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Different strokes for different banks: A heterogeneity analysis of Fed QE on bank lending[☆]

Marianna Blix Grimaldi [a], Supriya Kapoor [b,*]

[a] Sveriges Riksbank, Brunkebergstorg, Stockholm, Sweden
[b] Trinity College Dublin, Dublin 2, Ireland

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ABSTRACT

Using detailed data on U.S. bank holding companies and the Federal Reserve's Quantitative Easing (QE) programmes implemented after the 2007–09 financial crisis, we reveal a more nuanced transmission mechanism than previously documented in the literature. The effect of QE on bank lending varies systematically according to banks' liquidity and solvency profiles. Specifically, we find that the most vulnerable banks (e.g., those with high asset-risk exposure and low liquidity or low capital positions) tend to increase lending more aggressively than their safer counterparties in response to QE. Moreover, QE appears to increase risk-taking behaviour, especially among weaker banks. These findings highlight the non-linear nature of QE transmission and emphasize the importance of accounting for bank heterogeneity in the assessment of unconventional monetary policy.

1. Introduction

In the wake of the global financial crisis of 2007–2009, the Federal Reserve (Fed) began large-scale asset purchase programmes (LSAPs), commonly known as "quantitative easing" (QE). With QE, the central bank expands its balance sheet by creating money in the form of bank reserves and uses them to buy government bonds and other financial assets from the private sector. The Fed – as well as other major central banks – adopted QE because further cuts in the monetary policy rates near the zero lower bound were deemed insufficient to uphold demand and counter the deflationary and contractionary forces brought about by the crisis.

The aim of QE policies was to lower long-term borrowing costs, thereby supporting and stabilizing the economy. With money being less expensive, it should be easier for households to borrow and for firms to stay in business and invest, safeguarding the labor market. The Fed started its QE programme in November 2008. During the programme, the Fed bought a combined amount of about $3.9 trillion of assets — about 25 percent of U.S. GDP in 2014, thereby expanding its balance sheet considerably. In 2017, it started to reverse QE by quantitative tightening (QT). This policy was temporarily paused in 2019. The COVID-19 pandemic prompted the Fed (and other central banks) to reintroduce expansionary monetary policies. The QT programme restarted in June 2022. The pace of QT has been more cautious than the expansion of QE during the crisis. As a result, restoring central banks' balance sheet to pre-crisis levels may take longer than the time it took to escalate the QE programme.

Almost two decades after the Fed's first QE programme, assessing the impact of unconventional monetary policies remains a challenge. Although researchers have extensively analysed the effects of QE programmes on financial conditions, the yield curve and macroeconomic outcomes such as output and inflation, the impact of QE on bank lending has been less researched and the literature has yielded mixed results.

This paper contributes to the small literature on QE and bank lending. We investigate the role of banks' heterogeneity in determining bank lending following QE purchases. We consider heterogeneity at the bank level, due to differences in the banks' holdings of mortgage-backed securities (MBS) and Treasury securities (TSY) and in their liquidity and capital positions. Previous literature on bank heterogeneity has focused exclusively on conventional monetary policy

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* Corresponding author.
E-mail addresses: marianna.grimaldi@riksbank.se (M.B. Grimaldi), supriya.kapoor@tcd.ie (S. Kapoor).

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(Kim and Sohn, 2017; Osborne et al., 2017). Molyneux et al. (2019) argue that banks that were less capitalized (low solvency), more reliant on deposit funding and more interest income-oriented had weaker lending. The role of liquidity in the broad literature on banking has been thoroughly investigated. Thornton and Di Tommaso (2020), Kim and Sohn (2017) show that better capitalized banks increased lending after they retain sufficient liquid assets. Berger and Sedunov (2017) finds that bank liquidity supports real economic growth. According to Gropp and Heider (2010), bank liquidity renders bank capital structure more robust. Brunnermeier and Yogo (2009) finds that it reduces the risk of investing by ensuring that a bank can react quickly to market movements.

In the literature on QE and bank lending, the papers most closely related to ours are Rodnyansky and Darmouni (2017) and Chakraborty et al. (2020). Both papers exploit differences in bank holdings, but emphasize the role of MBS holdings especially, while focusing on specific types of lending — mortgages in Rodnyansky and Darmouni (2017) versus consumer and industrial (C&I) lending in Chakraborty et al. (2020). Rodnyansky and Darmouni (2017) find that banks with large exposures to MBS benefited from QE policies proportionally more than other banks. The Fed's MBS purchases increased bank lending significantly. Chakraborty et al. (2020) uncover a crowding-out effect that MBS purchases had on C&I lending. Following QE purchases, banks with larger MBS exposures increased mortgage lending but, at the same time, lowered C&I lending. Di Maggio et al. (2020) focus on the impact of unconventional monetary policy on new mortgages. They find that more mortgages that were eligible for Fed purchases were originated during that period. Kandrac and Schlusche (2021) find that, following the increase in bank reserves created by the Fed, lending growth increased and led to more risk-taking within banks' loan portfolios. Beyond the impact of QE on bank lending, the broader empirical literature on the effectiveness of QE on the economy has produced conflicting results.[1]

To our knowledge, this is the first study to provide empirical evidence on the role of bank heterogeneity in affecting lending behaviour of banks during periods of unconventional monetary policy. More specifically, we study the distributional effects of QE within the balance sheets of financial intermediaries using a sample of U.S. bank-holding companies from 2006:Q1-2014:Q4. We use an augmented difference-in-difference approach (DDD) to get a consistent estimate of the interaction between QE purchases, bank's exposure to specific QE-asset purchases and bank heterogeneity. As in Rodnyansky and Darmouni (2017) and Chakraborty et al. (2020), we divide the banks into two groups according to their exposure to the type of assets purchased by the Fed. In line with their research, we find that MBS-exposed banks increase lending. We add novel evidence by showing that banks that were Treasury-exposed reduce lending.[2] We label this effect an ***across-exposure*** effect. In addition, taking into account banks with a similar QE-asset exposure, we show that banks respond differently to QE purchases depending on their liquidity and solvency levels, a ***within-exposure*** effect. In particular, within the group of MBS-exposed banks, we find that riskier banks, i.e., banks with lower levels of liquidity or capital, increase lending more compared to their less risky counterparts. On the other hand, TSY-exposed banks reduce lending. Again, we find a differential effect within the group of similarly TSY-exposed banks, as banks that had lower liquidity risk or lower solvency risk decreased lending comparatively less. Our results show that the interaction between the type of asset purchased by the central bank under QE, the exposure of banks to QE purchases and bank heterogeneity determines the ultimate effect of QE policies on bank lending and that such interaction is non-linear.

To further enhance such findings and uncover the key factors driving the impact of QE on bank lending, we examine whether risk-taking behaviour differed significantly between QE-exposed banks using both *ex-ante* and *ex-post* measures of risk-taking. We show that weaker banks increased risk-taking by expanding riskier loans — an *ex-ante* measure of risk taking. Banks with weaker liquidity levels also increased *ex-post* risk-taking, as measured by higher levels of non-performing loans (NPLs).

For policy making, our findings offer valuable insights on bank-based channels of monetary transmission, emphasizing the need to account for bank heterogeneity when evaluating the impact of unconventional monetary policy on the real economy. In fact, the effectiveness of these policies is determined by the interaction between the distribution of banks' QE-asset exposure and bank capital and liquidity positions. In addition, and more significantly, 'vulnerable' banks — those characterized by lower liquidity or weaker capital positions increase their risk-taking following QE purchases, thereby potentially increasing financial stability risks.

The paper is organized as follows. Section 2 gives an account of the Fed QE programme. Section 3 discusses the transmission channels that are closely related to our research. Section 4 describes the data and the identification strategy. In Section 5 we present the estimation results, while Section 6 addresses the implications of our research for bank risk-taking. Section 7 shows the robustness of our results and Section 8 concludes.

2. The Fed's QE programmes

The QE programmes differed substantially in terms of the type and volume of securities that the Fed purchased as well as the timing. Between November 2008 and October 2014 the Fed launched three QE rounds.[3] The total amount of securities purchased under the QE programme reached about $3.9 trillion, close to 25 percent of U.S. GDP in 2014.[4] The first QE programme (QE1) began on November 25, 2008. The Fed announced a programme to buy up to 100 billion in US dollars of debt obligations issued by Fannie Mae and Freddie Mac and $500 billion of agency MBS. In March 2010, the programme was extended and expanded and, by the end of QE1 in March 2010, the Fed had bought $1.25 trillion in MBS, $175 billion in federal agency debt, and $300 billion in U.S. Treasury securities. At that point, the Fed's market share of agency MBS had reached approximately 25 percent of total MBS outstanding. The purchase of long-term government bonds was meant to exert pressure on the general level of interest rates whereas the purchases of debt obligations and agency debt was meant to provide support to mortgage lending and housing markets and to improve overall conditions in private credit markets. Such purchases were completed by March 2010.

In mid-2010 concerns about deflationary pressures and a possible protracted loss of economic growth led to a second round of QE (QE2) that was officially implemented in November 2010. Before that, in August 2010, to help support the waning economic recovery, the Fed had decided to keep constant the Federal Reserve's holdings of securities by reinvesting principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities. The Fed also decided to continue to roll over the Federal Reserve's holdings of Treasury securities as they were to mature. QE2 purchases entailed a total purchase of $778 billion in long-term Treasury securities, which

[1] See Chen et al. (2012), Acharya et al. (2024), among others.

[2] Rodnyansky and Darmouni (2017) find no effect of Treasury purchases whereas in Chakraborty et al. (2020) the effect is either positive or insignificant in most cases.

[3] The Federal Reserve Act restricts the Fed to purchase only government-guaranteed debt.

[4] Throughout the QE programme only fixed-rate agency MBS guaranteed by Fannie Mae, Freddie Mac and Ginnie Mae were eligible assets for purchases. In terms of Treasuries, the Fed could conduct purchases in nominal coupon securities, bills, Treasury Inflation-Protected Securities (TIPS), and Floating Rate Notes (FRNs).

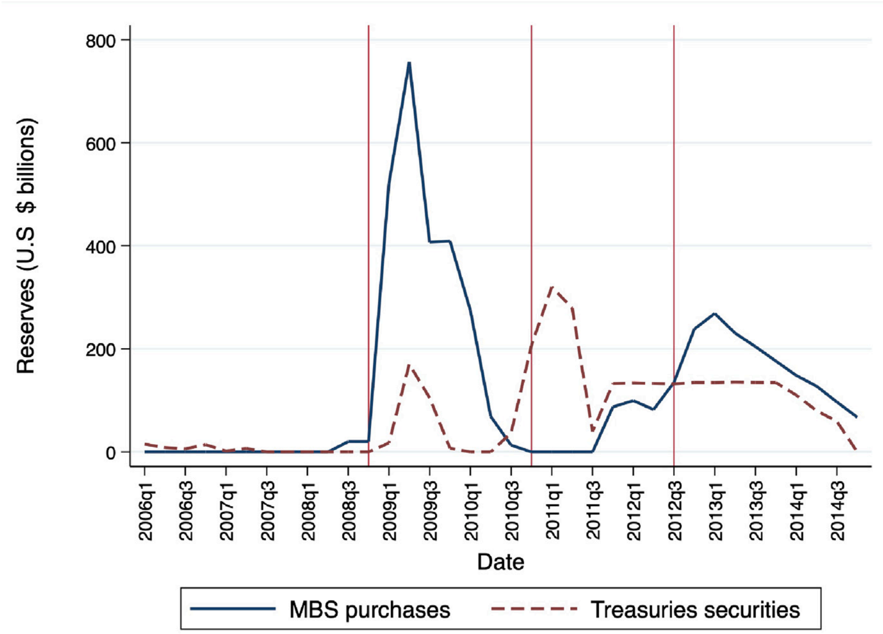


Fig. 1. MBS and Treasury securities purchase amounts.
Notes: Quarterly purchase of MBS and Treasury securities by the Fed. The figure shows the quarterly amount of mortgage-backed securities (solid line) and Treasury securities (dashed line) purchased by the Fed. The vertical lines indicate the commencement of the three rounds of quantitative easing.

included $600 billion in announced programme purchases and $178 billion as reinvestment of principal payments from Fed's agency debt and MBS holdings. This second round of QE lasted until end of June 2011 at a pace of about $75 billion per month.[5]

Finally, the Fed announced a third round of quantitative easing (QE3) in September 2012, calling for monthly purchases of $40 billion in agency MBS and, starting in January 2013, $45 billion in U.S. Treasury securities as well. The QE3 programme was largely unanticipated. In December of that year, the total amount of purchases dropped to $75 billion from $85 billion. The major novelty of the QE3 programme was its state-contingent and open-ended feature. It continued until October 2014, when no further purchases were made. In total, during the third purchase round, the Fed purchased $790 billion in Treasury securities and $823 billion in agency MBS. Fig. 1 shows the amounts of MBS and Treasury securities purchased during the implementation of each QE episode.

3. Transmission channels and bank heterogeneity

In this section, we discuss the transmission mechanisms that we consider to be more closely related to bank heterogeneity and QE. While there is a large literature on bank heterogeneity in the context of conventional monetary policy, surprisingly much less attention has been given to its role in unconventional monetary policy. We identify three transmission channels that are relevant to our analysis. It is important to note that our discussion does not intend to provide a comprehensive theoretical examination of these mechanisms; instead, we give an overview of the channels that we consider most likely to align with our empirical results.[6]

The first of such QE transmission channels is the *bank lending channel*(BLC) according to which lower monetary policy rates lead to an increase in banks' loan supply. Along the lines of Kashyap and Stein (1994), this occurs because lower policy rates lead to a cheap source of funding for banks in the form of increased reserves and deposits. QE provides banks with cheap liquidity both as new reserves and as new deposits. In principle, those expanded reserves and new deposits can lead to an increased supply of loans, as predicted by the traditional BLC. However, empirical evidence shows no or very little impact of QE on bank lending. Chakraborty et al. (2020) and Rodnyansky and Darmouni (2017) show that only banks with a certain asset mix increase lending. However, this is not sufficient to fully explain why in aggregate there is little impact on bank lending.

A second mechanism on which heterogeneity may have a more significant impact than previously recognized is the *risk-taking channel*. The potential relationship between a change in monetary policy interest rates and the risk-taking of banks works through bank incentives. According to the risk-taking channel, lower monetary policy rates reinforce the incentives of financial intermediaries to finance riskier projects. Borio and Zhu (2012) point to the tight interconnection between liquidity and risk-taking, where liquidity is defined broadly as encompassing both funding and market liquidity. Weaker constraints can support higher risk-taking by allowing intermediaries to engage in riskier projects, normally associated with higher expected returns, than would otherwise be possible. Empirical evidence suggests that lower policy rates lead to greater risk-taking in both the quantity of new loans and their interest rates (Ioannidou et al., 2015; Altunbas et al., 2010). These studies and the literature more broadly do not address the

[5] From September 2011 through 2012, the Fed conducted purchases within a programme of maturity extension (MEP) of Treasury securities that had already purchased, known also as Operation Twist. Operation Twist involved the sale of short-term Treasury securities and a purchase of long-term Treasury securities of equivalent amount. The programme was intended to contribute to a broad easing in financial market conditions and provide support for the economic recovery by exerting further downward pressure on long term interest rates without altering the total amount of securities purchased by the Fed (balance sheet neutral). Overall, it included purchases of $667 billion in Treasury securities with maturity between 6 and 30 years. Operation Twist also saw a change in the reinvestment policy. The reinvestment of principal payments from agency debt and agency MBS was shifted into agency MBS rather than Treasury securities.

[6] Note that the transmission channels of QE discussed in this section can operate alongside other channels explored in the literature.

question whether bank heterogeneity plays an active role in shaping the response to QE purchases through risk-taking.

A third mechanism is *portfolio re-balancing*. According to this channel, when central banks purchase a large quantity of assets held by the private sector through QE, they alter the relative supply of these assets, leading to changes in their relative yields. Because different financial assets are not perfect substitutes in investors' portfolios, the sellers of those assets may attempt to re-balance their portfolios by buying other assets with similar characteristics. This re-balancing process not only drives up the prices of the assets purchased under QE but also increases the prices of their close substitutes, thereby reducing associated term premiums and yields. An alternative perspective on portfolio re-balancing suggests that by lowering yields on safe long-term securities, QE programmes encourage investors to shift their investments towards assets with higher expected returns, thereby taking on more risk. This search-for-yield mechanism is considered an important channel for the transmission of QE as it enables issuers not directly targeted by QE purchases to benefit from lower yields, which in turn stimulates the supply of bank loans. However, this increased risk-taking can sow the seeds for future financial crises. Empirically, it has been proved hard to identify a distinct portfolio re-balancing channel. Albertazzi et al. (2021) find that in the euro area portfolio re-balancing was concentrated in vulnerable countries and resulted in more credit risk-taking. They do not investigate the role that bank capital and liquidity may play in the transmission of QE impulses.

4. Data and methodology

4.1. Data

This section describes the data we use for our analysis. We employ quarterly Consolidated Financial Statements for Bank Holding Companies (BHCs) in the United States, which are available from the Federal Reserve Bank of Chicago. All BHCs are subject to regulation by the Federal Reserve Board of Governors under the Bank Holding Company Act of 1956 and Regulation Y. Our data covers the sample period from 2006:Q1 to 2014:Q4 and include detailed information on the financial conditions of the BHCs, including on- and off-balance sheet exposures and statistics on different types of loan. Our sample consist of 7124 unique BHCs, after cleaning and omitting the BHCs with missing total assets values.[7] In each QE round, the Fed purchased different types of assets.[8] For a thorough analysis, we collect data on the actual amounts of MBS and Treasuries security purchases by the Fed and match this data with the BHCs balance sheet data.[9]

To identify and differentiate banks that were more likely to benefit from QE from those that were less, we resort to an identification strategy that relies on the interaction of cross-sectional variation among banks in their MBS or Treasuries holdings and the amount of security purchases by the Fed. More specifically, we compute the MBS-QE exposure as the share of MBS holdings to total assets for each bank in the period *before* the QE programme started, i.e., in 2007:Q4 in order to reduce potential endogeneity concerns to QE rounds' anticipation. We define treatment and control groups based on quartiles, i.e., banks in the top 25% of the MBS-to-total assets distribution are defined as treated banks and the ones in the bottom 25% of this distribution are control banks.[10] In robustness checks, we also use alternative definitions of the treatment and control variables based on decile values of MBS-to-total assets as well as a continuous measure of the ratio to allow for the entire sample of banks. Additionally, as part of the robustness checks, we also implement the treatment definition in the corresponding quarters just before each of the QE rounds instead of choosing the MBS-QE exposure measures fixed at its value as in 2007:Q4. We obtain results qualitatively similar to our baseline.

Next, we compute a Treasuries exposure measure which, similar to the MBS exposure measure, is based on information of bank-by-bank securities holdings. In particular, for the Treasury-QE (TSY-QE) exposure measure we only include Treasuries security, other US government agency or sponsored agency securities, securities issued by states and other US political subdivisions. This makes our measure relatively conservative compared to, for example, Chakraborty et al. (2020)'s preferred Treasuries exposure measure which also includes non-government securities information such as information on private sector asset-backed securities (ABS) and structured products, other private debt securities, investment and mutual funds and equity securities.[11] We compute the MBS-QE as well as TSY-QE exposure measures on a quarter-by-quarter basis.

Fig. 2 shows the evolution of MBS-to-total assets (Fig. 2(a)) and Treasuries as a share of total assets (Fig. 2(b)) for QE and non QE-exposed banks on the right-axis. There is a clear difference in the trends of securities that were purchased under QE for both exposed and non-exposed banks. Notably, the share of MBS holdings begins to decline significantly after QE3 (dashed blue) for MBS-exposed banks. In contrast, the control group (dashed red) shows an increase in MBS-to-total assets following QE1, with levels remaining relatively flat during the QE3 period. For TSY-exposed banks (dashed green), the share of Treasuries-to-total assets increases following QE1 and remains relatively stable after QE2. In contrast, non-TSY-exposed banks (dashed yellow) exhibit a steady increase in TSY holdings throughout the QE episodes. When comparing the lending behaviour of QE-exposed banks with their counterparts, we find that there is a fall in lending trend post QE1, however overall lending activity seems to pick up after QE3.

4.2. Estimation approach

The aim of our empirical analysis is to assess whether and how QE purchases affected the lending outcomes of banks that were more likely to derive benefit from QE policies (QE-exposed bank) with a specific focus on their liquidity and solvency positions. To do this, we estimate the impact of asset purchases on bank lending by using

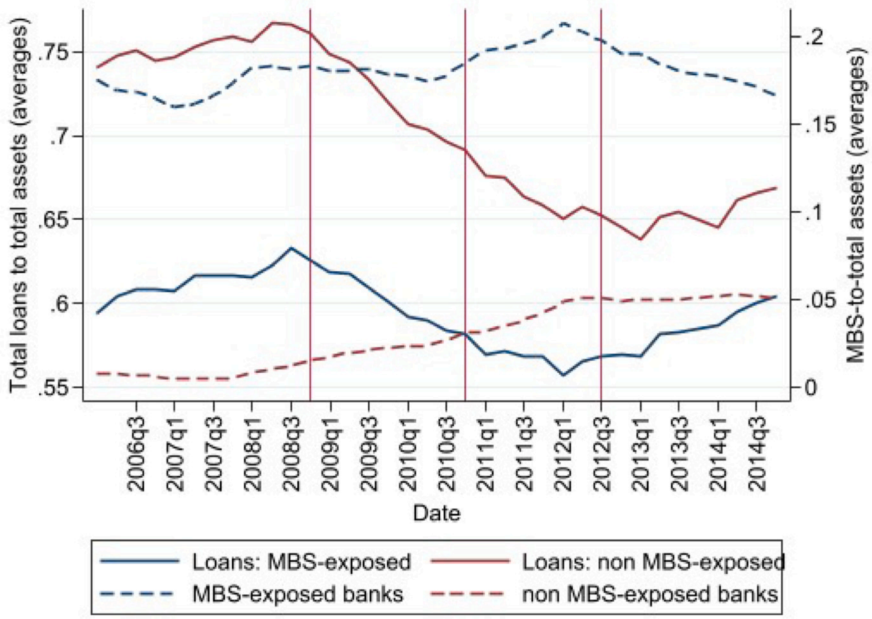
[7] The number of BHCs in the sample fluctuates across quarters because of differing reporting requirements. On average, about 1200 BHCs report data every quarter, while roughly 5500 BHCs submit reports only twice a year (in Q2 and Q4). The Consolidated Report of Condition and Income (FR Y-9C) also includes separate filings for the parent companies of large BHCs (FR Y-9LP) and small BHCs (FR Y-9SP). Since the Y-9SP is collected semiannually; in June and December, the number of observations increases significantly in those quarters. In contrast, the first and third quarters contain only those BHCs that file the Y-9C and Y-9LP. We conduct a sub-sample analysis by dropping observations in the first and third quarters in each year, in which small BHCs that only file the FR Y-9SP do not report data. The results are presented in Tables 16 and 17 in Appendix B. The results are qualitatively similar to those obtained in our main specification.

[8] As described in the previous section, during the first and third rounds of QE the central bank purchased both MBS and Treasury securities, while in the second round it purchased mainly Treasury securities. Apart from the three rounds, the Fed also implemented the Maturity Extension Programme (MEP) between 2011–12. We do not explicitly identify MEP.

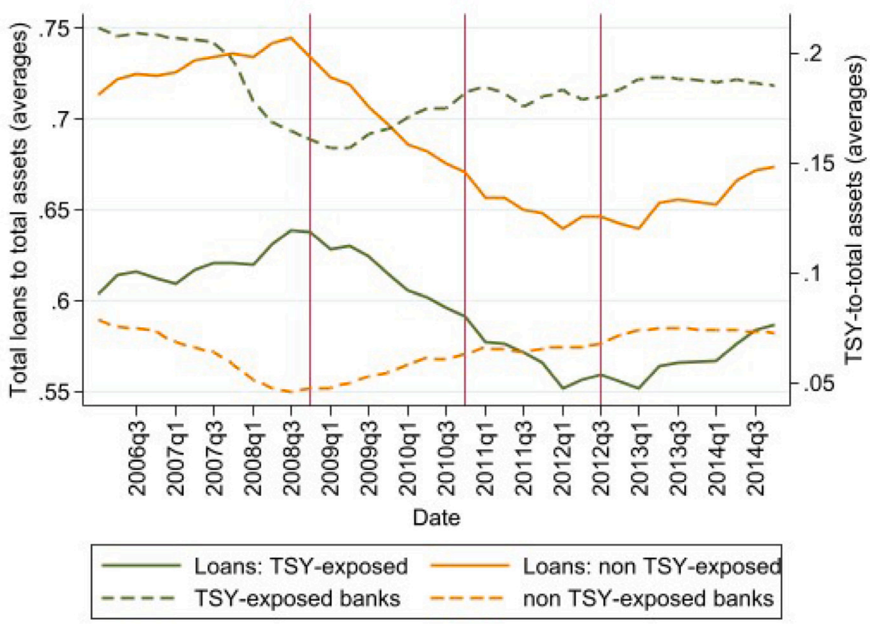
[9] Data for outright purchases of MBS and Treasury securities have been downloaded from https://www.newyorkfed.org/markets/programs-archive/large-scale-asset-purchases.

[10] Choosing the quartiles as a threshold results in a reasonable distinction between banks that were QE-exposed versus the ones that were not. More importantly, though, the two groups are sufficiently stable over time, that is, while banks move within the category tend to not change group over time.

[11] Also, Chakraborty et al. (2020) use a much broader definition of mortgage lending that pulls together MBS holdings and new mortgages that originated and eventually were sold in the to-be-announced (TBA) market to third parties. In the TBA market, the identity of the securities to be delivered to the buyer are not specified until delivery. In addition, Chakraborty et al. (2020) specification is at yearly frequency whereas our measure is at quarterly frequency.



(a) MBS-to-total assets and bank lending



(b) TSY-to-total assets and bank lending

Fig. 2. MBS/TSY purchases and bank lending behaviour.
Notes: The figure maps the evolution of the ratio of MBS-to-total assets and total loans to total assets ratio in Panel (a) and ratio of treasury securities to total assets and total loans to total assets ratio in Panel (b) for QE and non-QE exposed banks. In Panel (a), MBS-exposed banks are banks in the top 25th quartile of MBS-to-total assets ratio in 2007Q4, while non MBS-exposed are in the bottom 25th quartile. In Panel (b), TSY-exposed banks are banks in the top 25th quartile of treasury securities-to-total assets ratio in 2007Q4, while non TSY-exposed are in the bottom 25th quartile. The left-axis for both Panel (a) and (b) measures the ratio of total loans to total assets. The vertical lines indicate the commencement of the three rounds of quantitative easing.

a difference-in-difference (DiD) approach based on QE-exposed banks versus non QE-exposed banks, augmented with an interaction with bank-specific exposure to solvency and liquidity risk on our outcome variable.[12] The triple interaction captures the potential differential impact of QE-exposed banks depending on the level of banking sector heterogeneity. This specification allows us to test whether the path of lending outcomes for banks with distinct bank heterogeneity is systematically different in the presence of QE intervention. Specifically, we estimate the following regression based on a triple Difference-in-Difference (DDD) approach with a full set of interaction terms (Olden and Møen, 2022; Imbens and Wooldridge, 2009; Gruber, 1994):

$$\begin{aligned} Y_{i,j,t} = \alpha_i + \beta_{j,t} + \gamma_1 AssetPurchases_{t-4} + \gamma_2 Treat_i + \gamma_3 Heterogeneity_i^h + \\ \gamma_4 Treat_i \times AssetPurchases_{t-4} + \gamma_5 Heterogeneity_i^h \times AssetPurchases_{t-4} + \\ \gamma_6 Treat_i \times Heterogeneity_i^h + \gamma_7 Treat_i \times AssetPurchases_{t-4} \times Heterogeneity_i^h + \\ \delta' X_{i,t} + \epsilon_{i,t}. \end{aligned} \tag{1}$$

$Y_{i,t}$ denotes the dependent variable as measured by the logarithm of total loans or real estate loans or commercial and industrial (C&I) loans for bank i in state j in quarter t. $Treat_i$ is a dummy variable that takes the value of one if a bank belongs to the treatment group and zero if the bank belongs to the control group. $AssetPurchases_{t-4}$ are the amounts of MBS and TSY that are purchased by the Fed in each quarter. We take 4 lags (one year) as the effects of policy may follow a significant time lag. $Treat_i \times AssetPurchases_{t-4}$ is an interaction term between the treatment status of a bank and the security amount purchased during our sample period.

$Heterogeneity_i^h$ is an indicator variable that captures the heterogeneity of each bank i in terms of h. We differentiate banks according to the two key dimensions of liquidity and solvency (capital ratios). We approximate the liquidity of a bank based on their liquid asset holdings. More specifically, we categorize banks as highly liquid (low liquidity risk) if they are in the top quartile of the distribution of liquid assets to total assets ratio prior to the implementation of QE, i.e., 2007Q4. Similarly, we classify banks as low (high) solvency and therefore high (low) risk if their Tier I risk-based capital ratio is in the lowest (highest) quartile of this distribution.[13]

In order to mitigate potential omitted variable bias and isolate the heterogeneous supply-side effects of QE, Vector $X_{i,t}$ in Eq. (1) includes lagged bank-level controls such as bank size, ratio of cash to assets, loan-to-deposits ratio and return on assets (measured as net income-to-total assets). These controls account for cross-sectional differences in bank balance sheet strength, liquidity management, and profitability, all of which may influence lending behaviour independently of QE exposure. In addition, we incorporate the non-performing loans (NPL) ratio as a proxy for asset quality, and a measure of wholesale funding reliance, defined as the ratio of various market-based and non-core funding sources to total assets, to more accurately capture variation in funding structures across banks. These variables help ensure that our estimates of QE effects are not confounded by differences in credit risk or liquidity constraints that are not directly observable.

Furthermore, based on recent work of Orame et al. (2025), we control for the accounting treatment of securities, which has been shown to play a critical role in shaping the effectiveness of QE through the bank recapitalization channel. Specifically, we include two key variables in our baseline specification: the ratio of held-to-maturity (HTM) securities to total assets and the ratio of available-for-sale (AFS) securities to total assets. Under historical cost accounting (HCA), HTM securities do not revalue with market prices, thereby muting the effect of QE on bank capital. In contrast, AFS securities, which are marked-to-market, allow QE-induced price increases to pass through to banks' balance sheets, enhancing lending capacity. By controlling for the treatment of securities in this way, we ensure that variation in banks' QE responsiveness is not driven by differences in regulatory asset valuation. This aligns with the evidence in Orame et al. (2025), who demonstrate that the macroprudential accounting framework can significantly amplify or dampen QE transmission depending on the extent of mark-to-market exposure.

We interact the vector of bank-level controls with $AssetPurchases_{t-4}$ and $Treat_i$, to control for possible effect that Fed's asset purchases may have had on control variables. Thus, the vector $X_{i,t}$ includes the control variables and all double and triple interaction terms between the control variables, the QE-exposure and the Fed asset purchases measures. Table 1 reports summary statistics of the key variables employed in the analysis and we provide definitions and construction of each variable in Appendix A. The summary statistics for the treated and control groups in Table 1 describe, for example, that the mean of the ratio of MBS-to-total assets for treated banks is around 0.18, while that of the control group is close to 0. Similarly, for the ratio of Treasuries to total assets, the mean values for the treated group is 0.09, while for the control group is 0.11.

We include bank fixed effects (α_i) to control for fixed differences among banks, and $state \times time$ fixed effects ($\beta_{j,t}$) to control for residual inter-temporal differences in common shocks, for example, the implementation of regulation related to the Dodd-Frank Act and Basel Accord (including stress testing). The fixed effects $state \times time$ are included to partially account for the variation in local economic conditions that may influence the demand for and risk of bank lending between states over time. Although $state \times time$ fixed effects help capture common shocks to local lending demand and credit risk at the state level, we recognize that they cannot fully control for borrower-specific heterogeneity, which would require loan-level data with borrower fixed effects. Although access to granular data at the borrower-level remains a limitation in our study, we address this challenge by adopting the benchmark lending approach proposed by Raupach and Memmel (2021). Following their approach, our baseline regression specification includes a benchmark lending variable, where for each bank, we construct a hypothetical "benchmark bank" that replicates the institution's state-level lending composition but reflects the average lending activity of all other banks operating in the same region-time segments. This allows us to isolate idiosyncratic supply-side variation in lending from common demand-side influences. Specifically, benchmark lending is computed by aggregating total lending across all banks within a given state-time cell, excluding the bank in question, and normalizing by the number of contributing banks. By including this benchmark measure as a control in our regressions, we capture external credit demand conditions with greater granularity than conventional fixed effects allow. We include the lagged log of benchmark lending as a control in our baseline specification to mitigate endogeneity concerns and ensure that it captures pre-existing demand conditions rather than

[12] The DiD approach is well established in economics, public policy, health research, management and other fields. It has been around since the middle of the nineteenth century when John Snow showed with his DiD study that cholera was transmitted through polluted water rather than air, making a breakthrough for controlling and eventually winning over the disease (Caniglia and Murray, 2020).

In its simplest form the DiD estimate is equivalent to calculating the after–before difference in the so-called treatment group – for example, the target group of a certain public policy intervention – and subtracting from this difference the after–before difference of the control group, i.e. the group that was not affected by the policy.

[13] We define liquid assets as the sum of cash and balances due from depository institutions and federal funds sold. We use the ratio of Tier I capital to risk-weighted assets as our measure of solvency. In robustness checks, we provide alternative measures of solvency and liquidity. In addition, in robustness checks we choose the lowest and highest decile values to classify banks according to the two chosen heterogeneity dimensions and obtain similar results in qualitative terms.

Table 1
Summary statistics.

	Obs	Mean	Std.D.	p10	Median	p90
Treatment Group						
Treatment Variables						
$\left(\frac{MBS}{Total\,Assets}\right)_i$	7343	0.18	0.09	0.09	0.16	0.29
$\left(\frac{Treasury}{Total\,Assets}\right)_i$	7343	0.09	0.08	0.009	0.07	0.18
Dependent Variables						
log(Total Loans)	7343	14.02	1.45	12.60	13.68	15.92
log(RE Loans)	7332	13.67	1.37	12.32	13.37	15.44
log(C & I Loans)	7332	11.85	1.87	9.96	11.60	14.42
Heterogeneity Variables						
Liquidity	7343	0.05	0.05	0.02	0.04	0.10
Tier 1 Risk-based Capital Ratio (%)	7312	13.74	19.28	9.13	12.77	19.08
Control Variables						
Asset Size	7343	13.61	1.47	12.20	13.24	15.51
Cash-to-total assets	7343	0.04	0.05	0.01	0.03	0.09
Loans-to-deposits ratio	6943	0.84	0.63	0.55	0.82	1.03
Return on assets	7343	0.003	0.007	−0.00	0.03	0.01
Non-performing loans to total assets	7343	0.02	0.03	0.002	0.01	0.05
Wholesale funding	7343	0.15	0.11	0.03	0.13	0.30
Securities (HTM)-to-total assets	7343	0.03	0.06	0.00	0.00	0.12
Securities (AFS)-to-total assets	7343	0.2	0.1	0.1	0.2	0.4
Control Group						
Treatment Variables						
$\left(\frac{MBS}{Total\,Assets}\right)_i$	7312	0.03	0.04	0.00	0.01	0.08
$\left(\frac{Treasury}{Total\,Assets}\right)_i$	7312	0.11	0.09	0.01	0.1	0.23
Dependent Variables						
log(Total Loans)	7303	13.51	0.86	12.63	13.38	14.52
log(RE Loans)	7268	13.21	0.87	12.31	13.10	14.31
log(C & I Loans)	7291	11.35	1.16	10.15	11.32	12.66
Heterogeneity Variables						
Liquidity	7312	0.08	0.07	0.02	0.06	0.16
Tier 1 Risk-based Capital Ratio (%)	7308	12.92	24.18	8.12	11.94	17.53
Control Variables						
Asset Size	7312	12.53	1.08	11.43	12.39	13.71
Cash-to-total assets	7312	0.06	0.06	0.02	0.04	0.15
Loans-to-deposits ratio	6929	1.20	7.03	0.66	0.90	1.11
Return on assets	7312	0.004	0.08	−0.002	0.003	0.01
Non-performing loans to total assets	7303	0.02	0.03	0.002	0.01	0.06
Wholesale funding	7312	0.11	0.10	0.01	0.08	0.22
Securities (HTM)-to-total assets	7312	0.02	0.05	0.0	0.0	0.07
Securities (AFS)-to-total assets	7343	0.1	0.1	0.0	0.1	0.3

Summary statistics recorded from 2006Q1 to 2014Q4 for all U.S. BHCs. The statistics for $\left(\frac{Treasury}{Total\,Assets}\right)_i$ is based on the TSY-QE exposed treatment and control group. All variables are at quarterly frequency and are winsorized at the 1st and 99th percentile. Detailed definitions on the construction of each variable can be found in Appendix A.

contemporaneous treatment effects. This refinement strengthens the identification of our treatment effect and reduces the potential bias arising from region-specific credit cycles. In doing so, we provide a more robust assessment of how QE-exposed banks with differing solvency and liquidity characteristics adjust their lending behaviour in response to unconventional monetary policy interventions.

Our baseline specification as in Eq. (1) allows us to test for an *across-exposure* effect as banks are likely to respond differently depending on their asset type exposure — as also shown in Rodnyansky and Darmouni (2017).[14] Additionally, it allows us to test for a *within-exposure* effect as, even within the group of banks with a similar exposure to the type of asset purchased by the Fed, banks may have a differential response according to differences in liquidity and capital levels. The main variables of interest in our baseline model of Eq. (1) are therefore the coefficients γ_7 that capture interaction between Fed asset purchases, bank's exposure to the MBS or TSY purchases and bank heterogeneity.

An advantage of a specification as in Eq. (1) is that it minimizes the potential loss of information of simpler DiD approaches (Olden and Møen, 2022). Notably, it provides an estimate of potential "spillover" effects, i.e. γ_4, which is the effect of $Heterogeneity_i^h$ equal to 0 for banks exposed to MBS (or TSY) after the Fed started asset purchases. In addition, the point estimate of γ_7 is unbiased because it calculates the time change in means for highly liquid banks in the QE-exposed group by netting out both the change in means for highly liquid banks that were not QE-exposed (control group) and the change in means for low liquid banks that were QE-exposed. In other words, the specification as in Eq. (1) ensures the consistency of γ_7 by exploiting the triple differences and removing all the confounding trends within the heterogeneity

[14] As an alternative specification, we replicated the Rodnyansky and Darmouni (2017) and obtained very similar results to them.

Table 2
Number of treated banks based on bank heterogeneity.

Category	Number of banks	bank size (pre-QE) in million $	Bank size (post-QE) in million $	Bank lending (pre-QE) in million $	Bank lending (post-QE) in million $
MBS-exposed					
Liquidity= 0	153	14.23	12.10	4.85	5.42
Liquidity= 1	88	9.86	18.00	4.30	5.38
Capital= 0	93	27.63	31.95	9.90	11.94
Capital= 1	148	3.27	4.45	1.38	1.77
Non MBS-exposed					
Liquidity= 0	103	4.94	2.97	1.25	1.47
Liquidity= 1	139	5.82	4.16	1.45	1.46
Capital= 0	132	9.09	5.76	1.82	1.69
Capital= 1	110	1.18	1.43	0.83	0.94
TSY-exposed					
Liquidity= 0	93	1.85	1.96	1.13	1.23
Liquidity= 1	132	2.00	2.18	1.23	1.24
Capital= 0	56	3.77	3.40	2.41	2.06
Capital= 1	169	1.35	1.67	0.80	0.97
Non TSY-exposed					
Liquidity= 0	399	16.60	22.08	5.30	6.01
Liquidity= 1	342	17.42	24.17	3.42	4.29
Capital= 0	443	26.88	37.64	6.63	7.87
Capital= 1	298	2.31	3.62	1.17	1.63

Bank heterogeneity is constructed based on quartile. Particularly, $Liquid = 1$ represents banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE, while $Capital = 1$ banks in the top 25% of Tier-1 capital risk-based ratio prior to the implementation of QE. Treatment group represents banks in the top 25th percentile of the MBS-to-total assets (MBS-exposed) or TSY-to-total assets (TSY-exposed) ratio in 2007Q4. Control group represents banks in the bottom 25th percentile of the MBS-to-total assets (MBS-exposed) or TSY-to-total assets (TSY-exposed) ratio in 2007Q4. Pre-QE period is defined prior to 2008Q4. Post-QE period is defined from 2008Q4 onwards.

dimension, between QE-exposed and non QE-exposed banks, and across the heterogeneity dimension in the treated group of QE-exposed banks. In particular, this specification accounts for two possible confounding trends. First, a trend due to changes across QE-exposed and non QE-exposed banks due to heterogeneity status and unrelated to the Fed asset purchases, and second, changes in the bank lending outcomes of banks that are not QE-exposed possibly due to changes in the economy that affects all banks, whether or not highly liquid (or highly solvent).[15][16] In Section 7 on further results, for completeness we show the results of a classical DiD model where we divide banks into two groups along the two dimensions of liquidity and capital.

In Table 2, we report the number of QE-exposed banks with low (control) and high (treatment group) solvency and liquid positions. The table shows that bank heterogeneity and exposure to asset purchases overlap only partly and that, as a result, bank heterogeneity is likely to have exerted a non-trivial impact on the response of bank lending to Fed's QE. There are 88 treated banks (MBS-exposed) in our sample that are highly liquid, while 148 are well-capitalized. We also report the bank size and lending for different groups of banks pre- and post-QE. Table 2 shows that MBS-exposed banks tend to be larger than TSY-exposed banks both in the pre and post-QE period. In addition, MBS-exposed banks with higher liquidity have increased their asset size in the post-QE period relatively more compared to the MBS-exposed control group banks. In Table 2, we also report statistics for the non QE-exposed banks. The non-TSY exposed banks experience an increase in bank size in the post-QE period, although the increase in bank lending remains relatively low.

5. Estimation results

Tables 3–4 present the results of our baseline specification, as outlined in Eq. (1), along two key dimensions of bank heterogeneity: solvency and liquidity, while Table 5 explores the portfolio reallocation mechanism.

5.1. Baseline results

In Table 3, columns (1) through (3) report the estimated effects of the baseline model on lending outcomes, distinguishing between banks with relatively high and low exposure to MBS, with liquidity pooled over the entire QE period. Columns (4) through (6) present analogous estimations, but instead differentiate banks based on their exposure to TSY rather than MBS.

The findings indicate that less liquid banks with high exposure to MBS significantly increase lending in all three categories — total, real estate, and C&I loans, as shown in the positive and statistically significant coefficients for γ_4. Compared to this group, highly liquid banks, i.e., banks defined as those above the 75th percentile in the distribution of liquid assets to total assets, increase lending, but to a lesser extent (coefficients for γ_7). In terms of magnitude, for 1 percent increase in Fed MBS purchases, low-liquid banks expand total lending by approximately 4.5 percent, high liquid banks increase loans by about 3.8 percent (the difference between γ_7 and γ_4 in column, Table 3) and therefore about 0.74 percentage points less than the low liquid banks. In contrast, when focusing on banks with high exposure to Treasury securities, (indicative of lower credit risk), columns (4) through (6) suggest that low liquid banks decrease lending more than their high liquid counterparts. Quantitatively, our findings suggest that a 1 percent increase in Treasury securities purchased by the Fed results in an approximately 2 percent decrease in total lending volume for less liquid banks, with the effect being 0.69 percent smaller for high liquid banks.

The effects reported in our estimates are significant. By comparison, Borio and Gambacorta (2017), based on a large cross-section of countries, find that during a low interest rate environment a 1 percentage point reduction in policy interest rate increased lending by 1.5 percent in the short run (within a year) and by 1.7 percent in the long-run. Similar results are also found in other studies, e.g. Gambacorta and Marques-Ibanez (2011).

Taken together, these findings suggest that bank liquidity plays a critical moderating role in the transmission of QE to bank lending.

[15] See Wooldridge (2010) for a detailed discussion on DDD specification and confounding trends.

[16] We also estimate the model as a DD and found results qualitatively similar to the DDD results that we present in Section 5 but generally stronger.

Table 3
The impact of MBS and TSY purchases on lending: Effect of bank liquidity.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0448**	0.0544**	0.0334*			
	(0.0189)	(0.0235)	(0.0170)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	−0.0074***	−0.0068***	−0.0055*			
	(0.0016)	(0.0020)	(0.0032)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0209**	−0.0096**	−0.0198*
				(0.0086)	(0.0040)	(0.0116)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0069**	0.0046*	0.0087**
				(0.0028)	(0.0023)	(0.0036)
Observations	5526	5490	5519	10,776	10,726	10,723
R-squared	0.4591	0.3721	0.1610	0.1215	0.1600	0.0852
Linear combination (γ_4 and γ_7) (p-value)	0.046	0.040	0.076	0.052	0.054	0.306
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 4
The impact of MBS and TSY purchases on lending: Effect of capital.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0388***	0.0285***	0.0457***			
	(0.0102)	(0.0100)	(0.0162)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	−0.0025**	−0.0028*	−0.0107**			
	(0.0011)	(0.0014)	(0.0045)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0142***	−0.0206***	0.0471***
				(0.0044)	(0.0059)	(0.0165)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0084***	0.0075***	−0.0025
				(0.0017)	(0.0018)	(0.0028)
Observations	5489	5510	5484	10,792	10,792	10,756
R-squared	0.2784	0.2269	0.0968	0.2736	0.2352	0.1087
Linear combination (γ_4 and γ_7) (p-value)	0.001	0.020	0.029	0.151	0.019	0.016
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times Assetpurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Specifically, highly liquid banks appear to respond less aggressively in their lending behaviour when holding riskier QE assets (such as MBS), while responding more favourably when exposed to safer assets (such as Treasuries). This highlights the importance of considering the interaction between bank-level liquidity and asset composition in assessing the efficacy of QE on credit supply.

Next, in Table 4, we show the lending results of the Fed QE purchases for high- and low-capitalized banks. We find that banks with a level of Tier I capital ratio above the 75th percentile of the distribution and high exposure to MBS purchases tend to increase lending (across total, real estate and C&I loans), but to a lower extent compared to low-capitalized banks. In terms of total lending, MBS-exposed banks with low capital increase lending by approximately 3.88 percent whereas MBS-exposed banks with high capital levels expand lending by about 3.6 percent (the difference between γ_7 and γ_4 in column 1, Table 4). For C&I loans, well-capitalized banks expand loans by about 2.5 percent, which is 1.2 percentage points less than banks with weaker capital positions. In contrast, banks that had a high exposure to Fed Treasury securities purchases but had a low level of bank capital reduce total and real estate lending. Such reduction is lower for highly capitalized banks for total and real estate loans. We do not find a consistent impact for C&I lending.

In summary, our findings reveal that the impact of QE on bank lending is non-linear and strongly conditioned by the interaction between banks' exposure to specific asset purchases and their balance sheet characteristics, particularly liquidity and solvency. Banks with high MBS-exposure (representing greater credit risk) and lower liquidity (or capital) expand lending significantly more than their highly liquid (or better capitalized) counterparts. This suggests that QE had a stronger stimulative effect on MBS-exposed banks with lower liquid/capital levels. In contrast, when examining banks with high exposure to Treasury securities, we find that banks with higher liquidity (or capital) reduce lending less than low liquid (or less capitalized) banks, indicating that stronger balance sheet positions may cushion the contractionary effects associated with holding safer but lower-yield assets. Notably, the effect on lending was more pronounced among low liquid/capital banks, highlighting a differentiated response even in the context of low-risk asset purchases.

It is important to note that the coefficient for γ_7 that captures the differential effects of QE based on bank heterogeneity, vary in sign and magnitude across specifications, reflecting the nuanced role of bank liquidity and solvency in shaping the lending response to QE. For instance, for banks with high MBS exposure, γ_7 is negative and statistically significant, indicating that high liquid or well-capitalized banks increase lending to a lesser extent than their low liquid or under-capitalized counterparts, while for banks with high exposure to Treasury securities, γ_7 is positive. These patterns point to a heterogeneous response of 'safer' banks to QE. The underlying reasons for these differential effects remain an open question.

We conjecture that one possible explanation for these findings may be related to how banks assess portfolio risk and engage in balance sheet re-balancing following QE asset purchases. Giansante et al. (2020) show that UK banks, following the Bank of England's QE, used the resulting liquidity to shift towards lower-risk securities such as government bonds. In our context, we find that banks with high exposure to MBS, which entails higher credit risk but at the same time high levels of capital (lower solvency risk), increase lending less than similarly exposed banks with weaker capital positions. This suggests that well-capitalized banks may have opted to use QE-induced liquidity to invest in safer assets rather than expanding lending, consistent with a conservative reallocation strategy. The fact that less capitalized banks with high MBS exposure appear to have increased lending more aggressively may reflect a form of risk-taking behaviour, whereby weaker banks leverage the balance sheet expansion induced by QE to strategically seeking higher returns through increased lending activities, in a manner consistent with portfolio rebalancing dynamics or even, in the extreme, a "gambling for resurrection" incentive.[17]

For banks primarily exposed to Treasury securities, which carry lower credit risk, the pattern is reversed. We find that highly capitalized banks reduce lending less than their lower-capital peers. For UK banks, Giansante et al. (2020) argue that if banks are not adequately capitalized, QE might have led to reallocation of assets towards assets with lower risk weights like government securities. Joyce and Spaltro (2014) suggest that low levels of bank capital may have limited the effectiveness of QE in the UK. This suggests that a stronger capital buffer may help mitigate the contractionary effect of Treasury purchases on lending, possibly because these banks are better positioned to maintain credit supply despite lower asset yields.

Overall, these results indicate that weaker banks tend to translate QE-induced liquidity into higher lending, while stronger banks may respond more conservatively. This underscores the importance of accounting for bank-level heterogeneity in interpreting the QE credit channel. Understanding why better-capitalized or more liquid banks do not respond more strongly or why banks respond asymmetrically depending on asset type warrants further investigation. In Section 6 we discuss the implications that bank heterogeneity may have on risk-taking.

5.2. Portfolio reallocation vs. Credit-risk easing mechanism

The divergent lending responses to Treasury vs. MBS purchases suggest two distinct transmission mechanisms. When the central bank purchases safe assets like Treasuries, banks, especially those facing tighter capital or liquidity constraints, tend to use the influx of reserves to accumulate safe assets rather than extend new loans. This portfolio reallocation effect is evidenced by the increased holdings of Treasuries among constrained banks during Treasury purchase episodes (columns 2 and 4 in Table 5), accompanied by subdued loan growth (Tables 3 and 4). In essence, large reserves injections from QE are absorbed as safe assets on bank balance sheets (which carry low-risk weights and ease regulatory pressures), crowding out the supply of new loans (Diamond et al., 2024). The double-interaction terms in Table 5 confirm this mechanism: during periods of Treasury purchases, banks' net accumulation of safe securities rises markedly, a pattern most pronounced for banks with binding constraints on capital or liquidity.

By contrast, when the central bank buys assets with higher credit risk, such as MBS, it effectively eases the' risk exposure of banks and stimulates credit supply, as seen in Tables 3 and 4 . These credit risk easing purchases remove or reduce the credit risk on bank balance sheets and compress yields on riskier assets, thereby encouraging banks to substitute towards lending. Consistent with this channel, we find that QE episodes focused on MBS saw a significant increase in loan origination by banks, with no corresponding increase in safe-asset holdings. Banks appear to deploy the liquidity from MBS sales into new lending rather than investing it in Treasuries. This finding aligns with previous evidence that QE rounds targeting MBS induced banks with high MBS exposure to expand lending, whereas QE rounds focused exclusively on Treasuries had no such impact on credit supply (Rodnyansky and Darmouni, 2017). Other studies have documented that banks benefiting from MBS purchases substantially increased credit origination (especially mortgages), whereas the effect of Treasury purchases on lending was negligible (Chakraborty et al., 2020). Taken together, these results support the view that Treasury QE primarily induces a portfolio shift into safe assets (dampening loan growth), while MBS QE relaxes banks' effective risk constraints and stimulates loan supply, explaining why MBS purchases boost lending whereas Treasury purchases can end up reducing it in net terms.

6. Implications for risk-taking

In Section 5, we show that the impact of QE on bank lending is influenced by the heterogeneity of the bank. But what are the implications of this heterogeneity? We argue that weaker banks may have expanded lending as a strategy to negotiate their way out of a vulnerable position, suggesting a mechanism similar to the risk-taking channel in conventional monetary policy. According to this channel, low policy rates lead banks and other financial institutions to take on greater risks in different ways. As weaker banks may take even more risk on by exhibiting a "gambling for resurrection behaviour" their collective behaviour may raise concerns about financial stability.

[17] Based on euro area data, Albertazzi et al. (2021) finds a similar mechanism at country-level. For a sample of euro area countries, they show that following QE the portfolio reallocation is concentrated in 'vulnerable' economies, resulting in more credit-risk taking.

Table 5
The impact of MBS and TSY purchases on Government Securities.

	Government securities			
	Liquidity		Capital	
	(1)	(2)	(3)	(4)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	−0.0005		0.0028	
	(0.0013)		(0.0023)	
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Heterogeneity_i^Q$	0.0002		−0.0009**	
	(0.0001)		(0.0004)	
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$		0.0055*		0.0084***
		(0.0033)		(0.0025)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Heterogeneity_i^Q$		0.0004		−0.0007
		(0.0003)		(0.0005)
Observations	5542	10,638	5542	10,869
R-squared	0.0610	0.1262	0.1405	0.1129
Linear combination (γ_4 and γ_7) (p-value)	0.824	0.104	0.408	0.001
Bank-level Controls	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is the ratio of treasury securities to total assets. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

The existing literature highlights that public subsidies on debt, such as cheaper borrowing costs, can lead to higher leverage, increased risk-taking, larger balance sheets, and greater systemic risk to society (see, for example, Admati et al., 2018). Empirical evidence on "gambling for resurrection" in the banking sector is mixed. For example, Ben-David et al. (2019) find that distressed US banks generally deleveraged rather than gambled for resurrection during periods surrounding the savings and loans crisis and global financial crisis of 2007–2009. In contrast, Koudstaal and van Wijnbergen (2012) find that banks with a more troubled loan portfolio tend to take on more risk and that banks whose share price has slumped were more likely to gamble for resurrection by increasing the riskiness of their asset portfolios. More recently, Jiang et al. (2023) find limited evidence of hedging and gambling for resurrection among U.S. banks during the 2022 monetary tightening.

Observing higher risk-taking in the banking sector, particularly among banks benefiting from QE is not necessarily a negative outcome. Indeed, one of the objectives of monetary policy is to stimulate lending and economic activity by encouraging 'productive' risk-taking, as noted in Bernanke (2012) and Kandrac and Schlusche (2021). However, if weaker banks engage in riskier lending more aggressively than their more stable counterparts, this reveals a possible downside of QE and potential risks to financial stability. Hence, we ask a key question: did weaker QE-exposed banks increase their risk-taking comparatively more than safer QE-exposed banks?

In this section, we investigate whether risk-taking differs significantly between banks with similar QE-exposure. As before, we distinguish between banks that differ in terms of their liquidity and capital positions. We employ both *ex-ante* and *ex-post* measures of risk-taking. Specifically, we analyse risk-taking behaviour by assessing the impact of QE on the riskiest types of loans, such as consumer loans, C&I loans, commercial real estate loans (CRE) and construction loans. If weaker banks indeed increase risk-taking, one would expect the share of risky loans to total loans to increase. Conversely, safer banks may expand less or even reduce their exposure to riskier lending.

Additionally, to further corroborate our results we consider *ex-post* risk-taking as measured by the share of non-performing loans (NPL) on total loans. If banks used the cheap liquidity from QE to significantly increase loans to high-risk borrowers, the likelihood of those loans becoming non-performing over time would increase. However, there is an intrinsic limitation of NPLs as an ex-post measure of risk-taking in our sample. As NPLs tend to be recognized as such with a delay and remain on bank balance sheets for extended periods, they may partly reflect lending specific to QE period (Ari et al., 2021).

In Table 6 we present the results of a DDD specification similar to Eq. (1), but with the dependent variable being risky loans, representing *ex-ante* risk-taking, in columns (1)-(2) whereas in columns (3)-(4) we show the estimates with the share of NPLs in total loans, representing *ex-post* risk-taking, as the dependent variable. We find that weaker banks, i.e. banks with lower liquidity positions, expanded riskier lending, thereby increasing *ex-ante* risk-taking. Safer banks - i.e., banks with higher liquidity or capital reserves — increase their riskier lending by about 1 percentage point less.

Moving next to NPLs, column (3) shows that the share of NPLs loans to total loans of banks characterized by lower liquidity increased significantly. This *ex-post* measure of risk-taking did not increase as much for highly liquid banks. Interestingly, in terms of capital, low-capital banks reduced ex-post risk-taking (column (4)) although they significantly increased it ex-ante (column(2)) whereas safer banks reduced NPLs by about 0.5 percent less than banks with weaker capital positions.

In sum, we find that weaker banks more aggressively engaged in higher-risk lending activities, suggesting that, following QE purchases, weaker bank incentives to use their increased capacity to lend may have not been fully matched with improving their risk-return trade-off for granting loans, with lower liquid banks also having a steep increase in NPLs.

7. Further results and robustness checks

7.1. Timing of the effects

The estimations of the DDD model in Eq. (1) require the parallel trend assumption to hold to return unbiased estimates of the causal effect of the QE implementation. The parallel trend assumption states that, conditional on the control variables, treated banks (QE-exposed banks that benefited from QE purchases) would have followed similar trends in the lending outcomes as the non-treated banks (non

Table 6
The impact of QE purchases on high-risk lending.

	Ex-ante risk taking (1)	(2)	Ex-post risk taking (3)	(4)
$QEpurchases_{t-4} \times Treat_i^{QE^Q}$	0.0383**	0.1285***	0.1884**	−0.0691*
	(0.0178)	(0.0292)	(0.0724)	(0.0422)
$QEpurchases_{t-4} \times Treat_i^{QE^Q} \times Liquidity_i^Q$	−0.0077**		−0.0507***	
	(0.0035)		(0.0118)	
$QEpurchases_{t-4} \times Treat_i^{QE^Q} \times Capital_i^Q$		−0.0113*		0.0327***
		(0.0066)		(0.0056)
Observations	5758	5749	5704	6073
R-squared	0.1062	0.1355	0.1094	0.0948
Linear combination (γ_4 and γ_7) (p-value)	0.091	0.000	0.059	0.377
Bank-level Controls	Yes	Yes	Yes	Yes
Treat X Asset Purchases X Bank Controls	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (2) is logarithm of high-risk loans (commercial & industrial loans, consumer loans, commercial real estate, construction loans), while in columns (3) and (4) is the logarithm of non-performing loans. $Treat_i^{QE}$ is a dummy that takes the value one for banks in the top 25th percentile of the sum of MBS-to-total assets and treasury securities-to-total assets, and zero for banks in the bottom 25th percentile of this distribution. $QEpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

QE-exposed banks that did not benefited from QE purchases), distinguishing by liquidity and solvency (capital). This assumption is not directly testable because we cannot observe the counterfactual evolution of the outcomes. However, it can be supported by testing if liquid and non-liquid banks in the treated and control groups followed parallel trends before QE.

To further corroborate our results and the causal relationships between bank lending, QE and bank heterogeneity, we check that there is no significant "treatment" effect before QE implementation by examining the dynamic relationship between the treatment group and bank lending. The dynamic specification reduces concerns that banks in the control and treatment group were experiencing different pre-existing trends in lending prior to QE implementation. More specifically, we estimate the model as in Eq. (2), which applies the DiD approach to data, including pre-QE period and add to the specification interaction terms between each pre-QE period (quarter) and the treatment group indicators:

$$Y_{i,j,t} = \alpha_i + \beta_{j,t} + \sum_t \gamma_t D_t + \sum_t \theta_t D_t \times Treat_i \times Heterogeneity_i^h + \delta' X_{i,t} + \epsilon_{i,t}, \quad (2)$$

where, as before, $Y_{i,j,t}$ is the lending outcome, α_i and $\beta_{j,t}$ are bank and state-time fixed effects, respectively. $Treat_i$ is a dummy that equals one for banks in top quartile of the combined MBS and TSY-to-total assets distribution, and zero for banks in the 25th percentile and D_t is a vector of dummy variables for each $t \in \{2007Q1, 2007Q2, \dots, 2014Q4\}/\{2008Q3\}$, with 2008Q3 taken as the benchmark period.

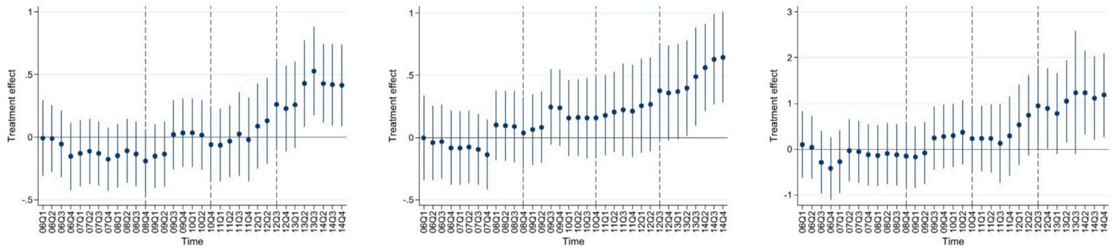
$D_t \times Treat_i \times Heterogeneity_i^h$ represents an interaction term between the time indicators, bank's treatment status and bank heterogeneity. The main parameters of interest are θ_t as they capture the difference between treated and control group banks over time. $X_{i,t}$ is a vector of control variables that includes bank size, ratio of liquid assets to total assets, ratio of equity to total assets and return on assets. $X_{i,t}$ variables are introduced as lagged variables and interacted with $Treat_i$ and the vector of time dummies.

The quarter-by-quarter dynamic effect of QE is shown in Figs. 3 and 4. Fig. 3 shows the estimated coefficients for the triple interaction term for the pre-treatment and post-treatment period for the liquidity dimension of $Heterogeneity_i^h$, with 90% confidence intervals around them. Fig. 4 shows the effect for capital, the second dimension of $Heterogeneity_i^h$. Figs. 3(a) and 4(a) refer to total lending, Figs. 3(b) and 4(b) relate to real estate loans, while Figs. 3(c) and 4(c) are plots C&I lending. The figures illustrate several important points. First, the treated and control group banks in the pre-QE period show no robust differences, reducing the concern that differences in the pre-existing trends between the groups are driving the results. Second, more significant exposure to QE is significantly related to an increase in bank lending in the post-QE period. Third, consistent with a gradual transmission of QE into bank lending, the figures show that for banks with high capital levels, most of the increase in total lending, real estate, and C&I loans occurs after the implementation of QE2, although some oscillations are present between QE1 and QE2. In contrast, for high liquidity banks, significant increases in lending across all three categories of loans become evident primarily after QE3. Finally, both figures show that the largest impact of QE on bank lending occurred during the QE3 round. The latter result is in line with previous findings in the literature.

7.2. Propensity score matching

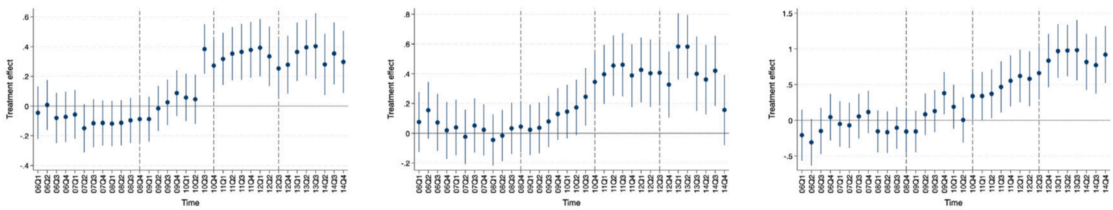
To ensure that our results are not driven by observable differences in bank characteristics between treated and control groups, we perform a robustness check using weights from propensity scores in our regressions. As shown in Table 1, treated banks differ systematically from control banks in several pre-treatment dimensions. If left unaddressed, these differences may bias our estimates of the effect of QE-exposure on bank lending.

We address this concern by implementing Propensity Score Matching (PSM) using kernel-matching method. Specifically, we begin by estimating a probit model in which the treatment indicator is regressed on a set of pre-treatment bank characteristics. These covariates include the logarithm of total assets, loan-to-deposit ratio, return on assets, wholesale funding, and the ratio of non-performing loans (NPLs). The resulting propensity scores represent the estimated probability of a bank receiving the treatment, conditional on these observed characteristics. Using kernel matching, each treated bank is matched with



(a) Total Lending (b) RE Lending (c) C&I Lending

Fig. 3. Timing of effects.
Notes: The figure shows coefficient plots for the parameters θ in Eq. (2) for liquidity with 90% confidence intervals. The vertical lines indicate the start of each episode of quantitative easing.



(a) Total Lending (b) RE Lending (c) C&I Lending

Fig. 4. Timing of effects.
Notes: The figure shows coefficient plots for the parameters θ in Eq. (2) for capital with 90% confidence intervals. The vertical lines indicate the start of each episode of quantitative easing.

a weighted average of control banks, where weights are inversely proportional to the distance in propensity scores, allowing for the use of all available observations and improving efficiency in estimating the treatment effect.

Following the matching procedure, we re-estimate our baseline difference-in-differences specification on the matched sample. The results (reported in Tables 7 and 8) remain qualitatively and statistically similar to our main findings, suggesting that our treatment effects are not driven by pre-existing differences in bank fundamentals. This exercise strengthens the causal interpretation of our results by ensuring a more balanced comparison between the treated and control banks.

7.3. Other robustness checks

In this section, we discuss a series of robustness tests to further support our empirical findings with respect to (i) varying definitions of treatment and control groups, (ii) alternative measures of liquidity and capital, and (iii) defining treatment and control banks on a rolling-basis to investigate the differential impact of the policy across banks.

7.3.1. Alternative definitions of treatment and control group

In addition to our treatment and control variables constructed based on quartile values of mortgage-backed securities and treasury securities (both scaled by total assets), we re-define our treatment variable, first based on decile values of MBS-to-total assets as well as for Treasury securities. We define a treated group as banks that are in the top 90th percentile of the MBS-to-total assets distribution, while the control group is in the bottom 10th percentile of this distribution. The results for treatment variable constructed based on deciles are reported in Figs. 5 and 6 for liquidity and capital, respectively. Consistent with our main results, we find that the three-way interaction terms for treatment, securities purchases (MBS in Panel 5(a) and 6(a), while TSY in Panel 5(b) and 6(b)) and heterogeneity are qualitatively similar to the baseline regressions and we find largely unchanged results in terms of statistical significance.

Second, we also employ continuous measure of MBS-total assets and Treasury securities to total assets distribution. The results are reported in Tables 9 and 10 pertaining to liquidity and capital, respectively. The magnitude and statistical significance of the coefficients is stronger across all specifications.

7.3.2. Alternative measures of liquidity and capital

We run robustness tests by taking alternative measures for bank liquidity and capital and find similar results to baseline estimates. While, in our main results, we measure liquidity as the ratio of cash balances and federal funds sold to total assets, in our robustness checks, we only take the ratio of cash balances to total assets as a measure for liquidity. Since cash is the most liquid assets out of all the liquid asset class, we believe this measure will closely measure a bank's liquidity. The results are presented in Table 11 and are largely consistent with our main analysis.

We also employ the ratio of equity to total assets as an alternative measure for bank capital and find the results are qualitatively similar to our baseline estimates. While tier I risk-based capital ratio compares bank equity to their risk-weighted assets that are specified under the Basel III accord, equity to assets ratio takes total assets as a whole in the denominator. The results are presented in Table 12 and are qualitatively similar to our baseline findings.

7.3.3. Constructing treatment and control groups on rolling-basis

The choice of time period 2007:Q4 that is well before the QE policy interventions reduces concerns about potential endogeneity. The MBS threshold is defined in a particular quarter so that we are able to track the effects for the same set of banks over time. As an alternative for robustness checks, we take the lag of MBS-to-total assets and TSY-to-total assets for each year and construct the treatment and control groups based on top 25% and bottom 25% respectively. We follow Chakraborty et al. (2020) and construct our treatment variables on rolling basis as opposed to a specific quarter prior to the implementation of QE, i.e., 2007Q4. Tables 13 and 14 relates to taking treatment and control

Table 7
Robustness Table 3 using matching techniques.

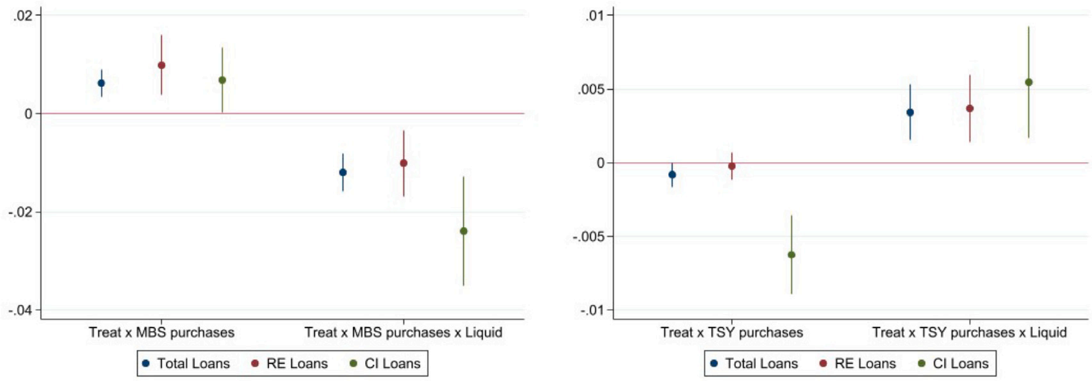
	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0636***	0.0693***	−0.0230			
	(0.0129)	(0.0151)	(0.0136)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	−0.0086***	−0.0081***	−0.0062**			
	(0.0015)	(0.0019)	(0.0026)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0216**	−0.0236**	−0.0206**
				(0.0084)	(0.0090)	(0.0079)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0078***	0.0093***	0.0038
				(0.0028)	(0.0029)	(0.0026)
Observations	5500	5464	5780	10,646	10,609	10,606
R-squared	0.4620	0.4104	0.1204	0.1367	0.1227	0.0900
Linear combination (γ_4 and γ_7) (p-value)	0.000	0.000	0.049	0.051	0.055	0.027
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Table shows coefficient estimates in Eq. (1) where dependent variable in columns (1) and (4) is log of total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. Data is weighted using propensity scores based on total assets, loan-to-deposit ratio, wholesale funding and non-performing loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 8
Robustness Table 4 using matching techniques.

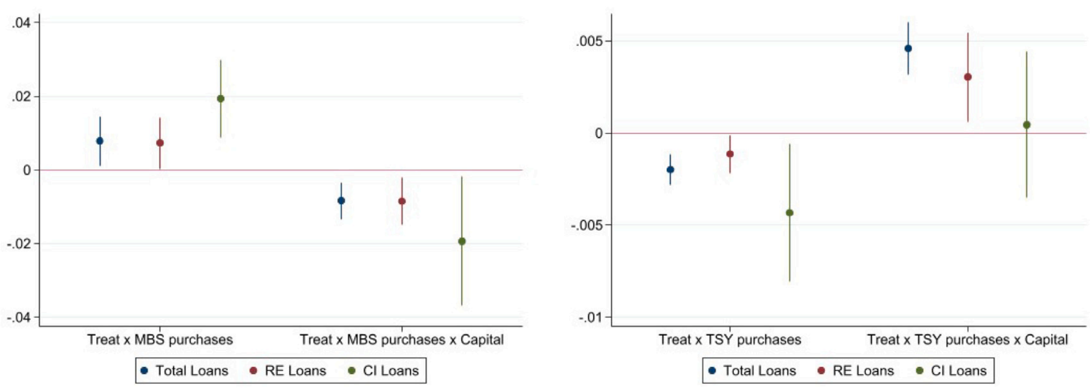
	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0290***	0.0314***	0.0655***			
	(0.0086)	(0.0103)	(0.0192)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	−0.0054*	−0.0053*	−0.0104			
	(0.0029)	(0.0029)	(0.0064)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0142***	−0.0192***	0.0052
				(0.0032)	(0.0047)	(0.0105)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0084***	0.0085***	−0.0049*
				(0.0016)	(0.0018)	(0.0026)
Observations	5468	5468	5463	10,661	10,661	10,625
R-squared	0.2781	0.2532	0.1165	0.1967	0.1605	0.0960
Linear combination (γ_4 and γ_7) (p-value)	0.008	0.015	0.007	0.083	0.021	0.971
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Table shows coefficient estimates in Eq. (1) where dependent variable in columns (1) and (4) is log of total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. Data is weighted using propensity scores based on total assets, loan-to-deposit ratio, wholesale funding and non-performing loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.



(a) MBS purchases (b) TSY purchases

Fig. 5. Robustness (Liquidity): Treatment variable based on Deciles.
Notes: The figure shows coefficient plots for γ_4 and γ_7 in Eq. (1), where dependent variable is total loans (blue), RE loans (red) and C&I loans (green). In both (a) and (b), the first three coefficients relate to γ_4, i.e., the interaction term between asset purchases and treatment variable, while the last three coefficients relate to γ_7, i.e., that captures the interaction term between asset purchases, treatment status and bank *liquidity*. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



(a) MBS purchases (b) TSY purchases

Fig. 6. Robustness (Capital): Treatment variable based on Deciles.
Notes: The figure shows coefficient plots for γ_4 and γ_7 in Eq. (1), where dependent variable is total loans (blue), RE loans (red) and C&I loans (green). In both (a) and (b), the first three coefficients relate to γ_4, i.e., the interaction term between asset purchases and treatment variable, while the last three coefficients relate to γ_7, i.e., that captures the interaction term between asset purchases, treatment status and bank *capital*. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

group on rolling basis for liquidity and solvency, respectively. Taking treatment definitions in alternative quarters yields results qualitatively similar to baseline estimates.

8. Conclusions

In this paper, we present novel empirical evidence on how bank heterogeneity influences lending behaviour during periods of unconventional monetary policy. Our results contribute to a small literature on QE and bank lending while also addressing a gap in the existing literature on bank heterogeneity and monetary policy.

By leveraging the precise timing of the Fed QE programme implementation, we differentiate between QE-exposed and non-QE-exposed US banks and estimate the impact of QE policy intervention on lending outcomes, differentiating between heterogeneous banks. To achieve a consistent estimate of the interaction between asset purchases, bank's exposure to the MBS or Treasuries purchases and bank heterogeneity, we use an augmented difference-in-difference approach (DDD).

We find that within the QE-exposed banks (treated group), the Fed's asset purchases under QE led to increased lending primarily among weaker banks, i.e banks with high asset-risk exposure and lower liquidity or capital levels. More specifically, banks with significant MBS-exposure and low liquidity/solvency expanded their lending significantly more compared to their safer counterparts. In contrast, Treasury-exposed banks reduced lending, but those with stronger capital positions reduced lending less.

The increased capacity to lend of weaker banks may not necessarily have corresponded to an improved risk-return trade-off. We show that

Table 9
Continuous measure of MBS-to-total assets and TSY-to-total assets: Effect of bank liquidity.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i}$	0.1622*	0.1565*	0.1530**			
	(0.0809)	(0.0863)	(0.0573)			
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i} \times Liquidity_i^Q$	−0.0192**	−0.0186*	−0.0379*			
	(0.0080)	(0.0098)	(0.0201)			
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i}$				−0.0576	−0.0427	−0.2626**
				(0.0463)	(0.0567)	(0.1112)
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i} \times Liquidity_i^Q$				0.0279*	0.0294**	0.0368*
				(0.0152)	(0.0138)	(0.0208)
Observations	10,668	10,726	11,186	11,224	11,217	11,186
R-squared	0.3578	0.1896	0.1800	0.3377	0.2856	0.1043
Linear combination (γ_4 and γ_7) (p-vaue)	0.66	0.095	0.045	0.557	0.811	0.055
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $\frac{MBS}{Assets_i}$ and $\frac{TSY}{Assets_i}$ is the ratio of MBS-to-total assets and treasury securities to total assets in 2007Q4. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 10
Continuous measure of MBS-to-total assets and TSY-to-total assets: Effect of bank capital.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i}$	0.1004**	0.1087***	−0.0797			
	(0.0365)	(0.0346)	(0.0481)			
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i} \times Capital_i^Q$	−0.0301***	−0.0320***	−0.0509**			
	(0.0054)	(0.0084)	(0.0247)			
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i}$				−0.1470***	−0.1492***	−0.9420***
				(0.0388)	(0.0392)	(0.2742)
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i} \times Capital_i^Q$				0.0648***	0.0524***	0.0460**
				(0.0109)	(0.0099)	(0.0208)
Observations	10,869	10,839	11,304	11,340	11,340	11,338
R-squared	0.5024	0.4057	0.1916	0.3642	0.3010	0.2351
Linear combination (γ_4 and γ_7) (p-value)	0.051	0.035	0.010	0.018	0.011	0.002
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $\frac{MBS}{Assets_i}$ and $\frac{TSY}{Assets_i}$ is the ratio of MBS-to-total assets and treasury securities to total assets in 2007Q4. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 11
Alternative measure of bank liquidity.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0435**	0.0549**	−0.0207			
	(0.0165)	(0.0211)	(0.0250)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	−0.0038**	−0.0029	0.0036			
	(0.0015)	(0.0018)	(0.0039)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0065**	−0.0194**	0.0539*
				(0.0028)	(0.0080)	(0.0297)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0016*	0.0042***	−0.0036
				(0.0016)	(0.0012)	(0.0032)
Observations	5495	5488	5545	10,782	10,774	10,811
R-squared	0.3872	0.3827	0.1851	0.1513	0.4357	0.1485
Linear combination (γ_4 and γ_7) (p-value)	0.017	0.014	0.518	0.030	0.055	0.108
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of *cash to total assets* prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 12
Alternative measure of bank capital.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0042	0.0163	−0.0378			
	(0.0155)	(0.0243)	(0.0227)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	−0.0044***	−0.0031**	−0.0026			
	(0.0014)	(0.0014)	(0.0023)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0411***	−0.0345***	−0.0465***
				(0.0071)	(0.0109)	(0.0119)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0013**	0.0020**	0.0004
				(0.0006)	(0.0009)	(0.0014)
Observations	5119	5087	5033	10,740	10,772	11,287
R-squared	0.2289	0.1975	0.1877	0.7201	0.2848	0.1164
Linear combination (γ_4 and γ_7) (p-value)	0.993	0.603	0.103	0.000	0.005	0.001
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets ratio, and zero for banks in the bottom 25th percentile. $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the top 25th percentile of the treasury securities-to-total assets ratio, and zero for banks in the bottom 25th percentile of the distribution. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of equity to total assets prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, cash-to-assets ratio, loan to deposits ratio and return on assets. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 13
MBS-to-total assets and TSY-to-total assets on rolling basis: Effect of bank liquidity.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	−0.0418***	−0.0326***	−0.0627***			
	(0.0097)	(0.0099)	(0.0166)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	0.0043**	0.0046***	0.0074***			
	(0.0016)	(0.0016)	(0.0021)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0131**	−0.0249**	−0.0483**
				(0.0059)	(0.0110)	(0.0233)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0009	0.0033*	−0.0044
				(0.0008)	(0.0017)	(0.0032)
Observations	10,632	10,625	10,594	10,630	10,638	10,600
R-squared	0.1672	0.1650	0.0807	0.8081	0.3229	0.2757
Linear combination (γ_4 and γ_7) (p-value)	0.000	0.003	0.002	0.033	0.046	0.022
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the treatment group based on MBS-to-total assets ratio, and zero for control banks. Similarly, $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the treatment group based on the treasury securities-to-total assets ratio, and zero for control banks. Both treatment variables are constructed on the rolling basis. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 14
MBS-to-total assets and TSY-to-total assets on rolling basis: Effect of bank capital.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	−0.0267***	−0.0370***	−0.0439***			
	(0.0090)	(0.0130)	(0.0153)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	0.0046**	0.0048**	0.0077***			
	(0.0017)	(0.0023)	(0.0016)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0153**	−0.0175**	−0.0360*
				(0.0068)	(0.0088)	(0.0206)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0027**	0.0026*	0.0045*
				(0.0011)	(0.0014)	(0.0023)
Observations	10,738	10,708	10,700	10,692	10,692	10,749
R-squared	0.2227	0.2064	0.1133	0.7467	0.6377	0.2936
Linear combination (γ_4 and γ_7) (p-value)	0.007	0.009	0.020	0.059	0.082	0.146
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4} \times$ Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ is a dummy that takes the value one for banks in the treatment group based on MBS-to-total assets ratio, and zero for control banks. Similarly, $Treat_i^{TSY}$ is a dummy that takes the value one for banks in the treatment group based on the treasury securities-to-total assets ratio, and zero for control banks. Both treatment variables are constructed on the rolling basis. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. p-values correspond to tests of the linear combination of coefficients (γ_4 and γ_7). Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 15

Variable name	Definition	Data sources	Acronym
Main variables			
Mortgage backed securities	Residential pass-through securities + other residential MBS + commercial MBS	FR-Y9C	MBS
Treasury Securities	U.S. Treasury securities + U.S. government agency obligations + securities issued by states and political subdivisions in the U.S.	FR-Y9C	TSY (used as "TSY exposure" or "TSY securities" in text)
MBS Purchases	Amount of MBS purchased by the Federal Reserve in a given quarter	New York Fed	–
Treasury Purchases	Amount of Treasury securities purchased by the Federal Reserve in a given quarter	New York Fed	–
Dependent variables			
Total lending	Logarithm of total loans	FR-Y9C	–
Real estate lending	Logarithm of loans secured by real estate	FR-Y9C	RE lending
Commercial and industrial lending	Logarithm of commercial and industrial loans to U.S. and non-U.S. addresses	FR-Y9C	C & I lending
High-risk loans	C&I loans + consumer loans + commercial real estate + construction loan	FR-Y9C	–
Bank-level controls			
Bank Size	Logarithm of total assets	FR-Y9C	–
Tier 1 Capital risk-based ratio	Tier 1 capital (Common equity tier 1 (CET1) capital and additional tier 1 capital:) divided by Total risk-weighted assets	FR-Y9C	–
Equity ratio	Total equity capital divided by total assets	FR-Y9C	–
Liquidity	Cash and balances due from depository institutions: non interest bearing balances and currency and coin + federal funds sold divided by total assets	FR-Y9C	–
Cash-to-assets ratio	Cash and balances due from depository institutions divided by total assets	FR-Y9C	–
Loan-to-deposit ratio	Total loans divided by Non-interest bearing deposits in domestic offices + interest-bearing deposits in domestic offices + non-interest bearing deposits in foreign offices	FR-Y9C	–
Wholesale funding	Fed funds purchased and repurchase agreements + other borrowed funds + subordinated debt + brokered deposits less than $100,000 with a remaining maturity of one year or less + brokered deposits less than $100,000 with a remaining maturity of more than one year	FR-Y9C	–
Return on assets	Ratio of net income to total assets	FR-Y9C	–
Non-performing loans -to-total assets	Non-performing loans (loans 90+ days past due and still accruing + loans in nonaccrual status) divided by total assets	FR-Y9C	NPL
Securities (held to maturity)	Held to maturity securities (not marked-to-market under accounting rules) divided by total assets	FR-Y9C	HTM (securities)
Securities (available for sale)	Available for sale securities (securities marked-to-market under accounting rules) divided by total assets	FR-Y9C	AFS (securities)

Notes: Table presents data sources and method of construction of variables used in analysis. FR-Y9C refers to balance sheet information of all BHCs from Federal Reserve Bank of Chicago. New York Fed refers to outright purchases and sales of MBS and treasury securities data during large-scale asset purchases between 2008 and 2014.

Table 16
The impact of MBS and TSY purchases on lending: Effect of bank liquidity.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0554*	0.0396*	0.0488			
	(0.0294)	(0.0223)	(0.0398)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	−0.0051**	−0.0059*	−0.0002			
	(0.0019)	(0.0033)	(0.0056)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0072*	−0.0081*	−0.0074
				(0.0037)	(0.0040)	(0.0052)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0065*	0.0065*	0.0058*
				(0.0037)	(0.0038)	(0.0031)
Observations	2815	2793	2804	5730	5712	5709
R-squared	0.4022	0.3724	0.1841	0.1408	0.1268	0.0655
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ ($Treat_i^{TSY}$)is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets (treasury securities-to-total assets) ratio, and zero for banks in the bottom 25th percentile of the ratio. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Liquidity_i^Q$ is a dummy variable that equals one for banks in the top 25% of ratio of liquid assets to total assets prior to the implementation of QE (liquid banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (illiquid banks). Bank-level controls include bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 17
The impact of MBS and TSY purchases on lending: Effect of capital.

	Total loans (1)	RE loans (2)	C & I loans (3)	Total loans (4)	RE loans (5)	C & I loans (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0313**	0.0040	0.0360**			
	(0.0134)	(0.0075)	(0.0139)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	−0.0032	−0.0039*	−0.0149*			
	(0.0021)	(0.0019)	(0.0075)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				−0.0181***	−0.0266***	−0.1285**
				(0.0060)	(0.0080)	(0.0546)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0075**	0.0058**	0.0010
				(0.0026)	(0.0026)	(0.0022)
Observations	2784	2794	2913	5732	5732	5692
R-squared	0.4908	0.2154	0.1151	0.2760	0.2334	0.2687
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
$Treat_i^Q \times AssetPurchases_{t-4}$ × Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$State \times Time$ Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1) and (4) is log of Total lending, in columns (2) and (5) is the log of real estate loans and in columns (3) and (6) is the log of C&I loans. $Treat_i^{MBS}$ ($Treat_i^{TSY}$)is a dummy that takes the value one for banks in the top 25th percentile of the MBS-to-total assets (treasury securities-to-total assets) ratio, and zero for banks in the bottom 25th percentile of the ratio. $MBSpurchases_{t-4}$ and $TSYpurchases_{t-4}$ is the lagged quarterly log-dollar amount of Federal Reserve MBS and Treasury (TSY) purchases, respectively. $Capital_i^Q$ is a dummy variable that equals one for banks in the top 25% of Tier I risk-based capital ratio prior to the implementation of QE (well-capitalized banks), i.e., 2007Q4, zero for banks in the bottom 25% of the distribution (under-capitalized banks). Bank-level control includes bank size, Tier I risk-based capital ratio, loan to deposits ratio, return on assets, logarithm of non-performing loans, share of wholesale funding and securities (held to maturity) to total assets. Benchmark lending (for definition, see Appendix A) is introduced as a control variable, but not interacted with treatment or QE exposure, as doing so would risk conflating demand-side variation with supply-side behaviour. Constant terms included, but not reported. Robust standard errors clustered at quarter-year, shown in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

especially weaker banks increased their risk-taking by engaging in higher-risk lending activities, thereby highlighting a downside of QE and a potential risk to financial stability. Our results shed light on the critical role that the interaction of bank QE-exposure and bank heterogeneity plays in reinforcing or offsetting the effects of QE on bank lending.

Looking ahead, policymakers face the challenge of appropriately timing the phase-out of QE programmes and support measures while also addressing gaps in the current understanding of QE policy design. More broadly, our findings provide insights for interpreting the effects of unconventional monetary policy and understanding how future monetary policies may influence lending outcomes across different types of banks.

CRediT authorship contribution statement

Marianna Blix Grimaldi: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Supriya Kapoor:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Appendix A. Variables definitions and acronyms

See Table 15.

Appendix B. Sub-sample analysis

See Tables 16–17.

Data availability

Data will be made available on request.

References

Acharya, V.V., Crosignani, M., Eisert, T., Eufinger, C., 2024. Zombie credit and (dis-)inflation: evidence from europe. J. Financ. 79 (3), 1883–1929.
Admati, A.R., DeMarzo, P.M., Hellwig, M.F., Pfleiderer, P., 2018. The leverage ratchet effect. J. Financ. 73 (1), 145–198.
Albertazzi, U., Becker, B., Boucinha, M., 2021. Portfolio rebalancing and the transmission of large-scale asset purchase programs: Evidence from the euro area. J. Financ. Intermediation 48, 100896.
Altunbas, Y., Gambacorta, L., Marques-Ibanez, D., 2010. Does monetary policy affect bank risk-taking?.
Ari, A., Chen, S., Ratnovski, L., 2021. The dynamics of non-performing loans during banking crises: A new database with post-COVID-19 implications. J. Bank. Financ. 133, 106140.
Ben-David, I., Palvia, A.A., Stulz, R.M., 2019. Do distressed banks really gamble for resurrection? Technical report, National Bureau of Economic Research.
Berger, A.N., Sedunov, J., 2017. Bank liquidity creation and real economic output. J. Bank. Financ. 81 (C), 1–19.
Bernanke, B., 2012. Monetary Policy since the Onset of the Crisis: a speech at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming, August 31, 2012. Technical report, Board of Governors of the Federal Reserve System (US).
Borio, C., Gambacorta, L., 2017. Monetary policy and bank lending in a low interest rate environment: diminishing effectiveness? J. Macroecon. 54, 217–231.
Borio, C., Zhu, H., 2012. Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism? J. Financ. Stab. 8 (4), 236–251.
Brunnermeier, M., Yogo, M., 2009. A note on liquidity risk management. Am. Econ. Rev. 99 (2), 578–583.
Caniglia, E.C., Murray, E.J., 2020. Difference-in-difference in the time of cholera: a gentle introduction for epidemiologists. Curr. Epidemiol. Rep. 7, 203–211.
Chakraborty, I., Goldstein, I., MacKinlay, A., 2020. Monetary stimulus and bank lending. J. Financ. Econ. 136 (1), 189–218.
Chen, H., Curdia, V.J., Ferrero, A., 2012. The macroeconomic effects of large-scale asset purchase programmes. Econ. J. 122 (564), 289–315.
Di Maggio, M., Kermani, A., Palmer, C.J., 2020. How quantitative easing works: Evidence on the refinancing channel. Rev. Econ. Stud. 87 (3), 1498–1528.
Diamond, W., Jiang, Z., Ma, Y., 2024. The reserve supply channel of unconventional monetary policy. J. Financ. Econ. 159, 103887.
Gambacorta, L., Marques-Ibanez, D., 2011. The bank lending channel: lessons from the crisis. Econ. Policy 26 (66), 135–182.
Giansante, S., Fatouh, M., Ongena, S.R., 2020. Does quantitative easing boost bank lending to the real economy or cause other bank asset reallocation? The case of UK. Bank Engl. Work. Pap. (883).
Gropp, R., Heider, F., 2010. The determinants of bank capital structure. Rev. Financ. 14 (4), 587–622.
Gruber, J., 1994. The incidence of mandated maternity benefits. Am. Econ. Rev. 622–641.
Imbens, G.W., Wooldridge, J.M., 2009. Recent developments in the econometrics of program evaluation. J. Econ. Lit. 47 (1), 5–86.
Ioannidou, V., Ongena, S., Peydró, J.-L., 2015. Monetary policy, risk-taking, and pricing: Evidence from a quasi-natural experiment. Rev. Financ. 19 (1), 95–144.
Jiang, E.X., Matvos, G., Piskorski, T., Seru, A., 2023. Limited hedging and gambling for resurrection by US banks during the 2022 monetary tightening? Available At SSRN 4410201.
Joyce, M., Spaltro, M., 2014. Quantitative easing and bank lending: a panel data approach.
Kandrac, J., Schlusche, B., 2021. Quantitative easing and bank risk taking: evidence from lending. J. Money, Credit. Bank. 53 (4), 635–676.
Kashyap, A.K., Stein, J.C., 1994. Monetary policy and bank lending. In: Monetary Policy. The University of Chicago Press, pp. 221–261.
Kim, D., Sohn, W., 2017. The effect of bank capital on lending: Does liquidity matter? J. Bank. Financ. 77, 95–107.
Koudstaal, M., van Wijnbergen, S., 2012. On risk, leverage and banks: do highly leveraged banks take on excessive risk? Duisenberg Sch. Finance-Tinbergen Inst. Discuss. Pap. TI 12–022.
Molyneux, P., Reghezza, A., Xie, R., 2019. Bank margins and profits in a world of negative rates. J. Bank. Financ. 107, 105613.
Olden, A., Møen, J., 2022. The triple difference estimator. Econom. J. 25 (3), 531–553.
Orame, A., Ramcharan, R., Robatto, R., 2025. Macroprudential regulation, quantitative easing, and bank lending. Rev. Financ. Stud. 38 (5), 1545–1593.
Osborne, M., Fuertes, A.-M., Milne, A., 2017. In good times and in bad: Bank capital ratios and lending rates. Int. Rev. Financ. Anal. 51, 102–112.
Raupach, P., Memmel, C., 2021. Banks' credit losses and lending dynamics.
Rodnyansky, A., Darmouni, O.M., 2017. The effects of quantitative easing on bank lending behavior. Rev. Financ. Stud. 30 (11), 3858–3887.
Thornton, J., Di Tommaso, C., 2020. Liquidity and capital in bank lending: Evidence from European banks. Financ. Res. Lett. 34, 101273.
Wooldridge, J.M., 2010. Econometric Analysis of Cross Section and Panel Data. MIT Press.