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CENTRAL BANK RESERVES AND BANKS' PORTFOLIO REBALANCING IN THE EURO AREA

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ABSTRACT

An important consequence of unconventional monetary policy is a substantial increase in the amount of reserves held in banks' balance sheets. In this article, we analyse whether a higher level of reserves affects credit supply to the real economy. Using data for euro area banks after the ECB initiated asset purchases in 2014-2015, we show that reserve creation related negatively to their security holdings and positively to bank loans, in line with portfolio rebalancing theories. The results account for endogeneity in reserve holding and are less pronounced for banks with higher risk of deposit outflows. However, reserve-induced lending is not limited to monetary easing. During the 2022-2023 ECB tightening cycle, reserve-rich banks mitigated credit declines to firms, impairing transmission. Results were stronger for banks facing frictions related to market fragmentation and financial constraints. Overall, our work implies that central bank reserves can have far-reaching consequences for monetary policy transmission through the bank lending channel.

Keywords: Monetary policy transmission; central bank reserves; quantitative easing; bank lending; balance sheets; portfolio rebalancing
JEL Codes: E52; G11; G21

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1. Introduction

In response to the Global Financial Crisis (GFC) and again following the COVID-19 pandemic, major central banks implemented unconventional monetary policy to provide economic stimulus. Monetary expansion in the form of large scale asset purchases, commonly referred to as quantitative easing (QE), was funded by central bank reserves.[1] Since transactions with reserves are settled only through the banking sector, banks' balance sheets were flooded with enormous amounts of liquidity. In the euro area, reserves increased dramatically from 100 billion euro before the GFC to 4,500 billion euro in mid-2022, right before the European Central Bank (ECB) embarked on policy rate hikes (Figure 1). To put that into perspective, it corresponds to a peak of 12% of banks' total assets, based on aggregate ECB data (Lane, 2023).

Theoretical predictions suggest that the injection of central bank liquidity can lower term premia by extracting duration risk from the market (e.g. Krishnamurthy and Vissing-Jorgensen, 2011; Vayanos and Vila, 2021). Faced with lower yields on safe assets, investors may reallocate towards riskier assets, increasing real investment. An extension of this argument to account for central bank assets suggests that portfolio balance effects of QE programmes may arise from an increase in the supply of reserves which pushes up prices of targeted assets and reduces yields on alternative non-money assets (Bernanke and Reinhart, 2004). While much of the literature has focused on asset purchases from non-banks, including non-bank financial institutions (NBFIs), little work has been done on substitution effects of reserve creation in banks' asset portfolios. In this paper, we study interactions of reserves with banks' security holdings and the implications thereof for bank lending. In addition, we examine whether reserve-induced credit supply effects are limited to central bank liquidity expansion at origination. For that scope, we examine the relationship between reserves and bank lending when monetary policy turns restrictive.

In principle, asset purchases from banks can be seen as an asset swap -- an exchange of reserves for securities -- which leaves banks' total assets unchanged, unlike purchases

[1] Central bank reserves are accounts of commercial banks held at the central bank and refer to holdings in the current account and the deposit facility as well as other assets related to monetary policy (Lane, 2023).

by non-banks which increase both bank reserves and deposits, resulting in monetary expansion. Still, under imperfect substitutability of central bank money (reserves) and financial assets, banks may rebalance away from low-yielding assets to alternative assets to restore their pre-expansion asset composition. Accordingly, QE-induced reserve creation may induce banks to offload part of their security holdings and increase loans, facilitating portfolio balance effects at the bank level. The idea of portfolio rebalancing has been developed in different contexts as a means to increase higher-yielding assets (Paludkiewicz, 2021), achieve a desired level of asset liquidity (Altavilla et al., 2025) or increase the marginal benefit of assets (Kandrac and Schlusche, 2021). Here, it is examined with respect to the amount of central bank liquidity absorbed at the bank level.

The euro area is particularly well-suited to explore the above arguments. Banks in the euro area were significant investors in securities eligible for asset purchases by the Eurosystem. Specifically, they held almost 40% of total eligible government bonds at the beginning of the QE period (Koijen et al., 2021). By comparison, US banks held only 1.1% of outstanding Treasuries before the GFC (Diamond et al., 2024). In addition, the Eurosystem's expanded asset purchase programme (APP), the equivalent of large-scale asset purchases in the euro area, was the main driver underlying the reduction in the term premia of sovereign bonds. In particular, asset purchases decreased by 20% the free float of outstanding public debt of euro area countries (ECB, 2025). Given that banks in the euro area play a prominent role in monetary transmission, these observations combined suggest that Eurosystem asset purchases were likely to have been important for banks' portfolio rebalancing with real side effects, an insight which we explore empirically in our paper.

We obtain proprietary bank-level data that span the 2007-2024 period and complement them with granular loan-level data that run for the 2019-2024 period. For assessing the QE-induced portfolio rebalancing channel, we focus on the Eurosystem's asset purchase programme (APP) initiated in 2014. Although the programme was eventually extended beyond the COVID-19 pandemic, we mainly account for the pre-pandemic APP in our regression analysis (i.e. up to end-2019), to avoid blending our results with the Eurosystem's pandemic emergency purchase programme (PEPP) and other parallel ECB measures targeting banks' reserves. Specifically, although in principle similarly engineered to stimulate the economy through yield compression, the PEPP

envelope was much larger than the APP and allowed greater flexibility in the conduct of purchases to reinforce transmission as well as to mitigate market stress and fragmentation risks, at least initially. Hence, the ECB may have at times targeted securities in certain jurisdictions to mitigate adverse yield changes, potentially leading to endogeneity issues in reserve creation at the bank level which might be less severe under the rule-based APP framework.[2] Also, by the time the PEPP set off, the ECB had initiated a two-tier remuneration system for reserves in late 2019 that lasted until 2022 and exempted part of those balances from the negative policy rate. As Altavilla et al. (2025) note, this contributed to a redistribution of reserves within the banking system that was not observed before that period. Hence, the pre-pandemic APP may provide a cleaner setting in which to examine asset purchases increasing bank liquidity directly through own sales of bonds, while also accounting for non-banks' bond sales intermediating through banks' balance sheets.

Our analysis proceeds in two steps. First, we examine the relationship between reserve creation and changes in banks' security and loan portfolios. On the one hand, we find that central bank reserves related negatively and significantly with banks' security holdings. Results were more pronounced for bond-intensive banks and those with higher shares of domestic government bonds, likely reflecting disposals in the context of the Eurosystem's public sector purchase programme (PSPP), the flagship programme of the APP. On the other hand, reserves related positively and significantly to bank lending. Results were stronger for long-term lending and limited for short-term lending, in line with reallocations towards higher-yielding long-term assets (Paludkiewicz, 2021). Combined, these findings suggest that higher reserves had positive credit supply effects by facilitating portfolio rebalancing at the bank level. Consistent with supply-side effects, banks granted new loans with lower interest rates. Importantly, the individual estimates from tests on banks' securities and loans were of a similar scale in bank assets. Each euro of additional reserves was associated with a shift of 20 cents from securities to loans, keeping non-reserve assets fixed but less liquid. Assuming full eligibility of disposed securities, results imply that euro area banks contributed 1/5 of the total amount of securities for asset

[2] Asset purchases under the APP were proportional to the 'capital key' for each country, i.e. an index of the contribution of each National Central Bank (NCB) to the ECB capital, reflecting the share in the aggregate euro area economic output and population. See also Section 2.

purchases by the Eurosystem. This figure fits well with data reported in Rogers (2024) who track the evolution of sovereign bonds by the private sector.

Mindful of endogeneity concerns in reserve hoarding, we follow the literature in using a Bartik-style instrument in our regressions which accounts for the differential exposure to common monetary policy shocks (e.g. Acharya et al., 2023; Altavilla et al., 2024). For robustness, we employ various falsification tests. Specifically, we check the sensitivity of results to the instrument used, we control for outside pricing of reserves, and we test results in a different period. With the help of a crude bank balance-sheet measure of 'portfolio tilting', we illustrate that rebalancing trends coincide well with the time the Eurosystem conducted asset purchases. What is more, the rebalancing intensity varied positively with the intensity of asset purchases, further showing how monetary policy shocks propagate through the banking sector.

In the second step of our analysis, we explore whether reserve-induced credit supply effects were limited to the portfolio rebalancing channel at origination. Given that reserves is a safe liquid asset, banks with sufficient reserves may avoid costly declines in illiquid assets such as loans when faced with liquidity risks. Hence, reserve-rich banks may mitigate credit supply declines amid restrictive monetary policy. Liquidity challenges of this sort are formalised in studies on central bank balance sheet expansion and its reversal known as quantitative tightening or QT (e.g. Lopez-Salido and Vissing-Jorgensen, 2023; Acharya and Rajan, 2024). Using data from AnaCredit, a granular ECB proprietary loan-level dataset, matched with banks' balance sheet data, we show that banks with larger reserve holdings were better positioned to buffer lending declines to firms after the ECB tightened its policy in 2022. Our results suggest that a bank holding 6-7% of assets in the form of reserves would offset the decline in firm lending. These results are derived after controlling for credit demand shocks using interactions of firm and time fixed effects, following Khwaja and Mian (2008). Importantly, our tests show that higher lending is not related to risk-shifting or banks' loose credit standards. Reserve-rich banks increased collateral requirements and did not lend out disproportionately more to smaller bank-dependent firms. Instead, credit supply effects were more pronounced for less well-capitalised banks and those in jurisdictions with lower liquidity concentration in the euro

area, that is frictions related to banks' financial constraints and market fragmentation, respectively.

Our work contributes to the literature which explores the credit supply effects of unconventional monetary policy. Drawing on early work discussing the channels through which large scale asset purchases affect the economy (e.g. Eggertsson and Woodford, 2003; Krishnamurthy and Vissing-Jorgensen, 2011), empirical studies show that banks with higher shares of eligible securities to asset purchase programmes increased lending relatively more than their peers (e.g. Rodnyansky and Darmouni, 2017; Chakraborty et al., 2020). Studies more directly on portfolio rebalancing document higher lending in response to policy-induced yield declines, but their results are mainly country-specific (Peydro et al., 2021; Paludkiewicz, 2021; Bottero et al., 2022). Differently from these papers, we exploit balance sheet data for a pool of banks from across the euro area. The cross-country setting allows us to draw more meaningful conclusions on the effectiveness of monetary policy transmission in a heterogeneous monetary union and the channels that it operates. This is crucial also because previous euro area studies mainly focused on asset pricing implications of purchases with limited inferences on the amount of central bank liquidity (e.g. Eser and Schwaab, 2016; Altavilla et al., 2021b).

We also add to studies which examine more directly central bank reserves and implications thereof on banks' balance sheets. While this work has mainly examined the impact on loans with respect to developments on the liability side when regulatory constraints bind (Diamond et al., 2024) or liquidity conditions tighten (e.g. Acharya et al., 2023; Altavilla et al., 2024), we belong to a few papers that examine direct implications of reserves on bank intermediation. The main idea in this literature is that reserves can encourage banks to extend credit by mitigating their liquidity needs (Altavilla et al., 2025), increasing their net worth when the policy rate increases (Fricke et al., 2024) or reaching for yield (Kandrac and Schlusche, 2021; Albertazzi et al., 2021). In our work, we focus on banks' management of own security and loan portfolios in response to reserve creation to draw inferences on its role in the transmission process through the banking sector. Transactions between commercial banks and the central bank were prevalent during unconventional times in the euro area but have largely been underexplored, with a few exceptions (Koijen et al., 2017; 2021). We track their implications on banks' balance sheets,

albeit not isolated from developments on the liability side. For example, we report that portfolio rebalancing was constrained in banks with higher shares of NBFI deposits. Prior literature has assigned to non-banks a higher risk of deposit outflows (e.g. Acharya and Rajan, 2024).

By examining what level of reserves would insulate banks from lending declines amid restrictive policy, we also contribute to an emerging strand in the literature which studies the determinants of banks' demand for reserves (e.g. Lopez-Salido and Vissing-Jorgensen, 2023; Afonso et al., 2025). These papers study banks' demand curve and calibrate a 'satiation point' below which reserves are scarce compared to the needs of the banking system. Although an explicit estimate for the euro area is outside the scope of our study, we provide some related inferences by studying the amount of reserves that would buffer lending declines amid tighter monetary conditions. By exploiting bank heterogeneity, we also reveal some important non-linearities in the transmission process. For example, we report that banks with higher deposit shares by NBFIs engaged less with portfolio rebalancing during QE but did not lend out less in the post-QE period, suggesting that these banks had likely reached their point of demand satiation for reserves. By contrast, less well-capitalised banks and banks in jurisdictions with lower liquidity concentration would have benefited from holding higher levels of reserves ex-ante. All in all, our findings that reserves can impair the transmission of restrictive policy add to those by Fricke et al. (2024) who highlight that net worth effects of higher policy rates stimulate lending. When we control for pricing effects, we continue to find positive credit supply effects, a likely reflection of reserves serving as a safe liquid asset in banks' balance sheets.

Finally, our work stresses that banks' liquidity management is important for monetary transmission. As such, it is related to the work of Altavilla et al. (2025) who document a positive influence of reserves on loans after a policy-induced reallocation of aggregate reserves towards banks with higher liquidity needs. It is also related to the contemporaneous studies by Darst et al. (2025) and Giannetti et al. (2026) who show that liquidity risks related to uninsured deposits and collateral constraints, respectively, can constrain bank lending.

The remainder of the paper is organised as follows. Section 2 describes the institutional setting. Section 3 reviews the related literature. Section 4 presents the data and the proposed empirical methodology. Section 5 reports the empirical results, and Section 6 concludes.

2. Institutional background

In the aftermath of the GFC, and with policy interest rates constrained by the effective lower bound, the ECB introduced a package of non-standard monetary policy easing measures to stimulate the euro area economy and achieve the price stability objective. These included the launch of targeted longer-term refinancing operations (TLTROs) and negative interest rate policy (NIRP) in June 2014, the introduction of two private sector asset purchase programmes in September 2014 and an expanded asset purchase programme (APP) in March 2015, along with forward guidance on rates and purchases. Although these instruments had their unique transmission channels and were designed overall to provide monetary policy stimulus (Altavilla et al., 2021a), they explicitly referred to easing financing conditions as relevant for transmission.[3]

In this paper, we primarily focus on asset purchases conducted by the Eurosystem, known as the expanded asset purchase programme (APP), since they directly increase the quantity of reserves held by the banking system, at least in the short term, and are documented to be the main driver of yield compression for euro area securities (ECB, 2025). The sovereign bond leg of the APP programme, the PSPP, is particular relevant to our study given its prevalence in central bank liquidity injection (Figure 2) and its mechanics which entailed cross-sectional variation in purchase volumes for reasons that were orthogonal to banks' liquidity needs (Figure 3). In particular, the allocation of purchases across national bond markets was guided by the '*capital key'* for each country, an index of the contribution of each National Central Bank (NCB) to the ECB capital,

[3] For example, at the launch of the APP, the ECB stated that "*these asset purchase programmes were aimed at further enhancing the transmission of monetary policy, facilitating credit provision to the euro area economy, easing borrowing conditions of households and firms and contributing to returning inflation rates to levels closer to 2%, consistent with the primary objective of the ECB to maintain price stability*." (Decision EU 2015/774 of the ECB of 4 March 2015).

reflecting the share in the aggregate euro area economic output and population. In addition, asset purchases were conducted in a decentralised manner, with each NCB buying government securities of its own jurisdiction. Taken together, we conjecture that banks with security holdings tilted to own-country government bonds would benefit relatively more during QE, freeing up balance sheet capacity to increase lending to the real sector, in line with the portfolio rebalancing channel.

To support cleaner identification in results, we fix banks' security holdings in our model before the launch of the APP, and in particular one year before its announcement in January 2025. This also serves to avoid interference with other Eurosystem stimulus programmes initiated in mid-2014, presented above. Although we use banks' security holdings for identification, it is important to account also for other sources of reserves on the liability side, such as liquidity in the form of collateralised loans and bank deposits. The former reflects bank borrowings from the central bank such as TLTROs while the latter captures purchases by non-banks. Transactions between non-banks and the central bank are settled through the former's accounts held in intermediating banks, given market segmentation (only banks can hold reserves). This results in monetary expansion but also to an increase in the amount of liquidity in banks' balance sheets beyond their control. To what extent banks use additional liquidity out of own security portfolios for lending purposes is an empirical question that we seek to answer.

3. Related literature

This paper contributes to the literature which explores the bank lending channel of monetary policy transmission (e.g. Bernanke and Getler, 1995; Kashyap and Stein, 2000). The starting point in the discussion is that monetary policy can affect the economy through credit supply so long as banks are unable to insulate their lending activities from shocks to reserves and firms are unable to undo adverse changes in external finance frictionlessly, i.e. conditions outside the Modigliani-Miller world. Building on this argument, early studies found evidence of a negative influence of monetary tightening on credit supply by relatively smaller banks (Kashyap and Stein, 1995), banks with fewer liquid assets (Kashyap and Stein, 2000) and those unrelated to large banking groups (Campello, 2002).

Following the onset of the GFC, several studies evaluated the negative consequences of lower intermediation on the economy, including curtailed lending by banks (e.g. Ivashina and Sharfstein, 2010) and reduced investment by firms (e.g. Duchin et al., 2010).

The launch by central banks of unconventional monetary policy triggered an academic interest in exploiting the channels through which they affect the economy. For example, Khrishnamurthy and Vissing-Jorgensen (2011) distinguish between the central bank's commitment to maintain policy rates at low levels for an extended period of time (*signalling* channel) and the amount of duration risk absorbed (*duration risk* channel). The latter works through a recomposition of investors' equilibrium portfolios under demand conditions that are not perfectly elastic, for example, due to imperfect substitutability of assets or market segmentation (e.g. Andres et al., 2004; Vayanos and Vila, 2021; Hamilton and Wu, 2012). Empirical studies report evidence consistent with the portfolio rebalancing view. They show that asset purchases contribute to a flattening of the yield curve through a compression of the term premium, which is stronger for longer horizons and may free up investors' risk bearing capacity (e.g. Altavilla et al., 2021b). Importantly, the literature suggests that portfolio rebalancing may take place beyond the 'narrow' asset purchase channel through a reduction in the term premia of assets other than those targeted by the central bank, as investors reach for yield across asset categories. We build on this literature by examining whether banks replace lower-yielding securities with higher-yielding loans in response to reserve creation.

By focusing on the amount of banks' security portfolios, we also contribute to the literature which studies differences in bank lending due to variation in banks' ex-ante exposure to non-standard monetary policy. For example, Rodnyansky and Darmouni (2017) find evidence of higher lending by US banks with greater exposure to Federal Reserve's asset programmes as measured by the prevalence of mortgage-backed securities (MBS) in their books while Chakraborty et al. (2020) document the crowding out of loans unrelated to the narrow purchase channel of US mortgages. More broadly, portfolio rebalancing effects on lending have been reported in relation to security valuation gains (Albertazzi et al., 2021), the negative interest rate policy (Bottero et al., 2022), the composition of banks' security portfolios (Paludkiewicz, 2021) as well as their capitalisation levels (Peydro et al., 2021).

In addition, our work builds on a recent strand in the literature which examines the transmission of unconventional monetary policy due to reserve creation. These studies draw on the observation that central bank reserves surged in the aftermath of QE policies, inflating banks' balance sheets. Portfolio balance theories are relevant here, assuming imperfect substitutability of reserves and financial assets (Christensen and Krogstrup, 2019). In this setting, banks may change the composition of their assets by increasing the share of higher-yielding assets such as loans. However, empirical work has provided mixed evidence. Butt et al. (2014) report no significant implications of QE-induced bank reserves on loan growth in the UK while Diamond et al. (2024) using US data show that reserve hoarding may crowd out bank lending. By contrast, Kandrac and Schlusche (2021) document a positive influence of US banks' reserves on loan growth and risk taking while Acharya et al. (2023) report similar findings for credit lines to corporations. While this literature has mainly focused on sell transactions of non-banks, we offer some inferences on the consequences of reserve generation from banks' perspective.

Perhaps, the work of Altavilla et al. (2025) is the closest to our paper. They similarly report a positive (negative) influence of reserves on loans (securities), but in a setting different than QE that is shaped by a policy-induced redistribution of aggregate reserves in the euro area banking system during 2019-2022. Also, their results are due to a change in the price of liquidity while we work on liquidity amounts, following the intuition that QE programmes signal a focus on targeting quantity variables (Joyce et al., 2012). In addition, their work draws implications on banks' precautionary behaviour in the cross section while we study the role of reserves in supporting lending across periods of time due to a shift in the monetary policy stance.

Finally, our work is related to a recent strand in the literature which examines banks' demand for reserves (e.g. Lopez-Salido and Vissing-Jorgensen, 2023; Altavilla et al., 2024; Afonso et al., 2025). These papers exploit the determinants of banks' reserve holdings and calibrate a 'satiation point' that distinguishes the downward sloping relationship between the price of reserves and the quantity of reserves from a flat demand curve in which reserves are abundant. This fits into an earlier discussion that banks may be inclined to hold central bank reserves to mitigate transaction costs from liquidity shocks which limit their ability to exercise loan intermediation (e.g. Ashcraft et al., 2011; Gertler and Kiyotaki, 2015).

Relatedly to this work, Acharya and Rajan (2024) formalise the liquidity challenges faced by banks in response to reserve creation when the central bank shifts to quantitative tightening. The idea that credit supply benefits from reserves under restrictive monetary policy is also entertained by Fricke et al. (2024), reflecting valuation gains from higher interest rates, and by Giannetti et al. (2026) capturing reduced collateral values.

4. Data and methodology

We perform our empirical analysis by exploring data on euro area banks using different sources of data. Bank balance sheet data for individual banks are extracted from the ECB's Individual Balance Sheet Items (IBSI) database. IBSI is a proprietary database containing granular information on euro area counterparty banks since September 2007 and has been used by most empirical banking studies on the euro area (e.g. Albertazzi et al., 2021; Altavilla et al., 2025). Bank balance sheet data are matched with data from IMIR, the IBSI counterpart for interest rates on loans and deposits at the bank level. Thus, we create a unified dataset of statistics for around 250 European banks on loan amounts and interest rates that expands from September 2007 to March 2024 on a quarterly basis. We augment this dataset with country-level variables to capture variation in economic conditions. In particular, we derive from Eurostat the time series of the industrial production and the unemployment rate for our period of study. We also obtain country-level data from an aggregate measure of firm demand for loans from the ECB's Bank Lending Survey (BLS). Finally, we make use of the AnaCredit dataset, which is a harmonised and granular credit register for the euro area starting in September 2018. It contains loan-level transaction data for loan instruments to non-financial corporates with a minimum exposure of 25,000 euro per borrower per bank. For our analysis, we obtain information on euro area banks, their outstanding exposures to borrowers as well as loan-level transaction data that include volumes, interest rates, maturities and collateral values. We collect this information at the end of each quarter for the period that extends to March 2024 and match it with bank-level data from IBSI, presented above.

Summary statistics of the main variables used in the empirical analysis are presented in Table 1. The average bank in our sample uses deposits as its main source of funding, a

fraction of which (5%) is held by NBFIs.[4] It also extends loans to the private sector, absorbing half of its assets, primarily with longer horizons. Asset liquidity in the form of securities and reserves is substantial, topping 20% of assets. Importantly, these variables are characterized by substantial cross-sectional variation. While reserves account on average for 6% of the total balance sheet, this figure amounts to around 14% for the upper-quartile bank. Displaying trends similarly reveals that euro area banks increased considerably their reserve holdings during the period of study (Figure 4). Cross-sectional variation is also reported for banks' security holdings, particularly government bonds, providing a setting in which banks of varying bond-holding intensity may differentially respond to central bank liquidity injection to acquire reserves.

To examine empirically banks' portfolio rebalancing, we need to account for possible endogeneity in the bank demand for reserves. For that scope, we estimate a two-stage least square specification, in which we instrument the change in bank level reserves in the first stage to obtain the impact of a plausibly exogenous change in bank reserves on their security and loan portfolios. In particular, we follow the methodology proposed by Acharya et al. (2023), and used by Altavilla et al. (2024), in adopting a 'shift-share' Bartik (1991)-style instrument which consists of the most recent change in aggregate bank reserves ('shift' component) interacted with each bank's share of eligible securities ('share' component). The first term is influenced by the ECB's monetary policy stance and hence is exogenous to the liquidity needs of the individual bank while the latter reflects the bank-level exposure ("beta") to reserve-supply liquidity creation.[5] For identification, we use banks' shares of eligible securities in the euro area banking sector at end-2013, i.e. before the set-off of the APP, under the assumption that banks holding a larger share of eligible securities for asset purchases are likely to be affected by a monetary policy shock relatively more than others, giving rise to cross-sectional differences in the pass-through to the bank lending channel (e.g. Rodnyansky and Darmouni, 2017; Chakraborty et al., 2020; Bottero et al., 2022). Formally, our proposed model specification has the following general form:

[4] This investor category includes other (non-bank) financial institutions such as mutual funds and hedge funds and is distinct from insurance companies and pension funds. See also Koijen et al. (2021).
[5] For a discussion on Bartik-style instruments, see Goldsmith-Pinkham et al. (2020), among others.

$$\Delta y_{b,c,t} = \beta_0 + \beta_1 \Delta \widehat{Reserves}_{b,c,t} + X'_{b,c,t}\beta_2 + \Psi'_{c,t}\beta_3 + \beta_b + \beta_c + \varepsilon_{b,c,t} \quad (1)$$

$$\Delta Reserves_{b,c,t} = \gamma_0 + \gamma_1 z^R_{b,c,t} + X'_{b,c,t}\gamma_2 + \Psi'_{c,t}\gamma_3 + \gamma_b + \gamma_c + \eta_{b,c,t} \quad (1a)$$

with instrument $z^R_{b,c,t}$ given by: $z^R_{b,c,t} = ln\left(\frac{\sum_b Reserves_t}{\sum_b Reserves_{t-1}}\right) \times Share^R_{b,c,t=0}$,

where $Share^R_{b,c,t=0} = \frac{Securities_{b,c,t=0}}{\sum_b Securities_{b,c,t=0}}$

and b denotes banks, c countries, and t is for the time period that denotes quarters and expands from December 2013 to December 2019. The outcome variable $\Delta y_{b,c,t}$ measures changes in banks' security holdings or loans scaled by beginning assets. The model includes a set of time-varying bank level variables $X_{b,c,t}$, namely bank size, capital adequacy and bank liquidity in the form of bank bonds, to control for cross-sectional differences in the response to central bank liquidity injection (e.g. Kandrac and Schlusche, 2021). It also controls for the amounts of bank borrowings from the central bank and of bank deposits to capture different sources of reserves on the liability side. In addition, it includes a set of time-varying country-level variables $\Psi_{c,t}$ to control for economic conditions and mitigate confounding macroeconomic dynamics (e.g. Peydro et al., 2021). Finally, the model includes bank-level and country-level fixed effects to control for time-invariant unobserved differences across banks and countries in the euro area, respectively. Standard errors are double clustered at the bank and time levels to allow for serial correlation from monetary policy affecting euro area banks in the cross section at the same time and within banks over time.

5. Results

A. Evidence from the period of monetary easing

5.1. Portfolio rebalancing effects on banks' security portfolios

5.1.1. Baseline results

We start presenting results from equation (1) in which the dependent variable $\Delta y_{b,c,t}$ is the quarterly percentage change in the book share of security holdings. The granularity of our dataset allows us to estimate results for different types of bonds in banks' books. Results of these tests are presented in Table 2. First, we present results on euro area

government bonds. In the unconditional model, the coefficient estimate of the instrumented change in reserves is negative and significant (column 1). It suggests that reserve creation correlated negatively with the amount of government bonds in bank assets. The coefficient estimate remains negative and is strongly significant even after controlling for bank level and country level variables that capture time-varying differences across banks and countries, respectively, as well as fixed effects that account for time invariant differences across banking models and jurisdictions (column 2). In our saturated model, results imply that one percentage point increase in reserves reduces government bond holdings by about 0.20 percentage points relative to beginning assets. To put that into perspective, given that the average bank in our sample with reported central bank accounts had roughly 100 billion euro of assets at the beginning of the study period (i.e. end-2013), each euro of additional reserves translates to an economically significant reduction of 20 cents in sovereign bonds. This negative relationship is in line with the portfolio rebalancing proposed in the literature (e.g. Paludkiewicz, 2021; Bottero et al., 2022; Altavilla et al., 2025). It also implies that reserve creation weakens the nexus between sovereign and financial sectors in the banking sector (Acharya and Steffen, 2015).

In the remaining columns, we examine reserve creation in relation to other types of bonds held in bank portfolios, namely corporate bonds (columns 3 and 4) and bank bonds (columns 5 and 6). While the former represent a small share in bank assets, the latter absorb a share equal to that of sovereign bonds (Table 1). Nonetheless, other than secured bonds meeting eligibility criteria of covered bonds, bank bonds were generally not eligible for asset purchases under the APP. Against this backdrop, we find a negative relationship between reserves and corporate bonds, implying a much weaker drop compared to our previous findings of about 2 cents for each euro of reserves. Results on bank bonds are stronger but not statistically significant at conventional levels. Taken together, evidence from examining different types of bonds suggests that sovereign bonds had a meaningful economic relationship to reserve creation in banks' books, in line with their relatively large shares in the balance sheet and their eligibility for central bank asset purchases.

5.1.2. Heterogeneities in sovereign bond portfolios

Next, we investigate further the negative relationship between reserve creation and bank portfolios of government securities, by exploiting heterogeneities within that security type. In particular, we decompose government bonds held by banks into domestic bonds, those issued by other euro area countries and bonds issued by non-euro area countries. The large footprint of the PSPP in the APP programme in conjunction with its decentralised operation suggests that our previous findings on reserves should be more pronounced for domestic sovereign bonds.

Results of these tests are presented in Table 3. Panel A reports results for the full sample of firms, while panel B explores cross-sectional differences to exploit possible non-linearities with respect to bank characteristics. In column 1, the dependent variable is the percentage change in the amount of domestic government bonds as a fraction of total assets. The coefficient estimate is negative and strongly significant, suggesting that reserve creation was associated with declines in the book share of own-country government bonds. By contrast, there is only weak evidence of declines in other euro area sovereign bonds.[6] Reserve creation also related to negative changes in banks' non-euro area government bonds, albeit results are quantitatively small (column 3). This finding can be attributed to the non-eligibility of foreign bonds for Eurosystem asset purchases. Alternatively, it may reflect banks' inclination to increase their composition in their security portfolios, amid yield declines in euro area securities.

From a different angle, in panel B we examine cross-sectional heterogeneities in banks' portfolio characteristics to understand better which banks were more likely to draw down their security holdings. First, we examine the sensitivity of our results to the amount of government securities in banks' portfolios. For that scope, we create three equal-sized groups of banks based on the intensity of their security portfolios in total assets and perform our regressions separately on each group (columns 1 to 3). Overall, our results show that reserve transformation grows larger with the amount of eligible securities in banks' books. Hence, the scale of banks' security portfolios was likely an important determinant of

[6] Although QE mechanics dictated purchases to operate on a country basis, in principle banks could trade away sovereign debt issued by other euro area countries in exchange for own country securities in the interbank market or through the use of internal capital markets in the case of banking groups.

reserve creation at the bank level. Note that our model includes bank fixed effects and hence this result is robust to banks' different business models (e.g. retail banking against wholesale banking). In the remaining columns, we examine the influence of the maturity of banks' security portfolios. Although we do not observe the maturity of government securities, we perform an indicative subsample analysis, similar to the one above, based on maturity buckets for bank bonds.[7] We find that the intensity of reserves decreases with bonds' maturity, a likely outcome of disposals of low-yielding securities amid central bank balance sheet expansion.

In sum, we document a significant liquidity transformation taking place in banks' balance sheets during monetary easing, with banks drawing down their security holdings simultaneously with increases in their central bank accounts. The results are stronger for bond-intensive banks and those with higher shares of domestic government bonds which suggests that the composition and scale of securities was likely important for the amount of reserves held at the individual bank level.

5.2. Portfolio rebalancing effects on banks' loan portfolios

Having presented balance sheet effects of reserve creation on bank securities, we next turn to results on loans to understand whether and to what extent these adjustments made their way to the real economy. We begin with the build-up of a bank balance-sheet measure that tracks the substitution between securities and loans as a fraction of assets in the cross section and over time (portfolio tilts). We then put this measure along with loan variables to testing using our model in equation (1).

5.2.1. Portfolio reallocations from securities to loans

Traditional portfolio balance models in the spirit of Tobin (1969) argue that imperfect asset substitution and market segmentation are key to portfolio rebalancing (e.g. Vayanos

[7] In particular, IBSI provides bank-level information on amounts of bank bonds with a remaining maturity up to 1 year, from 1 to 3 years and above 3 years. We use the mid-point of each maturity bucket (5 years for the upper) as indicative of the maturity of all bonds in the respective bucket to build a weighted-average maturity for each bank.

and Villa, 2021). Related theories which assign a role for the amount of central bank liquidity provide a direct link between reserve expansion and portfolio rebalancing in banks (e.g. Krogstrup and Christensen, 2019). They suggest that banks may seek to restore the pre-expansion composition of their assets which might include updating their loan schedules, particularly those with longer horizons. Indeed, the inclusion of a low return asset on the balance sheet pushes down the overall asset yield, inducing banks to pursue higher-margin intermediation (Diamond et al., 2024). Ashcraft et al. (2011) picture this colourfully by arguing that an investment in bank reserves is equivalent to "*making a zero term maturity loan at a zero interest rate*". These arguments give rise to a negative relationship between banks' security and loan portfolios during QE, which should be more (less) pronounced for lending with higher (lower) maturities.

To investigate these ideas, we formalise two-way substitution between securities and loans at the bank level in a simple balance sheet measure of portfolio tilting:

$$portfolio\ tilting = \frac{\Delta Loans_{\{NFC,HH\}}^{\{LT,ST\}} - \Delta Bonds_{\{Govt,Corp\}}}{Total\ Assets} \qquad (2)$$

where $\Delta Loans_{NFC}^{LT}$ and $\Delta Loans_{HH}^{LT}$ are quarterly changes in long-dated loans (with maturities above one year) to corporates and households, respectively, $\Delta Loans_{NFC}^{ST}$ and $\Delta Loans_{HH}^{ST}$ are their short-term counterparts (with maturities up to one year), and $\Delta GovtBonds$ and $\Delta CorpBonds$ are changes in government and corporate bond portfolios, all scaled by banks' total assets. Our proposed measure is in the spirit of Peydro et al. (2021) which use the ratio of bank securities to loans to assess policy-induced bank balance sheet adjustments. Although it amplifies by construction effects for banks which simultaneously reduce their security portfolios and increase lending (and similarly penalizes banks choosing differently), it is used here to reveal any cross-sectional variation in banks' non-reserve assets and changes thereof that may take place at the time of ECB's monetary easing measures.

First, we proceed with a visual inspection of the time series evolution of the cross sectional mean of *portfolio tilting.* Specifically, we disentangle between balance sheet adjustments towards higher long-dated loans and short-term loans, to test theory predictions that large scale asset purchases stimulate rebalancing towards other asset

classes with similar maturity structures (e.g. Gagnon et al., 2011). In Figure 5, higher tilting towards longer-dated lending coincides well with the period when the Eurosystem executed asset purchases. It levels off roughly at the time of the start of central bank asset purchases and continues unabated until the shift to a tighter monetary policy in 2022. By contrast, there are moderate and short-lived responses towards short-term loans. Hence, early evidence from this crude measure of portfolio rebalancing suggests that banks on average initiated adjustments towards non-liquid assets at the time of reserve expansion.

For robustness, we also test the empirical relevance of *portfolio tilting*, using it as the dependent variable in equation (1). Table 4 shows a positive and significant coefficient, after controlling for bank and country level variables and fixed effects (column 1). Importantly, the coefficient estimate is of an order of magnitude larger than that reported for government bonds alone (Table 2), implying that it is likely amplified by changes in bank lending. For short-term loans, the coefficient estimate is positive but close to that reported for government bonds, consistent with a limited pass-through to asset classes with similar maturities. In addition, to gauge whether *portfolio tilting* varies over time with ECB announcements that modify the intensity of asset purchases, we use an interaction term of our shift-share instrument with a time dummy variable taking values one for the period after the announcement of a slowdown in monthly net asset purchases (2017q1-2019q4) and zero before. Denoting 'PostPeak' the relevant period, we find a negative coefficient of the interaction term, which suggests that our results on portfolio tilting were more acute during the upstream phase of the APP, i.e. when net asset purchases were increasing and reserve transformation opportunities for investors were stronger, while they were likely to moderate during the downstream phase.

5.2.2. Baseline regressions on loan outcomes

For testing explicitly portfolio balance effects on bank intermediation, we employ our instrumental variables model in which we regress the quarterly change in bank loans as a fraction of assets on innovations in reserves and other control variables. We examine results separately for loans with a maturity above one year (longer-term loans), and those with a maturity up to one year (short-dated loans), given predictions from theoretical

studies as well as inferences from the tilting measure above that reserve-induced rebalancing was likely stronger for longer-dated loans.[8] To substantiate on supply-side effects, we complement this analysis with tests on loan interest rates.

We present these results in Table 5. In column 1, we find that the instrumented change in reserves is associated positively with long-term loans, after accounting for bank fundamentals and sources of reserves as well as country-level variables and fixed effects. Importantly, the coefficient estimate is close to that reported for government securities in Table 2, suggesting that banks shift between securities and loans in response to reserve creation. By keeping the amount of non-reserve assets unchanged, they avoid additional balance sheet costs proposed in the literature (e.g. Bianchi and Bigio, 2022; Diamond et al., 2024). By contrast, we find a negative relationship between bank reserves and short-term loans, albeit not significant (column 2). The negative sign can be attributed to yield declines during QE which likely incentivised banks to seek higher-yielding assets that extend beyond short maturities.

In the remaining columns of Table 5, we examine results on loan interest rates. Concomitantly with specifications on loan amounts, we report results separately for interest rates on new loans with long maturities (above 5 years) and short maturities (less than one year), net of benchmark rate fluctuations.[9] Our results show that increased bank balance-sheet liquidity in the form of reserves was associated with lower loan interest rates, in line with downward adjustments in the yield curve amid monetary easing, with effects being stronger for loan arrangements with longer horizons.

We conclude therefore from results in this section that the increase in reserves stimulated bank lending and reduced interest rates, consistent with supply-side effects. Given that reserves related negatively with banks' security portfolios and effects were of a similar magnitude to those of loans in terms of assets, our findings are overall supportive

[8] Our results are qualitatively unchanged when we use a stricter definition of long-term loans, confined to those with maturities above five years.

[9] We use similar-maturity overnight index swap (OIS) rates as benchmark rates, i.e. 3-month for short-term loans and 2-years for longer-dated loans. Results are qualitatively unchanged if we use the 3-month OIS rate for both loan categories.

of a reserve-induced portfolio rebalancing channel. In the section that follows, we perform a number of additional and robustness tests on the transmission mechanism.

5.3. Additional and robustness tests on the transmission mechanism

In this section, we report additional results on banks' reserve-induced portfolio rebalancing. First, we examine the sensitivity of results to the instrument used. Next, we test results after accounting for the short-term market interest rate to control for opportunity costs in holding reserves. In addition, we examine whether our results appear outside of the period of the APP. Finally, we study cross-sectional heterogeneities to explore frictions at the bank level that may mitigate the reserve-induced transmission mechanism.

5.3.1. Robustness tests

In our model, the instrument used for reserve creation is composed of a first weight component capturing growth in aggregate bank reserves and a second bank-specific component reflecting the share of eligible bonds held by banks prior to the start of QE. The use of the pre-existing share in eligible securities helps to alleviate endogeneity concerns in reserve creation (e.g. Anderson et al., 2025). For robustness, we replace the second component with the four-quarter average share of bank reserve at the most recent date following Acharya et al. (2023). In Table 6, results are reported separately for banks' security holdings (column 1) and outstanding loans (column 2). Our findings continue to support a significantly negative relationship for the former asset class and a positive for the latter, and the coefficients exhibit some stability. We assess, therefore, that our previous findings are not sensitive to the instrument used.

We also test results after controlling for the opportunity cost of holding reserves. A recent strand in the literature suggests that the reservation price of bank reserves, measured by the spread between the short-term interest rate in the market for reserves and the interest rate paid on reserve balances at the central bank, is important for determining banks' reserve demand (e.g. Lopez-Salido and Vissing-Jorgensen, 2023; Afonso et al., 2025). Drawing on these studies, we include among the regressors the spread between the ECB

deposit facility rate (DFR) and the 3-month OIS rate, which is used here as a proxy for the money market benchmark interest rate. Note that this variable appears with a different sign than that of reserves in the balance sheet, as it likely captures alternative uses of reserves (columns 3 and 4). Overall, results are qualitatively unchanged after controlling for reserves' outside pricing, albeit absorbing some significance from the impact on loans.

Finally, we examine whether balance sheet substitution effects is a systematic bank behaviour that takes place irrespective of the non-standard monetary easing measures of the Eurosystem. For that reason, we test results for the period 2007q4-2013q4 preceding the APP programme, fixing banks' sovereign bond holdings at end-2007 (columns 5 and 6). Overall, we produce results that are not supportive of portfolio balance effects, hence suggesting that substitution effects took place during the time the Eurosystem was conducting asset purchases and do not represent portfolio choices orthogonal to economic and monetary conditions. Interestingly, when we extend our baseline analysis to include non-standard monetary easing after the COVID-19 pandemic outbreak (i.e. for the period 2013q4-2021q4), we find that reserves continue to relate positively to bank lending but the bond selling mechanism becomes insignificant (columns 7 and 8). Hence, credit supply effects of reserve creation are likely persistent throughout the monetary easing period of the Eurosystem but initial conditions are likely important for substitution effects to materialise.

5.3.2. Examining frictions in the reserve pass-through to loans

Our work has so far produced results consistent with real effects of QE-induced reserve expansion. Amid higher balance sheet liquidity, euro area banks increased loans over securities, in line with portfolio rebalancing theories. In this section, we examine bank heterogeneities that might explain this level of loan pass-through. Specifically, we draw on the literature to exploit four plausible sources of frictions that might impair the transmission of monetary policy through the bank lending channel. Results of these tests are presented in Table 7.

First, we examine cross-sectional heterogeneity in banks' capital positions to investigate whether banks' capitalisation levels are important for the reserve-induced

transmission. Prior literature has shown that higher reserves may tighten banks' balance sheet costs (e.g. due to supervision limits on the leverage ratio) and thereby crowd out bank lending (e.g. Diamond et al., 2024). In a similar vein, studies on banks' demand for reserves view their optimization problem as that arising from holding a safe and liquid asset against absorbing balance sheet space for regulatory and funding purposes (Duffie, 2018; Anderson et al., 2025). Still, some other studies treat lower capital-to-asset ratios as indicative of banks' financial constraints (e.g. Altavilla et al., 2025) or conducive to risky lending (Kandrac and Schlusche, 2021; Bottero et al., 2022). To gauge the importance of banks' capitalisation levels, we include in our model an interaction term of the reserve variable with a dummy variable taking values one for banks with capital-to-asset ratios below the sample median prior to the launch of the QE, and zero otherwise. In our results, the interaction term appears with a different sign than the stand-alone reserve variable, suggesting that less well-capitalised banks were less likely to replace government securities with private sector loans, albeit results are not statistically significant (columns 1 and 2). Hence, we do not find strong evidence to suggest that capitalisation ratios may have interfered with the rebalancing process.

In addition, we study whether our results are sensitive to banks' profit margins, as measured by the spread between the weighted average interest rate on corporate loans and deposits, using as weights loan volumes for short-term and long-term maturity buckets. The traditional view in the literature is that a low interest rate environment poses downside risks to banks' lending margins (e.g. Claessens et al., 2018; Altavilla et al., 2017). We depart from this analysis by asking whether banks entering the QE period with an already low loan-deposit wedge (e.g. due to competition) might be less inclined to extend credit than their high margin peers. Methodologically, we introduce an interaction term of reserves with a dummy variable taking values one for banks with a loan-deposit gap below the sample median at end-2013, and zero otherwise. Results are overall not supportive of substitution effects, although banks with ex-ante tighter loan-deposit spreads were likely to reduce security holdings relatively more than their peers, perhaps to ameliorate pressures on profit margins (columns 3 and 4).

From a different perspective, we examine whether banks susceptible to higher deposit withdrawal risk constrain portfolio rebalancing. The literature suggests that reserve

expansion financed with uninsured deposits may exacerbate liquidity problems for banks if there is a shift in economic or monetary conditions, which props up aggregate demand for liquidity (Acharya et al., 2023; Acharya and Rajan, 2024; Altavilla et al., 2024). The culprit here is the increasing share of volatile NBFI deposits which renders banks susceptible to deposit withdrawal shocks. To test this idea in our results, we augment our model by interacting reserves with a dummy variable denoting banks with higher ex-ante deposit shares by NBFIs. This investor group has taken an overall sell position during the time of asset purchases by the Eurosystem (Koijen et al., 2021). Hence, they represent investors that increased reserves commensurate with deposits in euro area banks and were therefore likely to be a source of cross-sectional heterogeneity in deposit outflow risks.[10] Our findings show that the risk of deposit mobility was likely to constrain banks' portfolio rebalancing during QE. The coefficient estimates of the interaction term appear with a different sign than that to the standalone, with effects being stronger for lending outcomes (columns 5 and 6). Hence, evidence from the euro area suggests that banks vulnerable to adverse liquidity shocks were likely to maintain additional liquidity from own securities and forego lending opportunities, despite high balance sheet liquidity.

Finally, in the remaining columns we examine the sensitivity of our results to the ECB's negative interest rate policy (NIRP), which was also implemented around the same time of asset purchases. Existing evidence suggests that there is a positive contribution of NIRP on bank lending (Bottero et al., 2022), although it is mitigated for banks with greater reliance on deposit funding (Heider et al., 2019). As more exposed banks reduce liquid assets and extend lending, a portfolio rebalancing mechanism similar to that induced by QE may arise. Following Bottero et al. (2022), we distinguish banks' exposure to NIRP based on their ex-ante net lending position in the interbank market compared to the sample mean (columns 7 and 8). Interacting reserves with the identification variable produces coefficients of the same sign with the standalone for securities and loans, suggesting that NIRP and QE portfolio rebalancing worked in tandem, although they are not significant.

[10] We do not find similar evidence when examining deposit shares by insurance companies and pension funds (ICPF). Koijen et al. (2021) report that ICPF, unlike NBFIs, were net buyers of securities during QE, along with the Eurosystem.

We conclude therefore from tests on cross-sectional heterogeneity that portfolio rebalancing was likely weaker in banks with relatively high deposit shares by NBFIs. While similar findings have been documented for uninsured deposits in the US (Acharya et al., 2023), here they are explicitly linked to an investor group susceptible to runnable deposits in the euro area.[11] We do not find similar evidence when examining other frictions proposed in the literature, related to banks' capitalisation levels, profit margins or exposures to negative interest rate policy.[12]

B. Evidence from the post-QE period

The first part of the analysis focused on reserve creation in the euro area during monetary easing through nonstandard measures. Drawing on banks' balance sheets, it documented a reduction in security holdings and increased levels of lending, a realization of banks' balance-sheet portfolio rebalancing. Similar findings by Altavilla et al. (2025) on a policy-induced distribution of aggregate reserves are attributed to a weaker bank precautionary behaviour in the cross section. Although important on its own, the benefit of holding reserves remains elusive until banks come to face tighter funding and liquidity constraints due to a shift in the economic or monetary environment. In this section, we investigate such an episode by studying the role of bank reserves in mitigating credit supply declines in the period after the ECB tightened its monetary policy in 2022.[13]

For our empirical analysis, we exploit the granularity of AnaCredit which we match with bank level data from IBSI. Our framework is in the spirit of studies which highlight the importance of liquidity positions in buffering investment declines amid financial tightening (e.g. Duchin et al., 2010). In particular, it has the following form:

$$L_{f,b,t} = \beta_0 + \beta_1 After_t + \beta_2\left(After_t \times R_{b,QE}\right) + \beta_3 X_{b,t} + \gamma_{f,t} + \delta_{b,f} + u_{f,b,t} \quad (3)$$

[11] See the November 2025 ECB Financial Stability Review for a discussion on financial stability risks in the euro area from links to NBFIs.

[12] When examining all four factor dummies together in unconditional regressions, only that denoting a low profit margin appears significant for securities and that of NBFI deposits for loans. The latter remains significant in a regression on our 'portfolio tilting' measure.

[13] Although access to money markets and central bank facilities may in principle lower banks' need to hold reserve buffers (e.g. Aberg et al., 2021), here we focus on the role of reserves in relation to post-QE credit expansion.

where the dependent variable $L_{f,b,t}$ is the outstanding credit supply of bank b to firm f at time t, where time denotes quarters and expands from December 2019 to March 2024, $After_t$ is a dummy variable taking values one for the period after the ECB hiked its policy rates (2022q3-2024q1) and zero otherwise, $R_{b,QE}$ is the bank reserve as a fraction of total assets measured at end-2019, i.e. prior to the ECB's pandemic-related easing measures. We fix banks' reserve balances at an earlier time than the launch of monetary tightening to avoid blending our results with reserve-related ECB policies running in parallel such as the tiered reserve remuneration system between end-2019 and 2022 (Altavilla et al., 2025). However, to account for the fact that banks' reserves were inflated even further during the pandemic (Figure 1), we include in the model a time dummy $Covid_t$ and its interaction with $R_{b,QE}$ to control for ECB's monetary easing during that stress period (2020q1-2021q1).

The main variable of interest is the interaction term and its coefficient estimate β_2 which captures the loan outcome of reserve-rich banks compared to their peers with no such balances, given by β_1. The vector $X_{b,t}$ includes banks' financial characteristics that were also included in the first part of our analysis, i.e. measures for banks' assets, capitalisation, liquidity, deposits and borrowings from the central bank. In our main specification, we include interactions of bank-firm fixed effects and firm-time fixed effects in the spirit of Khwaja and Mian (2008) to disentangle banks' credit supply from firms' credit demand in our results.[14] Results of these tests are presented in Table 8.

Overall, results from using high-dimensional fixed effects reveal a negative impact of tightening on bank lending which is mitigated in the presence of reserve holdings. We find consistent evidence when including bank-level controls as well as bank and firm-time fixed effects (column 1), firm-time and bank-firm interaction effects (column 2), and additionally country effects at the bank and firm level (column 3). In our preferred model specification, which includes firm and time fixed effects to control for time-varying firm-level loan demand and bank-firm fixed effects that captures time-invariant aspects of loan relationships, results show that a percentage point increase in banks' reserves as a fraction

[14] This approach is used in the literature to identify credit supply for firms with more than one credit relationship, and is therefore used in our analysis to test the extent to which banks with different exposure to tightening due to a varying level of reserves supply credit to the same borrower.

of assets increases lending by 1.9%. Hence, while a bank with no such reserves would reduce credit supply by about 12%, a bank holding reserves at 6-7% of assets would completely offset lending declines. Given a similar figure reported for the QE period (Table 1), this result suggests that central bank reserve creation endowed banks with a safe liquid asset that appears important for cushioning lending when monetary conditions tightened. Hence, reserve-induced portfolio rebalancing can have far-reaching consequences for monetary transmission. This result is consistent with Fricke et al. (2024), who show that reserves can constrain the loan pass-through, although in their work this is due to higher reserve remuneration while in our results this is due to the liquidity amount provided. Also, compared to the US experience, our estimate stands below the 'satiation point' of 12-13% of assets calibrated for US banks by Afonso et al. (2025).

In column 4, we repeat the analysis controlling also for the policy rate (DFR) to capture valuation effects of reserve holdings, following Fricke et al. (2024) while in column 5 we replace the $After_t$ dummy with an indicator QT_{ct} taking values one for quarters in which net purchases of government bonds turned negative for a particular country (zero otherwise) to distinguish tightening due to a declining central bank's balance sheet and an increase in the DFR. After these tests, we continue to find evidence that banks rely on reserves to buffer credit supply declines, while controlling for demand conditions.

In the remaining columns, we examine the influence of reserves on different loan characteristics. In particular, we report that holding reserves helped banks to commit to longer-maturity loans, mitigating the negative impact of monetary policy tightening, albeit results are significant at 10% level (column 6). In addition, we find that higher bank reserves correlated positively with loan interest rates, boosting bank profitability for reserve-rich banks (column 7). Importantly, however, it does not appear that banks weakened credit standards, as credit supply was accompanied by higher pledged collateral (column 8). In addition, and as presented below, we do not find evidence that they shifted lending to riskier (smaller) borrowers.

In further tests, we examine the sensitivity of our findings to bank and borrower characteristics. Starting with the former, and for consistency with the first part of our analysis, we modify model (3) by including triple interaction terms of the reserve variable

with identification variables used in Table 7 as well as interactions with the rest of control variables. Results presented in Table 9 show that banks facing higher (ex-ante) risks of deposit outflows by NBFIs or low intermediation margins were not likely to experience significant differences in loan responses compared to their reserve-rich counterparts (columns 1 and 2). Hence, while our QE analysis showed that higher deposit mobility was likely to have weakened portfolio rebalancing motives, results from the post-QE period reveal that this did not have any ex-post real effects. Seen against theories on the reserve demand curve (e.g. Afonso et al., 2025), this result suggests that banks with higher deposit shares by NBFIs had reached their reserve 'satiation point'. One interpretation of this finding is that excess liquidity may have been concentrated in certain banks or jurisdictions in the euro area with a greater outreach to foreign investors selling securities to the Eurosystem ('money centre banks').[15] Past studies make the case for an uneven distribution of reserves in the euro area concentrating in Germany, France, and the Netherlands (Aberg et al., 2021; Altavilla et al., 2025). To test this argument, we disentangle between banks with origin in the aforementioned countries and the rest of the countries which are assumed to have a lower investor outreach. Results in column 3 reveal that credit supply effects were indeed more pronounced for reserve-rich banks in jurisdictions with less concentrated liquidity, supporting the view that holding a high reserve stock would relieve banks' liquidity constraints amid tight monetary policy.

In addition, results in column 4 show that credit supply effects were stronger for less well-capitalised banks, consistent with the view that a durable level of reserves might be of value to banks which are more likely to face binding financial constraints (Altavilla et al., 2025; Fricke et al., 2024). Note, however, that banks with weaker capital ratios did not exhibit a starker portfolio rebalancing performance than their peers in the QE period (Table 7). This can be attributed to their relatively high funding costs, which may have placed limits in holding reserves, a low-return asset. Finally, examining results with respect to borrower heterogeneity in Table 10, we find that the benefit of holding reserves was significant for buffering declines in lending to firms irrespective of their size or industry

[15] Koijen et al. (2021) report that foreign investors accommodated most of the Eurosystem purchases, followed by euro area banks.

classification, although results suggest that smaller firms and those belonging to the more bank-dependent manufacturing sectors were likely to benefit relatively more.

We conclude this section by summarising results that assign a unique role to reserves in supporting bank lending following a shift to a tighter monetary policy, with consequences on the real sector. Banks with large central bank reserves fared better than their peers with no such balances. This was particularly important for banks in jurisdictions with lower concentration levels of liquidity and with weaker capital ratios, suggesting that frictions related to market fragmentation and financial constraints might induce banks to maintain high central bank reserves. We do not find similar results for high deposit shares by NBFIs. These results speak to the existence of a 'steady state' level of reserves (Lane, 2023) or a 'satiation point' in reserve demand which distinguishes scarce from abundant liquidity levels and has recently been addressed in the literature (e.g. Aberg et al., 2025). Although an explicit threshold is outside the scope of our study, we offer some evidence of an indicative tipping point after which reserves can support lending from before to after the shift in the monetary policy, which might be useful for future research. We also offer some conclusions on which banks are likely to suffer more as central bank balance sheet normalisation in the form of quantitative tightening continues.

6. Conclusion

How important are central bank reserves for the credit supply in an economy? Using bank balance sheet data on the euro area from an ECB proprietary database, we show that banks jointly managed their security and loan portfolios in response to central bank reserve creation due to Eurosystem's non-standard monetary policy measures launched in 2014, consistent with portfolio rebalancing. The results support theories that asset purchases reduce risk premia and increase the attractiveness of non-money high-yielding instruments such as bank loans. They are particularly relevant to the euro area, as the banking sector is the primary conduit for monetary transmission.

While QE-induced reserve supply worked as expected in facilitating portfolio balance effects, the hoarding of reserves at the individual bank level had the unintended consequence of impairing the transmission after the ECB adopted a restrictive stance

during 2022-2023. Matching banks' balance sheet data with more granular loan-level data, we find that reserve-rich banks were better positioned to buffer lending declines to firms, controlling for demand conditions. Results were stronger for banks facing frictions related to market fragmentation and financial constraints, hence suggesting a role for reserves in the balance sheet as a safe liquid asset that is not easily replaced.

Implications of our findings are informative for the current debate on the 'ample' level of reserves in the banking system to avoid abrupt liquidity shocks. By mitigating liquidity frictions, a durable level of reserves at the bank level would smooth out variation in credit supply to the real economy. However, this poses challenges to monetary policy authorities and may delay their ability to meet their price stability objective.

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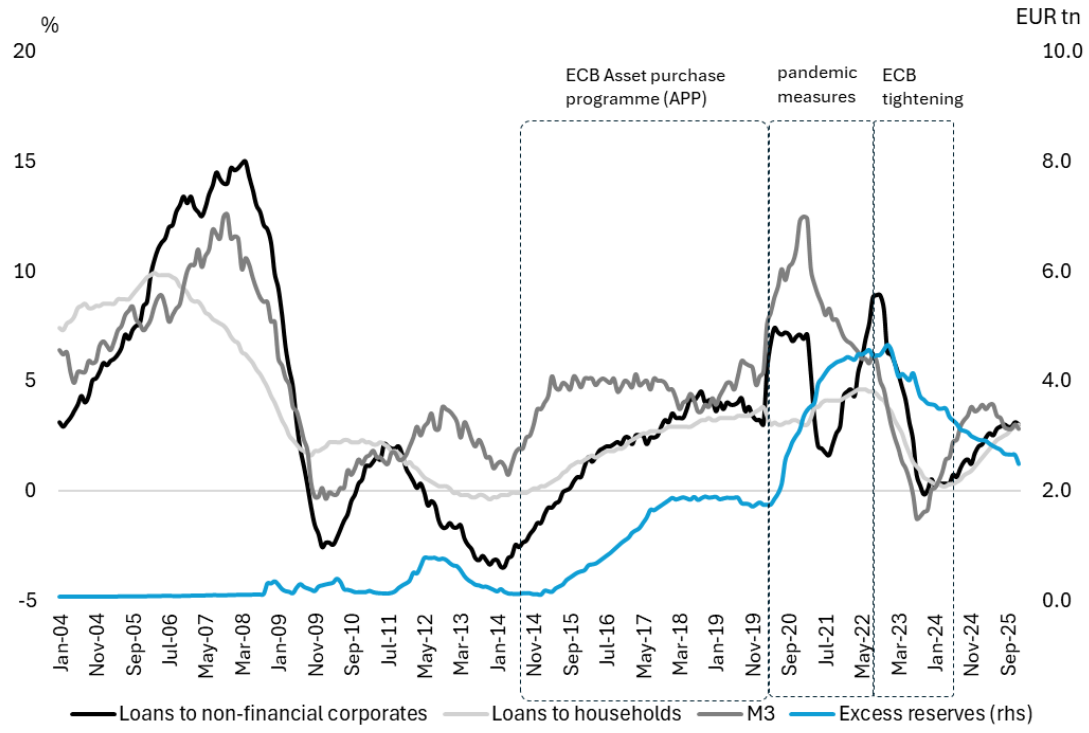
Table of Figures

Figure 1. Banks' aggregate excess reserves, M3 growth and private sector credit growth

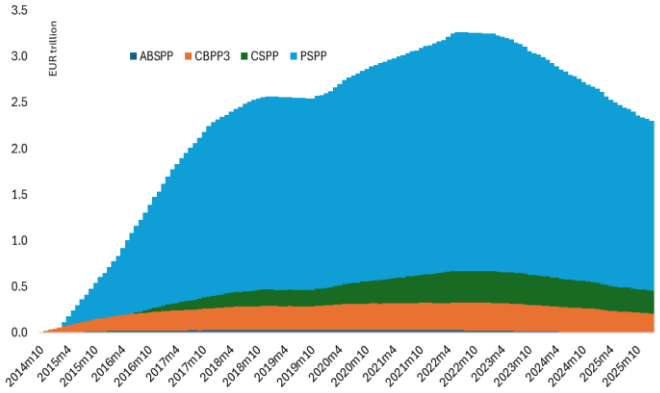


Source: ECB and authors' calculations

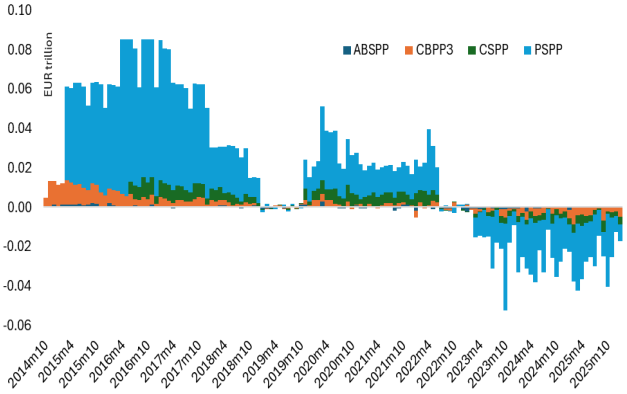
Note: This graph shows the time series evolution of monetary aggregates and aggregate bank reserves during 2004-2025. Annual growth rates for loans to non-financial corporates and households are depicted against levels of euro area banks' excess reserves.

Figure 2. Aggregate asset purchases by the Eurosystem

APP stock of aggregate holdings



APP monthly net purchases

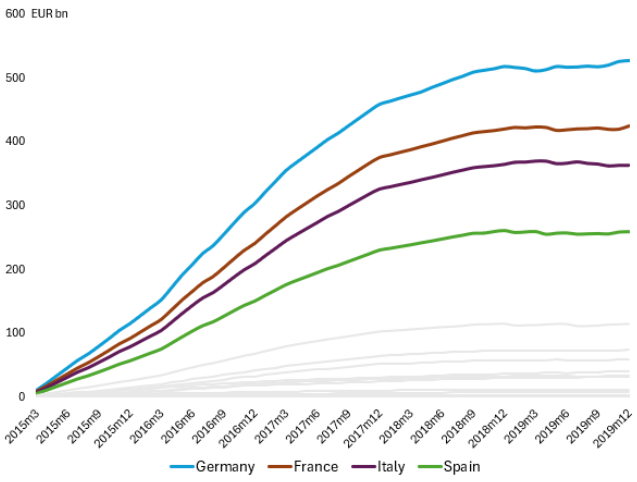


Source: ECB

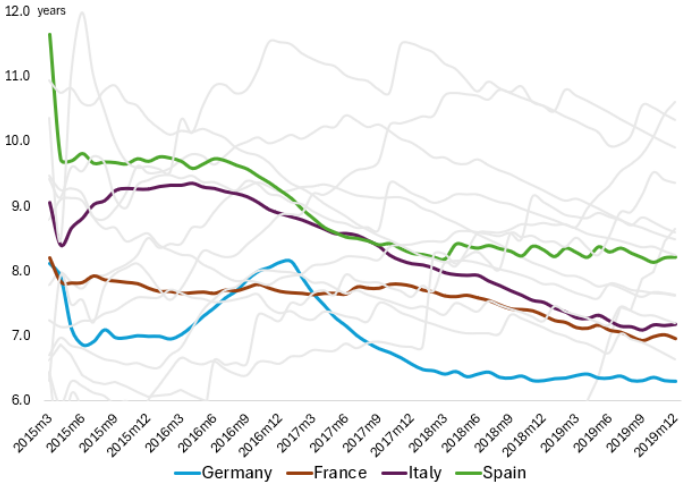
Note: This figure displays the evolution of Eurosystem aggregate asset purchases under its expanded asset purchase programme (APP) over time (in EUR trillion). The left graph depicts the APP cumultive holdings by programme type while the right graph the APP net monthly purchases. The APP accounted for the public sector purchase programme (PSPP) and three private sector programmes, namely the asset-backed securities purchase programme (ABSPP), the third covered bond purchase programme (CBPP3) and the corporate bond purchase programme (CSPP).

Figure 3. Asset purchases by country

Cumulative purchases (stock levels) of securities (in EUR bn)



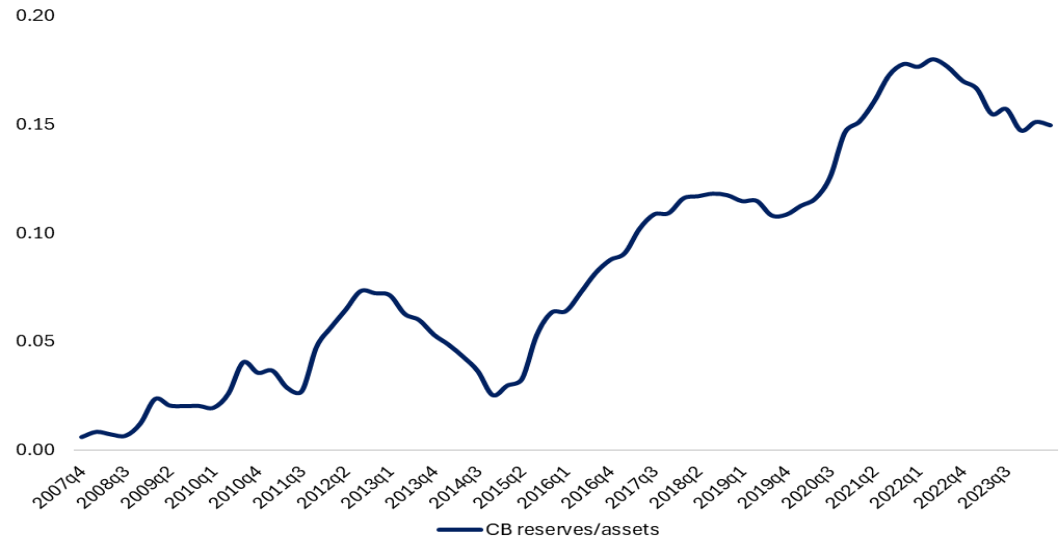
Average remaining maturity of securities purchased (in years)



Source: ECB

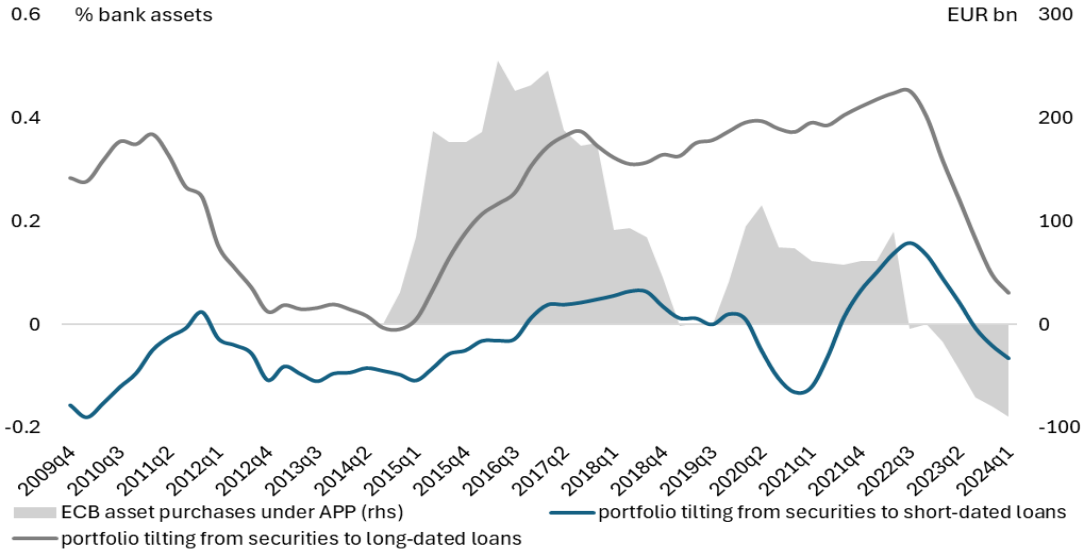
Note: This figure illustrates the asset purchases related to the ECBs' public sector purchase programme (PSPP) up to the end-2019. The left graph depicts the cumulative amount of government bond purchases by country while the right graph the weighted average remaining maturity of securities. The graphs are depicted coloured for the four largest euro area countries (Germany, France, Italy and Spain).

Figure 4. Bank reserves in total assets



Source: IBSI and authors' calculations
Note: This figure shows the time series evolution of central bank reserves in total assets for a sample of euro area banks during the period 2007q3-2024q1. Figures are for around 140 banks with non-missing data for reserves at the start of the study period.

Figure 5. Bank balance-sheet measure of portfolio tilting



Source: ECB, IBSI and authors' calculations
Note: This figure displays the time series of the cross-sectional mean of bank portfolio reallocation from securities held in their portfolios to longer-dated corporate and household loans (grey line) and the reallocation to short-dated corporate and household loans (blue line). Loans are considered longer-dated if they have a maturity above one year and short-dated if having a maturity up to one year, following the classification of IBSI. Portfolio tilting is measured as the quarterly change in loans less that of securities (government and corporate) in the unit of time and scaled by banks' assets. Figures appear on a 4-quarter rolling basis for around 190 banks with available data throughout the period against the total net asset purchases under the APP (averaged over quarters).

Table of Results

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Median	Obs.
Panel A. Bank level data				
Assets (ln)	8.34	2.26	8.36	12,988
Capital / Assets	0.11	0.04	0.10	12,988
Reserves / Assets	0.06	0.14	0.01	12,988
Central Bank Borrowings / Assets	0.01	0.02	0.00	12,988
NFC Deposits / Assets	0.09	0.08	0.08	12,988
HH Deposits / Assets	0.38	0.27	0.43	12,988
NBFI Deposits / Assets	0.05	0.09	0.02	12,998
Govt. Bonds / Assets	0.05	0.07	0.02	12,988
Corporate Bonds / Assets	0.01	0.01	0.00	11,582
Bank Bonds / Assets	0.05	0.07	0.03	12,988
Loans to NFC (>1yr) / Assets	0.13	0.11	0.11	12,988
Loans to NFC (<1yr) / Assets	0.04	0.08	0.02	12,988
Loans to HH (>1yr) / Assets	0.30	0.22	0.33	12,988
Loans to HH (<1yr) / Assets	0.02	0.04	0.01	12,988
Panel B. Country level data				
Industrial production (index)	102.2	3.40	102.0	12,381
Unemployment rate (%)	5.26	2.72	3.20	12,860
BLS firm loan demand	0.11	0.19	0.09	12,668
Panel C. Bank-firm level data				
Loan amount (ln)	12.11	2.22	12.00	33,697,664
Loan rate (%)	3.04	1.86	2.64	32,587,126
Loan maturity (years)	3.77	3.06	3.04	5,970,810
Collateral / Loans	0.98	0.90	0.86	33,683,698

This table provides descriptive statistics on variables used in the analysis. All data are on a quarterly basis. Panel A summarises information at the bank level for analysis on the QE period (2013q4-2019q4). Balance sheet data on around 250 euro area banks are from the ECB proprietary IBSI database, matched with loan interest rate data from the ECB dataset IMIR. Panel B presents country-level industrial production and unemployment rate figures from Eurostat and the index for the aggregate firm demand for loans from ECB's country-level Bank Lending Survey (BLS). Data are also for the QE period. 'NFC' stands for non-financial corporates, 'HH' for households and 'NBFI' for non-bank financial institutions. Panel C summarises information at the bank-firm level for the analysis on the post-QE period (2019q4-2024q1). Data are from the AnaCredit credit register on multiple-bank relationships.

Table 2: Baseline regressions on banks' security portfolios

	ΔGovt. Bonds		ΔCorp. Bonds		ΔBank Bonds		ΔReserves
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta\widehat{Reserves}$	-0.173**	-0.200***	-0.015*	-0.015**	-0.090	-0.073	
	(0.012)	(0.001)	(0.068)	(0.046)	(0.238)	(0.181)	
Bank Deposits		0.532***		0.040**		0.317**	1.836***
		(0.002)		(0.016)		(0.013)	(0.000)
CB Borrowings		0.541		-0.005		1.384***	1.168
		(0.314)		(0.898)		(0.002)	(0.234)
Bank Assets (ln)		0.009		0.000		0.013	0.048
		(0.581)		(0.872)		(0.268)	(0.403)
Bank Capital		1.336**		0.120**		1.471***	3.793***
		(0.017)		(0.025)		(0.001)	(0.003)
Bank Liquidity		0.723***		0.050*		0.397*	3.096***
		(0.001)		(0.054)		(0.065)	(0.000)
Ind. Production		-0.010***		-0.000		0.001	-0.004
		(0.000)		(0.563)		(0.483)	(0.525)
Unemployment		0.017**		0.000		-0.009	0.031
		(0.044)		(0.615)		(0.158)	(0.290)
BLS		-0.044		0.001		-0.056**	-0.081
		(0.184)		(0.585)		(0.013)	(0.388)
$Z(\Delta Reserves)$							5.433***
							(0.000)
Bank F.E.	X	X	X	X	X	X	X
Country F.E.	X	X	X	X	X	X	X
KP stat (weak)	32.75	40.55	28.51	29.48	34.64	40.28	--
KP p-value (under)	0.002	0.001	0.002	0.002	0.002	0.001	--
N	284	250	218	207	284	250	250
Observations	5,564	5,204	4,803	4,569	5,564	5,204	5,204

This table reports results on the relationship between reserves and banks' security portfolios. Results are based on equation (1) in which $\Delta y_{b,c,t}$ is the quarterly percentage change in the amount of government bonds (columns 1 and 2), corporate bonds (columns 3 and 4) and bank bonds (columns 5 and 6) scaled by beginning assets. Column 7 presents the first-stage regression results. The period of study is from 2013q4 to 2019q4. All control variables are scaled by beginning assets, except for country-level variables. All regressions include bank and country fixed effects. Results of first-stage diagnostic tests are reported at the bottom. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 3: Heterogeneities in banks' security portfolios

Panel A. Examining different types of sovereign debt

	Δ Domestic Govt. Bonds	Δ Other euro area Govt. Bonds	Δ Non-euro area Govt. Bonds
	(1)	(2)	(3)
$\Delta\widehat{Reserves}$	-0.117***	-0.024*	-0.002**
	(0.000)	(0.077)	(0.017)
Bank Deposits	0.258***	0.097***	0.007***
	(0.002)	(0.006)	(0.007)
CB Borrowings	0.359	-0.147	-0.004
	(0.275)	(0.169)	(0.578)
Bank Assets (ln)	0.006	0.001	0.000
	(0.568)	(0.629)	(0.252)
Bank Capital	0.511*	0.313**	0.018**
	(0.080)	(0.031)	(0.012)
Bank Liquidity	0.421***	0.099**	0.008**
	(0.001)	(0.036)	(0.024)
Ind. Production	-0.006***	-0.001**	-0.000
	(0.000)	(0.025)	(0.583)
Unemployment	0.009*	0.003	0.000
	(0.097)	(0.133)	(0.529)
BLS	-0.025	-0.015**	-0.000
	(0.209)	(0.016)	(0.566)
Bank F.E.	X	X	X
Country F.E.	X	X	X
N	250	250	207
Observations	5,204	5,204	4,569

Panel B. Examining different portfolio characteristics

	Bond-intensive			Maturity-exposed		
	low	medium	high	low	medium	high
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\widehat{Reserves}$	0.064	-0.081**	-0.150***	-0.091***	-0.130***	-0.112
	(0.391)	(0.010)	(0.000)	(0.008)	(0.002)	(0.135)
Bank Controls	X	X	X	X	X	X
Country Controls	X	X	X	X	X	X
Bank F.E.	X	X	X	X	X	X
Country F.E.	X	X	X	X	X	X
N	77	85	87	62	64	77
Observations	1,525	1,878	1,779	1,095	1,395	1,726

This table reports additional results on the relationship between reserves and banks' security portfolios. The period of study is from 2013q4 to 2019q4. In all regressions, the dependent variable is the percentage change in government securities to beginning assets. Panel A presents results after using a decomposition of bonds based on their country of origin, in particular domestic sovereign bonds (column 1), bonds issued by other euro area countries (column 2) and non-euro area country bonds (column 3). Panel B decomposes banks into three equal-sized (tercile) groups according to their share of government securities in total assets and the maturity of their bonds, measured prior to the launch of the APP. All control variables are scaled by beginning assets, except for country-level variables. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 4: Results on banks' balance-sheet portfolio tilting

	(1)	(2)	(3)	(4)
$\Delta\widehat{Reserves}$	0.459***	0.227***	0.580***	0.302***
	(0.001)	(0.001)	(0.001)	(0.002)
$\Delta\widehat{Reserves} \times PostPeak$			-0.279*	-0.174*
			(0.064)	(0.088)
Bank Deposits	0.128	-0.363**	0.178	-0.331**
	(0.745)	(0.050)	(0.634)	(0.040)
CB Borrowings	1.822	0.120	2.560*	0.580
	(0.205)	(0.886)	(0.092)	(0.494)
Bank Assets (ln)	0.090**	0.004	0.103**	0.011
	(0.026)	(0.840)	(0.011)	(0.490)
Bank Capital	0.538	-0.631	0.672	-0.547
	(0.700)	(0.274)	(0.609)	(0.274)
Bank Liquidity	-1.829***	-0.739***	-1.699***	-0.658***
	(0.000)	(0.003)	(0.000)	(0.002)
Ind. Production	0.011*	0.013***	0.014**	0.015***
	(0.089)	(0.001)	(0.045)	(0.000)
Unemployment	-0.074***	-0.017	-0.081***	-0.021*
	(0.001)	(0.132)	(0.000)	(0.060)
BLS	0.114	0.028	0.103	0.021
	(0.181)	(0.562)	(0.217)	(0.667)
Bank F.E.	X	X	X	X
Country F.E.	X	X	X	X
2-way clustered SEs	X	X	X	X
N	207	207	207	207
Observations	4,569	4,569	4,569	4,569

This table examines the empirical relevance of the balance sheet measure of *portfolio tilting* presented in equation (2). In all specifications, the dependent variable is the portfolio tilting defined at the bank-time level. Columns (1) and (3) study portfolio reallocations towards longer-dated loans (loans to non-financial corporates and households with maturities above one year). Columns (2) and (4) study portfolio reallocations towards short-term loans (loans to non-financial corporates and households with maturities up to one year). The period of study is from 2013q4 to 2019q4. The 'PostPeak' dummy takes values one for the period after the ECB announced a slowdown in net asset purchases (2017q1-2019q4) and zero for the time period before. All control variables are scaled by beginning assets, except for country-level variables. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 5: Results on banks' loan portfolios

	Volumes of long-term loans (1)	Volumes of short-term loans (2)	Interest rates of long-term loans (3)	Interest rates of short-term loans (4)
$\Delta\widehat{Reserves}$	0.188**	-0.022	-0.822***	-0.246**
	(0.048)	(0.491)	(0.002)	(0.011)
Bank Deposits	0.776**	0.340***	-0.312	-0.936**
	(0.018)	(0.001)	(0.770)	(0.027)
CB Borrowings	1.474	0.501	3.451	5.407***
	(0.275)	(0.348)	(0.152)	(0.003)
Bank Assets (ln)	0.091**	0.012	0.012	0.023
	(0.022)	(0.404)	(0.961)	(0.826)
Bank Capital	2.318**	0.793	2.040	0.408
	(0.029)	(0.112)	(0.567)	(0.816)
Bank Liquidity	-0.686*	0.184	3.944***	0.791*
	(0.064)	(0.152)	(0.002)	(0.053)
Ind. Production	0.001	0.004	-0.090***	-0.051***
	(0.853)	(0.146)	(0.000)	(0.000)
Unemployment	-0.063***	0.003	0.010	0.027
	(0.000)	(0.656)	(0.857)	(0.361)
BLS	0.080	0.003	0.239	0.071
	(0.211)	(0.939)	(0.144)	(0.455)
Bank F.E.	X	X	X	X
Country F.E.	X	X	X	X
2-way clustered SEs	X	X	X	X
N	250	250	193	214
Observations	5,204	5,204	3,599	4,359

This table examines the relation of reserve expansion to bank lending. The period of study is from 2013q4 to 2019q4. In column 1, the dependent variable is the quarterly percentage change in the amount of bank lending to non-financial corporates and households with a remaining maturity above one year (long-term loans) while in column 2 the respective changes for loans with a maturity up to one year (short-term loans). The remaining columns examine results on loan interest rates, net of the benchmark rate. In column 3, the dependent variable is the composite interest rate on new loans to non-financial corporates with a maturity above five years (long-term loans) while in column 4 the respective loan rate with a maturity up to one year (short-term loans). The 2-year and 3-month overnight index swap (OIS) rates are deducted from long-term and short-term loan interest rates, respectively. All control variables are scaled by beginning assets, except for country-level variables. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 6: Robustness tests

	Use 4-quarter avg. share in instrument		Control for outside use of reserves		Apply in period preceding APP		Apply in period including pandemic	
	Bonds	Loans	Bonds	Loans	Bonds	Loans	Bonds	Loans
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\widehat{Reserves}$	-0.152**	0.260**	-0.184***	0.144*	-0.097	0.352	-0.101	0.197**
	(0.029)	(0.039)	(0.000)	(0.069)	(0.375)	(0.168)	(0.140)	(0.025)
Bank Deposits	0.357***	0.638*	0.511***	0.832***	0.228	0.517	0.379**	0.939***
	(0.007)	(0.057)	(0.001)	(0.007)	(0.120)	(0.233)	(0.012)	(0.002)
CB Borrowings	-0.038	1.862	0.598	1.321	1.259*	0.135	0.429	0.259
	(0.947)	(0.204)	(0.282)	(0.328)	(0.066)	(0.939)	(0.428)	(0.795)
Bank Assets (ln)	0.016	0.068*	0.010	0.086**	0.017	-0.021	0.009	0.063*
	(0.185)	(0.054)	(0.502)	(0.023)	(0.141)	(0.463)	(0.464)	(0.077)
Bank Capital	1.078*	1.584	1.390***	2.174**	1.200**	-1.292	0.738*	1.216
	(0.066)	(0.137)	(0.007)	(0.027)	(0.015)	(0.412)	(0.071)	(0.170)
Bank Liquidity	0.431**	-0.745	0.677***	-0.562*	0.215	-0.487	0.387*	-0.963***
	(0.035)	(0.114)	(0.000)	(0.090)	(0.216)	(0.236)	(0.072)	(0.002)
Ind. Production	-0.007***	-0.001	-0.008***	-0.004	-0.006***	0.012	-0.010***	-0.004
	(0.000)	(0.789)	(0.000)	(0.456)	(0.004)	(0.118)	(0.000)	(0.314)
Unemployment	0.016**	-0.056***	0.011	-0.045**	-0.009	-0.087***	0.009	-0.065***
	(0.021)	(0.000)	(0.259)	(0.012)	(0.242)	(0.000)	(0.296)	(0.000)
BLS	-0.066**	0.120	-0.031	0.047	0.019	0.297***	-0.023	0.117*
	(0.024)	(0.104)	(0.295)	(0.459)	(0.587)	(0.008)	(0.383)	(0.059)
OIS3M-DFR			0.422*	-1.130***				
			(0.053)	(0.004)				
Bank F.E.	X	X	X	X	X	X	X	X
Country F.E.	X	X	X	X	X	X	X	X
2-way clustered SEs	X	X	X	X	X	X	X	X
N	309	309	250	250	137	137	254	255
Observations	5,954	5,954	5,204	5,204	3,424	3,424	6,821	6,818

This table presents robustness tests on banks' portfolio rebalancing during 2013q4-2019q4 (except for columns 5 to 8). For each test, results from the baseline equation (1) are presented for government securities (left column) and loans to non-financial corporates and households (right column). In columns 1 and 2, we use the 4-quarter average share of reserves at the bank level as the weight component for the instrument. In columns 3 and 4, we include among the regressors the spread between the ECB deposit facility rate (DFR) and the 3-month overnight index swap (OIS) rate which we use as benchmark for the short-term market interest rate. In columns 5 and 6, we present results for the period 2007q4-2013q4 which preceded the APP. In columns 7 and 8, we test our results for the period 2013q4-2021q4 which includes the period of the COVID-19 pandemic. All control variables are scaled by beginning assets, except for country-level variables. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 7: Additional tests on the transmission mechanism

	Low capital-to-assets ratio		Low loan-deposit margin		High deposit mobility		Negative interest rate policy	
	Bonds	Loans	Bonds	Loans	Bonds	Loans	Bonds	Loans
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\widehat{Reserves}$	-0.213***	0.222	-0.094*	0.075	-0.318***	0.422**	-0.152***	0.076
	(0.003)	(0.124)	(0.059)	(0.437)	(0.003)	(0.011)	(0.007)	(0.422)
$\Delta\widehat{Reserves} \times Identification$	0.022	-0.057	-0.130*	0.153	0.194*	-0.385**	-0.087	0.204
	(0.728)	(0.722)	(0.052)	(0.315)	(0.083)	(0.014)	(0.250)	(0.121)
Bank Deposits	0.517***	0.805**	0.730***	1.447***	0.522***	0.795**	0.495***	0.863***
	(0.003)	(0.015)	(0.000)	(0.005)	(0.003)	(0.023)	(0.002)	(0.007)
CB Borrowings	0.518	1.534	0.412	2.000	0.572	1.425	0.459	1.666
	(0.340)	(0.263)	(0.553)	(0.195)	(0.313)	(0.285)	(0.410)	(0.220)
Bank Assets (ln)	0.007	0.094**	-0.010	0.055	0.010	0.089**	0.006	0.097**
	(0.658)	(0.023)	(0.765)	(0.594)	(0.541)	(0.030)	(0.668)	(0.016)
Bank Capital	1.274**	2.414**	0.623	2.628**	1.440**	2.076*	1.275**	2.462**
	(0.023)	(0.024)	(0.339)	(0.036)	(0.011)	(0.070)	(0.016)	(0.019)
Bank Liquidity	0.723***	-0.700*	1.045***	-0.800	0.805***	-0.866**	0.654***	-0.525
	(0.001)	(0.057)	(0.000)	(0.178)	(0.002)	(0.038)	(0.001)	(0.152)
Ind. Production	-0.009***	0.000	-0.010***	-0.007	-0.010***	0.001	-0.009***	-0.000
	(0.000)	(0.996)	(0.001)	(0.312)	(0.000)	(0.782)	(0.000)	(0.939)
Unemployment	0.017**	-0.063***	0.024*	-0.072***	0.015	-0.058***	0.016*	-0.060***
	(0.043)	(0.000)	(0.056)	(0.001)	(0.115)	(0.001)	(0.054)	(0.001)
BLS	-0.044	0.074	-0.025	0.124	-0.056	0.099	-0.047	0.087
	(0.191)	(0.254)	(0.511)	(0.217)	(0.110)	(0.122)	(0.160)	(0.179)
Bank F.E.	X	X	X	X	X	X	X	X
Country F.E.	X	X	X	X	X	X	X	X
2-way clustered SEs	X	X	X	X	X	X	X	X
N	249	249	164	164	249	249	250	250
Observations	5,182	5,182	3,459	3,459	5,182	5,182	5,204	5,204

This table explores cross-sectional heterogeneity in the pass-through from reserve creation to securities and loans. The period of study is from 2013q4 to 2019q4. Results are presented separately for each asset class, after including in the model an interaction term of the reserve variable with an *identification* variable which exploits heterogeneity at the bank level and is entitled in each column. In columns 1 and 2, the identification variable is a dummy variable ('Low capital-to-assets ratio') taking values one for banks with capital-to-asset ratios below the sample median at end-2013 (and zero otherwise). In columns 3 and 4, the identification variable is an indicator variable ('Low loan-deposit margin') taking value one for banks with a wedge between the weighted average interest rate on corporate loans and that on corporate deposits below the sample median at end-2013 (zero otherwise). In columns 5 and 6, the model includes a dummy variable ('High deposit mobility') to denote banks with a share of NBFI deposits in total assets above the sample median at end-2013 (zero otherwise). In columns 7 and 8, the model includes a dummy variable ('NIRP') identifying banks with a higher exposure to negative interest rate policy as proxied by a low net loan position in the interbank market (loans to MFIs less deposits from MFIs). All control variables are scaled by beginning assets, except for country-level variables. Standard errors are double clustered at the bank and time levels with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 8: The effects of central bank reserves on bank lending in the post-QE period

	Loan amount (1)	Loan amount (2)	Loan amount (3)	Loan amount (4)	Loan amount (5)	Loan maturity (6)	Loan rate (7)	Loan collateral (8)
$After$	-0.099***	-0.125***		-0.088***		-0.198***	0.292***	-0.056**
	(0.001)	(0.000)		(0.003)		(0.000)	(0.001)	(0.030)
$After \times Reserves_{QE}$	0.019***	0.019***	0.019***	0.018***		0.007*	0.036***	0.018***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.095)	(0.000)	(0.000)
$Covid$	-0.150***	-0.075*		-0.075*	-0.035	0.267***	-0.135*	-0.054*
	(0.002)	(0.083)		(0.080)	(0.253)	(0.002)	(0.087)	(0.079)
$Covid \times Reserves_{QE}$	0.012**	0.006	0.013**	0.006		-0.029*	0.015**	0.010***
	(0.014)	(0.174)	(0.012)	(0.173)		(0.073)	(0.016)	(0.000)
Bank Deposits	0.234**	0.218**	0.251**	0.219**	0.257**	0.487**	-0.085	-0.212**
	(0.019)	(0.046)	(0.014)	(0.045)	(0.027)	(0.030)	(0.655)	(0.010)
CB Borrowings	-0.105	-0.079	-0.008	-0.135	-0.092	2.991***	-1.255	0.015
	(0.781)	(0.835)	(0.983)	(0.727)	(0.815)	(0.001)	(0.156)	(0.955)
Bank Assets (ln)	0.107**	0.188***	0.108**	0.188***	0.188***	0.075	0.076	0.003
	(0.015)	(0.000)	(0.015)	(0.000)	(0.000)	(0.457)	(0.323)	(0.920)
Bank Capital	-0.713*	-0.901**	-0.818*	-0.870**	-0.585	0.056	-1.958**	0.764**
	(0.087)	(0.032)	(0.054)	(0.039)	(0.164)	(0.941)	(0.030)	(0.040)
Bank Liquidity	-0.141	-0.206**	-0.124	-0.208**	-0.250***	0.084	0.671***	0.112
	(0.212)	(0.038)	(0.277)	(0.036)	(0.009)	(0.659)	(0.002)	(0.178)
QT					-0.006			
					(0.767)			
$QT \times Reserves_{QE}$					0.006**			
					(0.030)			
DFR				-0.034***	-0.037***			
				(0.000)	(0.000)			
Bank F.E.	X		X					
Bank-Firm F.E.		X		X	X	X	X	X
Firm-Time F.E.	X	X	X	X	X	X	X	X
Country(b)-Time F.E.			X					
Country(f)-Time F.E.			X					
adj. R^2	0.433	0.852	0.433	0.852	0.852	0.889	0.792	0.801
Observations	22,260,821	21,986,043	22,260,821	21,986,043	22,252,198	1,635,511	20,929,044	21,986,043

This table presents results from examining the impact of central bank reserves on bank lending in the post-QE period. The period of study is from 2019q4 to 2024q1. $After$ is a dummy variable taking values one for the period 2022q3-2024q1 (zero before). $Reserves_{QE}$ is the bank level amount of reserves at the end of the pre-pandemic QE period, defined at end-2019. $Covid$ is an indicator taking values one for the period 2020q1-2021q1 (zero otherwise). QT is an indicator taking values one for quarters in which the monthly asset purchases by the Eurosystem turn negative (zero if positive). All control variables are scaled by beginning assets, except for bank assets which appears in logs and the DFR which is the ECB's deposit facility rate averaged over the quarter. All specifications include interaction fixed effects that limit the sample of firms to those with multiple-bank relationships, following Khwaja and Mian (2008). Standard errors are clustered at the bank-time level with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 9: Bank heterogeneity and post-QE loan outcomes

	High deposit mobility	Low loan-deposit margin	Low concentration	Low capital-to-asset ratio
	(1)	(2)	(3)	(4)
$After$	-0.192***	-0.190***	-0.159***	-0.157***
	(0.000)	(0.000)	(0.000)	(0.000)
$After \times Reserves_{QE}$	0.028***	0.031***	0.003	0.020***
	(0.000)	(0.000)	(0.179)	(0.000)
$After \times Reserves_{QE} \times Identification$	0.003	0.005	0.023***	0.013***
	(0.289)	(0.272)	(0.000)	(0.000)
$Covid$	-0.060	0.003	-0.055	-0.022
	(0.366)	(0.966)	(0.352)	(0.734)
$Covid \times Reserves_{QE}$	0.002	-0.004	0.003	-0.000
	(0.791)	(0.671)	(0.306)	(0.957)
$Covid \times Reserves_{QE} \times Identification$	0.002	-0.005*	-0.000	-0.003
	(0.315)	(0.097)	(0.994)	(0.189)
Deposits	0.921***	0.110	0.225*	0.361**
	(0.000)	(0.402)	(0.074)	(0.028)
$Deposits \times Identification$	-0.889***	0.188	0.026	-0.289
	(0.000)	(0.607)	(0.893)	(0.217)
CB Borrowings	-1.420	0.051	0.364	-0.718
	(0.114)	(0.922)	(0.211)	(0.192)
$CB\ Borrowings \times Identification$	1.322	-1.864***	-0.692	0.762
	(0.103)	(0.001)	(0.246)	(0.183)
Bank Assets	0.049	0.287***	0.354***	0.192**
	(0.542)	(0.001)	(0.000)	(0.011)
$Bank\ Assets \times Identification$	0.208*	-0.027	-0.209***	-0.146
	(0.063)	(0.819)	(0.010)	(0.234)
Bank Capital	-1.794***	-1.577**	-1.196*	-2.998***
	(0.003)	(0.035)	(0.052)	(0.000)
$Bank\ Capital \times Identification$	-1.037	-0.040	0.385	2.972***
	(0.223)	(0.968)	(0.631)	(0.002)
Bank Liquidity	-0.741***	-0.118	-0.570***	-0.115
	(0.000)	(0.535)	(0.000)	(0.371)
$Bank\ Liquidity \times Identification$	0.896***	-0.101	0.518***	-0.155
	(0.000)	(0.666)	(0.003)	(0.513)
Bank-Firm F.E.	X	X	X	X
Firm-Time F.E.	X	X	X	X
adj. R^2	0.834	0.830	0.852	0.834
Observations	15,944,069	14,291,106	21,986,043	15,944,069

This table presents results on bank lending in the post-QE period due to variation in reserve holding with respect to bank-level characteristics. The period of study is from 2019q4 to 2024q1. $After$ is a time dummy variable taking values one for the period 2022q3-2024q1 (zero before). $Reserves_{QE}$ is the bank level amount of reserves at the end of the pre-pandemic QE period, defined at end-2019. $Covid$ is a time dummy taking values one for the period 2020q1-2021q1 (zero otherwise). Time variables appear in triple interaction terms with an *identification* variable that exploits heterogeneity at the bank level and entitles each column. Definitions of the identification variables are provided in Table 7, except for column 3 which denotes banks that belong to countries other than those with high concentration of excess reserves in the euro area (France, Germany and the Netherlands). All control variables are scaled by beginning assets, except for bank assets which appears in logs. All specifications include interaction fixed effects that limit the sample of firms to those with multiple-bank relationships, following Khwaja and Mian (2008). Standard errors are clustered at the bank-time level with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

Table 10: Firm heterogeneity and post-QE loan outcomes

	By firm size			By firm activity	
	Large	Medium	Small & Very Small	Manufacturing	Services
	(1)	(2)	(3)	(4)	(5)
$After$	-0.094**	-0.144***	-0.125***	-0.175***	-0.108***
	(0.012)	(0.000)	(0.000)	(0.000)	(0.000)
$After \times Reserves_{QE}$	0.013***	0.020***	0.019***	0.026***	0.015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Covid$	0.016	-0.029	-0.107**	-0.044	-0.081*
	(0.708)	(0.558)	(0.019)	(0.397)	(0.065)
$Covid \times Reserves_{QE}$	-0.002	-0.000	0.009**	0.002	0.006
	(0.538)	(0.943)	(0.038)	(0.703)	(0.145)
Bank Deposits	0.164	0.284**	0.197*	0.269**	0.225**
	(0.240)	(0.042)	(0.054)	(0.035)	(0.034)
CB Borrowings	-0.476	-0.241	-0.012	-0.329	-0.045
	(0.200)	(0.610)	(0.974)	(0.508)	(0.901)
Bank Assets (ln)	0.413***	0.290***	0.119**	0.196***	0.177***
	(0.000)	(0.000)	(0.015)	(0.002)	(0.001)
Bank Capital	-0.477	-0.895*	-0.965**	-0.274	-1.207***
	(0.352)	(0.077)	(0.023)	(0.551)	(0.004)
Bank Liquidity	-0.504***	-0.316**	-0.119	-0.198	-0.191**
	(0.000)	(0.023)	(0.223)	(0.137)	(0.036)
Bank-Firm F.E.	X	X	X	X	X
Firm-Time F.E.	X	X	X	X	X
adj. R^2	0.867	0.843	0.837	0.823	0.863
Observations	2,508,188	3,520,525	15,876,039	5,149,290	13,290,472

This table presents results on bank lending in the post-QE period due to variation in reserve holding with respect to firm characteristics. The period of study is from 2019q4 to 2024q1. $After$ is a time dummy variable taking values one for the period 2022q3-2024q1 (zero before). $Reserves_{QE}$ is the bank level amount of reserves at the end of the pre-pandemic QE period, defined at end-2019. $Covid$ is a time dummy taking values one for the period 2020q1-2021q1 (zero otherwise). Results from subsample analysis are presented on subgroups of firms based on their size (columns 1 to 3) and industry sectors (columns 4 and 5). The size classification is adopted by AnaCredit and follows the EU recommendation 2003/361/EC. The industry classification is based on NACE 2 codes provided by AnaCredit. All control variables are scaled by beginning assets, except for bank assets which appears in logs. All specifications include interaction fixed effects that limit the sample of firms to those with multiple-bank relationships, following Khwaja and Mian (2008). Standard errors are clustered at the bank-time level with *, **, and *** indicating significance at the 10%, 5% and 1% levels, respectively.

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