equal to one during the period when the deposit facility rate stayed at levels equal or less than 0.25%, as well as the interaction between this dummy variable and each of the three CIRP measures just described. Even though the 0.25% threshold is arbitrary, it provides a framework to analyse the issue, and coincides with the level that some central banks appeared to have identified in practice as a key lower bound.

Before presenting the estimations, a few words about what we do not do in this initial analysis. First, we do not attempt to directly analyse the impact of FG. This is a distinct tool from policy rates and asset purchases, which does not leave an imprint in the policy interest rates and balance sheet data that we described so far. Most studies of FG (i.e., Pelizzon et al. 2016, Bundick et al. 2019) rely on high-frequency trading data, as we do in the second part of our analysis, when we add FG to the policy toolbox analysed. Similarly, we do not explicitly account for the effect of the Outright Monetary Transactions (OMT) programme announced in 2012. Though potentially powerful, and often linked to the reduction in the credit spreads of some euro area sovereigns at the time, OMT was never effectively deployed, and it has not left a mark in the ECB balance sheet. FG and OMT did have an impact on market interest rates, which ultimately affected banks' costs and revenues, for which we include bank-level controls. Moreover, the possible time-series effects stemming out of shifts in FG or the initial approval of OMT should be absorbed by the time fixed-effects in our panel regression estimations. In the second part of the paper, the effect of OMT should be subsumed within the QE factor.

Table 2
Summary Statistics of Euro Area Monetary Policy Variables

Variable	Mean	S.D.	Min	Max
ECBTA	21.81	0.181	21.25	22.90
ECBER	16.51	2.342	13.72	20.42
MRO	1.23	1.196	0.050	4.000
MLF	1.87	1.342	0.300	5.000
DF	0.62	1.052	-0.300	3.000

Notes: This table reports the descriptive statistics for the key variables. ECBTA: natural log of the ECB's total assets; ECBER: natural log of banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate. The sample includes banks headquartered in 19 countries of the Euro-area. The period sample is 2007-2018.

Finally, Bluwstein and Canova (2016) construct a proxy of QE consisting of the total amount of reserves directly injected into the banking system through asset purchases and longer-term refinancing operations. They compute this variable by including all the amounts of the different relevant programmes as they are implemented, rather than announced. We included their variable in earlier stages of this study but those results, available upon request, are qualitatively similar to the reported results. Removing that proxy simplifies the presentation, without any loss of insights.

4. Results From Generalised 2SLS Estimations

4.1. Baseline results: panel regression estimations

As baseline results, we present the maximum likelihood estimation of panel regression model (1), using our unbalanced panel data set. As previously stated, there exists heterogeneity across Member States of the Euro area where banks are headquartered, and across bank business focus (i.e. commercial banks, cooperatives, investment banks, real estate banks, and saving banks).

Given this heterogeneity, we opt for a maximum likelihood estimator with random effects while we control for country, bank specialisation and time effects.[8] Essentially, we estimate a mixed random effects model given that country specific variables and monetary policy variables are invariant at bank level. This is an efficient model approach given that such variables are outside the control of the bank i, and thereby are considered as random effects.

To this end, we estimate the following specification of model (1):

$$lnZ_{ijt} = \beta_1 X_{ijt} + \beta_2 M^i_{jt} + \sum_{s=1}^{S} \mu^i_s + \tau_t + \beta_3 CIRP_t + \beta_4 UMP_t + \upsilon_i + \varepsilon_{ijt} \qquad (2)$$

As described above in model (1), X_{ijt} is a vector including bank specific control variables, and M^i_{jt} is a vector that includes a set of macroeconomic controls specific to the country j where bank i is headquartered, and a country fixed effect. The coefficients μ^i_s correspond to fixed-effects denoting the specialisation s of bank i, υ_i is a bank-level random effect, and τ_t is a time fixed-effect. The variables $CIRP_t$ and UMP_t include, respectively, the proxies of conventional and unconventional (NIRP and QE) monetary policy.

This specification accounts for the heterogeneity described above, including country and bank-specialisation fixed-effects, and the time fixed-effects that aim at absorbing the impact of background events over time, including changes in FG or the approval of OMT, among others. The random effect υ_i captures any residual bank-level heterogeneity, and it is normally distributed ($\upsilon_i \sim N(0, \sigma^2_\upsilon)$). We also assume that the idiosyncratic error term ε_{ijt} is normally distributed with zero mean ($\varepsilon_{ijt} \sim N(0, \sigma^2_\varepsilon)$). At this initial step, we assume that both error terms are uncorrelated with the variables on the right-hand side.

Table 3 shows the maximum likelihood estimation results of alternative implementations of the panel regression specification (2), with different combinations of CIRP, NIRP and QE policy proxies.[9]

In general, all the CIRP variables, as represented by policy rates (MLF, DF and MRO), show a positive impact on bank ln(Z-scores), indicating a directly proportional impact on bank resilience. In other words, tighter monetary policy, i.e., higher interest rates, enhance the resilience of banks (i.e., their ability to survive a large bad shock). Depending on the policy rate measure, a 1% increase in policy rates is associated with an increase in Z-scores of between 5 and 12%. Given our definition of loss-absorbing buffers, the increase in resilience is most likely associated with an increase in the underlying banks' ROA, or a decrease in its volatility. Changes in policy rates are unlikely per se to drive a change in capital ratios. These results appear to support the assessment by the European Systemic Risk Board (ESRB, 2016) that low interest rates in the Euro area are weak-

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[8] Maximum likelihood estimation is flexible enough to permit both between- and within- variability across our main variables. This is of key importance in our sample as bank resilience varies across banks within the same country and in one year, but it also varies across countries and the various time observations. The latter variability is also important in view of the underlying heterogeneity of the banking industry in the Euro area.

[9] To ensure that the selection of estimation method is efficient, we run Hausmann test, and Wald-test on auxiliary regressions where we take time averages of all time-varying regressors. Results available on request show that the maximum likelihood estimator of the random effects model is not rejected.

Table 3
Panel estimation for all banks in the Euro area

Variables	1	2	3	4	5	6
SIZE	-0.0237***	-0.0243***	-0.0267***	-0.0264***	-0.0236***	-0.0239***
	(0.00846)	(0.00847)	(0.00841)	(0.00843)	(0.00848)	(0.00848)
LIQRAT	-0.249***	-0.253***	-0.242***	-0.245***	-0.248***	-0.254***
	(0.0294)	(0.0294)	(0.0294)	(0.0294)	(0.0294)	(0.0294)
ASSETDIV	-0.212***	-0.219***	-0.214***	-0.217***	-0.212***	-0.219***
	(0.0315)	(0.0315)	(0.0315)	(0.0315)	(0.0315)	(0.0315)
REVDIV	0.0272***	0.0269***	0.0263***	0.0264***	0.0272***	0.0270***
	(0.00829)	(0.00829)	(0.00829)	(0.00829)	(0.00829)	(0.00829)
COST2INC	-0.0134***	-0.0134***	-0.0135***	-0.0135***	-0.0134***	-0.0134***
	(0.00239)	(0.00239)	(0.00239)	(0.00239)	(0.00239)	(0.00239)
ROAA	0.0529***	0.0530***	0.0530***	0.0530***	0.0529***	0.0530***
	(0.000978)	(0.000978)	(0.000978)	(0.000978)	(0.000978)	(0.000978)
GDPG	0.491***	0.525***	0.455***	0.462***	0.484***	0.524***
	(0.0715)	(0.0743)	(0.0707)	(0.0749)	(0.0710)	(0.0737)
INFLATION	0.272	-0.149	0.456	0.226	0.288	-0.158
	(0.278)	(0.260)	(0.283)	(0.269)	(0.278)	(0.258)
NIRP	0.189***	0.174***	0.261***	0.267***	0.211***	0.194***
	(0.0180)	(0.0218)	(0.0199)	(0.0231)	(0.0185)	(0.0222)
MLF	0.0540***	0.0557***				
	(0.00408)	(0.00382)				
NIRP×MLF	-0.0450***	-0.0415***				
	(0.00576)	(0.00736)				
DF			0.110***	0.115***		
			(0.00814)	(0.00762)		
NIRP×DF			-0.103***	-0.109***		
			(0.0141)	(0.0272)		
MRO					0.0726***	0.0743***
					(0.00543)	(0.00507)
NIRP×MRO					-0.0600***	-0.0509***
					(0.00788)	(0.0110)
ECBTA	-0.0254		-0.0262		-0.0233	
	(0.0169)		(0.0179)		(0.0170)	
ECBER		0.00138		-0.000565		0.00185
		(0.00124)		(0.00181)		(0.00135)
Constant	2.591***	2.038***	2.586***	2.019***	2.525***	2.007***
	(0.381)	(0.117)	(0.406)	(0.117)	(0.386)	(0.117)
Observations	31,601	31,601	31,601	31,601	31,601	31,601
R^2	0.1535	0.1566	0.1578	0.1577	0.1544	0.1535

Notes: We include fixed effects that capture country, time, and bank specialisation (i.e., commercial, investment, savings). The estimation method is maximum likelihood and covers the whole sample. The dependent variable is ln(Z-score), where the Z-score is defined in the text. ECBTA: ECB's total assets; ECBER: banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy (that is DF ≤ 0.25), 0 otherwise; SIZE = *ln*(total assets); ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: return on average assets over a calendar year; INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth (%); N: the number of observations; standard errors are in parentheses. The sample includes in 19 countries of the Euro-area. The period is 2007-2018. *,**, +: denote significance at the 10%, 5%, 1% confidence levels.

ening the resilience of the banking industry. As suggested by ESRB this outcome responds to banks' reduced net interest income, and thereby the negative impact on their profitability. ESRB (2016) goes on to highlight that '*search for yield'* in an environment of low interest rates may also hamper bank resilience, as banks might overstretch their balance sheets beyond their underlying risk bearing capacity.

Table 3 also provides supporting evidence about the existence of non-linear policy rate effects in the vicinity of our proposed lower bound (i.e. the DF rate at 0.25%). The interactions between the NIRP dummy variable and the policy rates have negative and significant coefficients. In fact, the coefficients for the interactions between NIRP and the policy rates (whether it is DF, MRO, or MLF rate) are almost equal in absolute values than their direct individual coefficients. That implies that the net marginal effect on banks' resilience of further reductions in policy rates below the threshold is much reduced and close to zero. Similar effects across all policy rates are to be expected, because during the sample period the ECB tended to move all three rates in concert, so that the signal given by the policy decision would also be analogous across rates. The results are consistent with Borio et al. (2017), which illustrates the existence of non-linearities in the effect of interest rates on net interest margins. Along these lines, as short-term interest rates turned increasingly negative, investors searching for yield and duration would cause long-term fixed income yields to become increasingly compressed (see Domanski et al, 2017). In this event, capital gains in banks' security portfolios may have also enhanced ROA and capital ratios, and thereby our measure of banks' loss-absorbing buffers. Moreover, another study of Swedish and Danish banks by Madaschi and Pablos-Nuevo (2017) shows that bank profitability improves as increased volume in loans compensates for lower interest income per loan in an environment of negative interest rates.

The results for measures of QE are not conclusive. The coefficients are negative for all models using the logarithm of ECB total assets (ECBTA), suggesting a detrimental impact of QE on bank resilience. But the coefficients are quantitatively small and none of them are statistically significant at the usual significance levels. The coefficients of the logarithm of banks' excess reserves held at the ECB (ECBER) are also small, switch signs between models, and they are not statistically significant. These estimates suggest that QE may have a small negative effect on bank resilience: loosening monetary policy by means of QE may slightly reduce Z-scores. But further evidence is necessary.

Turning to bank-specific controls, the results show that liquidity (LIQRAT), asset diversification (ASSETDIV), and (in)efficiency ratios (COST2INC), have a negative relation with the ln(Z-score). Liquid assets tend to generate lower returns than less liquid assets, at least in the short run and especially during most of the sample period, when central banks in general, and the ECB, provided plenty of liquidity. Thus there is a trade-off between liquidity and profitability (Rose and Hudgins, 2006). Lower profits, *ceteris paribus*, lead to lower Z-scores. On the other hand, holding more liquid assets can reduce liquidity risk, and lead to reduced capital requirements, another possible source of negative impact on Z-scores. In a similar vein, Tabak, et al. (2012) report that banks holding more liquid assets appear farther from the stability frontier. This can be the result of these banks knowing that they are fragile, which moves them to hold more liquidity for precautionary reasons, as they could be more exposed to runs. This argument introduces an aspect of reverse causality: liquidity does not weaken bank buffers, but weaker banks decide to hold more liquid assets. Relatedly, Altunbas et al. (2007), provide evidence that European banks with higher liquidity levels take higher risks.

Higher asset diversification is not associated with bank resilience either. This finding implies that a larger percentage of securities in banks' balance sheets (relative to total assets) would make banks riskier, and indirectly suggesting that traditional lending activities would contribute to the resilience of banks. The result is not surprising, as higher security holdings would naturally increase the volatility of ROA, pulling our measure of resilience down. Admittedly, we employ a relatively narrow definition of diversification, but the finding is consistent with those of Turk and Ariss (2010), who also report that, in developing countries, banks with larger loan-to-asset ratios are less exposed to overall bank risk.

A higher cost-to-income ratio, which is an indication of bank inefficiency, reduces bank resilience, in line with the findings of Liu and Wilson (2013): inefficient banks may take on more risk to improve their performance. This positive relationship between inefficiency and risk can also be explained through the rationale of the '*bad management*' hypothesis (Berger and DeYoung, 1997). They argue that the rise in nonperforming loans or credit risk is a result of bank managers' incompetence in credit screening and loan monitoring. Such bank managers are also more likely to be cost-inefficient in their day-to-day operations. Ultimately, the end result would be banks with poor profitability and loan portfolios of mediocre quality, which compromise their capital buffers and make them less resilient than their better-managed peers.

An increase in the ratio of revenue diversification (REVDIV), in contrast, enhances bank buffers. This finding gives support to Nguyen et al. (2012) who report similar results for South Asian banks. Our straightforward gauge of bank profitability (ROAA) is also directly proportional to our measure of bank resilience, in line with intuition and other studies in this field (Mamatzakis et al., 2016; Mamatzakis and Bermpei, 2016).

To complete the review of bank-specific controls, Table 3 reports that bank size (SIZE) carries a negative coefficient, as larger banks held relatively lower loss absorbing buffers than smaller banks. Schaeck and Cihák (2014) also report a negative relation between bank size and Z-scores for a sample of European banks during 1995-2005. The lower buffers of the larger banks may be explained in terms of their implicit reliance on their '*too-big-to-fail*' character. Alternatively, one may argue that given the pool of lending opportunities in the real economy, larger banks are necessarily subject to diminishing returns to scale: they may have to finance relatively less profitable (and possibly riskier) projects, which would reduce their overall profitability, and thereby our Z-score measure. This outcome may be related to the typical decline in the return of an investment fund as its assets under management increase.[10]

Finally, Table 3 reports the coefficients of the macroeconomic controls, whose results are consistent with other studies and intuition. Higher GDP growth (GDPG) enhances the Z-score, as would be expected given the improved financial health of existing and potential borrowers, and the better lending opportunities and projects that are likely to prevail on the back of a stronger economy. Soedarmono et al. (2013) find a similar positive relationship between GDP growth and bank soundness. The coefficient of inflation (INFLATION) is positive for most implementations, although it is not statistically significant for any of them, suggesting a more tenuous connection between inflation and bank resilience. That said, the positive coefficient of inflation may point to a structural feature of Euro area banks, whereby their assets tend to reprice (i.e., adjust their interest rates) faster than their liabilities. Depending on accounting conventions, this may improve profitability and capital ratios, temporally boosting the Z-scores that we use as measure of resilience.

4.2. G2SLS (instrumental variable) estimations: full sample results

The evidence provided so far points towards meaningful correlations between two forms of UMPs (NIRP and QE) and our measure of individual bank resilience. We have introduced several bank-specific and macroeconomic controls, as well as country, time, and bank-specialization fixed effects to absorb heterogeneity and help in the identification of the policy

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[10] This empirical finding has been documented in numerous studies for investment funds, including among others Jensen (1968), Gruber (1996), Carhart (1997) and a broad survey by Berk and Green (2004). More recent evidence relates the lack of persistence in fund performance to fund family size and its impact on diversification and investment strategies, as in Pollet and Wilson (2008) and Bessler et al (2016).

parameters of interest. However, those tools cannot properly address the potentially large endogeneity issues arising in this context, and the resulting correlation between the proposed explanatory variables and the errors.

To address this limitation, we employ an instrumental variables estimator that fits our underlying unbalanced panel data-set. For simplicity and to gain computational power, we opt for the estimator proposed by Balestra and Varadharajan-Krishnakumar (1987), which is a two-stage least-squares generalisation (G2SLS) of a panel data estimator.

This estimator is applied to a variation of the basic model (1), as follows:

$$\ln Z_{ijt} = \beta_1 X_{1,ijt} + \beta_2 X_{2,ijt} + \upsilon_i + \varepsilon_{ijt} \tag{3}$$

where $X_{1,ijt}$ is a vector of endogenous variables for bank i headquartered in country j and period t, and $X_{2,ijt}$ is a vector of exogenous variables that also includes some of the variables in M_{jt}^i (the macroeconomic control variables of model 2) and the country, bank specialisation and time fixed effects. Our IV estimator considers that the idiosyncratic error term ε_{ijt} has zero mean and is uncorrelated with the variables in $X_{2,ijt}$. As before, the variable υ_i is assumed to be random and uncorrelated with the variables in $X_{2,ijt}$. The estimation strategy employs the exogenous variables $X_{2,ijt}$ after they have been passed through the feasible GLS transformation. The instruments are selected from the vector of exogenous variables $X_{2,ijt}$, and a vector of instrumental variables. In our case the instruments are selected from first lags of the suspected endogenous variables. Concretely, in our specification we take the policy rates, QE proxies and country-specific GDP growth, inflation as endogenous variables and use their first lags as instruments.[11] These variables are autocorrelated, but their first lags do not reflect the information contained in the innovation ε_{ijt}, with which they remain uncorrelated.

Table 4 presents the results for the coefficients of interest in the full sample. By and large, all the main results are robust to the change in the estimation strategy, in particular those about the impact of CIRP and NIRP. Conventional monetary policy, as described by the policy rates managed by the ECB, continue to have a directly proportional and significant impact on banks' loss-absorbing buffers, and in fact the size of the coefficients is very similar to the maximum likelihood estimates in Table 3. In addition, the coefficients of the interactions of NIRP with the policy rates are still negative and statistically significant, and the non-linearity holds. Yet, these coefficients are now smaller in absolute value than the ones in Table 3. The initial conclusion from the simple panel estimations was that NIRP mostly diluted the impact of policy rate changes on banks' loss absorbing buffers below the lower bound. The G2SLS results in Table 4 suggest that these negative net marginal effects on bank resilience may be larger than initially assessed, before controlling for endogeneity.

The assessment of the effect of QE changes somewhat with the new estimation strategy. The elasticities of the Z-scores to the QE measures continue to be small, negative, and statistically non-significant when QE is proxied by ECBTA. But the new coefficient estimates suggests that QE, when measured as excess reserves (ECBER), contribute to bank resilience: the elasticities are positive in all three cases, and statistically significant at the conventional levels when combined with either the MLF or MRO policy rates. However, the evidence is still tentative.

Overall, the evidence presented in Table 4 supports a more nuanced version of our initial findings: (i) policy rate reductions have a slightly detrimental effect on resilience even at very low or negative interest rates; and (ii) QE, as represented by excess reserves injected in banks' balance sheets through asset purchases, may increase our measure of bank resilience.

The results corresponding to bank-specific controls (size, liquidity, asset and revenue diversification, efficiency, and profitability) are qualitatively like those reported in Table 3, and no further comments are needed. As for the macroeconomic controls, a better economic environment indicated by higher GDP growth still boosts bank resilience in all models. The inflation semi-elasticities are typically negative but mostly not statistically significant.

4.3. Robustness analysis: Euro area periphery vs the core

In the next stage of analysis, we investigate whether the main results summarised in the previous section hold for different country sub-samples. As argued by Eichler and Hielscher (2012), the ECB implements monetary policy for the euro area as a whole, thus it could be hard to achieve the same impact across every Member State at all times. Even though we do include country fixed-effects in the previous estimations, those only control for level effects across countries. There may still exist some residual cross-country heterogeneity that affects the elasticities, perhaps related to the financial conditions of countries, or the way they were affected by the global financial crisis.

As institutional and macroeconomic heterogeneity exists,[12] we consider that ECB's UMPs may affect differently different groups of Euro area's Member States. To this end, we start by selecting two sub-groups. The first one comprises Member States which have been under the sharpest financial distress during the European sovereign financial crisis and happen to be in the geographical periphery of the Euro area. These are Cyprus, Italy, Ireland, Portugal, Slovenia, and Spain, denoted as the 'periphery' herein. These are also countries that had high non-performing loan ratios as reported in 2016 by the European Banking Authority.[13] The second sub-group corresponds to all countries in the euro area that are not in this so-defined periphery. Member States in the periphery of the euro-area were widely regarded as the most vulnerable countries and were the most affected

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[11] Note that the Balestra and Varadharajan-Krishnakumar two-stage least-squares generalization (G2SLS) panel data estimator also has the additional advantage that controls for possible measurement errors across the variables.

[12] See Eichler, Hielscher (2012) for the literature on EMU member countries' differences or divergence in business cycles, labour markets, and inflation rates.

[13] https://www.eba.europa.eu/documents/10180/1360107/EBA+Report+on+NPLs.pdf

Table 4
Panel G2SLS regression results for all banks in the Euro area

Variables	1	2	3	4	5	6
SIZE	-0.0333***	-0.0337***	-0.0347***	-0.0350***	-0.0333***	-0.0335***
	(0.00572)	(0.00571)	(0.00570)	(0.00569)	(0.00572)	(0.00572)
LIQRAT	-0.307***	-0.311***	-0.302***	-0.305***	-0.306***	-0.311***
	(0.0280)	(0.0280)	(0.0280)	(0.0280)	(0.0280)	(0.0280)
ASSETDIV	-0.167***	-0.174***	-0.171***	-0.173***	-0.167***	-0.175***
	(0.0300)	(0.0300)	(0.0300)	(0.0300)	(0.0300)	(0.0300)
REVDIV	0.0190**	0.0187**	0.0182**	0.0181**	0.0190**	0.0187**
	(0.00837)	(0.00838)	(0.00838)	(0.00838)	(0.00837)	(0.00837)
COST2INC	-0.0151***	-0.0152***	-0.0152***	-0.0152***	-0.0151***	-0.0152***
	(0.00242)	(0.00242)	(0.00242)	(0.00242)	(0.00242)	(0.00242)
ROAA	0.0525***	0.0526***	0.0526***	0.0526***	0.0525***	0.0526***
	(0.000985)	(0.000985)	(0.000985)	(0.000986)	(0.000985)	(0.000984)
GDPG	0.586***	0.632***	0.551***	0.580***	0.576***	0.626***
	(0.0723)	(0.0751)	(0.0716)	(0.0759)	(0.0718)	(0.0745)
INFLATION	-0.0572	-0.473*	0.0976	-0.169	-0.0338	-0.466*
	(0.281)	(0.262)	(0.286)	(0.272)	(0.280)	(0.260)
NIRP	0.172***	0.149***	0.248***	0.239***	0.196***	0.171***
	(0.0181)	(0.0220)	(0.0202)	(0.0235)	(0.0187)	(0.0224)
MLF	0.0528***	0.0530***				
	(0.00415)	(0.00388)				
NIRP×MLF	-0.0404***	-0.0327***				
	(0.00581)	(0.00745)				
DF			0.109***	0.110***		
			(0.00827)	(0.00774)		
NIRP×DF			-0.0888***	-0.0688**		
			(0.0142)	(0.0276)		
MRO					0.0712***	0.0709***
					(0.00551)	(0.00515)
NIRP×MRO					-0.0539***	-0.0385***
					(0.00794)	(0.0111)
ECBTA	-0.0150		-0.0112		-0.0121	
	(0.0171)		(0.0181)		(0.0173)	
ECBER		0.00226*		0.00150		0.00282**
		(0.00125)		(0.00183)		(0.00137)
Constant	2.521***	2.183***	2.396***	2.141***	2.438***	2.153***
	(0.379)	(0.0818)	(0.403)	(0.0831)	(0.383)	(0.0825)
Observations	31,601	31,601	31,601	31,601	31,601	31,601
R^2	0.1367	0.1315	0.1345	0.1325	0.1325	0.1318

Notes: Instrumental variables estimation method follows Balestra and Varadharajan-Krishnakumar (1987), which provides a two-stage least-squares generalization (G2SLS). We use the first lag of endogenous variables (QE proxies, conventional monetary policy proxies, GDP, inflation) as instruments. The dependent variable is the ln(Z-score), where the Z-score is defined in the text. ECBTA: ECB's total assets; ECBER: banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy (that is DF ≤ 0.25), 0 otherwise. Bank-level and macroeconomic controls are included, as described in Table 3. N is the number of observations; standard errors are in parentheses. *, **, +: denote significance at the 10%, 5%, 1% confidence levels.

by the 2011 sovereign debt crisis (Eichler and Hielscher, 2012). In this stage, Greece is excluded from both sub-samples as its liabilities were not eligible for any of the several QE programmes launched by the ECB during our sample period.

We continue with the G2SLS regressions in this sub-sample analysis. Table 5 show the results for the euro area periphery and the remaining Member States in panels A and B, respectively. The results indicate a remarkable difference in the impact of both QE and NIRP between the two groups. For the periphery of the euro area, we find a negative and statistically significant elasticity of bank resilience to QE (panel A, columns 1 through 4), when QE is both measured by its impact on ECB total assets and banks' excess reserves. That means that, as the ECB implemented asset purchases and lending programmes, bank resilience in the periphery weakened. As before, there is an overall positive relationship between interest rates and bank resilience (panel A, all columns). But the coefficients of the interaction between interest rates and NIRP are positive and significant for the periphery. That implies that when interest rates become very low, they do not soften their impact on Z-scores, as the estimates for the full sample suggested. To the contrary, for the banks headquartered in the periphery, further cuts to the policy rate after reaching our chosen threshold have an even higher detrimental effect on bank resilience. These results suggest that both low interest rates and QE unambiguously increased bank fragility in this group.

In contrast, for banks headquartered in Member States outside the periphery, the results are fully in line, and even stronger, than those corresponding to the whole sample. For instance, there is no ambiguity about QE: whatever the proxy, Z-score elasticities are positive and, in all specifications but one, statistically significant. Moreover, in all model specifications, negative interest rates are found to slightly increase banks' Z-scores at the margin (if QE is measures as ECB total assets), or at least moderate the overall detrimental impact of further loosening the monetary policy stance (when the QE proxy is banks' excess reserves). The take-away is that, at least in our sample period, the menu of non-standard measures deployed by the

Table 5
Panel G2SLS regression results for the Euro area periphery

A. Euro area periphery

Variables	1	2	3	4	5	6
SIZE	-0.0389***	-0.0385***	-0.0410***	-0.0390***	-0.0381***	-0.0378***
	(0.00809)	(0.00808)	(0.00809)	(0.00808)	(0.00809)	(0.00809)
LIQRAT	-0.0135	-0.0109	-0.0209	-0.0202	-0.0114	-0.00977
	(0.0537)	(0.0537)	(0.0538)	(0.0537)	(0.0537)	(0.0537)
ASSETDIV	0.0756	0.0775	0.0134	0.0200	0.0867	0.0872
	(0.0560)	(0.0560)	(0.0555)	(0.0554)	(0.0559)	(0.0559)
REVDIV	-0.164***	-0.162***	-0.165***	-0.166***	-0.163***	-0.162***
	(0.0179)	(0.0179)	(0.0180)	(0.0179)	(0.0179)	(0.0179)
COST2INC	-0.246***	-0.245***	-0.245***	-0.246***	-0.246***	-0.245***
	(0.0170)	(0.0170)	(0.0171)	(0.0170)	(0.0170)	(0.0170)
ROAA	0.0669***	0.0669***	0.0672***	0.0666***	0.0668***	0.0668***
	(0.00210)	(0.00210)	(0.00210)	(0.00210)	(0.00210)	(0.00210)
GDPG	-0.625***	-0.720***	-0.991***	-1.627***	-0.663***	-0.625***
	(0.218)	(0.243)	(0.211)	(0.243)	(0.212)	(0.234)
INFLATION	-1.369*	-1.656**	0.0976	1.417**	-1.542**	-2.109***
	(0.739)	(0.655)	(0.727)	(0.625)	(0.727)	(0.642)
NIRP	-0.261***	-0.187***	-0.0322	0.207***	-0.220***	-0.205***
	(0.0510)	(0.0715)	(0.0493)	(0.0672)	(0.0498)	(0.0703)
MLF	0.0408***	0.0551***				
	(0.00956)	(0.0105)				
NIRP×MLF	0.0496***	0.0122				
	(0.0167)	(0.0268)				
DF			0.108***	0.170***		
			(0.0189)	(0.0203)		
NIRP×DF			0.0690*	-0.357***		
			(0.0411)	(0.0913)		
MRO					0.0596***	0.0686***
					(0.0126)	(0.0137)
NIRP×MRO					0.0817***	0.0659*
					(0.0228)	(0.0396)
ECBTA	-0.118**		-0.136**		-0.0850	
	(0.0518)		(0.0578)		(0.0529)	
ECBER		-0.00824**		-0.0312***		-0.00331
		(0.00376)		(0.00557)		(0.00414)
Constant	4.644***	2.155***	4.937***	2.218***	3.892***	2.083***
	(1.121)	(0.123)	(1.256)	(0.131)	(1.147)	(0.126)
Observations	5,796	5,945	5,945	5,945	5,945	5,945
R^2	0.2839	0.2550	0.2369	0.2506	0.2117	0.2527

B. Euro area excluding the periphery

Variables	1	2	3	4	5	6
SIZE	-0.0215***	-0.0221***	-0.0219***	-0.0229***	-0.0218***	-0.0220***
	(0.00636)	(0.00636)	(0.00634)	(0.00634)	(0.00637)	(0.00637)
LIQRAT	-0.299***	-0.299***	-0.294***	-0.296***	-0.297***	-0.298***
	(0.0297)	(0.0297)	(0.0297)	(0.0297)	(0.0297)	(0.0297)
ASSETDIV	-0.0918***	-0.0955***	-0.0906***	-0.0930***	-0.0913***	-0.0951***
	(0.0337)	(0.0337)	(0.0337)	(0.0337)	(0.0337)	(0.0337)
REVDIV	0.0561***	0.0553***	0.0554***	0.0546***	0.0557***	0.0553***
	(0.0118)	(0.0118)	(0.0118)	(0.0118)	(0.0118)	(0.0118)
COST2INC	-0.0067***	-0.0068***	-0.0068***	-0.0068***	-0.0067***	-0.0068***
	(0.00222)	(0.00222)	(0.00222)	(0.00222)	(0.00222)	(0.00222)
ROAA	0.0418***	0.0418***	0.0418***	0.0418***	0.0418***	0.0418***
	(0.00100)	(0.00100)	(0.00100)	(0.00100)	(0.00100)	(0.00100)
GDPG	0.816***	0.884***	0.809***	0.867***	0.816***	0.878***
	(0.0700)	(0.0720)	(0.0695)	(0.0729)	(0.0696)	(0.0716)
INFLATION	-0.563*	-0.814***	-0.431	-0.707**	-0.544*	-0.784***
	(0.299)	(0.281)	(0.304)	(0.295)	(0.298)	(0.279)
NIRP	0.284***	0.234***	0.333***	0.299***	0.302***	0.255***
	(0.0176)	(0.0208)	(0.0200)	(0.0226)	(0.0182)	(0.0213)
MLF	0.0566***	0.0509***				
	(0.00410)	(0.00376)				
NIRP×MLF	-0.0633***	-0.0416***				
	(0.00566)	(0.00685)				
DF			0.111***	0.103***		
			(0.00818)	(0.00752)		
NIRP×DF			-0.145***	-0.0805***		
			(0.0138)	(0.0257)		

Table 5 (*continued*)

| B. Euro area excluding the periphery | | | | | | |
Variables	1	2	3	4	5	6
MRO					0.0751***	0.0682***
					(0.00545)	(0.00500)
NIRP×MRO					-0.0865***	-0.0547***
					(0.00773)	(0.0102)
ECBTA	0.0351**		0.0222		0.0328**	
	(0.0164)		(0.0171)		(0.0165)	
ECBER		0.00523***		0.00513***		0.00531***
		(0.00120)		(0.00174)		(0.00130)
Constant	1.374***	2.096***	1.605***	2.052***	1.411***	2.076***
	(0.366)	(0.0911)	(0.383)	(0.0922)	(0.369)	(0.0917)
Observations	17,849	17,849	17,849	17,849	17,849	17,849
R^2	0.1516	0.1515	0.1534	0.1507	0.1505	0.1549

Notes: Instrumental variables estimation method follows Balestra and Varadharajan-Krishnakumar (1987), which provides a two-stage least-squares generalization (G2SLS). The Euro area periphery includes 6 countries: Cyprus, Ireland, Italy, Portugal, Slovenia, and Spain. We use the first lag of endogenous variables (QE proxies, conventional monetary policy proxies, GDP, inflation) as instruments. The dependent variable is the ln(Z-score), where the Z-score is defined in the text. ECBTA: ECB's total assets; ECBER: banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy (that is DF ≤ 0.25), 0 otherwise; SIZE = *ln*(total assets); ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: return on average assets over a calendar year; INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth (%). N is the number of observations; standard errors are in parentheses. *, **, +: denote significance at the 10%, 5%, 1% confidence levels.

ECB has not homogeneously contributed to build up bank resilience in all jurisdictions. In fact, in those jurisdictions that had experienced acute financial distress during the sovereign debt crisis, bank resilience appears to have suffered as a result of UMP implementation. Nevertheless, it has been beneficial for banks located in the remaining and more stable countries of the euro area, in terms of enhancing their soundness and resilience.[14]

UMPs were designed with the ultimate purpose of achieving certain monetary policy objectives, and any financial stability outcomes are essentially side effects. Thus, it could be the case that the UMPs, as implemented, had the unintended consequence of directing a large amount of support towards banks in Member States outside the periphery. For instance, the capital key that guided the jurisdictional distribution of ECB asset purchases during the sample period did not take into consideration the outstanding size of national bond markets, or the stress level of the different jurisdictions.

Table 6 reports figures per country for the public-sector purchase programme of the ECB as of 31 August 2017. The Table reports monthly net purchases, cumulative monthly net purchases, outstanding amounts of sovereign bonds as of the third quarter of 2017, the share of outstanding sovereign bonds held by the ECB and the remaining weighted average maturity (WAM) in years. For large Member States, namely Germany, France, and Italy, and to a lesser extent Spain, the net purchases are the highest among all countries, as required by the capital key. But Italy has a much larger amount of sovereign debt outstanding than any of the others, while receiving about 70% of the cumulative purchases that the top jurisdiction did. As a result, as of the third quarter of 2017, the ECB was holding about 35% of the total outstanding German government debt securities and about 15% of the debt issued by the Italian sovereign. More generally, the median ECB holdings as share of outstanding sovereign bonds was 17% for the periphery countries, and 26% for the rest. This unbalanced bond demand push may have been irrelevant in highly integrated capital markets. But given a starting point of remarkable home bias in euro area banks' holdings of sovereign debt, and the increasing fragmentation of the euro area capital markets after the 2011 sovereign debt crisis (Durré et al. 2014), it seems reasonable to conclude that the ultimate impact of this strategy could have been a very uneven degree of bank support across jurisdictions. Our results provide some perspective on the possible consequences of such disparity.

Alternatively, we cannot rule out the possibility that, at least during the sample period, banks in vulnerable countries anticipated that continued ECB support would allow them to relax their buffer building discipline. Several studies have documented the low capitalization of most banks in the euro area periphery during at least part of the sample period. The estimates of the coefficient of the dummy variable NIRP show that the loss-absorbing buffers of banks in the periphery were typically lower during the NIRP period than before (Table 5, panel A), while the buffers were higher during the NIRP period for banks in the rest of the Euro area (Table 5, panel B), and the whole sample (Table 4).

Moreover, banks in the periphery may not have been able to benefit from ECB policy, given their initial conditions of weaker balance sheets. Boeckx et al. (2017) suggests that, as a result of low capitalization, the banks most affected by the financial crisis would have not received the intended impact of the ECB UMPs, or would have seen a rather anemic impact. Eichler and Hielscher (2012) find that the ECB acted as a lender of last resort during the subprime crisis for the GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain). Afterwards, the ECB has increased lending and lowered interest rates in

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[14] This type of variability of the effect of negative interest rates is also observed in Lopez et al. (2018). However, the authors argue that negative interest rates, overall, have little effect on banks in Europe and Japan.

Table 6

Public sector purchase programme, ECB

	Monthly net purchases*	Cumulative monthly net purchases*	Debt securities outstanding Q317*	ECB Holdings as share of outstanding	Remaining Weighted Average Maturity (WAM) in years
Austria	1,223	46,310	237,879	19.5%	9.15
Belgium	1,544	58,299	372,373	15.7%	10.22
Cyprus	0	215	6,870	3.1%	4.52
Germany	9,803	413,868	1,171,094	35.3%	6.89
Spain	5,086	206,189	918,650	22.4%	8.46
Finland	528	26,661	101,491	26.3%	7.22
France	9,270	334,568	1,710,652	19.6%	7.73
Ireland	488	22,873	135,849	16.8%	8.67
Italy	7,657	291,366	1,921,517	15.2%	8.47
Luxembourg	47	2,188	8,250	26.5%	5.70
Malta	27	994	5,371	18.5%	10.94
Netherlands	2,174	92,680	327,540	28.3%	7.63
Portugal	414	29,076	150,839	19.3%	8.64
Supranational	4,347	187,531	NA	NA	7.46

Source: ECB Asset Purchases Programme. Figures are preliminary and may be subject to revision. The monthly purchase volumes are reported net of redemptions. Principal payments on securities purchased under the PSPP are reinvested by the Eurosystem in a flexible and timely manner in the month they fall due or in the following months if needed. Therefore, net purchases may fluctuate owing to the timing of these reinvestments. The first principal payments occurred in March 2017. Debt securities outstanding from Eurostat, Quarterly government debt.

* Book value in euro million. Cumulative purchases as of 31 August 2017.

response to a rise in the vulnerability of these countries. They argue that in doing so, the ECB's purpose was to keep Member States within the EMU rather than solely pursue macro-economic stabilisation. The ultimate effect of such actions would have been to heighten a negative association between easier monetary policy and the key components of our measure of bank resilience (profitability and capital). This kind of endogeneity, however, should be controlled by our estimation approach.

Differences in macroeconomic conditions also could be among the reasons explaining UMPs dissimilar impact on bank resilience across jurisdictions. Banducci, et al. (2009) document that differences in national economic cycles and structures lead to heterogeneous effects of monetary policy decisions on member countries.

In terms of the macroeconomic controls we considered, higher GDP growth results in lower bank Z-scores for the periphery of the Euro area, probably because support by the ECB and the respective governments backstopped the results and capital of these banks even on the face of very challenging macroeconomic conditions. The contrary is reported for the remaining Member States, in line with intuition and the results for the full sample. Inflation negatively affects the Z-score of banks in both groups.

The results of bank-level controls for banks headquartered outside the periphery are fully consistent with those recorded using the whole sample. In contrast, banks in the periphery of the Euro area exhibit some different coefficients. First, these banks appear to gain resilience as they diversify their assets more broadly (ASSETDIV), although those positive coefficients are not statistically significant. Also, opposite to the whole sample results, a higher proportion of non-interest income relative to total operating income (REVDIV) is correlated with lower loss-absorbing buffers (Table 5, all models). Both these findings suggest that the losses that periphery's banks suffered on their traditional loan portfolios became problematic in the aftermath of the European sovereign crisis. A higher reliance on non-lending activities, such as securities trading, probably enhanced their profits and helped to moderate the drain on their capital. On the other hand, a high reliance on non-interest income, in particular fees, offer revenue steadiness, but it does not help to compensate the volatility introduced by the poor performance of loan portfolios. Finally, the coefficients of size, efficiency and profitability repeat the findings of the full sample also in the periphery of the Euro area.

4.4. Robustness analysis (continued): banks headquartered in Germany and the core

Note that in our sample, Germany is the most dominant country with respect to the number of banks. Banks in Germany make up for more than 53% of the total number of banks in the full sample, and more than 70% of the total number of banks in Member States outside the periphery. Accordingly, it may be the case that the results for Member States outside the periphery are driven by the effects of UMPs in German banks. Therefore, we extend the robustness analysis by grouping our dataset in four sub-groups: (i) German banks, (ii) banks headquartered in countries considered the financial core of the Euro area (CEA), (iii) banks headquartered in countries at the epicentre of the 2011 sovereign debt crisis (GIIPS), and (iv) banks headquartered in any non-CEA country. Table 7 reports G2SLS instrumental variable regression results for the policy coefficients of interest.[15]

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[15] The coefficient estimates of the bank-specific and macroeconomic variables are qualitatively like those for all Member States but the periphery, except for the GIIPS (Greece, Ireland, Italy, Portugal and Spain), whose results qualitatively resemble results for the periphery. All those results are available from the authors upon request.

Table 7
Panel G2SLS regressions for alternative country-groups

A. Germany

VARIABLES	1	2	3	4	5	6
SIZE	-0.0352***	-0.0355***	-0.0361***	-0.0371***	-0.0361***	-0.0357***
	(0.00859)	(0.00857)	(0.00854)	(0.00848)	(0.00861)	(0.00860)
LIQRAT	-0.261***	-0.254***	-0.255***	-0.252***	-0.258***	-0.253***
	(0.0363)	(0.0363)	(0.0362)	(0.0362)	(0.0363)	(0.0363)
ASSETDIV	-0.126***	-0.129***	-0.127***	-0.128***	-0.125***	-0.129***
	(0.0368)	(0.0367)	(0.0367)	(0.0367)	(0.0367)	(0.0367)
REVDIV	-0.00590	-0.0109	-0.0117	-0.0150	-0.0107	-0.0127
	(0.0456)	(0.0455)	(0.0451)	(0.0451)	(0.0456)	(0.0455)
COST2INC	0.142***	0.141***	0.142***	0.142***	0.143***	0.142***
	(0.0192)	(0.0192)	(0.0192)	(0.0192)	(0.0192)	(0.0192)
ROAA	0.0833***	0.0832***	0.0833***	0.0833***	0.0834***	0.0833***
	(0.00248)	(0.00248)	(0.00248)	(0.00247)	(0.00248)	(0.00248)
GDPG	0.381***	0.540***	0.268**	0.668***	0.394***	0.515***
	(0.113)	(0.102)	(0.121)	(0.148)	(0.112)	(0.0991)
INFLATION	0.878	0.106	2.337*	-0.919	0.816	0.298
	(1.101)	(0.699)	(1.210)	(1.110)	(1.090)	(0.677)
NIRP	0.326***	0.245***	0.367***	0.256***	0.337***	0.268***
	(0.0202)	(0.0297)	(0.0203)	(0.0413)	(0.0197)	(0.0289)
MLF	0.0490***	0.0391***				
	(0.00426)	(0.00364)				
NIRP×MLF	-0.0630***	-0.0300***				
	(0.00550)	(0.00913)				
DF			0.0875***	0.0739***		
			(0.00890)	(0.00819)		
NIRP×DF			-0.146***	0.00945		
			(0.0133)	(0.0539)		
MRO					0.0648***	0.0529***
					(0.00568)	(0.00479)
NIRP×MRO					-0.0866***	-0.0418***
					(0.00754)	(0.0134)
ECBTA	0.0592		-0.00431		0.0574	
	(0.0374)		(0.0421)		(0.0374)	
ECBER		0.00742***		0.0122***		0.00709***
		(0.00185)		(0.00410)		(0.00196)
Constant	1.100	2.335***	2.430***	2.282***	1.138	2.323***
	(0.813)	(0.120)	(0.922)	(0.121)	(0.813)	(0.121)
Observations	12,666	12,666	12,666	12,666	12,666	12,666
R^2	0.0676	0.0643	0.0671	0.0617	0.0687	0.0632

B. Core Euro-area (CEA)

VARIABLES	1	2	3	4	5	6
SIZE	-0.0289***	-0.0296***	-0.0292***	-0.0325***	-0.0291***	-0.0293***
	(0.00658)	(0.00658)	(0.00655)	(0.00655)	(0.00659)	(0.00659)
LIQRAT	-0.304***	-0.300***	-0.303***	-0.298***	-0.303***	-0.299***
	(0.0302)	(0.0302)	(0.0302)	(0.0302)	(0.0302)	(0.0302)
ASSETDIV	-0.101***	-0.104***	-0.100***	-0.102***	-0.100***	-0.103***
	(0.0342)	(0.0342)	(0.0342)	(0.0342)	(0.0342)	(0.0342)
REVDIV	0.0237*	0.0227*	0.0234*	0.0207	0.0234*	0.0229*
	(0.0132)	(0.0132)	(0.0132)	(0.0132)	(0.0132)	(0.0132)
COST2INC	-0.00916***	-0.00921***	-0.00919***	-0.00939***	-0.00919***	-0.0092***
	(0.00224)	(0.00224)	(0.00224)	(0.00224)	(0.00224)	(0.00224)
ROAA	0.0367***	0.0367***	0.0367***	0.0367***	0.0367***	0.0367***
	(0.00103)	(0.00103)	(0.00103)	(0.00103)	(0.00103)	(0.00103)
GDPG	0.945***	1.023***	0.941***	1.090***	0.936***	0.998***
	(0.0871)	(0.0915)	(0.0875)	(0.0984)	(0.0863)	(0.0901)
INFLATION	-4.270***	-3.568***	-4.270***	-4.086***	-4.214***	-3.438***
	(0.557)	(0.472)	(0.581)	(0.541)	(0.554)	(0.465)
NIRP	0.237***	0.140***	0.305***	0.188***	0.262***	0.167***
	(0.0192)	(0.0259)	(0.0208)	(0.0288)	(0.0195)	(0.0260)
MLF	0.0631***	0.0438***				
	(0.00407)	(0.00400)				
NIRP×MLF	-0.0602***	-0.00957				
	(0.00564)	(0.00837)				
DF			0.127***	0.0853***		
			(0.00817)	(0.00815)		
NIRP×DF			-0.120***	0.0862**		

Table 7 (*continued*)

B. Core Euro-area (CEA)

VARIABLES	1	2	3	4	5	6
			(0.0140)	(0.0345)		
MRO					0.0843***	0.0595***
					(0.00542)	(0.00530)
NIRP×MRO					-0.0815***	-0.00762
					(0.00770)	(0.0124)
ECBTA	0.158***		0.160***		0.157***	
	(0.0223)		(0.0241)		(0.0225)	
ECBER		0.0107***		0.0164***		0.0112***
		(0.00146)		(0.00236)		(0.00159)
Constant	-1.075**	2.246***	-1.194**	2.177***	-1.079**	2.213***
	(0.487)	(0.0940)	(0.529)	(0.0951)	(0.492)	(0.0947)
Observations	17,313	17,313	17,313	17,313	17,313	17,313
R^2	0.0812	0.0889	0.0813	0.0765	0.0785	0.0832

C. GIIPS

VARIABLES	1	2	3	4	5	6
SIZE	-0.0397***	-0.0394***	-0.0417***	-0.0403***	-0.0391***	-0.0388***
	(0.00799)	(0.00798)	(0.00798)	(0.00797)	(0.00799)	(0.00798)
LIQRAT	0.00750	0.0100	-0.000193	0.000720	0.00939	0.0112
	(0.0542)	(0.0542)	(0.0544)	(0.0543)	(0.0542)	(0.0542)
ASSETDIV	0.0463	0.0474	-0.0131	-0.00708	0.0554	0.0556
	(0.0572)	(0.0572)	(0.0566)	(0.0565)	(0.0572)	(0.0572)
REVDIV	-0.204***	-0.202***	-0.205***	-0.206***	-0.203***	-0.202***
	(0.0221)	(0.0221)	(0.0222)	(0.0221)	(0.0221)	(0.0221)
COST2INC	-0.273***	-0.272***	-0.272***	-0.272***	-0.272***	-0.271***
	(0.0195)	(0.0195)	(0.0195)	(0.0195)	(0.0195)	(0.0194)
ROAA	0.0700***	0.0701***	0.0701***	0.0699***	0.0700***	0.0701***
	(0.00226)	(0.00226)	(0.00226)	(0.00226)	(0.00226)	(0.00225)
GDPG	-0.715***	-0.775***	-1.035***	-1.482***	-0.758***	-0.713***
	(0.219)	(0.241)	(0.212)	(0.239)	(0.213)	(0.234)
INFLATION	-1.713**	-2.032***	-0.508	0.361	-1.849***	-2.364***
	(0.711)	(0.626)	(0.700)	(0.594)	(0.703)	(0.617)
NIRP	-0.252***	-0.199***	-0.0387	0.131**	-0.211***	-0.205***
	(0.0502)	(0.0691)	(0.0490)	(0.0648)	(0.0493)	(0.0683)
MLF	0.0422***	0.0534***				
	(0.00964)	(0.0103)				
NIRP×MLF	0.0432***	0.0155				
	(0.0167)	(0.0260)				
DF			0.109***	0.154***		
			(0.0191)	(0.0200)		
NIRP×DF			0.0651	-0.243***		
			(0.0409)	(0.0876)		
MRO					0.0613***	0.0680***
					(0.0127)	(0.0135)
NIRP×MRO					0.0710***	0.0627
					(0.0228)	(0.0387)
ECBTA	-0.0980*		-0.103*		-0.0683	
	(0.0506)		(0.0563)		(0.0518)	
ECBER		-0.00625*		-0.0229***		-0.00207
		(0.00365)		(0.00535)		(0.00404)
Constant	4.256***	2.184***	4.272***	2.213***	3.577***	2.116***
	(1.097)	(0.123)	(1.226)	(0.130)	(1.126)	(0.125)
Observations	5,796	5,796	5,796	5,796	5,796	5,796
R^2	0.0611	0.0631	0.0621	0.0622	0.0687	0.0645

D. Non-core Euro-area (all countries ex-CEA)

VARIABLES	1	2	3	4	5	6
SIZE	-0.00738	-0.00895	-0.00775	-0.00845	-0.00746	-0.00885
	(0.0248)	(0.0247)	(0.0247)	(0.0246)	(0.0248)	(0.0247)
LIQRAT	-0.420***	-0.424***	-0.418***	-0.423***	-0.420***	-0.423***
	(0.127)	(0.127)	(0.127)	(0.127)	(0.127)	(0.127)
ASSETDIV	-0.111	-0.108	-0.116	-0.113	-0.111	-0.108
	(0.135)	(0.135)	(0.136)	(0.135)	(0.135)	(0.135)
REVDIV	-0.0274	-0.0271	-0.0271	-0.0269	-0.0273	-0.0271
	(0.0236)	(0.0236)	(0.0236)	(0.0236)	(0.0236)	(0.0236)
COST2INC	-0.131***	-0.132***	-0.129***	-0.130***	-0.131***	-0.132***
	(0.0257)	(0.0257)	(0.0257)	(0.0258)	(0.0257)	(0.0256)

Table 7 (*continued*)

D. Non-core Euro-area (all countries ex-CEA)						
VARIABLES	1	2	3	4	5	6
ROAA	0.0648***	0.0649***	0.0647***	0.0648***	0.0648***	0.0648***
	(0.00371)	(0.00371)	(0.00371)	(0.00372)	(0.00372)	(0.00371)
GDPG	2.582***	2.548***	2.552***	2.539***	2.580***	2.546***
	(0.300)	(0.286)	(0.297)	(0.286)	(0.299)	(0.286)
INFLATION	0.00253	-0.117	0.186	0.121	0.0150	-0.125
	(0.686)	(0.671)	(0.692)	(0.673)	(0.687)	(0.671)
NIRP	-0.0892	-0.131	-0.0854	-0.0870	-0.0928	-0.136
	(0.142)	(0.152)	(0.157)	(0.165)	(0.147)	(0.157)
MLF	-0.0154	-0.0155				
	(0.0318)	(0.0287)				
NIRP×MLF	0.0128	0.0286				
	(0.0443)	(0.0470)				
DF			-0.0280	-0.0246		
			(0.0623)	(0.0573)		
NIRP×DF			-0.0273	-0.0208		
			(0.103)	(0.156)		
MRO					-0.0204	-0.0206
					(0.0421)	(0.0382)
NIRP×MRO					0.0149	0.0432
					(0.0607)	(0.0699)
ECBTA	0.000968		-0.0165		5.38e-06	
	(0.101)		(0.103)		(0.101)	
ECBER		0.00539		0.000625		0.00591
		(0.00740)		(0.0102)		(0.00803)
Constant	1.568	1.544***	1.947	1.589***	1.593	1.541***
	(2.218)	(0.400)	(2.283)	(0.415)	(2.222)	(0.405)
Observations	10685	10685	10685	10685	10685	10685
R^2	0.0625	0.0828	0.0511	0.0601	0.0645	0.0611

Notes: Instrumental variable estimation method follows Balestra and Varadharajan-Krishnakumar (1987), which provides a two-stage least-squares generalization (G2SLS). Bank-level and macroeconomic controls are included in all specifications. Bank-level controls include: SIZE = *ln*(total assets); ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: weekly average return on assets over a calendar year. Macroeconomic controls include INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth in the country where bank is headquartered (%). The instruments are the first lag of endogenous variables (QE proxies, conventional monetary policy proxies, GDP, inflation). The dependent variable is the ln(Z-score), where the Z-score is defined in the text. ECBTA: ECB's total assets; ECBER: banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy (that is DF $\leq$ 0.25), 0 otherwise. Core Euro area countries include Austria, Belgium, Finland, France, Germany, Luxembourg, and Netherlands. GIIPS denote Greece, Ireland, Italy, Portugal, and Spain. N is the number of observations; standard errors are in parentheses. *, **, +: denote significance at the 10%, 5%, 1% confidence levels.

The panel A of Table 7 presents the regression results for the impact of monetary policy on bank resilience in Germany. The estimates mirror those reported in the panel B of Table 5 for all Member States outside the periphery. As policy rates decrease, bank buffers weaken, but when they turn very low or negative the detrimental impact moderates when QE is proxied by excess reserves, or it is marginally reversed when QE is proxied by ECB total assets (i.e., the interaction coefficients are larger than the direct coefficients). Even though not all our proxies of QE seem equally informative, banks' excess reserves (ECBER) clearly signal that QE enhances bank resilience as its coefficients are positive and statistically significant at the 1% confidence level.

Next, we compare the experience of the countries at the epicentre of the 2011 sovereign debt crisis (Greece, Ireland, Italy, Portugal and Spain, '*GIIPS*') with the countries widely regarded as the financial core of the Euro area: Austria, Belgium, Finland, France, Germany, Luxembourg and Netherlands ('*CEA*'). The results are presented in Panels B (CEA) and C (GIIPS) of Table 7. In the case of the '*core*' countries, the results in Panel B closely mimic those of the panel B of Table 5 (Member States outside the periphery), which are slightly weaker than the results of Panel A for Germany. Once again, NIRP compensates the direct negative effect of reducing policy rates in most cases, but its interaction elasticities are never larger than the direct elasticities corresponding to policy rates. Both measures of QE clearly suggest that these programmes have strengthened the buffers of banks headquartered in the CEA countries. In contrast, the estimates for GIIPS (panel C) indicate that unconventional monetary policies tend to hamper the resilience of the respective banking systems. Both easing policy rates (CIRP and NIRP) and QE reveal a detrimental effect to banks' Z-scores, in the way already described above in the discussion of Table 5.

There are several reasons why easing UMPs could have had a detrimental effect on the resilience of banks headquartered in GIIPS. The weak capital position of the 'GIIPS banks' may have hampered the overall transmission of UMPs (Burriel and Galesi 2018; Georgiadis 2015; Ciccarelli et al. 2013). Banks in GIIPS had to deal with large losses that eroded their capital base in the wake of the sovereign debt crisis. Therefore, the banks in these jurisdictions may have been unable to capitalise

on the more forgiving financial conditions created by ECB support. One possibility is that, given the ongoing difficulties of those banks, NIRP failed to effectively reduce their funding costs, while QE was indeed effective in compressing the yields on their assets, reducing their ROA, and potentially increasing its volatility. This may have reflected a self-reinforcing feedback loop as weaker banks initially failed to benefit from the ECB stimulus, and their increasing relative weakness made them even less likely to benefit later.

The macroeconomic conditions in GIIPS were slow to improve during the sample period, also negating any fundamental boost to bank resilience. This interpretation would be consistent with Boeckx et al. (2017), which also find smaller effects of UMPs in the countries most exposed to the financial crisis. Once again, this muted reaction is linked to the lower capitalisation of the banks in those jurisdictions. Our results seem to be in line with the macroeconomic global VAR model of Burriel and Galesi (2018) which report that Member States of the euro area with fragile banking systems did not benefit from QE when compared to other Member States.[16] The authors argue that this reported asymmetry would dampen the aggregate real activity of the whole euro area, whilst shocks from QE have significantly smaller and less persistent effects compared to conventional monetary policy tools. Altavilla et al. (2016a) provide evidence that there exist heterogeneous pass-through of interest rate shocks to lending rates at bank level, and this heterogeneity is explained by capital ratios and sovereign debt holdings. Moreover, if the credit quality of new borrowers in GIIPS did not improve, and their non-performing loans did not normalise, but the UMPs reduced intermediation spreads, banks in the GIIPS may have ended assuming relatively more risk than their CEA peers, and still being poorly compensated for that risk-taking.

To complete this stage of analysis, we ran G2SLS regressions for the whole sample excluding the banks headquartered in the core Euro area countries, with the results presented in panel D of Table 7. None of the coefficients for the policy variables are statistically significant in this sub-sample. First, interest rate policy does exhibit non-linearities, so that NIRP does have a moderating effect on the overall detrimental impact of lower policy rates over bank resilience. But QE appears to have an impact that ranges between neutral to slightly helpful as the coefficients for the different measures of QE are typically positive, but not statistically significant. In any case, the evidence suggests that QE has no beneficial effect on bank resilience outside those banks headquartered in the core countries.

4.5. Sensitivity analysis: quantile regression results

The results reported above showed some variability in the response of bank level loss-absorption buffers to UMPs across euro area national jurisdictions. As stated, this outcome could be a consequence of the initial conditions faced by the banks as regards their capitalisation or, more generally, the size of their loss-absorbing buffers. Thus, it could be the case that the tails of the underlying distributions of the ln(Z-score) may harbour some additional variability. To investigate this possibility, we proceed to estimate quantile regression models. Table 8 reports the results for the usual model specifications and quantiles 0.25 (panel A) and 0.75 (panel B).

The results suggest that the size of banks' loss-absorbing buffers does affect the overall impact of unconventional balance sheet policies, but not so much that of negative interest rate policy. QE strengthens the Z-score of all banks, using either proxy. But for any level of intensity in the use of QE, banks with higher buffers benefit the most. The coefficients of the different proxies of QE for banks in the 75th percentile are generally between fifty and one hundred percent higher than the corresponding coefficients for banks in the 25th percentile. In contrast, the effect of NIRP is unambiguously detrimental for all these banks, and if anything, it tends to be more so for banks in the higher percentile (stronger buffers). The elasticities of CIRP are not statistically significant for those specifications that include ECBTA as QE proxy. For those specifications that include ECBER, the elasticities are negative and highly significant, implying that easing policy rates improve the resilience of all banks when considered from this perspective. Yet again, the benefits of more accommodating interest rate policy were much stronger for the banks with higher Z-scores, that is, those that were already more resilient. The effect of CIRP on banks in the 75th percentile of ln(Z-score) is roughly double the effect on banks in the 25th percentile.

These quantile panel regressions are a first step in trying to disentangle the effect of bank capitalisation from headquarter jurisdiction when assessing the impact of UMPs on bank resilience. They suggest the headquarter jurisdiction has a distinct effect, over and above the mere level of bank capitalisation. The results also highlight the importance of the measure of QE to identify the effect of CIRP, which in turn suggests that both types of policy cannot be fully separated in their overall impact, at least when proxied by using these measures.

5. Monetary Policy Surprises And Bank Resilience

5.1. Identifying monetary policy surprises

Studies of the transmission of monetary policy have increasingly relied on the identification of monetary policy surprises (i.e., Kuttner 2001, Cochrane and Piazzesi 2002, Gürkaynak et al. 2005, Gertler and Karadi 2015, among many others). In this

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[16] Similarly, Georgiadis (2015) demonstrate that there are asymmetries in the transmission of the conventional monetary policy shocks across the euro-area due to country specific characteristics, which is in line with Ciccarelli et al. (2013) who argue of the importance of sovereign debt crisis to explain this heterogeneity.

Table 8
Quantile regression analysis.

Quantile 0.25 results						
VARIABLES	1	2	3	4	5	6
SIZE	-0.0324***	-0.0330***	-0.0324***	-0.0330***	-0.0319***	-0.0326***
	(0.00309)	(0.00252)	(0.00410)	(0.00246)	(0.00309)	(0.00253)
LIQRAT	-0.381***	-0.380***	-0.380***	-0.387***	-0.377***	-0.375***
	(0.0454)	(0.0335)	(0.0372)	(0.0262)	(0.0415)	(0.0495)
ASSETDIV	0.141***	0.139***	0.141***	0.135***	0.140***	0.140***
	(0.0333)	(0.0406)	(0.0370)	(0.0421)	(0.0336)	(0.0443)
REVDIV	-0.456***	-0.460***	-0.454***	-0.474***	-0.461***	-0.464***
	(0.0721)	(0.0567)	(0.0696)	(0.0581)	(0.0511)	(0.0657)
COST2INC	-0.354***	-0.356***	-0.347***	-0.354***	-0.343***	-0.353***
	(0.110)	(0.0821)	(0.0994)	(0.103)	(0.114)	(0.116)
ROAA	0.107***	0.107***	0.108***	0.109***	0.108***	0.107***
	(0.0209)	(0.0183)	(0.0158)	(0.0136)	(0.0163)	(0.0129)
GDPG	4.742***	5.381***	4.597***	5.556***	4.603***	5.204***
	(0.253)	(0.239)	(0.243)	(0.189)	(0.196)	(0.213)
INFLATION	-11.77***	-12.88***	-11.77***	-14.19***	-11.37***	-12.35***
	(0.946)	(0.948)	(1.282)	(0.814)	(0.931)	(0.862)
NIRP	-0.476***	-0.915***	-0.270***	-0.840***	-0.394***	-0.837***
	(0.0572)	(0.0722)	(0.0725)	(0.0675)	(0.0382)	(0.0691)
MLF	-0.0114	-0.0711***				
	(0.0110)	(0.00959)				
NIRP×MLF	0.155***	0.353***				
	(0.0211)	(0.0259)				
DF			0.0182	-0.139***		
			(0.0225)	(0.0173)		
NIRP×DF			0.410***	1.469***		
			(0.0616)	(0.119)		
MRO					-0.00529	-0.0863***
					(0.0125)	(0.0122)
NIRP×MRO					0.198***	0.508***
					(0.0192)	(0.0397)
ECBTA	0.381***		0.510***		0.405***	
	(0.0624)		(0.0790)		(0.0683)	
ECBER		0.0430***		0.0834***		0.0474***
		(0.00400)		(0.00864)		(0.00470)
Constant	-5.851***	2.049***	-8.724***	1.563***	-6.408***	1.961***
	(1.384)	(0.0738)	(1.693)	(0.137)	(1.498)	(0.125)
Pseudo R²	0.0565	0.0687	0.0653	0.0683	0.0681	0.0692
Observations	23,794	23,794	23,794	23,794	23,794	23,794
Quantile 0.75 results						
VARIABLES	1	2	3	4	5	6
SIZE	-0.0433***	-0.0431***	-0.0429***	-0.0431***	-0.0428***	-0.0437***
	(0.00586)	(0.00422)	(0.00497)	(0.00546)	(0.00466)	(0.00707)
LIQRAT	-0.741***	-0.735***	-0.720***	-0.682***	-0.740***	-0.740***
	(0.0503)	(0.0756)	(0.0524)	(0.0632)	(0.0630)	(0.0669)
ASSETDIV	0.340***	0.302***	0.333***	0.277***	0.343***	0.312***
	(0.0708)	(0.0672)	(0.0746)	(0.0889)	(0.0730)	(0.0623)
REVDIV	-0.810***	-0.817***	-0.818***	-0.812***	-0.815***	-0.815***
	(0.0841)	(0.141)	(0.0879)	(0.0919)	(0.0658)	(0.0921)
COST2INC	-0.215*	-0.217	-0.212*	-0.193	-0.212	-0.200
	(0.120)	(0.158)	(0.115)	(0.180)	(0.140)	(0.149)
ROAA	0.0391***	0.0433***	0.0392***	0.0427***	0.0394***	0.0414***
	(0.0117)	(0.00902)	(0.01000)	(0.0112)	(0.00986)	(0.0106)
GDPG	7.822***	8.539***	7.627***	8.764***	7.670***	8.399***
	(0.382)	(0.452)	(0.374)	(0.448)	(0.468)	(0.300)
INFLATION	-23.70***	-24.10***	-24.97***	-27.63***	-23.30***	-23.52***
	(3.033)	(2.621)	(2.766)	(2.317)	(2.929)	(2.152)
NIRP	-0.653***	-1.241***	-0.458***	-1.332***	-0.567***	-1.174***
	(0.103)	(0.177)	(0.129)	(0.130)	(0.103)	(0.131)
MLF	-0.0386	-0.127***				
	(0.0323)	(0.0219)				
NIRP×MLF	0.187***	0.459***				
	(0.0333)	(0.0555)				
DF			-0.0153	-0.270***		
			(0.0513)	(0.0437)		
NIRP×DF			0.527***	2.068***		

Table 8 (*continued*)

Quantile 0.75 results						
VARIABLES	1	2	3	4	5	6
			(0.0742)	(0.196)		
MRO					-0.0365	-0.161***
					(0.0290)	(0.0317)
NIRP×MRO					0.231***	0.663***
					(0.0373)	(0.0624)
ECBTA	0.624***		0.857***		0.675***	
	(0.138)		(0.112)		(0.107)	0.0656***
ECBER		0.0599***		0.123***		(0.00684)
		(0.00965)		(0.0141)		
Constant	-9.518***	3.473***	-14.66***	2.795***	-10.68***	3.389***
	(3.031)	(0.185)	(2.388)	(0.301)	(2.340)	(0.197)
Pseudo R^2	0.0614	0.0689	0.0622	0.0616	0.0654	0.0671
Observations	23,794	23,794	23,794	23,794	23,794	23,794

Notes: Variables defined in Table 1. The dependent variable is the ln(Z-score), where the Z-score is defined in the text. ECBTA: ECB's total assets; ECBER: banks excess reserves held at the ECB; MRO: Main Refinancing Operations rate; MLF: Marginal Lending Facility rate; DF: Deposit Facility rate; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy (that is DF ≤ 0.25), 0 otherwise. Bank level and macroeconomic controls are included in all specifications, as described in Table 3. N is the number of observations; standard errors are in parentheses. The sample period is 2007-2018. *, **, +: denote significance at the 10%, 5%, 1% confidence levels.

final part of our analysis, we proceed to insert monetary policy surprises in a modified version of the empirical model (1), to provide another perspective about the effects of monetary policy on bank resilience, including its impact across banks' business models and over time.

As indicated above (see Section 3.1.), endogeneity is a major concern in this sort of study. Expected policy actions are endogenously determined together with other economic variables, and therefore their correlations are not necessarily evidence of a causal relationship flowing from monetary policy to such economic variables. As Altavilla et al (2019) indicate, to gauge the effects of monetary policy, the researcher needs to identify changes in the monetary policy stance that are orthogonal to either the state of the economy (usually called shocks), or to the information set of market participants (usually called surprises). In the previous section we attempted to identify shocks with a two-stage least-squares IV estimation strategy. One advantage of that approach is that it allows us to distinctly map the effect of decisions with respect to specific central bank tools (interest rates, asset purchases, banks' excess reserves) onto changes in our measure of individual bank resilience. In other words, in that section we estimated actionable semi-elasticities and elasticities: a change of X percentage points in the DF rate, or an expansion of ECB assets of X%, caused a change of Y% in the Z-scores. As discussed below, that connection becomes more diffuse when the instruments are monetary policy surprises.

Initial studies within this literature (e.g., Christiano et al. 1996) focused on identifying monetary policy shocks from vector autoregression (VAR) analyses, using relatively low frequency data (monthly or quarterly). However, it was soon recognised that, at those frequencies, many other confounding factors and information can contaminate the measure of monetary policy shocks. Moreover, VAR estimates face a hard to overcome time-varying parameter problem: as the business cycle evolves, central banks may place more weight in different aspects of the conjuncture (inflation, growth, employment) and modify their decision-making parameters accordingly. VAR models may not adapt so quickly, and thus may incorrectly compute anticipated policy actions as shocks.

Recognising those limitations, Kuttner (2001) and Cochrane and Piazzesi (2002) propose a procedure for high-frequency identification (HFI) of monetary policy surprises, based on the reaction of asset prices to monetary policy decisions and announcements during a tight window around the day of the announcement. In other words, they conduct event studies with daily financial data. Such HFI strategy easily overcome the time-varying parameter problem (investors' expectation are not tied to a parameterised model defined by the econometrician), and within a narrow window of two or three days there is little scope for confounding factors to intrude. More recently, other researchers have honed that logic by conducting similar event studies within tight intraday windows around the time of the announcements.[17]

Altavilla et al (2019) conduct such a study for the euro area. Using intraday data for a broad array of euro denominated interest rates, they conduct intraday event studies to measure the impact of ECB monetary policy decisions since the first Governing Council's monetary policy meeting in January 1999. The outcome of their event studies is published in the ECB website as the Euro Area Monetary Policy Event-Study database (EA-MPD), which is regularly updated. Their event studies encompass results for 45 financial assets, including rates of overnight index swaps (OIS) of several tenors, euro area sovereign yields, stock market returns and exchange rates of the euro with other major currencies.

From this broad array of reactions to monetary policy decisions across assets and tenors, we need to extract a few factors that will summarise the surprises embedded in policy rate decisions, forward guidance communications, and asset purchase

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[17] The list of studies is long, including Kuttner 2001, Gürkaynak, Sack and Swanson 2005, Hamilton 2008, Campbell et al 2012, Gertler and Karadi 2015, Swanson 2017, Altavilla et al 2019, Cieslak and Schrimpf 2019, and many others.

announcements. Those factors will be our instruments for interest rate target policy (TGT), FG and QE. Notice that we will no longer distinguish between CIRP and NIRP, which will be simply subsumed as interest rate surprises within our TGT factor, free of interest rate level considerations. Moreover, our measure of QE will continue to reflect its *stock effect*, but through the reaction of investors to the initial announcement. In exchange, we obtain very precise measures of the scale of surprises for TGT and QE, and a well-defined measure of FG surprises. However, our measures will not reflect the effect of specific adjustments in a policy tool, but how they were perceived by investors based on their expectations before the announcement.

We compute those factors from a subset of the assets reported in the EA-MPD, following closely the methodology of Altavilla et al (2019), which in turn rely on the methodology developed by Gürkaynak et al (2005) and Swanson (2017). They extract factors from changes in risk-free yields within tight windows of the two main policy communication vehicles used by the ECB (the press releases and press conferences).[18] As a result, we use the surprises computed from OIS rates of one, three, six, twelve and twenty-four months, and German government bond yields of five and ten years. Our dataset of monetary policy events starts in January 2002 and ends in December 2019.

Our TGT factor is the direct reaction of the one-month OIS rate to the monetary policy press releases. To obtain factors representing the surprises related to FG and QE, we start by obtaining principal components from the indicated subset of rate changes in response to the press conference announcements. Those components do not have a clear economic interpretation as monetary policy factors because they cannot be ascribed to any specific tool. To obtain them, we keep the first three components, and apply to them an orthonormal rotation, imposing additional restrictions that allow an economic interpretation of the rotated factors. We require that the second and third factors do not load on the one-month OIS rate, and the third rotated factor has minimum variance in the pre-crisis period (January 2002-August 2008). As a result, the third rotated factor has a natural interpretation as QE surprises (Swanson 2017), while the first and second rotated factors correspond to the "timing" and FG surprises of Gürkaynak et al (2005). All this data processing is performed over the event-specific, disaggregated data.

Figure 2 presents the loadings of the rotated factors with respect to the seven surprises used in the analysis. We scale the factors so that TGT has a unit effect on the one-month OIS rates, "timing" has unit effect on the 6-month OIS rate, FG has a unit effect on the 24-month OIS rate, and QE has a unit effect on the 10-year Bund yield. Then we run regressions of the reactions of rates to monetary announcements on the factors and report the coefficients of such regressions together with their 90% confidence intervals. Our results are similar to those of Altavilla et al (2019) despite a few small differences in implementation: (i) our sample extends from January 2002 to December 2018 (theirs end in September 2018); (ii) we use the direct reactions of one-month OIS as TGT (they use principal components for two potential factors, and find that only one is present in the press release window); (iii) we use bund yields for the tenors of 5- and 10-years (they combine bund yields before 2011 with OIS rates after); and (iv) we do not control for the standardised surprises associated with the release of the US initial jobless claims. In fact, Altavilla et al (2019) experiment with alterations of their benchmark formulation like (ii)-(iv) and indicate that their results do not change significantly. The results we report confirm those statements.

As expected, the QE factor loads heavily on the Bund yields, particularly on the 10-year tenor, has zero loading in the one-month OIS rate, and has no or minimal bearing on the OIS rates of 2 years or less (Figure 2, lower right panel). The FG loadings peak between the 2- and 5-year tenor, maintaining very high correlation with the rate of 12 months, and declining quickly towards the tails (lower left panel). By construction, the TGT factor has a unit correlation with the surprises of the 1-month OIS rates, declining quickly afterwards, with loadings lower than 0.5 for all tenors of 12 months or more. Finally, the "timing" factor, associated with central bank guidance about policy actions for the next few meetings, loads more heavily on the OIS rates from 3 months to 2 years.

Table 9 shows further diagnostics. These are the relative contributions of the rotated factors to the overall variability of the respective event window surprises.[19] Once again, these results closely match those of Altavilla et al (2019). The TGT factor explains 50% or more of the variability of all rates of 12 months or less and has almost no incidence in the Bund yields. On the opposite side, our QE factor explains almost 70% of the variability of the 10-year Bund yield, but almost zero percent of the variability of the OIS rates. The FG factor turns out to be powerful in explaining the variability of a wide array of rate surprises, with contributions higher than 60% in the belly of the yield curve (2 and 5 years) which gradually decline towards the tails. Finally, the timing factor has contributions in excess of 50% for all OIS rates of two years or less. Its contributions decline quickly towards the longer maturities.

Notice that the rotated factors introduce a clean conceptual separation of the different types of monetary policy surprises conveyed by central bank communication. However, a direct mapping from concrete monetary policy actions (interest rate decisions, asset purchases, guidance) to the different factors is not possible. All announcements may have an incidence on the size and shape of the factors, by shocking the outlook away from the information set of investors. Therefore, by using monetary policy surprises we lose the clear connection between the effect of specific policy tools and bank resilience. In return, we gain a better understanding about how bank resilience responds to the stylised surprises. However, the combination of announcements moulded such outcomes. Moreover, we can be reasonably confident in the exogeneity of the monetary surprises so estimated.

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[18] Altavilla et al (2019) also provide a detailed description of the ECB monetary policy communication practices.

[19] That is the sum of residuals attributable to each factor, as a percentage of the total sum of residuals for the rates in the press release and the press conference windows.

Figure 2. Monetary policy factor loadings. Note: the dots show the loadings (in basis points) for factors computed during the press release window (target, in blue) and the press conference window (timing, forward guidance and quantitative easing, in orange). The timing and forward guidance factors are normalized to have unit effect on the 6-month and 2-year OIS rates, respectively. The quantitative easing factor is normalized to have unit effect on the 10-year Bund yield. The dashed lines indicate 90% confidence intervals.

Table 9
Relative contribution of factors in explaining policy surprises, full sample

	OIS	OIS	OIS	OIS	OIS	Bund	Bund	Std Dev
	1-m	**3-m**	**6-m**	**12-m**	**24-m**	**5-yr**	**10-yr**	**Factor (bps)**
Press release								
TGT	100.0%	84.0%	69.1%	49.8%	25.7%	2.1%	0.5%	2.8
Residual	0.0%	16.0%	30.9%	50.2%	74.3%	97.9%	99.5%	–
Std Dev OIS/Bund (bps)	2.8	2.0	1.8	1.6	1.5	1.6	1.4	–
Press conference								
Timing	50.5%	85.8%	74.5%	56.0%	34.6%	12.4%	8.1%	2.4
FG	0.0%	7.4%	23.4%	41.9%	60.8%	64.0%	23.1%	3.3
QE	0.0%	0.4%	0.5%	1.0%	3.3%	21.4%	67.5%	2.5
Residual	49.5%	6.5%	1.7%	1.1%	1.3%	2.3%	1.4%	–
Std Dev OIS/Bund (bps)	1.0	2.0	2.7	3.8	4.3	4.2	3.1	–

Note: the table reports for the instruments indicated in the headline, the fraction of the total sum of squared errors explained by the factor TGT (target) in the ECB press release window; and of the factors Timing, FG (forward guidance), and QE (quantitative easing) in the ECB press conference window. The "Residual" row reports the variance not explained by the factors. Windows are defined and factors are estimated as in Altavilla et al (2019). The last row in each group reports the standard deviation of each instrument in the respective window. The last column reports the standard deviation of the factors.

5.2. Baseline results and discussion

As customary in this literature (i.e., Bundick et al. 2019, Jung and Uhlig 2019), we add the monetary factor observations that occur within the unit of time that we study – in this case a calendar year – into a single total annual monetary factor observation. Since the factors represent identified surprises rather than level variables, we transform the linear specification of equation (2) by taking the first difference of all bank-specific level variables, to obtain their annual change. As a result,

time invariant fixed effects disappear from the specification. The macroeconomic controls (GDP growth and inflation), which do not have a bank-level cross sectional dimension, are kept in the original yearly growth rates. We keep the dummy variable NIRP, as described in the previous section. We also keep as controls the first difference of some of the policy variables we used in the first part. We include in the regressions first difference of the deposit facility rate (DF), ECB total assets (ECBTA), and banks' excess reserves (ECBER).[20] We use the DF rate because it was the only one of the ECB administered rates that reached negative levels, and therefore its information content is likely to encompass and exceed that of the other rates.[21] In contrast, we include both accounting gauges of QE because, as explained above, their information content may be different. In fact, the estimates presented in the previous section often varied slightly and consistently depending on which on these measures we included. Since the effect of the "timing" factor would become mostly diluted within a year, as illustrated in Table 10, we only include the rotated factors TGT, FG and QE in the remaining of the analysis.

Figure 3 presents the time series of the aggregated annual factors. The time profile of TGT factor (left-hand panel) shows a strong tightening of policy at the beginning of the 2000s, the Duisenberg-Trichet years, when the ECB needed to establish its inflation-fighting credibility. The factor also points to a moderate tightening into the start of the global financial crisis, followed by a loosening in the face of the 2011 European sovereign crisis. The time series of FG (centre panel) confirms that, as monetary economists often remark, forward guidance existed well before receiving such name. Finally, the QE factor (right-hand panel) is mostly inactive before the 2008 crisis, in line with the requirements imposed through the orthonormal rotation of the raw factors.

Table 10 presents the results for the full sample. The original rotated factors are orthogonal and including them jointly or separately would not make a difference in estimations. But the annual aggregation and the use of a subsample in our estimation eliminates that property, so we introduce them all together in the regressions. Notice initially that the familiar variable NIRP is positive in the full sample (column (1)), indicating that during the period of very low or negative deposit facility rate the Z-scores have increased (i.e., bank resilience generally improved). And they increased faster than in the full sample, as captured by the also positive and significant constant term. The coefficient of TGT is positive and statistically significant, indicating that *negative* surprises captured by this factor, corresponding to monetary *loosening*, tend to slow that general improvement of the period. This negative effect of TGT on resilience may be related to a drop in net interest margins because of policy rate cuts, as floating rate loans are common in European banks' portfolios and tend to track short-term benchmarks such as Euribor. The coefficient of FG is negative and statistically significant, meaning that negative surprises captured by this factor (again, a policy loosening) contributes to increased resilience. Although not equivalent, this result echoes the negative coefficient of the interaction between NIRP and policy rates in the previous section. As said, FG has existed for many years, but the ECB only had a chance to use this tool more forcefully after the start of the global financial crisis in 2008, and after reaching the nominal zero lower bound in interest rates in 2009, and then again in 2011, as Figure 3 suggests. Finally, the coefficient for QE is also negative and highly statistically significant, implying that looser QE policy (that is, a negative surprise) would improve bank resilience in the euro area. This finding goes in the same direction of the static results in the previous section in Table 4. As indicated before, this positive effect on bank resilience may be directly related to the increase in the valuation of the portfolio of government and other fixed income securities in banks' balance sheets because of asset purchases. The inclusion of the control variables of ECBER, ECBTA and DF confirms previous findings and enhance the exogeneity assumption over QE, FG, and TGT. However, caution is warranted in comparing results across various models as the Table 10 model employs dynamic variables and therefore it refers to the short run.

The coefficients of the bank-level controls mostly coincide with those of previous sections. The exceptions are SIZE and COST2INC, which now are positive. It is worth noting again that dynamic relationships shows that, for example, the positive sign of bank inefficiency as measured by COST2INC is in line with the '*skimping*' hypothesis (Berger and DeYoung, 1997). According to this hypothesis, in the short run it could be possible for a bank to increase its resilience and reduce its risk as it increases operating expenses. For instance, banks may invest in developing business networks and infrastructure, which have high initial fixed costs, but end up improving profitability and controls. In addition, the positive sign of SIZE could indicate that in the short run banks could exploit economies of scale: the faster a bank grows, the more likely it is to capture network and other effects that improve its profitability, also improving the rate of change of its Z-scores to increase their resilience. That coefficient sign for SIZE could also be evidence supporting the hypothesis that larger banks tend to be 'too big to fail'. Finally, the macroeconomic controls essentially reproduce previous findings in a dynamic setting.

The remaining columns in Table 10 extends the monetary policy factors analysis to different country groupings, similarly to section 4.4. We start by noticing that, for core countries (including Germany, column (2)), the coefficient of NIRP is not statistically significant, implying that, in general, the banks in this group did not exhibit a significant change in their resilience during the NIRP period, or the full sample, as the constant term suggests. The coefficients of the monetary policy factors have the opposite signs to those in the full sample, implying that they would have benefitted from easing of TGT, but not from easing of FG and QE. But all these coefficients are far from being statistically significant, indicating the resilience of banks in the CEA were mostly unaffected by monetary policy. As a result, the full sample results stem from the impact of monetary policy on the resilience of non-CEA banks (column (4)), particularly those headquartered in GIIPS (column (3)).

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[20] We acknowledge the contribution of one Reviewer who pointed out that we should also include as control variables other monetary policy variables (like ECBER, ECBTA and DF). These variables should not be correlated with the TGT, FG, and QE shocks by construction, while if they are indeed correlated not including them would cause issues with the exogeneity assumption.

[21] Results computed by using the other rates, MRO and MLF, are qualitatively similar to those presented below.

Table 10
Panel regressions with monetary factors

VARIABLES	Full Sample	CEA	GIIPS	Non-CEA
SIZE	0.0905***	0.0382***	0.0731**	0.0536***
	(0.0128)	(0.0124)	(0.0365)	(0.0122)
LIQRAT	-0.0608*	0.0473	0.341***	0.0139
	(0.0343)	(0.0367)	(0.0787)	(0.0362)
ASSETDIV	-0.226***	0.0415	0.0418	-0.00348
	(0.0404)	(0.0443)	(0.0857)	(0.0439)
REVDIV	0.0576***	0.0983***	-0.00757	0.0961***
	(0.00717)	(0.0132)	(0.0200)	(0.0105)
COST2INC	0.00605**	0.0103***	-0.0614***	0.00997***
	(0.00250)	(0.00231)	(0.0221)	(0.00227)
ROAA	0.0228***	0.0149***	0.0545***	0.0169***
	(0.000771)	(0.000733)	(0.00234)	(0.000728)
GDPG	2.263***	-0.450	1.645***	1.127***
	(0.185)	(0.289)	(0.537)	(0.205)
INFLATION	5.098***	2.596***	1.807**	3.830***
	(0.295)	(0.653)	(0.740)	(0.332)
NIRP	116.3***	-9.533	115.0***	47.75***
	(6.592)	(12.73)	(16.88)	(6.998)
DF	61.98***	-5.148	61.38***	25.41***
	(3.513)	(6.999)	(8.999)	(3.730)
ECBER	6.656***	-0.540	6.565***	2.741***
	(0.377)	(0.729)	(0.965)	(0.400)
ECBTA	-55.94***	4.409	-55.29***	-23.14***
	(3.156)	(6.119)	(8.061)	(3.355)
TGT	1.186***	-0.0979	1.175***	0.487***
	(0.0673)	(0.130)	(0.172)	(0.0715)
FG	-0.313***	0.0271	-0.312***	-0.127***
	(0.0179)	(0.0343)	(0.0456)	(0.0189)
QE	-0.342***	0.0267	-0.342***	-0.142***
	(0.0193)	(0.0374)	(0.0491)	(0.0205)
Constant	989.9***	-75.13	978.0***	411.4***
	(55.70)	(108.0)	(142.2)	(59.22)
Observations	23,798	14,768	5,082	9030
R-squared	0.087	0.095	0.259	0.111
Number of idn	3,208	2,325	812	2,396

Notes: Variables defined in Table 1. The dependent variable is the first difference of ln(Z-score). Interest rate target policy is noted by TGT, forward guidance by FG and quantitative easing by QE; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy, 0 otherwise. Control variables include: SIZE = ln(total assets); ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: weekly average return on assets over a calendar year; INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth (%). N is the number of observations; standard errors are in parentheses. The sample period is 2007-2018. Core Euro area countries include Austria, Belgium, Finland, France, Germany, Luxembourg, and Netherlands. GIIPS denote Greece, Ireland, Italy, Portugal, and Spain. N is the number of observations; standard errors are in parentheses.
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
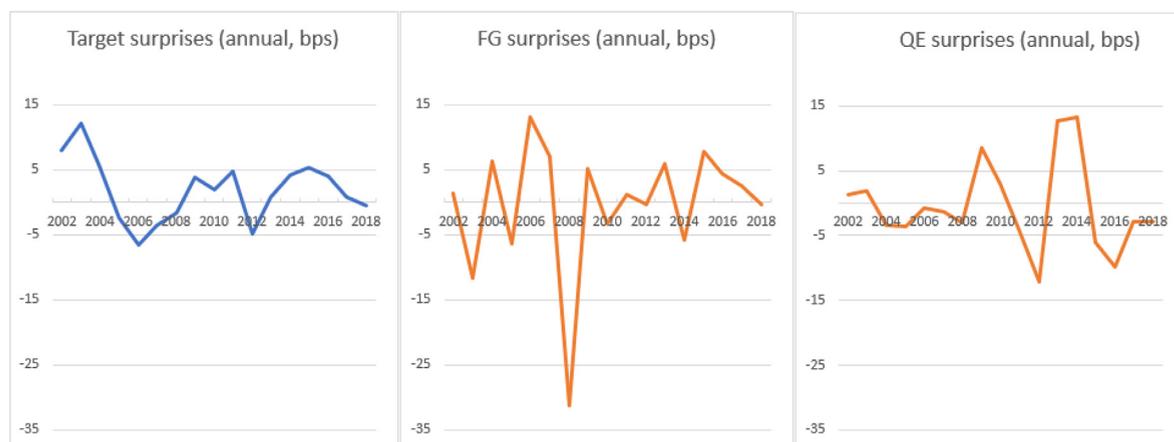

Figure 3. Annualized monetary policy factors. Note: annualized factors are computed by adding all surprises corresponding to each calendar year.

Table 11

Composition of sample, by bank business specialisation

Bank type (business model)	N		Percent	Cum. %
Commercial banks	4,608	19.27	19.27	
Cooperative banks	12,467	52.13	71.39	
Investment banks		666	2.78	74.18
Real Estate & Mortgage banks		775	3.24	77.42
Savings banks		5,401	22.58	100.00

Source: Authors' sample.

Notice that the coefficients for all monetary policy surprises are significantly larger in absolute value for banks headquartered in GIIPS, suggesting that monetary policy affected substantially more the resilience of those banks.

Coming back to bank-level controls, bank inefficiency as measured by COST2INC carries a negative sign for countries in the periphery, contrary to the result for the other groups of countries. That also insinuates the existence of some variability in the resilience effect of bank-specific variables across jurisdictions. These results suggest that, in terms of financial integration, there is still significant room for improvement in the Euro area. That is to some extent surprising, as not only monetary policy but also, to a large extent, financial and bank surveillance and regulation are common in the area.

5.3. Banks' business models and monetary policy

In the previous section we have investigated how monetary policy affected banks with different levels of Z-scores, by using quantile regressions. In this section, we extend our analysis of heterogeneity across banks by exploring how the policy surprises reflected in the monetary policy factors affected banks specialising in different business lines.

For that purpose, we bring back the business model fixed-effect variables that had fallen off the regression in first differences, and we interact them with the rotated factors. As a reminder, our data source identifies five main types of banks (i.e., business lines): (1) commercial banks, (2) cooperative banks, (3) investment banks, (4) real estate banks, and (5) savings banks. Table 11 presents the detail of the composition of our sample by bank type. Cooperative banks are the most common type, encompassing more than 12,000 observations. Commercial and savings banks follow, each one representing about 5,000 observations. Investment and real estate banks have a relatively small footprint in the euro area banking system.

We introduce the business lines indicators one at time in the first-difference estimation equation, to create the interactions between the monetary policy factors and the business lines, which produces five new regressions. The results are presented in Table 12. The magnitude of the direct coefficient estimates for the monetary policy factors do not change much with respect to the original ones, and the signs and significance level are essentially identical across all columns. Columns (1) through (5) show the results, respectively for commercial banks, cooperative banks, investment banks, real estate and mortgage banks, and savings banks.

We begin by focusing on the interaction effects of TGT. The coefficient is positive and statistically significant for commercial banks and real estate banks, and marginally significant for investment banks. Accordingly, these banks resilience seems to be hampered by loosening interest rate policy. Cooperative banks, however, seem to benefit, as their interaction coefficient is negative and highly significant. Savings banks appear unaffected by TGT surprises.[22] Over the course of a full calendar year, commercial, real estate and investment banks should have enough time to reprice their funding (especially deposits in the case of European commercial banks) and a part of their assets. The negative effect of the TGT loosening suggests that the impact tends to stronger on the asset side of their balance sheets.

The coefficients of the interactions of FG have statistically significant and negative coefficients with regards to commercial, real estate, and cooperative banks, i.e. their resilience improvement accelerates with loosening FG surprises. The 'low-for-long' message of the ECB's FG during most of the sample period may not boost the revenues of the loan portfolios of these banks, but probably helped the valuation of securities and other real assets. On the other hand, FG surprises are detrimental to the resilience of savings banks, whose coefficient is positive and highly statistically significant. Investment banks appear unaffected.

Finally, QE surprises only seems to boost the resilience of real estate banks, whose portfolios tend to hold the longest duration assets among all bank types under consideration. The coefficient is also negative for commercial banks, but only at the 10% confidence level. Gains from their portfolio of assets are likely to explain this result as well. The resilience of cooperative banks, typically more dedicated to straightforward lending activities, seems to suffer with easing QE. Once again, investment banks appear unaffected, as well as saving banks.

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[22] It is worth noting at this point that the latter two types of banks are mainly found in the German banking industry, which is traditionally dominated by many locally based small saving and cooperative banks. So, the Table 13 result sheds light of the impact of loosening interest rate policy on the bank resilience of local markets and appear to confirm the finding of Table 7, regarding the impact of unconventional monetary policy in the German banking industry.

5.4. The lagged response of bank resilience

It is well understood that monetary policy works with long and variable lags. So far, our estimates in this section capture the initial response of the rate of change of our measure of bank resilience, the ln(Z-score), to monetary surprises during the sample period. Since our data are annual, that initial response provides a good sense of the change in the direction of adjust-

Table 12

panel regressions with monetary policy factors, bank business line interactions.

VARIABLES	Commercial	Cooperative	Investment	Real Estate	Savings
SIZE	0.0926***	0.0973***	0.0960***	0.0946***	0.0922***
	(0.0129)	(0.0128)	(0.0128)	(0.0128)	(0.0128)
LIQRAT	-0.0770**	-0.0863**	-0.0838**	-0.0792**	-0.0700**
	(0.0344)	(0.0343)	(0.0344)	(0.0344)	(0.0343)
ASSETDIV	-0.228***	-0.232***	-0.231***	-0.228***	-0.212***
	(0.0405)	(0.0405)	(0.0405)	(0.0405)	(0.0404)
REVDIV	0.0558***	0.0548***	0.0549***	0.0552***	0.0560***
	(0.00719)	(0.00718)	(0.00719)	(0.00719)	(0.00717)
COST2INC	0.00546**	0.00524**	0.00532**	0.00513**	0.00542**
	(0.00250)	(0.00250)	(0.00250)	(0.00250)	(0.00250)
ROAA	0.0231***	0.0230***	0.0230***	0.0231***	0.0231***
	(0.000773)	(0.000772)	(0.000774)	(0.000772)	(0.000771)
GDPG	3.070***	3.069***	3.027***	3.039***	3.044***
	(0.192)	(0.192)	(0.192)	(0.192)	(0.192)
INFLATION	4.992***	5.270***	5.124***	5.108***	4.910***
	(0.367)	(0.361)	(0.360)	(0.360)	(0.360)
NIRP	94.28***	95.14***	93.05***	93.48***	92.87***
	(6.226)	(6.201)	(6.203)	(6.201)	(6.193)
DF	50.21***	50.67***	49.56***	49.79***	49.47***
	(3.318)	(3.305)	(3.305)	(3.304)	(3.300)
ECBER	5.398***	5.447***	5.328***	5.353***	5.319***
	(0.356)	(0.355)	(0.355)	(0.355)	(0.354)
ECBTA	-45.62***	-46.04***	-45.05***	-45.25***	-44.96***
	(2.987)	(2.975)	(2.976)	(2.975)	(2.971)
TGT	0.962***	0.975***	0.950***	0.955***	0.949***
	(0.0636)	(0.0634)	(0.0634)	(0.0634)	(0.0633)
FG	-0.253***	-0.254***	-0.249***	-0.251***	-0.250***
	(0.0169)	(0.0168)	(0.0168)	(0.0168)	(0.0168)
QE	-0.280***	-0.283***	-0.276***	-0.278***	-0.276***
	(0.0183)	(0.0182)	(0.0182)	(0.0182)	(0.0182)
COM×TGT	0.00626***				
	(0.00174)				
COM×FG	-0.00105**				
	(0.000449)				
COM×QE	-0.00108*				
	(0.000621)				
COOP×TGT		-0.00539***			
		(0.00138)			
COOP ×FG		-0.00171***			
		(0.000340)			
COOP ×QE		0.00106**			
		(0.000491)			
INV×TGT			0.00772*		
			(0.00419)		
INV ×FG			0.000664		
			(0.00111)		
INV ×QE			0.000396		
			(0.00150)		
REST×TGT				0.00944**	
				(0.00372)	
REST ×FG				-0.00239**	
				(0.000965)	
REST ×QE				-0.00492***	
				(0.00131)	
SAV×TGT					-0.000513
					(0.00167)
SAV ×FG					0.00369***
					(0.000410)
SAV ×QE					0.000289
					(0.000596)

Table 12 (*continued*)

VARIABLES	Commercial	Cooperative	Investment	Real Estate	Savings
Constant	808.6***	816.2***	798.7***	802.3***	797.1***
	(52.73)	(52.52)	(52.54)	(52.52)	(52.45)
Observations	27,998	27,998	27,998	27,998	27,998
R-squared	0.083	0.085	0.082	0.083	0.087
Number of idn	3,208	3,208	3,208	3,208	3,208

Notes: Variables defined in Table 1. The dependent variable is the first difference of ln(Z-score). Interest rate target policy is noted by TGT, forward guidance by FG and quantitative easing by QE; NIRP: is a dummy that is equal to 1 in periods of negative and/or very low interest rate policy, 0 otherwise. Control variables include: SIZE = ln(total assets); ASSETDIV: asset diversification = securities/assets; LIQRAT: liquidity ratio = liquid assets/total assets, REVDIV: revenue diversification = non-interest incomes/total operating income; COST2INC: cost to total income ratio; ROAA: weekly average return on assets over a calendar year; INFLATION: inflation rate in the country where bank is headquartered (%); GDP: GDP growth (%). N is the number of observations; standard errors are in parentheses. The sample includes 3,229 banks in 19 countries of the Euro-area. The sample period is 2007-2018. Core Euro Area (CEA) countries include Austria, Belgium, Finland, France, Germany, Luxembourg, and Netherlands. GIIPS denote Greece, Ireland, Italy, Portugal, and Spain. N is the number of observations; standard errors are in parentheses. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

ment introduced by the shocks. In this final section of our study, we expand that analysis by computing impulse response functions from a panel VAR that allows us to track the response of ln(Z-scores) to monetary policy surprises over several periods. As we turn back to levels of our dependent variable, the impulse responses provide a view about the dynamics of the reaction to monetary policy surprises.

We estimate a set of panel VAR models in levels of the ln(Z-scores) and each of the monetary policy factors, taken one at a time. We perform the estimation for the full sample, and the subsamples of core Member States of the euro area (CEA) and the Member States most affected by the European sovereign debt crisis (GIIPS). Since the ln(Z-scores) are in levels, we follow
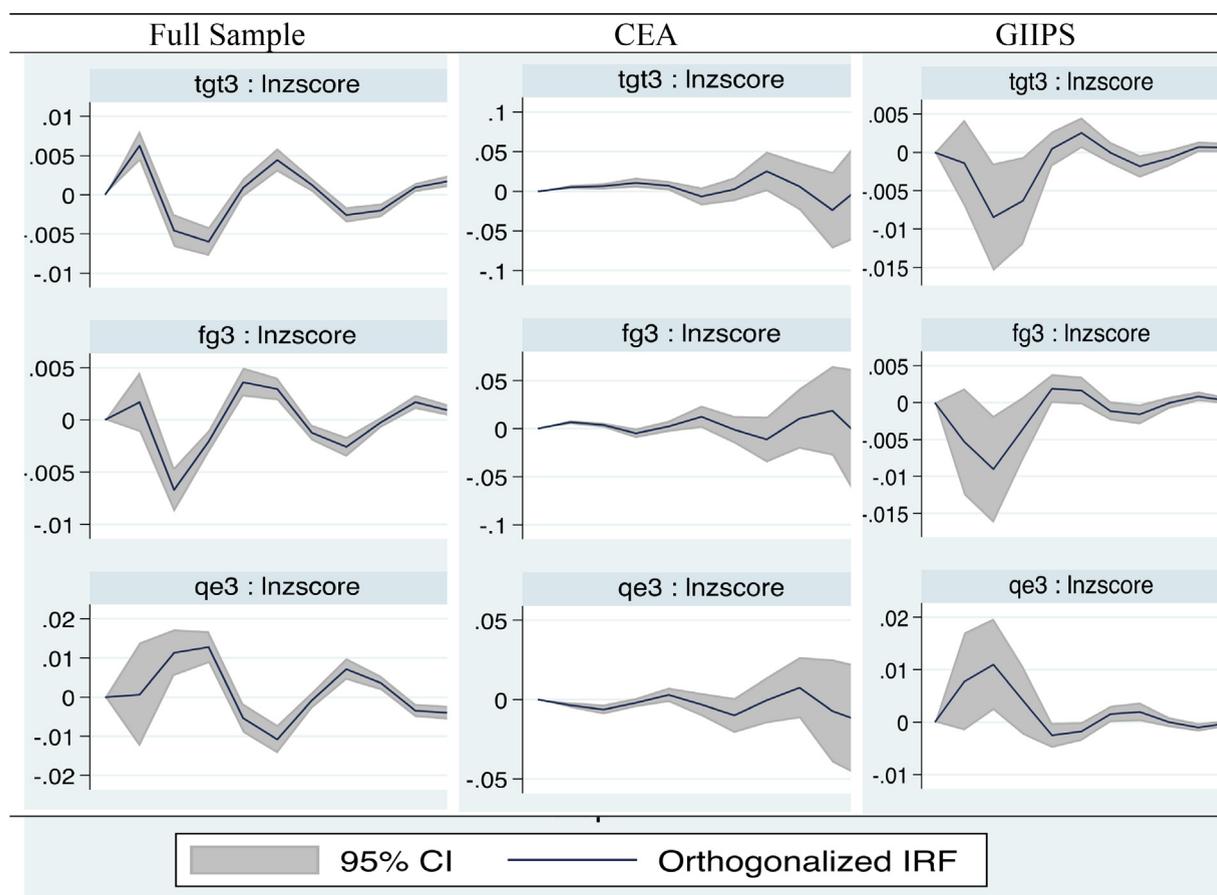

Figure 4. Impulse Response Functions. Note: Authors' estimations with 95% Confidence Intervals (CI). CEA is Core Euro Area and includes Austria, Belgium, Finland, France, Germany, Luxembourg, and Netherlands. GIIPS includes Greece, Ireland, Italy, Portugal, and Spain. Interest rate target policy is noted by tgt3, forward guidance by fg3 and quantitative easing by qe3; lnzscore notes bank's resilience.

Romer and Romer (2004) and introduce as endogenous variables the cumulated version of the monetary policy rotated factors. That means that starting in year 2007 we recursively cumulate the successive yearly factor observations. In this way, we produce a level variable that measures the monetary policy stance in each year with respect to the starting year. We assume that all cross-sectional units share the same data generating process, and cross-sectional heterogeneity is absorbed with bank-level fixed-effects. Moreover, we introduce macroeconomic controls, including GDP growth, inflation, the variable NIRP, and also the levels of ECBTA and ECBER. We implement the estimations with a GMM procedure that follows Arellano and Bover (1995), performing a joint estimation of the system of equations. To compute the impulse response functions, we recognize that within any given year, the ECB responds to macroeconomic conditions that could eventually have an impact on the resilience of banks. But those conditions work slowly, and we assume the ECB does not respond to the financial conditions of banks per se. As a result, we rely in a Cholesky identification strategy that assumes that monetary policy affects the ln(Z-scores) within the year, as shown in previous sections, but does not respond to them, not even indirectly when responding to macroeconomic conditions. We report 95% confidence intervals around the impulse response point estimates, computed using a Gaussian approximation based on 100 Monte Carlo draws from the fitted panel VAR model.

Figure 4 presents the results to unexpected tightening of monetary policy, as it is customary. The first row of panels displays the dynamic response to the TGT surprises, and the subsequent rows show the responses to FG and QE surprises, respectively. Despite the difference in the specification of the ln(Z-score) variable, the responses repeat some patterns of the panel regressions. For all factors, the full sample exhibit statistically significant responses that are qualitatively similar to those of banks headquartered in GIIPS. CEA banks are largely unaffected over the response window, which spans 10 years. A tightening TGT surprise has a positive initial impact on bank resilience in the full sample, which turns quickly negative in the second and third year, before gradually fluctuating while it vanishes towards the tenth year. As European banks tend to reprice their existing loans relatively quickly, their revenues may benefit initially from the rate hiking. But as the effect of the hiking affects loan performance and reduces new issuances, the initial boost wanes. The response to a surprise tightening through FG is a fall in resilience in the early years, before turning positive in year 5 and subsequently fluctuating while becoming non-significant towards the end of the window of analysis. Notice that for both TGT and FG surprises the initial response exhibits the same sign as the coefficient of the panel regressions in section 5.2. Also, it takes several years for the response to turn statistically not significant, even though it may not be large initially. Finally, a QE tightening surprise is met with an early positive response of bank resilience in the full sample and the GIIPS banks. The results in the full sample are also long lasting, only vanishing towards the tenth year, the end of the response window.

6. Conclusion

Unconventional monetary policies have gained an increasing role among monetary policy tools in recent years, as the space for continuing accommodation through standard monetary policies waned. This paper complements previous studies by focusing on the financial stability consequences. These are admittedly side-effects of unconventional policies, but nevertheless important from a policy perspective to assess their overall usefulness in the context of a full cost-benefit analysis.

We study the euro area, where the impact of UMPs is of special importance for bank stability, because of interconnectedness, cross-jurisdictional activities, and the liberalisation of capital flows. The evidence herein shows that, in a static empirical model that can be interpreted as a vehicle for a comparative static analysis, UMPs enhance bank soundness overall across the euro area. Nevertheless, the effect varies across jurisdictional sub-samples. For Member States at the periphery of the euro area that have experienced financial distress, QE and very low interest rates could impair bank stability by weakening the banks' loss absorbing buffers. The opposite is reported for the Member States at the core of the euro area that have experienced net inflows of bank deposits from the periphery.

Thus, the results highlight that the side-effects of ECB's non-conventional monetary policies have not been symmetric across the euro area. Differences in the institutional settings, the lack of a banking union and the considerable difference in underlying economic fundamentals across Member States may have played a role in this divergent outcome, and it should be considered for a single monetary policy to work effectively.

The dynamic setting of the second part of the paper nuances and complements the initial results. We start with the identification of orthogonal monetary policy factors as in Altavilla et al (2019). Then we use those factors to assess the dynamic impact of policy on bank resilience. We find that most of the banks in the full sample and subsamples improved their Z-scores during our sample period. For GIIPS banks and the full sample, easier interest rate policy slowed down that improvement, while FG and QE accelerated it. Banks headquartered in the core countries were largely irresponsive to the monetary policy surprises, as their overall resilience did not tend to change during the sample period. We also find that the impact of policy varied depending on the business specialisation of the banks, in ways consistent with intuition. Finally, in this second part we also emphasise the time variation of monetary policy effects. Our impulse response analysis reveals that monetary policy often affect bank resilience with significant lags or persistence, and its effects tend to build up over time, sometimes taking a different direction than the initial impact.

Our results in the full sample are largely consistent with the notion that overall UMPs enhance bank soundness in the euro-area across both methodologies. Some variability emerges in the consideration of the effects of QE for the subsamples, where the static analysis suggests that looser QE is helpful for banks at the core of the euro-area and weakens the resilience of banks at the periphery of the euro-area, while the dynamic analyses find that the rate of change in buffers improves in the

periphery while it is not affected in a statistically significant way in the core euro area. These findings are not necessarily contradicting, however. More research would be needed to fully understand the mechanisms and developments underlying these results.

Data availability

The authors do not have permission to share data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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