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428

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Fed QE and bank lending behaviour: a heterogeneity analysis of asset purchases*

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Sveriges Riksbank Working Paper Series
No.428

November 1, 2023

Abstract

Though unconventional monetary policy is still new, already there is a conventional wisdom that the impact of monetary policy is related to the composition of the asset mix. This turns out to be incomplete and potentially misleading. In this paper, we find more complex effects on bank lending from Quantitative Easing (QE) introduced by the Federal Reserve Bank in 2008. The novelty of our approach is to augment the model with bank-level heterogeneity. While there is a relation between lending and the type of assets purchased by the central bank, the impact on similarly QE-exposed banks is also crucially dependent on banks' solvency and liquidity exposures. Our results highlight that it is necessary to take heterogeneity of exposure into account when assessing the effects of QE.

Keywords: large-scale asset purchases, Federal Reserve, quantitative easing, heterogeneity, liquidity, solvency

JEL codes: E52, E58, G21

*We thank seminar participants at the Sveriges Riksbank for their helpful comments and suggestions. The views expressed in this paper are the sole responsibility of the authors and should not be interpreted as reflecting the views or policies of Sveriges Riksbank or the Swedish National Debt Office.

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1 Introduction

In the wake of the global financial crisis of 2007-09, the Federal Reserve (FED) began large-scale asset purchase programs (LSAPs), commonly known as "quantitative easing" (QE). With QE, the central bank expanded its balance sheet by creating money in the form of bank reserves and used them to buy government bonds and other financial assets from the private sector. The FED - as well as other major central banks that resorted to the same policy - adopted QE because cuts in the monetary policy rates near to their floor of zero were deemed insufficient to counter the deflationary and contractionary forces brought about by the crisis. The stated aim of QE policies was to reduce the cost of borrowing money over the long-term and, by so doing, support and stabilize the economy, making it easier for households to borrow money and for firms to stay in business, invest and safeguard the labor market. Under QE, the FED bought a combined amount of $4.5 trillion of assets thereby expanding its balance sheet considerably.

In 2017, the FED started to unwind and reverse its QE with quantitative tightening (QT), thereby contracting the balance sheet. The policy was paused in 2019. The Covid-19 pandemic pushed the FED (and other central banks) to increase monetary expansion and QT was restarted as late as in June 2022. The pace of QT is more cautious than the expansion of QE during the crisis. Hence, as a result of QT, it may take longer time to restore central banks' balance sheet back to pre-crisis levels.

Fifteen years from the FED's first QE program, it has been hard to assess the impact of QE and possibly, by extension, QT. Researchers have studied the effects of QE programs on financial conditions and yield curve as well as on macroeconomic outcomes such as output and inflation extensively. Results about the effectiveness of QE have been mixed (Chen et al., 2012; Acharya et al., 2020), among others. Surprisingly though, the impact of QE on *volumes*, and more precisely, on bank lending has instead remained an under-researched area. More importantly, only few studies take explicitly into account the potential heterogeneity of the banking sector and therefore the plausible differential effect that QE can exert on banks with different risk profiles. Moreover, during its three rounds of the QE program, the FED purchased securities that differed substantially in terms of type and by amount. It mainly bought Treasuries and mortgage backed securities (MBS). During the first and third round of QE (QE1 and QE3) it purchased both MBS and Treasuries while in the second round (QE2) bought primarily Treasuries. The FED's choice of the type of securities purchased ought to influence financial institutions differently, depending on how much MBS and Treasuries the banks owned. From September 2011 through 2012, the FED also engaged in the so-called Maturity Extension Program (MEP), also known as Operation Twist. The MEP consisted of selling short-term dated Treasury securities and buying long-term Treasury securities. That too should have influenced banks differently

depending on their relative holdings of short towards long term government securities.

This paper contributes to the limited empirical literature on QE and bank lending. First, we exploit the heterogeneity of the FED QE program both in terms of volumes and type of assets purchased. Banks with relatively large holdings of MBS and/or Treasuries will likely benefit more from the Fed purchases than banks with smaller holdings and therefore ought to be more likely to expand lending. A close paper to ours is Rodnyansky and Darmouni (2017) who also exploit the heterogeneity of MBS and Treasuries holdings. They find that FED's MBS purchases increased bank lending significantly whereas Treasuries purchases did not.[1] Chakraborty et al. (2020) show that following the QE programs banks with larger MBS exposures increased mortgage lending but lowered consumer and industrial (C&I) lending. This *crowding-out effect*- which was not found in Rodnyansky and Darmouni (2017) - appears to substantially weaken the positive effect on bank lending of FED's MBS purchases. Maggio et al. (2016) find that following the QE program financial institutions originated more mortgages that were eligible to be purchased by the FED than the ones that were not.[2]

Second, we analyse whether banks that had a similar exposure to MBS and/or Treasuries purchases react differently depending on their liquidity and solvency. This analysis is the first of its kind. Previous literature has focused on conventional monetary policy and bank sector heterogeneity (Kim and Sohn, 2017; Osborne et al., 2017), among others. Sclip et al. (2021) found that the impact of monetary policy actions can be both amplified and attenuated by changes in the health of the banking sector. Altunbas et al. (2009); Gambacorta and Marques-Ibanez (2011) show that bank capital matters in the propagation of shocks to the supply of bank credit and that banks with weaker capital positions, greater dependence on market-funding and on non-interest sources of income decreased lending during the global financial crisis. 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 banking has been vastly investigated with conflicting empirical evidence as to whether it exerts positive or negative effects on banks' valuation and transmitting the impact to investment and bank lending. Kim and Sohn (2017); Thornton and Di Tommaso (2020) show that better capitalized banks increased lending after they retain sufficient liquid assets.[3] However, the interaction of bank liquidity and QE has been much less investigated. Kim and Sohn (2017) find that bank liquidity affects positively

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

[2]A differential impact of FED's QE programs is also found by Luck and Zimmermann (2020) on employment. The authors find that only the third round of QE (QE3) translated into higher overall employment by increasing lending to firms as well as origination of home purchase mortgages whereas Kapoor and Peia (2021) find that only QE3 had a robust effect on bank liquidity creation.

[3]Bank liquidity supports real economic growth (Berger and Sedunov (2017)), it renders bank capital structure more robust (Gropp and Heider (2010)) and reduces investing risks by ensuring that a bank will be able to quickly react to market moves(Brunnermeier and Yogo (2009)).

bank investments and lending activity in the U.S. They do not investigate the impact of QE. Longo et al. (2022) find a beneficial role of liquidity for a sample of European banks that were exposed to the European Central Bank announcements of QE during 2015-2016, but they do not distinguish between high and low liquid banks.

Our assumption is that those banks that receive cheap liquidity as an effect of FED purchases are more encouraged to expand lending. Banks with lower solvency and/or liquidity and relatively high exposure to QE purchases may have an extra incentive to improve their prospective profits by increasing lending relatively more when cheap liquidity is made available. In other words, banks that differ for their liquidity and solvency ought to react differently to the FED stimulus.

We find that banks' exposure to QE purchases affects lending depending on the type of assets purchased by the central bank. Such results are in line with results from Rodnyansky and Darmouni (2017) and Chakraborty et al. (2020). We also show that the impact on QE purchases crucially depends on banks' differential exposure to credit, liquidity and solvency risk. Our results highlight that the transmission of unconventional monetary policy to the real economy critically depends not only on the composition of assets purchased but also the degree of heterogeneity of the banking sector. Our main conclusion is that bank differential exposures to risk are quantitatively important for understanding the impact of QE purchases on bank lending. Notably, the observed heterogeneity across banks attenuates the impact of QE.

The paper is organised as follows. Section 2 gives an account of the FED QE program. Section 3 describes the data and the identification strategy. In Section 4 we present the estimation results. Section 5 show the results from our robustness checks and Section 6 concludes.

2 The FED's QE programs

The QE programs 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. The total amount of securities purchased under the QE program reached $4.5 trillion, close to 30 percent of GDP.[4] The first QE program (QE1) began on November 25, 2008. The FED announced a program 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 program was extended and expanded and, by the end

[4]Throughout the QE program only fixed-rate agengy 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).

of QE1 in March 2010, the FED had bought $1.25 trillion in MBS, $175 billion US dollar 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 MBS total outstanding (to be checked). 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 purchases of $778 billion in long-term Treasury securities, which included $600 billion in announced program 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 program 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 program was its state-contingency and open-end 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.

Figure 1 shows the amounts of MBS and Treasury securities purchased during the implementation of each QE episode.

[5]From September 2011 through 2012, the FED conducted purchases within a program 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 program 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.

3 Data and Methodology

3.1 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 loans. Our sample consist of 7,124 unique BHCs, after cleaning and omitting the BHCs with missing total assets values.[6] In each QE round the FED purchased different types of assets.[7] 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.[8]

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 program started, i.e., in 2007:Q4.[9] 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. 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.[10] Additionally, as part of the robustness checks, we also implement the treatment definition in the corresponding quarters just before each of the QE rounds

[6] It is to be noted that parent companies of large BHCs and parent companies for small BHCs report data differently and as a result the number of BHCs varies across quarters. On average, 1,200 BHCs report data in all quarters whereas 5,500 BHCs report only bi-annually (in Q2 and Q4). Further, we control for any merger activity by excluding banks that have more than 10% of asset growth from one quarter to the other.

[7] 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 Program (MEP) between 2011-12. We do not explicitly identify MEP.

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

[9] Choosing a period prior to the implementation of QE reduces potential endogeneity concerns to QE rounds' anticipation.

[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, i.e. while banks move within the category tend to not change group over time.

with 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.

Figure 2 shows the evolution of MBS-to-total assets (Figure 2a) and Treasuries as a share of total assets (Figure 2b) for treated and control banks. There is a clear difference in the trends of securities that were purchased under QE for treated and control banks. Notably, the share of MBS holdings starts to decline immediately after QE1 for treated banks whereas the control group sees an increase in MBS holdings to total assets. On the other hand, for treated banks the Treasuries exposure measure only starts to decline after QE2, while it increased for control banks in the same period. This is consistent with the trend in Treasuries as it was during QE2 that the FED mainly bought Treasury securities.

3.2 Estimation approach

In order to estimate the impact of asset purchases on bank lending, we use 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 latter interaction captures the potential differential impact of QE-exposed banks depending on the level of bank sector heterogeneity.[13] We estimate

[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.

[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.
In its simplest form the DiD estimate is equivalent to calculating the after-before difference in the so-called treatment group, i.e the target group of a certain public policy intervention, for example, 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] The simpler DiD analysis with no interaction term assumes that the path of lending outcomes for banks with distinct bank heterogeneity would not be systematically different in the absence of QE intervention.

the following regression:

$$\begin{aligned} Y_{i,t} = \alpha_i + \beta_{j,t} + \gamma_1 AssetPurchases_{t-4} + \gamma_2 Treat_i + \gamma_3 Heterogeneity_i^j + \\ \gamma_4 Treat_i \times AssetPurchases_{t-4} + \gamma_5 Heterogeneity_i^j \times AssetPurchases_{t-4} + \\ \gamma_6 Treat_i \times Heterogeneity_i^j + \gamma_7 Treat_i \times AssetPurchases_{t-4} \times Heterogeneity_i^j + \\ \delta X_{i,t-1} + \epsilon_{i,t}. \end{aligned} \tag{1}$$

$Y_{i,t}$ 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 quarter t. $Treat_i$ is a dummy variable that takes the value of one if a bank belongs to the treatment group and zero otherwise. $AssetPurchases_{t-4}$ are the amounts of MBS and Treasury (TSY) securities 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 a bank's treatment status and security amount purchases during our sample period.

$Heterogeneity_i^j$ is an indicator variable that captures the heterogeneity of each bank i in terms of j. We differentiate banks according to the two key dimensions of liquidity and solvency. We approximate the liquidity of a bank based on their liquid assets holdings. More specifically, we categorize banks as high (low risk) liquid banks if they are in top quartiles 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 solvency (high-solvency) if their Tier I risk-based capital ratio is in the lowest (highest) quartile of this distribution.[14]

Vector $X_{i,t-1}$ includes a series of bank-level controls such as bank size, ratio of cash to assets, loan-to-deposits ratio and return on assets (measures as net income-to-total assets). The bank-level control variables capture differences in characteristics that would affect their activities and also account for the extent to which a bank absorbs potential losses. 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. We present summary statistics for the treated and control groups in Table 1. The mean of the ratio of MBS-to-total assets for treated banks is around 0.2, while that of control group is close to 0. Similarly, for the ratio of Treasuries to total assets, the mean values for treated group is 0.2, while for

Instead, we use the bank-specific information to understand how bank heterogeneity defines the effectiveness of QE policies on bank lending.

[14]More specifically, 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.

control group is 0.1.

We include bank fixed effects (α_i) to control for fixed differences among banks, and state-quarter 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 state-quarter fixed effects control for possible variation in bank lending demand and risk.

Our hypothesis is that banks that may be similarly exposed to asset purchases may have a significant differential response according to differences in bank-risk exposures. The main variable of interest is therefore the coefficient γ_7 that captures interaction between asset purchases, bank's exposure to the MBS or TSY purchases and bank heterogeneity.[15]

In Figure 3 we show the lending behaviour of banks that are in the highest 25% of the MBS-to-total assets distribution (treatment group), relative to banks in the bottom 25% of the distribution (control group). The right vertical axis measures the MBS holdings (green dashed line) as well as the Treasury securities holdings (orange dashed line) from 2008:Q1 to 2014:Q4.

In Table 2 we report the number of QE-exposed banks, high solvency and high liquid banks. 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 43 treated banks in our sample that are highly liquid, while 74 are well-capitalized.

4 Estimation Results

4.1 Results for the baseline model

Table 3 - 4 present the results of our baseline model as in equation 1 according to the two dimensions of bank heterogeneity, i.e. solvency and liquidity.

In Table 3 columns 1 through 3 we present the results concerning the lending outcomes

[15] Alternatively, we estimate

$$\begin{aligned} Y_{i,t} = \alpha_i + \beta_{j,t} + \gamma_1 AssetPurchases_{t-4} + \gamma_2 Treat_i + \\ \gamma_3 Treat_i \times AssetPurchases_{t-4} + \delta X_{i,t-1} + \epsilon_{i,t}. \end{aligned} \tag{2}$$

but divide banks into two groups along two dimensions: liquidity and capital. We present the results in Appendix B (Table 13 and Table 14). One advantage of our preferred specification as in equation 1 is that it minimises the loss of information. For example, it provides an estimate of potential "spillover" effects, i.e. γ_4, which is the effect of $Heterogeneity_i^j$ equal to 0 for MBS-exposed (or TSY-exposed) banks after the FED started asset purchases. This information is lost in the DiD estimated for the two bank groups separately.

between banks with relatively low and high MBS holdings and liquidity pooled across the entire QE period. It is worth to note here that while most of the purchases occurred during QE rounds (QE1, QE2, and QE3), the FED continued to buy MBS and Treasury securities in sizeable amounts also outside the rounds to replace maturing securities, see Figure 1. Column (1) shows the effect on total lending, while columns (2) and (3) show the results for real estate lending and commercial and industrial (C&I) loans, respectively.

We find that highly liquid banks, i.e. banks that are above the 75th percentile of the distribution of liquid assets to total assets, and with high exposure to the FED MBS purchases decrease total, real estate as well as C&I lending. Banks that are similarly exposed to FED MBS purchases but have instead a low liquidity tend to increase lending (coefficients for γ_4). In contrast, banks with a high TSY-exposure (low credit risk) and high liquidity tend to increase lending whereas low credit risk but also poor liquidity (high liquidity risk) banks decrease lending (columns 4 and 6). In other words, we find that QE impact on bank lending crucially depends not only on the type of asset purchased by the central bank but also the level of bank liquidity.

Next, we show the lending results of the FED QE purchases for highly and low capitalized banks. Giansante et al. (2020) argue that if banks are not adequately capitalised, QE might coincide with adverse investment incentives in the presence of risk-weighted capital requirements. In addition, they find very little or no increase in lending for UK banks following the Bank of England QE. Joyce and Spaltro (2014) suggest a positive impact of the first round of QE on bank lending in UK. They also find that the low level of bank capital may have limited the effectiveness of QE. In Table 4 we show our results. 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 reduce total lending, real estate as well as C&I loans. However, Treasuries purchases appear to have led to an increase in total and real estate lending for TSY-exposed and high solvency banks. We do not find an impact for C&I lending. Once again, it is evident that the impact of QE on bank lending is highly dependent not only on the type of asset purchased but also bank heterogeneity.

Banks' MBS/TSY exposure and the interaction of the exposure measure with bank liquidity and solvency appear to play a key role for understanding the effectiveness of QE interventions. Our results point to a significant non-linear impact of QE on bank lending depending on the QE-exposure of banks and their solvency and liquidity. In particular, banks that were the most and the least 'vulnerable', i.e. banks with high MBS-exposure (credit risk) and high liquidity/solvency risk and those with low credit risk (TSY-exposed) and low liquidity/solvency risk increased lending whereas the banks that are 'in the middle' decreased lending.

One possible explanation for our distinct findings is related to banks' assessment of overall

portfolio risk following QE and a balance sheet re-balancing following QE. Giansante et al. (2020) find that UK banks used the additional liquidity created by the Bank of England QE to buy low risk securities (government bonds). We find that banks that were MBS-exposed and therefore had a relatively higher credit risk in some instances reduced lending. It is reasonable to assume that they diverted funds from lending and used the FED liquidity to invest in other types of assets, including government bonds. However, low liquid banks that were also MBS-exposed had an incentive to further increase lending and, by so doing, their expected returns.[16] On the other hand, banks that had a higher exposure to Treasuries and thus a relatively lower credit risk and at same time low solvency risk were least "vulnerable" and increased lending.

The non-linear impact of QE and bank heterogeneity on bank lending shown in our results help to explain, at least partly, the mixed empirical evidence found in the literature on the effect of QE on bank lending.

4.2 Timing of the effects

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 equation 3, 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:

$$Y_{i,j,t} = \alpha_i + \beta_{j,t} + \sum_t \gamma_t D_t + \sum_t \theta_t D_t \times Treat_i \times Heterogeneity_i^j + \delta' X_{i,t} + \epsilon_{i,t}, \qquad (3)$$

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 and $X_{i,t}$ is a matrix of control variables that includes bank size, ratio of liquid assets to total assets, ratio of equity to total assets and return on assets. $Treat_i$ is a dummy that takes the value one for banks in the 75^{th} percentile of the combined MBS and TSY-to-total assets distribution, and zero for banks in the 25^{th} percentile, D_t is a vector of dummy variables for each $t \in \{2007Q1, 2007Q2, ..., 2014Q4\}/\{2008Q3\}$, with 2008Q3 taken as the benchmark period. $D_t \times Treat_i \times Heterogeneity_i^j$ 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

[16]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.

group banks over time.

The quarter-by-quarter dynamic effect of QE is shown in Figure 4 and 5. Figure 4 shows the estimated coefficients for the triple interaction term for the pre-treatment and post-treatment period for the liquidity dimension of $Heterogeneity_i^j$, with 90% confidence intervals around them. Figure 5 shows the effect for capital, the second dimension of $Heterogeneity_i^j$. Figure 4a, 4b and 4c are plots for three types of lending relate to liquidity. Figure 5a, 5b and 5c relate to capital. 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 only for the banks that were more liquid or had a higher solvency. Third, as would be consistent with a gradual impact of QE on bank lending, the figures also show that, while there is some oscillations in the results between QE1 and QE2, most of the impact for both real estate and C&I loans as well as total lending comes consistently after the implementation of QE2. Finally both figures show that the larger impact of QE on bank lending happened during the QE3 round. The latter result is in line with previous findings in the literature.

4.3 An alternative specification of the baseline model

In Table 5 and 6 we present estimates for an alternative specification of our baseline in equation 1. This new specification follows Rodnyansky and Darmouni (2017) closely as we use a dummy variable for each of the QE rounds instead of a continuous variable of QE purchases. As in the baseline model, also in this new specification the dependent variable is bank lending for three aggregates: total lending, real estate and C&I loans. In addition, similarly to the model in equation 1, we introduce a triple interaction term to determine the impact of bank heterogeneity of QE-exposed banks on bank lending. In contrast to the equation 1 model specification, the new specification in equation 4 captures the impact of each round of QE separately. This new model is as follows:

$$\begin{aligned} Y_{i,t} = \alpha_i + \beta_{j,t} + \gamma_1 QE_t + \gamma_2 Treat_i + \gamma_3 Heterogeneity_i^j + \\ \gamma_4 Treat_i \times QE_t + \gamma_5 Heterogeneity_i^j \times QE_t + \\ \gamma_6 Treat_i \times Heterogeneity_i^j + \gamma_7 Treat_i \times QE_t \times Heterogeneity_i^j + \\ \delta X_{i,t-1} + \epsilon_{i,t}. \end{aligned} \tag{4}$$

where the new variable QE_t is a dummy variable that takes value 1 for each QE round and zero otherwise such that $QE_t = \{QE1_t, QE2_t, QE3_t\}$ and γ_7 is the coefficient of the new triple interaction term we discuss above. All other variables are as in equation 1, including

fixed effects and MBS/TSY-exposure measures $Treat_i$. Similarly to previous studies, the new estimates show that each round of QE had a differential impact on bank lending. In particular, bank lending increased during QE1 and QE3 rounds whereas the effects tend to be weaker for QE2.[17] More importantly though, our results highlight the importance of also considering bank heterogeneity when assessing the impact of QE. In fact our estimates show a significant differential impact of QE rounds for bank heterogeneity on bank lending. In particular, MBS-exposed banks with high liquidity diminish their lending during both QE1 and QE3. When the FED bought mostly Treasury securities as during QE2, banks that had relatively larger Treasury holdings increased their lending.

In addition, the results presented in Table 5 and 6 are in line with the baseline model results discussed above. Thus, the baseline results are robust also to the alternative specification.

5 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.

5.1 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 now re-define our treatment variables, first based on decile values of MBS-to-total assets as well as for treasury securities. We define treated group as banks that are in the top 90th percentile of the MBS-to-total assets distribution, while control group in the bottom 10th percentile of this distribution. The results for treatment variable constructed based on deciles are reported in Figure 6 and 7 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 6a and 7a, while TSY in Panel 6b and 7b) 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 Table 7 and 8 pertaining to liquidity and capital, respectively. The magnitude and statistical significance of the coefficients is

[17] In a specification where we do not include the triple interaction term, we obtain coefficient estimates that are close to Rodnyansky and Darmouni (2017).

stronger across all specifications.

5.2 Alternative measures of liquidity and capital

We run robustness tests by taking alternative measures for bank liquidity and capital and find similar results. 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 9 and are largely consistent with our main analysis as we find statistically significant coefficients on the effects of FED's quantitative easing policy on liquid banks.

We also employ the ratio of equity to total assets as an alternative measure for bank capital and find the results are qualitatively similar. 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 10 and are qualitatively similar to our baseline findings.

5.3 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. However, in our robustness check 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 prior to the implementation of QE, i.e., 2007Q4. Table 11 and Table 12 relates to taking treatment and control group on rolling basis for liquidity and solvency, respectively. Taking treatment definitions in alternative quarters yields similar results qualitatively.

6 Conclusions

Fifteen years from the FED's first quantitative easing (QE) program, it has been hard to assess the impact of QE and possibly, by extension, QT (quantitative tightening). Results about the effectiveness of QE have been mixed. In this paper, we show that the impact of QE on bank lending crucially depends not only on the type of assets purchased by the FED - MBS versus Treasury securities, but also on bank heterogeneity. We investigate heterogeneity along the two key dimensions of bank liquidity and capital.

We find that only banks that are in the 'extremes'. i.e. high (low) QE-exposure and low (high) liquidity/solvency expand lending. Banks "in the middle' ground decreased lending. The non-linear impact of QE on bank lending shown in our results help to explain, at least partly, the mixed empirical evidence found in the literature on the effects of QE on bank lending. More importantly, our results shed light on the role that bank heterogeneity plays for reinforcing or offsetting effects following QE.

To understand the transmission mechanisms of unconventional monetary policy as well as its redistribution effects, considering the distribution of QE assets across banks is as crucial as taking into account bank diverseness. This paper is the first to provide empirical support for the importance of evaluating the effects of QE asset purchases through the key lenses of bank heterogeneity. For policy makers knowing this is important for more precisely identifying the effects of unconventional monetary policy and calibrate future interventions.

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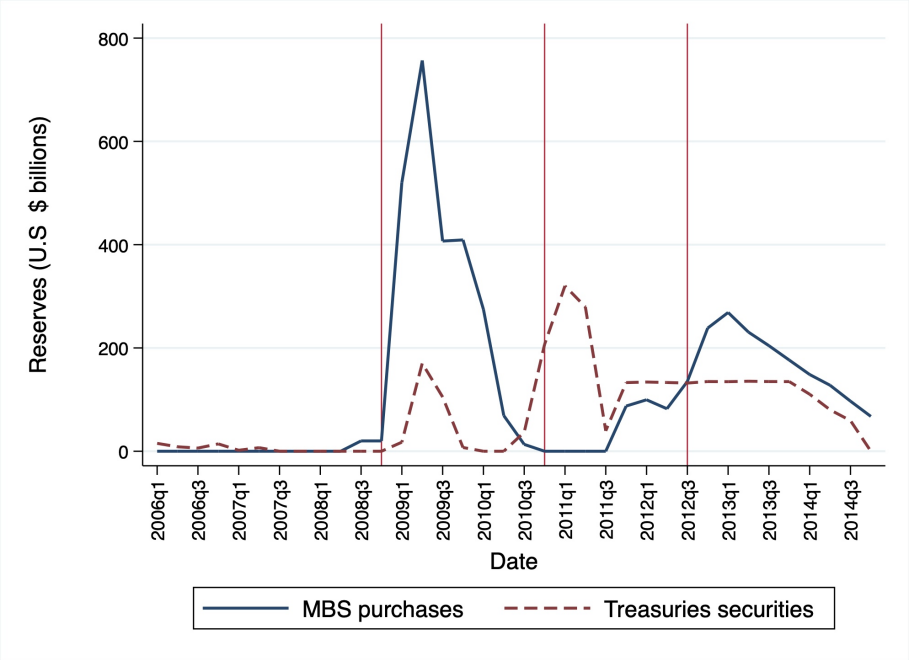
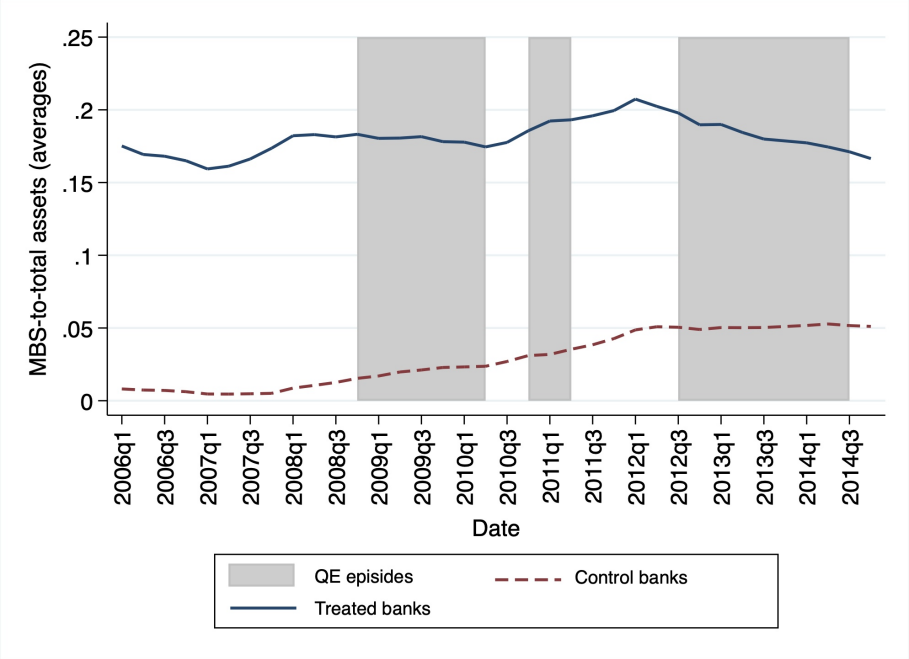
Figures

Figure 1: MBS and Treasury securities purchases amounts

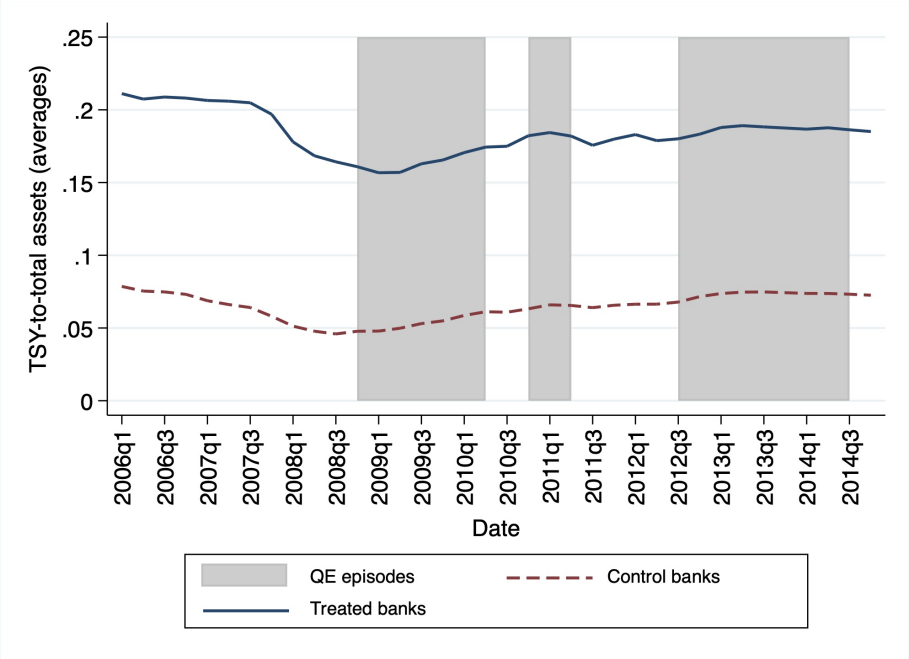


Notes: Quarterly purchase of MBS and Treasury securities by the Fed. The figure shows the quarterly amount of mortgage-backed securities (solid line) and Treasury securities (dashed line) purchased by the Fed. The vertical lines indicate the commencement of the three rounds of quantitative easing.

Figure 2: MBS and Treasury purchases for treated and control banks



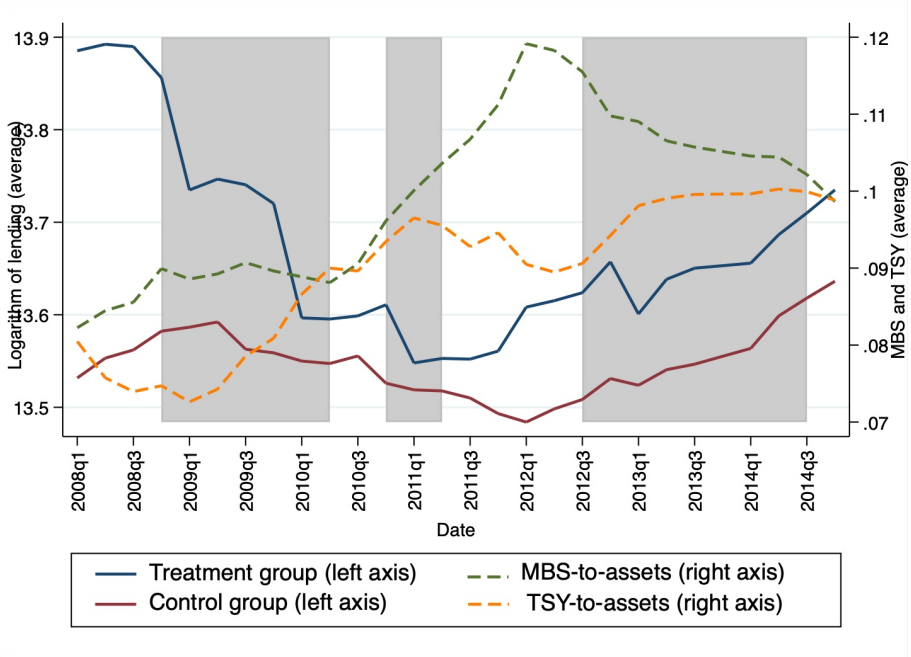
(a) MBS-to-total assets for treated and control banks



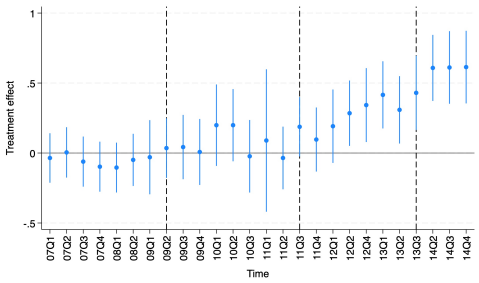
(b) Treasury securities-to-total assets for treated and control banks

Notes:The figure maps the evolution of the ratio of MBS-to-total assets in Panel (a) and ratio of treasury securities to total assets in Panel (b) for treated and control banks. In Panel (a), treated banks are banks in the top 25th quartile of MBS-to-total assets ratio in 2007Q4, while control are in the bottom 25th quartile. In Panel (b), treated banks are banks in the top 25th quartile of treasury securities-to-total assets ratio in 2007Q4, while control are in the bottom 25th quartile. Shaded areas highlight the three episodes of QE.

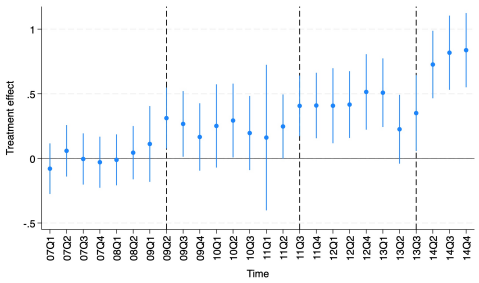
Figure 3: Quantitative Easing and Bank Lending



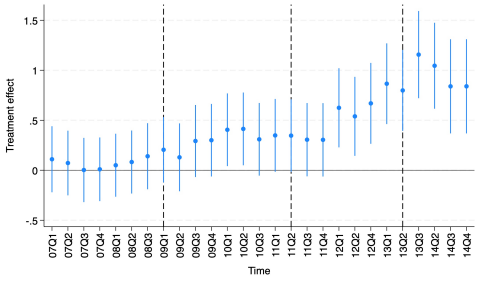
Notes: The figure shows average lending amounts for treatment and control group on the left axis. The figure also shows the average amounts of mortgage backed securities (green dashed line) and treasury securities (orange dashed line) held by U.S. BHCs from 2008:Q1 to 2014:Q4. The shaded areas indicate the three rounds of quantitative easing.



(a) Total Lending

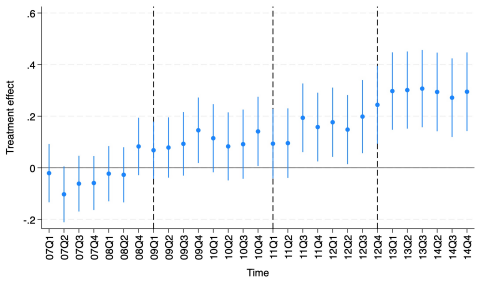


(b) RE Lending

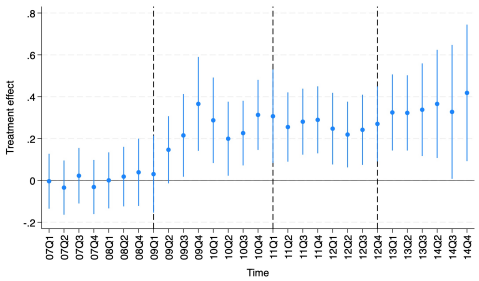


(c) C&I Lending

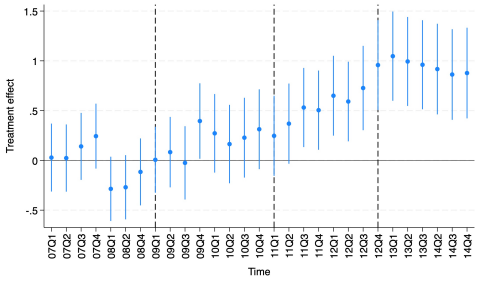
Figure 4: Timing of effects.
The figure shows coefficient plots for the parameters θ in Eq. 2 for liquidity with 90% confidence intervals. The vertical lines indicate the start of each episode of quantitative easing.



(a) Total Lending



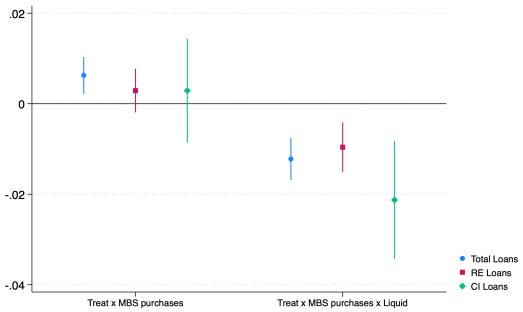
(b) RE Lending



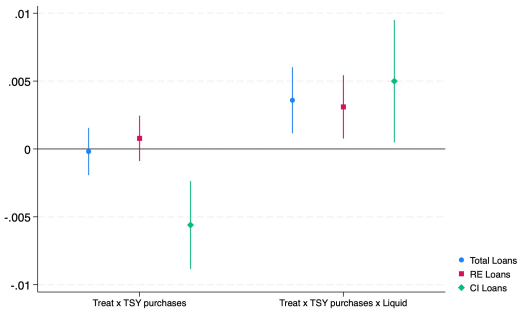
(c) C&I Lending

Figure 5: Timing of effects.
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.

Figure 6: Robustness (Liquidity): Treatment variable based on Deciles

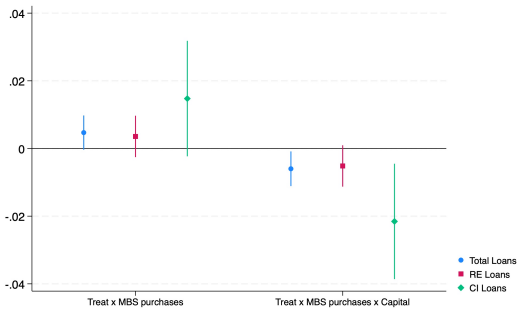


(a) MBS purchases

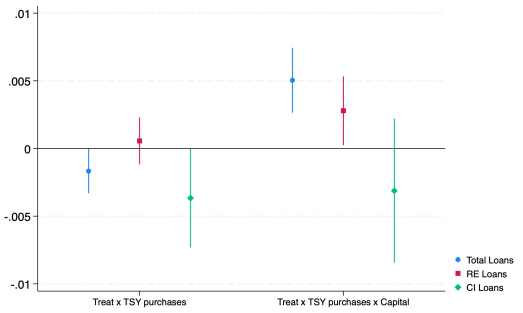


(b) TSY purchases

Figure 7: Robustness (Capital): Treatment variable based on Deciles



(a) MBS purchases



(b) TSY purchases

Tables

Table 1: Summary Statistics

	Obs	Mean	Std.D.	p10	Median	p90
Treatment Group						
$\left(\frac{MBS}{TotalAssets}\right)_i$	7,343	0.2	0.1	0.1	0.2	0.3
$\left(\frac{Treasury}{TotalAssets}\right)_i$	7,343	0.2	0.1	0.0	0.1	0.2
log(Total Loans)	7,343	14.0	1.4	12.6	13.7	15.9
log(RE Loans)	7,332	13.7	1.4	12.3	13.4	15.4
log(C&I Loans)	7,332	11.9	1.9	10.0	11.6	14.4
Asset Size	7,343	13.6	1.5	12.2	13.2	15.5
Liquidity	7,343	0.1	0.1	0.0	0.0	0.1
Tier 1 Risk-based Capital Ratio	7,312	13.7	19.3	9.1	12.8	19.1
Net Income/Total Assets	7,343	0.0	0.0	-0.0	0.0	0.0
Cash/ Total Assets	7,343	0.0	0.0	0.0	0.0	0.1
Loans to Deposit ratio	6,942	0.8	0.6	0.5	0.8	1.0
Control Group						
$\left(\frac{MBS}{TotalAssets}\right)_i$	7,312	0.0	0.0	0.0	0.0	0.1
$\left(\frac{Treasury}{TotalAssets}\right)_i$	7,312	0.1	0.1	0.0	0.1	0.2
log(Total Loans)	7,303	13.5	0.9	12.6	13.4	14.5
log(RE Loans)	7,268	13.2	0.9	12.3	13.1	14.3
log(C&I Loans)	7,291	11.3	1.2	10.1	11.3	12.7
Asset Size	7,312	12.5	1.1	11.4	12.4	13.7
Liquidity	7,312	0.1	0.1	0.0	0.1	0.2
Tier 1 Risk-based Capital Ratio	7,308	12.9	24.2	8.1	11.9	17.5
Net Income/Total Assets	7,312	0.4	19.5	-0.0	0.0	0.0
Cash/ Total Assets	7,312	0.1	0.1	0.0	0.0	0.1
Loans to Deposit ratio	6,918	36.4	1,302.0	0.7	0.9	1.1

Summary statistics recorded from 2006Q1 to 2014Q4 for all U.S. BHCs. All variables are at quarterly frequency. The statistics for $\left(\frac{Treasury}{TotalAssets}\right)_i$ is based on the TSY-QE exposed treatment and control group.

Table 2: Number of treated banks based on bank heterogeneity

Category	**Number of banks**
(Liquid= 1); (Capital != 1); (Treatment !=1)	238
(Liquid= !1); (Capital = 1); (Treatment !=1)	232
(Liquid= 1); (Capital != 1); (Treatment =1)	43
(Liquid= !1); (Capital = 1); (Treatment =1)	74
(Liquid= 1); (Capital = 1); (Treatment =1)	20

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. $Treatment = 1$ represents banks in the top 25th percentile of the MBS-to-total assets ratio in 2007Q4.

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)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0045***	0.0049***	0.0029			
	(0.0013)	(0.0014)	(0.0031)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	-0.0036**	-0.0048***	-0.0078*			
	(0.0018)	(0.0018)	(0.0040)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				-0.0031**	0.0002	-0.0075***
				(0.0014)	(0.0013)	(0.0025)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0058***	0.0041**	0.0087***
				(0.0017)	(0.0017)	(0.0031)
Observations	5,524	5,490	5,806	10,761	10,726	10,723
R-squared	0.1014	0.1569	0.0210	0.0762	0.0768	0.0544
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 includes bank size, Tier I risk-based capital ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 4: The impact of MBS and TSY purchases on lending: effect of bank capital

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0045***	0.0031**	0.0105***			
	(0.0011)	(0.0012)	(0.0032)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	-0.0044***	-0.0029*	-0.0072*			
	(0.0015)	(0.0016)	(0.0042)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				-0.0024	-0.0001	-0.0017
				(0.0019)	(0.0020)	(0.0041)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0049**	0.0042*	0.0000
				(0.0021)	(0.0023)	(0.0046)
Observations	5,540	5,510	5,535	10,867	10,833	10,831
R-squared	0.1623	0.1606	0.0140	0.1410	0.0746	0.0315
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State X 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 includes bank size, liquidity ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 5: Alternative identification strategy: role of liquidity

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)	**Total Loans** (7)	**RE Loans** (8)	**C & I Loans** (9)
$QE_1 \times Treat_i^{MBS}$	0.0838***	0.0623**	0.0872*						
	(0.0156)	(0.0245)	(0.0467)						
$QE_1 \times Treat_i^{MBS} \times Liquidity_i^Q$	-0.0386**	0.0230	0.0279						
	(0.0180)	(0.0304)	(0.0578)						
$QE_2 \times Treat_i^{TSY}$				0.0069	-0.0486	-0.0022			
				(0.0291)	(0.0342)	(0.0461)			
$QE_2 \times Treat_i^{TSY} \times Liquidity_i^Q$				0.0240	0.0810**	0.0785*			
				(0.0347)	(0.0370)	(0.0520)			
$QE_3 \times Treat_i^{MBS}$							0.1730***	0.2365***	0.0125
							(0.0277)	(0.0308)	(0.0552)
$QE_3 \times Treat_i^{MBS} \times Liquidity_i^Q$							-0.0829**	-0.1431***	-0.0380
							(0.0345)	(0.0410)	(0.0705)
Observations	5,885	5,839	5,874	11,259	11,229	11,246	6,297	6,251	6,271
R-squared	0.7383	0.6114	0.1448	0.2399	0.1606	0.2928	0.1664	0.1113	0.0611
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1), (4) and (7) relate to log of Total lending, while columns (2), (5) and (8) is the log of real estate loans and columns (3), (6) and (9) relate to 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. $Liquidity_i^Q$ 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). QE_1, QE_2, QE_3 are dummies for each QE wave. Bank-level controls include the bank size, ratio of equity to total assets and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 6: Alternative identification strategy: role of capital

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)	**Total Loans** (7)	**RE Loans** (8)	**C & I Loans** (9)
$QE_1 \times Treat_i^{MBS}$	0.0481***	0.0961***	0.0904**						
	(0.0108)	(0.0191)	(0.0360)						
$QE_1 \times Treat_i^{MBS} \times Capital_i^Q$	-0.0536***	-0.0989***	-0.1517***						
	(0.0128)	(0.0217)	(0.0505)						
$QE_2 \times Treat_i^{TSY}$				-0.3857***	-0.1361	-0.0783			
				(0.1005)	(0.0898)	(0.0576)			
$QE_2 \times Treat_i^{TSY} \times Capital_i^Q$				0.3502***	0.1864*	0.0003			
				(0.1162)	(0.1054)	(0.0692)			
$QE_3 \times Treat_i^{MBS}$							0.0585***	0.0493**	0.2720***
							(0.0097)	(0.0236)	(0.0365)
$QE_3 \times Treat_i^{MBS} \times Capital_i^Q$							-0.0265*	-0.0135	-0.4049***
							(0.0155)	(0.0326)	(0.0607)
Observations	6,898	6,859	7,313	12,804	12,771	14,201	6,898	6,859	6,883
R-squared	0.7591	0.6563	0.1566	0.6804	0.3554	0.2648	0.7562	0.4118	0.1847
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns (1), (4) and (7) relate to log of Total lending, while columns (2), (5) and (8) is the log of real estate loans and columns (3), (6) and (9) relate to 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. $Capital_i^Q$ 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). QE_1, QE_2, QE_3 are dummies for each QE wave. Bank-level controls include the bank size, ratio of cash to total assets and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 7: 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)
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i}$	0.0455***	0.0418***	0.0870***			
	(0.0060)	(0.0057)	(0.0107)			
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i} \times Liquidity_i^Q$	-0.0344***	-0.0274***	-0.1098***			
	(0.0089)	(0.0085)	(0.0160)			
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i}$				0.0012	0.0119	-0.0437***
				(0.0083)	(0.0080)	(0.0155)
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i} \times Liquidity_i^Q$				0.0222**	0.0235**	0.0430**
				(0.0104)	(0.0101)	(0.0195)
Observations	10,761	10,726	11,269	11,307	11,272	11,269
R-squared	0.0823	0.0841	0.0594	0.0839	0.0796	0.0318
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
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 includes bank size, Tier I risk-based capital ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 8: The impact of MBS and TSY purchases on lending: effect of bank capital

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i}$	0.0247***	0.0225***	0.0511***			
	(0.0074)	(0.0081)	(0.0164)			
$MBSpurchases_{t-4} \times \frac{MBS}{Assets_i} \times Capital_i^Q$	-0.0177**	-0.0164*	-0.0302			
	(0.0084)	(0.0091)	(0.0186)			
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i}$				-0.0313***	-0.0046	-0.0504**
				(0.0103)	(0.0108)	(0.0222)
$TSYpurchases_{t-4} \times \frac{TSY}{Assets_i} \times Capital_i^Q$				0.0606***	0.0321***	0.0765***
				(0.0114)	(0.0121)	(0.0246)
Observations	10,867	10,839	10,825	10,867	10,839	10,831
R-squared	0.1485	0.0906	0.0231	0.0876	0.0861	0.0209
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
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 includes bank size, liquidity ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 9: 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)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0043***	0.0052***	-0.0015			
	(0.0013)	(0.0014)	(0.0033)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	-0.0030*	-0.0030*	-0.0012			
	(0.0017)	(0.0018)	(0.0043)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				-0.0029**	-0.0003	-0.0043*
				(0.0013)	(0.0012)	(0.0026)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0055***	0.0050***	0.0073**
				(0.0017)	(0.0016)	(0.0033)
Observations	5,550	5,524	5,847	10,845	10,810	10,811
R-squared	0.0934	0.0938	0.0078	0.1009	0.1074	0.0323
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 includes bank size, equity to total assets, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 10: The impact of MBS and TSY purchases on lending: effect of bank capital

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0000	-0.0015	0.0016			
	(0.0008)	(0.0010)	(0.0027)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	-0.0024**	-0.0023*	-0.0064*			
	(0.0012)	(0.0014)	(0.0037)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				-0.0011	0.0032**	-0.0035
				(0.0014)	(0.0014)	(0.0026)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0032*	0.0001	0.0003
				(0.0018)	(0.0018)	(0.0033)
Observations	4,354	4,029	4,350	10,859	10,830	10,826
R-squared	0.6076	0.5527	0.1370	0.1249	0.1307	0.0595
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 includes bank size, ratio of cash to total assets, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 11: Treatment variable on rolling basis: The impact of asset 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)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	0.0048***	0.0023	-0.0030			
	(0.0016)	(0.0014)	(0.0030)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Liquidity_i^Q$	-0.0066***	-0.0033*	-0.0006			
	(0.0021)	(0.0019)	(0.0039)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				0.0443	0.0748	-0.5235***
				(0.0434)	(0.0467)	(0.0966)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Liquidity_i^Q$				0.0041**	0.0056***	0.0019
				(0.0019)	(0.0021)	(0.0043)
Observations	5,355	5,330	5,332	4,928	4,904	4,899
R-squared	0.0794	0.0832	0.0336	0.0613	0.0502	0.0173
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 includes bank size, Tier I risk-based capital ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 12: Treatment variable on rolling basis: The impact of asset purchases on lending - effect of bank capital

	Total Loans (1)	**RE Loans** (2)	**C & I Loans** (3)	**Total Loans** (4)	**RE Loans** (5)	**C & I Loans** (6)
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q}$	-0.0007	-0.0003	-0.0013			
	(0.0011)	(0.0012)	(0.0031)			
$MBSpurchases_{t-4} \times Treat_i^{MBS^Q} \times Capital_i^Q$	-0.0000	-0.0019	-0.0003			
	(0.0015)	(0.0016)	(0.0040)			
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q}$				-0.2669***	-0.2097***	0.0315
				(0.0453)	(0.0491)	(0.1049)
$TSYpurchases_{t-4} \times Treat_i^{TSY^Q} \times Capital_i^Q$				0.0126***	0.0112***	0.0109**
				(0.0022)	(0.0024)	(0.0051)
Observations	5,307	5,215	5,221	5,224	5,202	5,121
R-squared	0.0907	0.0825	0.0310	0.1262	0.1057	0.0351
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State X 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 includes bank size, liquidity ratio, loan to deposits ratio and return on assets. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

A Variables employed: construction and corresponding definitions

Variable Name	Definition	Data Sources
Mortgage backed securities	Residential pass-through securities + other residential MBS + commercial MBS	FR-Y9C
Treasury Securities	U.S. Treasury securities + U.S. government agency obligations + securities issued by states and political subdivisions in the U.S.	FR-Y9C
Total lending	Logarithm of total loans	FR-Y9C
Real estate lending	Logarithm of loans secured by real estate	FR-Y9C
C & I lending	Logarithm of commercial and industrial loans to U.S. and non-U.S. addresses	FR-Y9C
Bank Size	Logarithm of total assets	FR-Y9C
Equity ratio	Total equity capital 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
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
Return on assets	Ratio of net income to total assets	FR-Y9C
Treasury Purchases	Amount of Treasury securities purchased by the Federal Reserve in a given quarter	New York Fed
MBS Purchases	Amount of MBS purchased by the Federal Reserve in a given quarter	New York Fed

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.

B Estimating two-way interactions for different bank characteristic group

Table 13: The impact of MBS and TSY purchases on lending: based on bank liquidity

	Low Liquid banks			**High Liquid banks**		
	Total Loans	**RE Loans**	**C & I Loans**	**Total Loans**	**RE Loans**	**C & I Loans**
Panel A: MBS purchases	(1)	(2)	(3)	(4)	(5)	(6)
$MBSpurchases_{t-4} \times Treat_i^{MBS}$	0.0025***	0.0025***	-0.0054	-0.0036***	-0.0028**	-0.0048*
	(0.0008)	(0.0009)	(0.0035)	(0.0009)	(0.0012)	(0.0027)
Observations	2,492	2,492	2,488	2,624	2,586	2,623
R-squared	0.6783	0.6209	0.1112	0.6628	0.5515	0.2631
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: TSY purchases						
$TSYpurchases_{t-4} \times Treat_i^{TSY}$	-0.0018	0.0009	-0.0048*	0.0029***	0.0046***	0.0012
	(0.0015)	(0.0012)	(0.0027)	(0.0010)	(0.0011)	(0.0019)
Observations	5,224	5,223	5,192	5,185	5,161	5,446
R-squared	0.0872	0.1220	0.0322	0.2251	0.2051	0.1152
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 Column (3) and (6) is the log of commercial and industrial 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 constructed similarly. Liquidity is a dummy variable that equals one for banks in the top 25th percentile of the ratio of liquid assets to total assets prior to the implementation of QE, i.e., 2007Q4 (low liquid banks), zero for banks in the bottom 25th percentile of the ratio of liquid assets to total assets in 2007Q4 (high liquid banks). $TSYpurchases_{t-4}$ and $MBSpurchases_{t-4}$ are the lagged quarterly log-dollar amount of Federal Reserve Treasury (TSY) purchases and MBS purchases respectively. Bank-level controls include the bank size, Tier 1 capital ratio, the net income to total assets and loan to deposits ratio. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

Table 14: The impact of MBS and TSY purchases on lending: based on bank capital

	Low Liquid banks			High Liquid banks		
	Total Loans	**RE Loans**	**C & I Loans**	**Total Loans**	**RE Loans**	**C & I Loans**
Panel A: MBS purchases	(1)	(2)	(3)	(4)	(5)	(6)
$MBSpurchases_{t-4} \times Treat_i^{MBS}$	0.0000	-0.0012	0.0032	-0.0016***	-0.0016**	-0.0007
	(0.0007)	(0.0010)	(0.0025)	(0.0006)	(0.0007)	(0.0022)
Observations	2,216	2,216	2,216	5,467	5,433	5,463
R-squared	0.6963	0.5453	0.2576	0.6908	0.6128	0.1811
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: TSY purchases						
$TSYpurchases_{t-4} \times Treat_i^{TSY}$	-0.0009	0.0014	-0.0010	0.0017*	0.0029***	-0.0031
	(0.0021)	(0.0022)	(0.0039)	(0.0010)	(0.0011)	(0.0026)
Observations	5,179	5,179	5,149	5,312	5,284	5,305
R-squared	0.0660	0.0787	0.0450	0.2223	0.2065	0.0234
Bank-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x 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 Column (3) and (6) is the log of commercial and industrial 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 constructed similarly. Liquidity is a dummy variable that equals one for banks in the top 25th percentile of the ratio of liquid assets to total assets prior to the implementation of QE, i.e., 2007Q4 (low liquid banks), zero for banks in the bottom 25th percentile of the ratio of liquid assets to total assets in 2007Q4 (high liquid banks). $TSYpurchases_{t-4}$ and $MBSpurchases_{t-4}$ are the lagged quarterly log-dollar amount of Federal Reserve Treasury (TSY) purchases and MBS purchases respectively. Bank-level controls include the bank size, Tier 1 capital ratio, the net income to total assets and loan to deposits ratio. Constant terms included, but not reported. Robust standard errors in parentheses. ***, **, * represent significance at the 1%, 5% and 10%, respectively.

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