The determinants of bank liquid asset holdings

René M. Stulz[a,b,c], Alvaro G. Taboada[d], and Mathijs A. van Dijk[e]*

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ABSTRACT

Bank liquid asset holdings vary significantly across banks and through time. The determinants of liquid asset holdings from the corporate finance literature are not useful to predict banks' liquid asset holdings. Banks have an investment motive to hold liquid assets, so that when their lending opportunities are better, they hold fewer liquid assets. We find strong support for the investment motive. Large banks hold much more liquid assets after the Global Financial Crisis (GFC), and this change cannot be explained using models of liquid asset holdings estimated before the GFC. We find evidence supportive of the hypothesis that the increase in liquid assets of large banks is due at least in part to the post-GFC regulatory changes.

[a] Fisher College of Business, The Ohio State University, Columbus, USA

[b] National Bureau of Economic Research (NBER), Cambridge, USA

[c] European Corporate Governance Institute, 1000 Brussels, Belgium

[d] College of Business, Mississippi State University, Starkville, USA

[e] Rotterdam School of Management, Erasmus University, Rotterdam, the Netherlands

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1. Introduction

Bank liquid asset holdings play a critical role in the health of the financial system and in the financial strength of individual banks. Banks with a low liquid assets ratio, defined as liquid assets over total assets, which we call LAR, are at risk of collapse if there is a run on their deposits. Banks with a high LAR lend less, so that banks with good lending opportunities would rather have a low LAR, all else equal. When the banking sector as a whole has a low LAR, systemic risk is high as many banks are likely to have difficulties coping with unexpected adverse shocks. In contrast to non-financial firms, there is surprisingly little evidence on the determinants of bank liquid asset holdings. In this paper, we investigate the determinants and the evolution of US bank liquid asset holdings from 1984 to 2020.[1]

Given the importance of liquid assets for banks and the financial system, the lack of evidence on the determinants of bank liquid asset holdings is surprising. This neglect is even more surprising given the magnitude of these holdings, their variation over time, and their variation across banks. At the end of our sample period, banks with assets of $10 billion or more have aggregate liquid assets that exceed $5 trillion; in comparison, non-financial firms with assets of $10 billion or more have aggregate liquid assets of less than $2 trillion in total. From 1984 to 2006, the ratio of aggregate liquid assets to assets falls by 30% for banks with assets of $10 billion or more in 2018 dollars, but then it increases by 28% from 2009 to 2019. As evidence of variation in the LAR across banks, in our panel of observations from 1984 to 2006, the 25th percentile of the LAR for banks with assets in excess of $10 billion in 2018 dollars is 15.8% and the 75th percentile is 26.3%. Before 2012, large banks, defined as banks with assets in excess of $50 billion in 2018 dollars, have a lower LAR than small banks, defined as banks with assets between $2 billion and $10 billion in 2018 dollars, but after 2012 large banks have a much larger LAR than small banks. At the end of our sample period, the average LAR of banks with assets in excess of $250 billion is 40.3%, while the average LAR of banks with assets from $2 billion to $10 billion is almost 20 percentage points lower at 20.9%.

[1] Cornett, McNutt, Strahan, and Tehranian (2011) show how the global financial crisis (GFC) affected banks differentially depending on their liquid asset holdings and how banks changed their liquid asset holdings during the GFC. Our focus is not on the GFC but on normal times. We refer readers to that study for evidence on how bank liquidity policies were affected by the crisis.

Though the empirical evidence on bank liquid asset holdings is extremely limited, there is a large literature on the liquid asset holdings of non-financial firms (for a survey, see Almeida, Campello, Cunha, and Weisbach, 2014). In the literature on holdings of liquid assets by non-financial firms, these firms hold liquid assets mostly because of the precautionary and transaction motives. Much of that literature has focused on assessing the importance of the precautionary motive. Though studies differ on the importance of the precautionary motive, there is considerable evidence showing that this motive is a key determinant of liquid asset holdings for non-financial firms. Following the literature on liquid asset holdings of non-financial firms, we use a simple empirical model where liquid asset holdings in year *t* depend on eight firm characteristics measured in year *t*-1. We apply this model to public industrial firms with assets greater than $10 billion and to public banks with assets greater than $10 billion (in 2018 dollars) for the period from 1984 to 2006. We use that period for this investigation to make sure that differences in liquid asset holdings between industrial firms and banks are not caused by the liquidity regulations enacted after the Global Financial Crisis (GFC). Seven firm characteristics have statistically significant coefficients for non-financial firms. The only significant coefficient for banks is that of the dividend payout rate, which has a negative coefficient (in line with expectations).

Since the determinants of liquid asset holdings for non-financial firms do not appear to explain bank liquid asset holdings, we explore why it is so and what the determinants of liquid asset holdings of banks are. There are five key differences between banks and non-financial firms that are relevant:

1) Banks are in the business of raising funds through deposits and investing them in financial assets (see DeAngelo and Stulz, 2015, for references). They earn a return through the spread between the rate at which they invest and the rate they pay on deposits. The literature generally takes the view that banks have market power in setting deposit rates (e.g., Drechsler, Savov, and Schnabl, 2017; Whited, Wu, and Xiao, 2021). They can invest the funds available to them in a variety of assets, such as loans, trading assets, liquid assets, and less liquid securities. Everything else equal, we would expect banks to invest across asset classes so that the risk-adjusted expected return is equalized. Unless liquid assets are dominated assets, a bank will hold liquid assets for portfolio

reasons. We call this the investment motive for holding liquid assets. With this motive, a bank is likely to hold more liquid assets when the demand for loans is lower.

2) Banks engage in maturity transformation. They raise funds through deposits but invest in assets with longer maturities than deposits. Banks have runnable liabilities. A bank that puts all its assets into loans would not be able to meet unexpectedly large demands for redemptions of deposits. Therefore, banks have a precautionary motive to hold liquid assets that arises from their liabilities (see Diamond and Kashyap, 2016, for references). Though non-financial firms may increase liquid asset holdings when their funding is vulnerable, runs on their liabilities are highly unusual. The typical non-financial firm holds liquid assets to cope with revenue shortfalls.

3) Banks often have large contingent liabilities that are not on their balance sheets. For instance, banks enter contracts with firms in the form of credit lines. If these credit lines are drawn down, banks must have cash available to honor their contracts (see Acharya and Mora, 2015). Relatedly, derivatives and other types of contingent liabilities may require the posting of collateral, which takes the form of liquid assets.

4) Excess reserves kept at the Federal Reserve are one component of liquid assets. Since the total amount of reserves outstanding is controlled by the Federal Reserve, an increase in reserves outstanding can lead to an increase in excess reserves.

5) Banks are highly regulated compared to non-financial firms. Risk-based capital regulations make it more advantageous for banks to hold liquid assets than loans or illiquid riskier securities. Following the GFC, capital requirements for banks increased and this increase was larger for larger banks, which made it more advantageous to hold liquid assets rather than loans. Further, while banks had no liquidity requirements before the GFC, such requirements were introduced afterwards. The most relevant liquidity requirement during our sample period is the liquidity coverage ratio (LCR). We would expect the changes in capital and liquidity regulations after the GFC to have an impact on bank holdings of liquid assets (see Cecchetti and Kashyap, 2016, for how capital and liquidity requirements interact).

For banks to have an investment motive to invest in liquid assets, it has to be that liquid assets improve the expected performance of their portfolio of invested assets. A bank with limited opportunities to make profitable loans but with a large deposit franchise has funds to invest, and it will generally invest some of these funds in liquid assets. If liquid assets are dominated assets, in that illiquid assets with returns perfectly correlated with those of liquid assets have a higher risk-adjusted expected return, and if liquidity has no investment value, we would not expect banks to hold liquid assets for investment purposes. Instead, they would choose to invest in less liquid securities. In general, however, less liquid securities are not perfectly correlated with liquid securities, so that there will be a diversification benefit from holding liquid assets. Further, there is an investment advantage to liquid assets as exposure to such assets can be changed easily compared to exposure to illiquid assets. For instance, should loans become more profitable, a bank could easily sell liquid assets to increase its holdings of loans. It might miss such opportunities if it had to sell illiquid investments.

The investment view of liquid asset holdings implies that liquid asset holdings and loans are substitutes. If a bank's lending opportunities improve, it will hold fewer liquid assets. Using a sample of banks with assets in excess of $2 billion in 2018 dollars, in line with the investment motive, we find that banks with better lending opportunities have lower liquid asset holdings across different panel regression specifications, different subsamples, different subperiods, and different estimation approaches. When we proxy the change in lending opportunities with the change in loans, we show that the relation is robust when we instrument the change in loans using a Bartik-like instrument (Bartik, 1991). With our framework, we expect that banks with good lending opportunities that experience an increase in deposits will use the additional resources to lend more even though they have low liquid asset holdings. In contrast, banks with poorer lending opportunities, and hence more liquid assets, that experience an increase in deposits will invest relatively more of the new funds in liquid assets. We corroborate this conjecture in regressions that include an interaction term of instrumented deposits with an indicator variable for banks with relatively low liquid asset holdings.

We show that our empirical model of bank liquid asset holdings estimated before the GFC does reasonably well at predicting bank liquid asset holdings after the GFC for the sample as a whole and for banks with assets of less than $50 billion. However, the model understates the liquid asset holdings of banks with assets in excess of $50 billion after the GFC by more than six percentage points every year starting in 2015. This finding suggests that a large part of the increase in the LAR of large banks post-GFC cannot be explained by changes in bank characteristics from before to after the GFC. The GFC led to large changes in bank regulations and Federal Reserve policies. Such changes include the payment of interest on reserves started after the Lehman bankruptcy and the introduction of quantitative easing. Regulations change for banks, but the changes depend on bank size and bank business model. Specifically, capital requirements increased much more for the largest banks than for other banks. Liquidity requirements, which did not exist before the GFC, constrain the largest banks to hold a minimum amount of liquid assets.

We investigate the impact of post-GFC regulatory changes on liquid asset holdings using a difference-in-differences design. Identifying the impact of the various post-GFC regulatory changes is difficult in part because 1) many regulations change at the same time, 2) banks typically change their policies much before regulations become final, and 3) there is no unambiguous way to date the regulatory changes. We focus on results using the end of 2013 as the first year for which we can observe bank balance sheets incorporating the regulatory changes, but also discuss results for alternative choices. Using a difference-in-differences analysis, we find evidence that banks with assets in excess of $50 billion and especially those with assets in excess of $250 billion have higher liquid asset holdings starting with the end of 2013. Such an increase could be consistent with an impact of the introduction of the LCR, but it could also result from increases in capital requirements. To distinguish between the effect of the LCR and of capital requirements, we investigate using a triple-interaction whether the liquid asset holdings change more for treated banks that have low liquid asset holdings before treatment. We find that this is so, which is consistent with an impact of the LCR on liquid asset holdings. We also find that the increase in liquid asset holdings is higher for the largest banks, which is consistent with the fact that the LCR rules are more demanding for these banks. However, when we investigate whether liquid assets increase more for banks with low Tier 1 ratios, we

also find that banks with low Tier 1 ratios increase liquid asset holdings more. With higher capital requirements, banks with low Tier 1 ratios can satisfy the new requirements by reducing their holdings of risky assets and replacing them with liquid asset holdings. Consequently, our investigation finds that both the LCR and the change in capital requirements help explain the increase in liquid asset holdings for large banks and especially for the largest banks.

The central bank controls the aggregate amount of reserves and the rate that they earn. Though aggregate reserves are under the control of the central bank, the liquid asset holdings of individual banks are not directly under the control of the central bank. Our approach is that banks choose the amount of liquid assets they want to hold. We find that banks hold fewer liquid assets when they have better lending opportunities if we consider only non-reserve liquid assets.

Overall, this paper documents substantial variation in liquid asset holdings across banks and through time and shows that the determinants of liquid asset holdings from the corporate finance literature offer little help in understanding this variation. Rather, we provide evidence in line with an investment view of bank liquid asset holdings in which liquid asset holdings and loans are substitutes, and in which banks respond to changes in deposits differently depending on their liquid asset holdings. We also show that the determinants of large bank holdings of liquid assets are different after the GFC and that post-GFC regulatory changes involving both liquid asset holdings and capital may explain some of the changes.

This paper contributes to several strands of the banking literature and the literature on the stability of the financial system. Especially following Diamond and Dybvig (1983), there is an enormous literature that focuses on the risk of depositor runs and bank stability. This literature generally takes the view that banks are in the business of making loans. In subsequent papers, banks hold liquid assets as a way to cope with deposit withdrawals (see Diamond and Kashyap, 2016). With this literature, there is a liquidity risk management motive for holding liquid assets but no investment motive. The bank holdings of liquid assets may be too low as banks do not internalize the systemic benefits of their risk management. As a result, there is a growing literature focused on the optimality and design of liquidity requirements (see Allen (2018) for a review).

Acharya, Shin, and Yorulmazer (2010) develop a model where banks hold liquid assets because these assets enable them to benefit from fire sales during a crisis. They find that equilibrium holdings of liquid assets are inversely related to the pledgeability of risky cash flows, so that holdings of liquid assets are countercyclical. In this paper, the strategic considerations emphasized by Acharya et al. (2010) are part of the investment motive for holding liquid assets. Diamond and Rajan (2011) have a related paper that has healthy banks hoarding liquid assets to take advantage of fire sales. In that paper, the hoarding of liquid assets comes at the expense of loans, so that banks cut back on lending when liquid assets are especially valuable because they can be used to pay for assets bought in fire sales.

Bank holdings of liquid assets play an important role in the transmission of monetary policy. Kashyap and Stein (2000) show that monetary policy affects lending much more for banks with low liquid assets. Their results hinge on the substitutability of loans and securities on a bank's balance sheet. They argue that a tightening of monetary policy that reduces a bank's deposits has less of an impact on loans for banks that have plenty of liquid assets as these banks can substitute funding of loans through deposits by funding of loans through sales of liquid assets. Their measure of liquid assets is securities holdings. This is a broader measure than our measure as it includes stocks, corporate bonds, and trading assets that we do not include in our definition of liquid assets. Our focus is on why banks hold liquid assets, while the focus of Kashyap and Stein (2000) is how liquid assets affect the transmission of monetary policy. More recently, Bianchi and Bigio (2022) develop a model of bank liquidity management with an over-the-counter interbank market to study the credit channel of monetary policy. Their model centers around the tradeoff between profiting from lending and incurring greater liquidity risk arising from deposit withdrawals. In their model, liquid assets are disadvantaged because of a liquidity premium. The central bank changes the ratio of liquid assets to loans by affecting the liquidity premium. They rely on evidence from Nagel (2016) that the liquidity premium of short-term assets is strongly negatively correlated with short-term rates. While we find evidence supportive of this role of the liquidity premium before the GFC, we do not find it after the GFC.

A related literature is the literature on bank liquidity creation. In modern banking theory, an important role of banks is to create liquidity. With this view, banks create liquidity by issuing liquid liabilities that

they invest in illiquid assets. The literature attempting to measure the extent of liquidity creation by banks is relatively sparse. The seminal paper in that literature is by Berger and Bouwman (2009). They divide assets into three categories: illiquid assets, semiliquid assets, and liquid assets. The liquid assets include cash, securities, and trading assets. They then measure the liquidity of a bank's assets and of its liabilities. The difference in liquidity between the liabilities and assets of a bank is their measure of a bank's liquidity creation. In this paper, we only include cash and some securities as liquid assets. Specifically, we exclude securities that have credit risk and stocks since we want to focus on assets that can be readily converted into cash if a bank faces unexpectedly large demands for cash. Bai, Krishnamurthy, and Weymuller (2018) develop a measure of liquidity mismatch for banks that builds on Berger and Bouwman (2009). In contrast to Berger and Bouwman (2009), their measure of asset and liability liquidity is dynamic, so that the liquidity of an asset changes over time. They further use market values instead of book values. Our paper focuses on liquid asset holdings. Two banks with the same amount of liquidity creation or the same liquidity mismatch can have very different holdings of liquid assets. The extent of liquidity creation is endogenous, and our research helps better understand the determinants of the amount of liquidity creation by banks.

Lastly, there is a growing literature on the effect of the post-GFC policy and regulatory changes on bank policies. Some papers focus on the channels through which quantitative easing affects the economy. Acharya and Rajan (2022) develop a model showing that central bank balance sheet expansion can exacerbate episodes of stress because banks finance reserves through runnable liabilities. Relatedly, Piazzesi and Schneider (2021) distinguish between liquidity within the banking sector and liquidity in the non-banking sector. Within the banking sector, securities are used to back the creation of money. They differentiate between a regime of scarce reserves and a regime of abundant reserves. In the abundant regime, the cost of liquidity is zero within the banking sector. Diamond, Jiang, and Ma (2021) examine how quantitative easing increases the cost of loans by forcing banks to hold more reserves within a structural model. Their focus is on how the mechanism they develop impacts the effect of quantitative easing on the economy. Their mechanism hinges on a substitution effect between reserves and loans. In our paper, there need not be such a substitution as banks could increase reserves but decrease their holdings of other liquid

assets. Darmouni and Rodnyansky (2017) find that quantitative easing increases loans more for banks that hold more mortgage-backed securities. Chakraborty, Goldstein, and McKinlay (2020) show that quantitative easing changed the composition of lending, so that banks with more mortgage lending that could be securitized increased that lending at the expense of C&I lending.

Other papers study the LCR. Cetina and Gleason (2015) show how difficult it is to figure out exactly how much liquid assets a bank has to hold to meet the LCR requirement. Roberts, Sarkar, and Shachar (2019) find that the LCR decreased bank liquidity creation and that it did so in part through a decrease in lending. Bosshardt and Kakhbod (2020) conclude that the LCR increased the non-performing loans ratio of banks as well as the liquid assets ratio. Their definition of liquid assets is much broader than ours, so that they include relatively illiquid securities that are penalized with the LCR. Banks are likely to have replaced relatively illiquid securities with more liquid securities as a result of the LCR. Ihrig, Kim, Vojtech, and Weinbach (2019) show that high quality liquid assets held by banks are mostly reserves, US Treasuries, and GSE MBS. Lastly, Whited, Wu, and Xiao (2021) examine the impact of low interest rates on bank risk-taking in a structural model. Their model has banks holding reserves, government securities, and loans. They have substitution between loans and liquid assets. However, their balance sheet assumptions do not include credit-risky and illiquid securities. They focus on the impact of low rates and liquidity requirements on bank values. They find that low rates decrease bank values more than liquidity requirements.

The paper is organized as follows. In Section 2, we define bank liquid assets and show how they evolve over time. We then compare the determinants of bank liquid assets to the determinants of liquid assets for non-financials in Section 3. In Section 4, we develop a conceptual framework for holdings of liquid assets by banks. In Section 5, we provide evidence supportive of our framework and investigate the determinants of the composition of liquid asset holdings. In Section 6, we investigate why the determinants of bank liquid asset holdings differ post-GFC and assess whether the differences can be explained by the post-GFC regulatory changes. We conclude in Section 7.

2. Bank liquid assets: Definition and evolution over time

We investigate holdings of liquid assets by banks. Liquid assets are assets that can be sold rapidly with little or no price pressure (Grossman and Miller, 1988). For our definition of liquid assets, we use the top high-quality assets of the liquidity coverage ratio (LCR). The LCR was introduced in December 2010 as part of Basel III. In the US, a version of the LCR was proposed in 2013 and finalized in 2014. Level I liquid assets include excess reserves with the Federal Reserve, US Treasuries, government agency debt, and some sovereign bonds. Level IIA liquid assets include GSE debt, MBS, and sovereign debt with risk weights between 0 and 20 percent. We obtain the data for liquid assets from the Reports of Conditions and Income (Call Reports). Our measure of liquid assets includes bank cash holdings, US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We define bank cash holdings as vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. All the assets we include in the definition trade in liquid markets, have little or no credit risk, and can easily be used for repurchase agreements.

We compute the liquid asset holdings from March 1984 to December 2020 for all US-chartered commercial banks (charter type 200) with assets in excess of $2 billion in constant 2018 dollars. We drop banks with missing data on assets and those with a negative book value of equity. In the following, all dollar amounts are in constant 2018 dollars (using the CPI deflator). We have 1,282 unique banks. At times, we divide banks between large, medium, and small banks. We define large banks to be banks with assets in excess of $50 billion dollars. Medium banks have assets between $10 billion and $50 billion. Small banks have assets between $2 billion and $10 billion. Small and medium banks form the category of "other banks." Some of our analyses focus on the subsample of 238 unique large publicly listed banks in our sample.[2] The

[2] Large publicly listed banks are public banks with assets greater than $10 billion (in constant 2018 dollars). We classify banks as public if stock price data are available for the bank or for its bank holding company. For multibank holding companies, a large publicly listed bank is the largest entity in the holding company. We obtain stock price data from CRSP using the FRB New York link file. The linkage table can be found at: https://www.newyorkfed.org/research/banking_research/datasets.html.

total number of banks is higher at the end of the sample period than at the beginning, reflecting the greater concentration of the banking sector, so that there are more banks with more than $2 billion of assets but many fewer with assets lower than $2 billion. We have 324 banks in 1984. The lowest number of banks is 288 in 2010. In 2020, we have 405 banks.

Figure 1 shows the evolution of the aggregate LAR. The aggregate LAR is computed by summing liquid assets for all banks in the sample and dividing them by the sum of assets for all banks. Aggregate LAR hovers around 20% until the early 1990s, when it increases to a pre-GFC peak of 24% in December 1992. After the pre-GFC peak, it falls to reach a trough of 12.4% in the first quarter of 2008. After that trough, the aggregate LAR doubles to reach 25.4% in December 2019 before the COVID crisis and 33.2% at the end of our sample period. We show in the same figure the percentage of assets represented by loans. The aggregate loan ratio is computed by summing loans across banks and dividing them by the sum of assets. The fraction of the balance sheet of the banking sector corresponding to loans falls for most of our sample period, but it increases slightly between 2015 and 2019 before falling again in 2020. The peak aggregate loans-to-assets ratio before the GFC is 65%. The trough aggregate loans-to-assets ratio is 47.3% at the end of the sample. Before the COVID crisis, the trough of aggregate loans-to-assets is 49.4% in the third quarter of 2011. The figure suggests an inverse time-series association between the aggregate loan ratio and the aggregate LAR over time, which is what one would expect if loans and liquid assets are substitutes.

For banks, liquid assets are the sum of cash and non-cash liquid assets. We show the evolution of the components of liquid assets in Figure 1. We compute the aggregate cash-to-assets ratio, which is the sum of cash holdings of sample banks scaled by the sum of assets of sample banks. These cash holdings include reserves held at the Federal Reserve. Before the GFC, reserves held at the Federal Reserve pay no interest. Shortly after the collapse of Lehman, on October 9, 2008, the Federal Reserve starts paying interest on excess reserves of 75 basis points. The interest rate stays positive but varies over time during the remainder of our sample period. The aggregate cash-to-assets ratio falls dramatically from 16% in 1984 to a low of 4.1% in 2006. After staying between 4.1% and 4.7% from 2006 to the second quarter of 2008, it then

increases sharply, starting with the bankruptcy of Lehman, before eventually dropping before the COVID crisis. At the end of 2019, this ratio is the lowest since the first quarter of 2011. At the end of our sample period, the ratio stands at 15.2%.

Early in the sample period, the aggregate cash-to-assets ratio exceeds the aggregate non-cash liquid assets-to-assets ratio. The non-cash liquid assets-to-assets ratio is 5.9% at the beginning of the sample period. It increases steadily and eventually exceeds the cash-to-assets ratio in 1991 as the cash liquid assets-to-assets ratio falls. Once the non-cash liquid assets-to-assets ratio exceeds the cash-to-assets ratio, it does so every year except in the last two quarters of 2013, 2014, and the first quarter of 2015. After the GFC, the ratio of non-cash liquid assets-to-assets ratio increases steadily, while the ratio of cash-to-assets increases at first and then falls. Just before the COVID crisis, at the end of 2019, the non-cash liquid assets-to-assets ratio peaks at 16.2%, which is almost three times the level of the ratio at the beginning of the sample period. The inverse time-series association between the aggregate loan ratio and the aggregate liquid assets ratio is more pronounced for the non-cash component of the LAR, which is consistent with our conjecture that the investment view of banks' LAR applies in particular to non-cash liquid asset holdings, while changes in cash holdings may be more driven by the transaction and the precautionary motives for holding liquid assets.

In Panel A of Figure 2, we show results for equally-weighted averages of the LAR for small, medium, and large banks. Before the GFC, the LAR for small and medium banks always exceeds the LAR of large banks. In the 2000s, before the GFC, the LAR falls for all three groups of banks, but more so for small banks. In the last quarter of 1999, the LAR is 23.2% for small banks and 16.7% for large banks. In the middle of 2008, the LAR of small banks is 15.0% and the LAR of large banks is 13.4%. From the end of 1999 to the middle of 2008, the LAR of small banks falls by 8.2 percentage points and the LAR of large banks falls by 3.3 percentage points. During the GFC, the LAR initially falls for all three groups of banks and then rebounds sharply. The increase in the LAR following the trough in 2008 is the largest for the large banks, so their LAR increases to match the LAR of medium and small banks in 2009. By 2013, the LAR of large banks exceeds the LAR of small and medium banks. It stays that way until the end of the sample

period. In the last quarter of our sample period, the LAR of large banks exceeds the LAR of small banks by 10.7 percentage points.

In Panel B of Figure 2, we show results for equally-weighted averages of loans-to-assets by bank size. Early in the sample period, large banks lend more than medium and small banks (as a fraction of assets), but that changes around 1992 when they lend less for the remainder of the 1990s and they lend similarly to medium and small banks. We see that starting from the end of 2006, small and medium banks lend more than large banks. The difference in loans-to-assets for small and medium banks versus large banks increases over time, so that in 2019 the difference exceeds ten percentage points.

It follows from this section that liquid assets are higher post-GFC than before when looking at the aggregate LAR. Aggregate LAR reaches a trough in 2008 and a peak in 2020. The rise of the aggregate LAR is driven by large banks. Small and medium banks have fewer liquid assets at the end of the sample period than at the beginning. Further, the LAR for small and medium banks falls after 2012 in contrast to the LAR of large banks, which increases.

3. Comparing the determinants of liquid asset holdings for non-financial firms and banks

In this section, we compare the determinants of liquid asset holdings for banks and non-financial firms. To have an apples-to-apples comparison, we compare the holdings of public banks to those of public non-financial firms since we only have data on liquid asset holdings for public non-financial firms. We also require the firms in the sample to have $10 billion of assets to focus on established firms. For non-financial firms, we use a definition of liquid assets that is common in the literature, namely cash and short-term liquid assets. For banks, we use the definition of liquid assets presented in the previous section. We use quarterly data. The data for non-financial firms is from Compustat and we obtain market data for public banks from CRSP/Compustat. We show summary statistics for the non-financial firms and the banks in the Internet Appendix. We have 9,119 bank-years in our comparison sample. The average LAR across all quarter-bank observations is 22%. The average ratio of cash-to-assets is 7.78%. We have 23,527 firm-years in the sample

of non-financial firms. The average liquid assets-to-assets ratio for these firm-years is 8.3%. To mitigate the influence of outliers, all firm-level variables are winsorized at the top and bottom 1% of the distribution.

As we show in Figure 3, the evolution of liquid asset holdings is quite different between banks and non-financial firms. To capture the effect of size, we show results for aggregate liquid asset holdings over assets (Panel A) and equally-weighted ratios of liquid asset holdings to assets (Panel B). The aggregate ratio for banks is 17.96% in 1984 compared to 5.99% for non-financial firms. Just before the COVID crisis, at the end of 2019, the aggregate ratio for banks is 26.35%, and the aggregate ratio for non-financial firms is 9.49%. Panel A shows that, during our sample period, the ratio for non-financial firms falls initially and then increases sharply. The trough of the ratio is 3.69% in 1992, and its peak before the GFC is 10.04% in 2004. The ratio in 2019 is below its pre-GFC peak. In contrast, the ratio for banks reaches its pre-crisis trough of 12.55% in 2007. After the GFC, the ratio reaches a peak before COVID of 27.94% in 2017. The difference in the evolution of the ratios is striking as the ratio for non-financial firms has a dramatic increase in the late 1990s and early 2000s compared to a decrease for banks. The ratio for non-financial firms is steady from 2010 to 2018, while the ratio for banks keeps increasing until 2017.

Panel B shows the evolution of equally-weighted ratios. The overall evolution of the ratio for non-financial firms is similar, except that it falls after the GFC until 2019. The equally-weighted ratio for banks does not exhibit the same increase after the GFC that the aggregate ratio shows as it falls from 2010 to 2019. This is because the largest banks experience a large increase in liquid asset holdings compared to the other banks. Though we already saw in Figure 2 that after the GFC, the large banks increase their holdings of liquid assets considerably compared to other banks, Figure 3 shows that this evolution is specific to banks rather than large firms in general.

To assess how well firm characteristics known to be related to liquid asset holdings of non-financial firms explain liquid asset holdings of banks, we use quarterly data for the period from 1984 through 2006. The reason for doing so is that the GFC period is quite unusual as it involves large policy interventions in the banking sector and, following the GFC, regulations for liquid asset holdings for banks are introduced. The liquid asset holdings literature for non-financial firms often estimates regressions of liquid asset

holdings at *t* on firm characteristics at *t*-1, and we estimate such regressions. We use firm characteristics commonly used in the liquid asset holdings literature (see, for instance, Opler, Pinkowitz, Stulz, and Williamson, 1999). These characteristics are the logarithm of book assets (*Log(assets)*), the ratio of long-term debt plus debt in current liabilities divided by the book value of assets (*Leverage*), the ratio of the book value of assets minus the book value of equity plus the market value of equity to the book value of assets (*Market-to-book*), the dividend payout rate (*Dividend payout*), earnings after interest expense, taxes, and dividends, but before depreciation, divided by assets (C*ash flow-to-assets*), capital expenditures/assets (*Capex-to-assets*), acquisition activity scaled by assets (*Acquisitions/assets*), and the volatility of return on assets (*ROA volatility*). All variables are defined in the Appendix.

We provide estimates for the regressions using non-financial firms in Columns (1) through (3) of Table 1. We show results with three sets of fixed effects: time only, firm only, and firm and time. Standard errors are clustered at the firm (or bank) level. In Column (3), all firm characteristics have significant coefficients at the 5% level or better, except for cash flow. Firm liquid asset holdings fall with log(assets), leverage, dividend payout, capital expenditures, and acquisitions. They increase with market-to-book and ROA volatility. The coefficients on firm characteristics have signs that are typical of the findings in the literature. In that literature, there has been much focus on the volatility of ROA as a proxy for the precautionary motive of cash holdings (Opler et al., 1999). The coefficient on ROA volatility has a positive coefficient as expected. Firms with more growth opportunities and intangible assets have a higher market-to-book ratio. Such firms have greater holdings of liquid assets as they have less collateral and a greater risk of losing investment opportunities if hit by adverse cash flow shocks. Firms with higher leverage, lower capital expenditures, and fewer acquisitions are more likely to be financially constrained, so that they are more likely to hold liquid assets to cope with adverse shocks as they will have less access to outside funding. In Column (1), log(assets) and cash flow are not significant, and in Column (2) market-to-book is not significant. All other variables have significant coefficients in all the regressions irrespective of the fixed-effects we use.

In Columns (4) through (6) of Table 1, we report estimates of exactly the same regressions, but now the sample is our sample of public banks. We find that Column (6), which has both time and bank fixed effects, has only two bank characteristics with a significant coefficient. The first characteristic is leverage. While leverage has a negative and significant coefficient for non-financial firms, the coefficient for banks is positive and significant. As for non-financial firms, we find a significant negative coefficient on the dividend payout rate. All the other firm characteristics have insignificant coefficients, except for ROA volatility, which has a positive coefficient that is marginally significant (at the 10% level). Two variables have coefficients that change significance when we omit fixed effects. Without bank fixed effects, log(assets) has a significantly negative coefficient, and the dividend payout has an insignificant coefficient.

We investigate two potential concerns about these results. The first one is the definition of leverage. The second is the definition of liquid assets. The definition of leverage we use is standard in the literature for liquid asset holdings for non-financial firms. However, this definition of leverage is problematic for banks. Banks have very high leverage, but that is because they have deposits. Though deposits are on sight or short-term, they tend to be sticky and more like long-term debt in practice. We, therefore, repeat our regressions using a different definition of leverage for banks, namely the equity-to-assets ratio. With this variable, the lower the ratio, the higher leverage. To save space, we only report the regression with both time and bank fixed effects in Column (7) of Table 1. We find that the coefficient on the equity-to-assets ratio is negative, so that holdings of liquid assets are positively related to leverage, but it is not significant. We then turn to a narrower definition of liquid assets for banks, namely cash holdings, which are mostly reserves. We report the results in the Internet Appendix. No variable is significant in those regressions. It follows that when we use a narrow definition of liquid assets, the firm characteristics used to explain liquid asset holdings for non-financial firms are not successful either.

4. Why do banks hold liquid assets?

In this section, we first discuss the role of the transaction and precautionary motives for bank liquid asset holdings. We next introduce what we call the investment motive. We then discuss the role of

regulation and reserves. We conclude with a summary of empirical predictions that we examine in the remainder of the paper.

4.1. The precautionary and transaction motives

Banks are affected by different shocks than non-financial firms. Non-financial firms are typically not in the business of raising funds to invest them in financial assets for the purpose of getting income from such assets. They generally want to finance and grow their business activities. As a result, they tend to be highly concerned about the risk of cash flow shocks (e.g., Smith and Stulz, 1985; Froot, Scharfstein, and Stein, 1993). In contrast, banks create shareholder wealth through their liabilities. In particular, bank deposits are valuable. Some banks are valued only for their deposit franchise. Banks raise deposits at an average cost that is less than their cost of funding if they had to raise funding from financial markets.

Banks face the risk of having to deliver cash to counterparties that have claims that are redeemable on sight. Banks have demand deposits that have that property. At times, holders of such deposits run on a bank to protect their assets. Moreover, banks have other claims that are redeemable on sight besides deposits as well as claims that have very short maturities. This is especially the case for dealer banks (Duffie, 2010). Banks often borrow overnight or at very short maturities. These borrowings may be large. If its short-term liabilities do not roll over, a bank may have to default. In addition, banks have commitments that may be exercisable on sight or on short notice. These commitments include credit lines and derivatives contracts. Further, banks have customers who trade through the banks and have collateral to back their trades held by the banks. If these customers choose to trade with another bank, they will want to take their collateral with them. To protect themselves against claimants redeeming their claims or against the possibility of not being able to rollover short-term claims, banks hold liquid assets for precautionary reasons.

From the literature, the main concern that precautionary holdings of liquid assets address is the risk of a run on the bank's liabilities. Everything else equal, we would expect the risk of such a run to be lower if a bank has more liquid assets. With this view, we would expect liquid assets to be higher if the bank has more demand deposits. In general, however, deposit accounts are insured directly up to some amount, and

the excess over that amount is viewed as insured implicitly. Banks have other runnable or short maturity liabilities, on and off their balance sheets, that do not benefit from implicit government insurance. The risk of loss on such liabilities is reduced if the bank holds more equity. As a result, we would expect that banks with more equity, everything else equal, require lower precautionary holdings of liquid assets. Given a bank's leverage, we would expect a bank with more loans to require more precautionary holdings as it is more likely to experience losses that could reduce its equity buffer. Banks with more commitments, such as non-drawn credit lines, are expected to hold more liquid assets because they have to be able to honor these commitments. We would therefore expect liquid assets to increase with commitments and derivatives.

Note that with deposit accounts and commitments, banks also hold liquid assets for the transaction motive. Holders of deposit accounts use them for transactions, and the bank has to be in a position to honor the payments they make through their accounts. These payments affect the liquidity position of banks and have a strong network dimension (Li, Li, and Sun, 2021). The best liquid asset for the transaction motive is cash, which generally means reserves held at the Federal Reserve. Reserves are also the liquid asset that is most easily usable if the bank has an unexpected demand for payment. We, therefore, expect that the precautionary and transaction motives involve holdings of cash first. Other liquid assets have to be converted into cash, so that they do not have proceeds that are generally instantly usable. For our sample period, as already discussed, banks receive no interest on their reserves until October 2008. This means that holding excess reserves is especially expensive before the GFC.

4.2. The investment motive

In general, banks can allocate the proceeds from deposits to loans, cash, and securities. There is much evidence in the literature that banks face a downward-sloping demand for loans. For instance, Degryse and Ongena (2005) show that banks charge less for loans to firms that are farther away from them, which is consistent with an inelastic demand for loans that enables banks to price discriminate. Therefore, we assume that banks have a downward-sloping demand for loans. The demand for loans varies across banks and over time. When the demand is high, the profitability of loans will be higher and a bank will underwrite more

loans. However, even then, a bank may have a surplus of investable funds. A bank can invest these funds in liquid securities, illiquid securities, and trading assets. Consequently, a bank may have an investment motive to hold liquid assets. Specifically, the bank may allocate part of this portfolio of financial assets to liquid assets because it is advantageous for it to do so from a portfolio investment perspective. In other words, liquid assets may offer a risk-return profile that is attractive for the bank's overall portfolio. These assets may be attractive because of their diversification benefit, because of the flexibility they provide, and because of the low cost of monitoring a portfolio of liquid assets. With liquid assets, banks can easily reallocate their portfolio if the investment opportunity set changes. In other words, the liquidity of the liquid assets can be valuable for a bank's investment portfolio because of the added flexibility it provides. As opposed to investing the surplus of funds it has, the bank could shrink its balance sheet. This would make sense for the bank if its marginal cost of funding were higher than its expected return on the funds it invests. In general, banks will earn more than the marginal cost of deposits on liquid assets up to some level of deposits. A bank will, therefore, optimally choose to issue deposits up to that level.

To analyze the determinants of the investment motive, it is useful to think about a risk-neutral bank with a balance sheet that has loans, liquid assets, deposits, and equity. For simplicity, we first ignore the precautionary motive for holding liquid assets. Let's assume that deposits, D, and equity, E, are fixed. The assets are funded at a cost of r per dollar. The bank can invest in liquid assets. These investments have an expected return of r^*. The supply of liquid assets to the bank is perfectly elastic, so that there is a constant expected marginal revenue curve for investment in liquid assets at r^*, as shown in Panel A of Figure 4. If $r^* > r$, the bank could be profitable by just investing in liquid assets. Consider now the demand for loans the bank faces. Let L be the amount of loans the bank makes. We assume that the demand for loans decreases as a function of the expected return on loans, r_L, so that we write $L(r_L)$. The expected return on loans is the rate the borrower promises to pay minus the expected credit losses and minus the expected cost of making and managing the loan. As a result, the demand for loans is downward-sloping as shown in Figure 4. With a downward-sloping demand curve, the marginal revenue curve, $L'(r_L)$, is downward-sloping as well. The bank will set the amount of loans, L, at the point where the expected marginal revenue from loans equals

the expected marginal revenue from investing in liquid assets provided that $L < D + E$. In that case, the bank will not invest all its internal funds in loans. Instead, it will invest some in liquid assets. In contrast, if the loan demand is high, then $L = D + E$, and the bank will be better off not investing in liquid assets. With this setup, a decrease in the demand for loans that moves the demand curve to the left causes the bank to invest more in liquid assets. An increase in the expected return on liquid assets causes a decrease in the quantity of loans made by the bank.

The model discussed in the previous paragraph has the key implication of our theory of the determinants of liquid asset holdings: banks will hold liquid assets for investment purposes as long as the demand for their loans is not so large that loans always dominate liquid assets as investments for the bank. In the model above, we ignore deadweight costs of financial distress. In general, however, sufficiently adverse outcomes have deadweight costs. With deadweight costs of adverse outcomes, the bank wants to manage its risk. In this case, diversification across investments becomes valuable. A bank may find it optimal to invest both in loans and in liquid investments to manage the risk of its assets. If liquid assets are not dominated by illiquid assets, the bank will invest in liquid assets, illiquid assets, and loans.

As discussed, banks have transaction and precautionary motives to hold liquid assets. Hence, there is an optimal amount of liquid assets held for these motives. One way to introduce these motives in our simple model is that the expected return from liquid assets is computed to include the benefit these assets provide in terms of enabling the bank to deal with high demands for payments. With this approach, the expected return on liquid assets decreases as the amount of liquid assets becomes greater because each additional dollar of liquid assets has a lower benefit for the transaction and precautionary motives. If, at some point, an additional dollar of liquid assets has no benefit for the transaction and precautionary motives, then the expected net return on liquid assets is r^*. If the intersection of the marginal revenue curve from loans is on the flat part of the marginal revenue curve from liquid assets, then the quantity of liquid assets does not depend on the transaction and precautionary motives. Panel B of Figure 4 shows this case.

If the investment motive is sufficiently strong, the marginal dollar of liquid assets is held for the investment motive, not the transaction and precautionary motives. In this case, to a first-order

approximation, the amount of liquid assets held by the bank fluctuates because of changes in the investment motive rather than because of changes in the precautionary motive. The key prediction implied by our framework is that holdings of liquid assets are higher when the demand for loans is lower as long as the marginal revenue curve of loans intersects with the marginal revenue curve from investing in liquid assets so that $L < D + E$. This prediction implies that an increase in the demand for loans causes a decrease in holdings of liquid assets. We investigate this prediction in Section 5.

Now suppose that the demand for deposits increases so that the bank can have a larger amount of deposits for the same rates, everything else equal. In this case, the bank's assets would increase. The loan amount would be unchanged because the demand for loans is unchanged. As a result, the increase in the demand for deposits would result in an increase in holdings of liquid assets. We show this in Panel C of Figure 4. With this figure, if the marginal revenue curve for loans were to intersect the red line on its upward-sloping part or if it were to intersect the blue vertical line, an increase in deposits would increase loans. Hence, for a bank with high lending opportunities, an increase in deposits causes an increase in loans. We investigate these predictions in Section 5 as well.

Our framework can be used to consider the impact of a Fed policy shock that increases interest rates. In this case, we would expect r^* to increase and the demand curve for loans to be unaffected. Suppose now that the bank does not increase its deposit rate fully to match the increase in rates because the demand for its deposits is inelastic (see Drechsler, Savov, and Schnabl, 2017). In this case, an increase in rates would decrease deposits and loans. The net effect on liquid assets could be positive or negative. If the bank increases deposit rates to match the increase in rates, then the increase in rates decreases loans and hence increases holdings of liquid assets.

4.3. Reserves and liquid asset holdings.

Banks have a reserve requirement, but the requirement can be satisfied with vault cash as well as reserves held at the Federal Reserve. The marginal reserve requirement for our sample period is 10% of net transaction accounts until March 2020 when it goes to zero. As discussed in Bennett and Peristiani (2002),

reserve requirements become less important over time because banks use sweep accounts to reduce the size of net transaction accounts. Starting with the GFC, the Federal Reserve expands its balance sheet massively, so that it creates reserves that have to be held by the banking system. The expansion of the Federal Reserve balance sheet raises the question of how the creation of additional reserves affects bank holdings of liquid assets. One could think of an extreme case where reserves are so abundant that banks collectively have to hold an amount of reserves so large that all liquid asset holdings are reserves, so that liquid asset holdings for the banking sector are set by the Federal Reserve. However, at the bank level, the aggregate amount of reserves is not relevant as a bank chooses its amount of excess reserves. An individual bank can choose the composition of its liquid assets as it pleases as long as it satisfies regulatory requirements (the reserve and capital requirements throughout the sample period and the liquidity requirement after the GFC).

Before the GFC, since reserves do not pay interest, banks attempt to minimize reserves. The situation is more complicated after the GFC. When reserves pay interest, banks do not necessarily attempt to minimize reserves. Reserves may turn out to be substitutes for some liquid assets. If reserves are perfect substitutes for some non-reserve liquid assets, we expect banks to be indifferent between holding reserves and these non-reserve liquid assets.

Given the importance of excess reserves after the GFC, we investigate the role these excess reserves play in our results. We provide results where we consider only bank holdings of non-reserve liquid assets.

4.4. Regulation and bank liquid asset holdings.

Banks are subject to capital requirements and liquidity requirements. We consider these requirements in turn. Starting with capital requirements, it is important to note that banks would be subject to capital requirements by the market even if there were no requirements from the official sector. If a bank has too little capital, it will not be able to find counterparties and will fail. As a result, the bank has to satisfy a minimum capital requirement which is the highest among the regulatory capital requirements and the market capital requirement. For simplicity, suppose that this minimum capital requirement can be formalized as the requirement that the equity-to-assets ratio is higher or equal to x. If the bank has an equity-

to-assets ratio equal to y, which is higher than x, we say that the bank is not constrained by capital. An unconstrained bank can expand its balance sheet without raising equity. A constrained bank has $y = x$, and it cannot expand the balance sheet without raising equity. We distinguish between constrained and unconstrained banks. For simplicity, we assume that raising capital is not possible in the short run. This reflects the well-known reluctance or difficulty that banks have in raising equity.

Suppose that the bank requires more capital to support a dollar of loans than a dollar of liquid assets. Such an outcome holds with the risk-based capital requirement. In this case, a constrained bank can become unconstrained by replacing loans with liquid assets. Consequently, the decision of how much liquid assets to hold is affected by capital requirements. However, if the binding capital requirement for a bank is the leverage ratio, then replacing loans with liquid assets will not enable the bank to become unconstrained. An unconstrained bank can make decisions on the allocation of assets without being constrained by capital requirements as long as it remains unconstrained. A bank that is unconstrained can become constrained because of an increase in capital requirements. Capital requirements increase substantially after the GFC (Walter, 2019). With our framework, one way that a bank can at least partly accommodate an increase in risk-based capital requirements is by replacing loans with liquid assets. It follows from this that a bank that targets its capital ratios so that it has a margin of safety over the regulatory and market required ratios will typically hold more capital if it has more loans, as loans are capital intensive. Hence, the capital requirements induce a negative relation between equity and holdings of liquid assets.

We turn now to liquidity regulation. The US did not have such a regulation before the GFC. After the GFC, it eventually implemented new liquidity regulations that were finalized in 2014. Consider a regulation that requires a bank to have liquid asset holdings such that LAR is equal to or greater than k. Suppose that the same bank wants to have liquid assets of m as a fraction of assets for the precautionary motive. These liquid assets have to be in excess of k as the bank cannot use the liquid assets held for regulatory reasons. Consequently, the bank wants a LAR at least equal to $k + m$. Before the implementation of the regulation, the bank has a LAR of $w > m$, so that the marginal dollar is not held for the transaction and precautionary motives. If the new regulation is such that $w > m + k$, the bank can keep holding its liquid assets and does

not need to change anything. However, suppose that $w < m + k$. In this case, the bank does not have enough liquid assets. The bank can shrink its balance sheet or it can acquire liquid assets. In particular, the bank could build its holdings of liquid assets by decreasing the size of its loan book through loan sales or through loan repayments.

Panel D of Figure 4 shows the impact of a liquidity requirement. The liquidity requirement means that some fraction of the balance sheet has to be immobilized in liquid assets. Now, the liquid assets held for the precautionary motive come in addition to the required liquid assets, so that the intersection between the marginal revenue curve for loans and the marginal revenue curve for liquid assets moves from L to L^* and the expected net return on loans increases from r^* to r^{**}. The imposition of a liquidity requirement reduces loans and makes loans more expensive.

4.5. Summing up and hypotheses

Figure 4 summarizes the interaction of the various motives we have discussed in the simplified case where a bank's assets are only loans and liquid assets and where its liabilities are only deposits and equity. An increase in loans means a decrease in liquid assets in our simplified example. The demand for loans is downward-sloping, so that the marginal revenue curve for loans is downward-sloping as well. The marginal revenue for liquid assets is the pecuniary expected return plus the non-pecuniary benefits arising from liquidity. These benefits are negatively related to the amount of liquid assets. We assume that the function is convex. With this, the amount of loans corresponds to the intersection of the marginal revenue curve from loans and the marginal revenue curve from liquid assets. In the simple case shown in Panel B of Figure 4, an increase in the demand for loans causes a decrease in holdings of liquid assets. An increase in deposits has the effect of increasing loans if the bank draws non-pecuniary benefits from liquid assets, but in the absence of such a benefit, the increase in deposits is fully absorbed by an increase in liquid assets.

Figure 4 neglects many complications. Most importantly, it neglects that banks have assets other than liquid assets and loans and that they have other liabilities besides deposits. However, there is no reason to believe that our main empirical predictions do not hold if we take these complications into account. For

instance, we would still expect an increase in the demand for loans to decrease other assets held by banks. Keeping the marginal gain from investing in these other assets constant, we would expect a proportional reduction in their holdings as the demand for loans increases. It follows that, in a model that allows for more types of assets, the key predictions of the investment motive are:

1) There is a negative relation between lending opportunities and liquid assets. An increase in the demand for loans causes a decrease in liquid assets. This decrease in liquid assets is smaller for banks with good lending opportunities (that have a low LAR in the first place).
2) If a bank experiences an increase in deposits, liquid assets increase for banks unless the bank has extremely good lending opportunities. As a result, high LAR banks (which tend to have relatively poor lending opportunities in our framework) increase LAR when deposits increase, but low LAR banks (with good lending opportunities) may not.
3) A liquidity requirement increases liquid asset holdings only if the transaction and precautionary motives to hold liquid assets exceed the holdings of liquid assets in excess of the liquidity requirement before the imposition of the liquidity requirement.

The predictions of the transaction and precautionary motives are that a bank holds more liquid assets if it has more deposits, especially demand deposits, and holds fewer liquid assets if it has less leverage. The latter prediction follows from the fact that a bank with less leverage, everything else the same, is less likely to become distressed. To the extent that runs are more likely when a bank is distressed, greater equity means less risk of a run and hence lower holdings of liquid assets.

5. Are the determinants of bank liquid asset holdings consistent with our framework?

In this section, we investigate whether there is support for the investment motive of holdings of liquid assets. We proceed in three steps. First, we assess the role of the determinants of liquid asset holdings implied by the framework. Second, we consider the relation between liquid asset holdings, deposits, and loans using exogenous variation in deposits and loans through instrumental variables. Third, we test the

proposition that low LAR banks are not liquidity-constrained but instead are banks with valuable lending opportunities.

5.1. The determinants of liquid asset holdings

In this section, we first examine regressions of the LAR at time *t* on determinants observed at *t*-1. This approach is similar to one approach used in the literature on liquid asset holdings for non-financial firms (e.g., Opler et al., 1999). Another approach used in the corporate finance literature is to investigate how firms save cash flow in the form of liquid assets (Almeida, Campello, and Weisbach, 2004; Riddick and Whited, 2009). Banks allocate assets rather than save from cash flow. We, therefore, estimate regressions that are in the spirit of the regressions used in the literature on liquid asset holdings but focus instead on variables related to banks' balance sheet decisions. In particular, an increase in deposits brings new resources to a bank so that it can allocate across assets.

In Panel A of Table 2, we regress the LAR at *t* of bank *i* in state *s* on variables that proxy for the transaction, precautionary, and investment motives determined at *t*-1. With the investment motive, banks with better lending opportunities, which translate into a higher ratio of loans-to-assets, have a lower LAR. With the precautionary motive, banks with more demand deposits have a higher LAR, and banks with more equity have a lower LAR. We regress the LAR on previous quarter log assets, loans-to-assets, demand deposits-to-assets, other deposits-to-assets, equity-to-assets, net income to assets, ROA volatility, and an indicator variable for whether the bank has trading assets:

$$LAR_{ist} = c + \beta_{LA} Log\ Assets_{ist-1} + \beta_{L} Loans/Assets_{ist-1} + \beta_{DD} Demand\ deposits/ Assets_{ist-1} + \beta_{OD} Other\ deposits/Assets_{ist-1} + \beta_{E} Equity/Assets_{ist-1} + \beta_{NE} Net\ income/ Assets_{ist-1} + \beta_{ROA} ROA\ volatility_{ist-1} + \beta_{TA} Trading\ assets_{ist-1} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \quad (1)$$

We show the estimates in Panel A of Table 2. The detailed definitions of the variables are given in the Appendix. We estimate regressions for the whole period, the pre-GFC period, and the post-GFC period.

Further, we show results for large banks (more than $50 billion of assets in 2018 dollars) and other banks. The regressions use state-time fixed effects and bank fixed effects. A state is denoted by the subscript *s*. The coefficient on *Loans-to-assets* is negative and roughly similar for the whole sample period and for the two shorter periods. We find that the absolute value of the coefficient on *Loans-to-assets* is much larger in absolute value for other banks than for large banks for the period 1984-2006 (coefficients of -0.463 versus -0.208).[3] In contrast, there is no meaningful difference between the coefficients for other banks versus large banks for 2010-2020. We then show coefficients for *Demand deposits-to-assets* and *Other deposits-to-assets*. These coefficients are mostly insignificant. Except for large banks before the GFC, the coefficient on *Equity-to-Assets* is significantly negative. This finding is consistent with the precautionary motive. While the evidence of Panel A of Table 2 provides strong support for a negative relation between holdings of liquid assets and loans, it provides at most weak support for the view that holdings of liquid assets increase with exposure to demand deposits because of the risk of runs.

We estimate additional regressions but report the results only in the Internet Appendix. First, we estimate the same regressions, but lag the regressors by four quarters instead of one. The results are very similar. Second, we estimate the regressions using individual loan categories instead of overall loans-to-assets. These categories are C&I loans, real estate loans, and consumer loans. We find that large banks behave quite differently in the 1984-2006 period from other banks. Specifically, the coefficient on *C&I loans-to-assets* is not significant for large banks but is significant and three times larger in magnitude for other banks. Third, we re-estimate the regressions of Panel A of Table 2, adding *Wholesale funding-to-assets*, *Commitments-to-assets*, and *Derivatives-to-assets*.[4] The coefficient on *Commitments-to-assets* is never significantly positive. The coefficient on *Wholesale funding-to-assets* is insignificant, except in the 1995-2006 period, where it is positive and weakly significant for the full sample and for other banks. *Derivatives-to-assets* never has a significant positive coefficient. None of the coefficient estimates on these

[3] The coefficient for large banks is insignificant when we use state-time fixed effects but significant with time fixed effects. Since large banks are national banks, time fixed effects may be more appropriate for them.
[4] Derivatives data are only available since 1995. In these regressions, our sample period is from 1995-2020.

additional variables supports the view that, at the margin, the LAR is determined by the precautionary and transaction motives of liquid asset holdings.

One might be concerned that the negative coefficient on *Loans-to-assets* in Panel A of Table 2 may be mechanical since at *t* an increase in loans-to-assets leaves less balance sheet room for liquid asset holdings. Because we include the lag of *Loans-to-assets*, there is no direct mechanical relation in that a given level of *Loans-to-assets* at *t-1* is consistent with any level of the LAR at *t*. In other words, the relation between the LAR and *Loans-to-assets* could be anything. This is even more the case when we lag *Loans-to-assets* by four quarters. We nevertheless show estimates of regressions that include no balance sheet ratios as regressors. Instead, these regressions use a proxy for lending opportunities which is the lagged eight-quarter average growth for loans. For deposits, we use the four-quarter volatility of deposits-to-assets. Our other regressors are the log of assets, net income-to-assets, ROA volatility, and the indicator variable for trading assets. The regressions include state-time and bank fixed effects. We estimate the following regression using quarterly data:

$$LAR_{ist} = c + \beta_{LA} Log\ Assets_{ist-1} + \beta_{L} Loan\ growth_{ist-8,t-1} + \beta_{D} Deposit\ volatility_{ist-4,t-1} + \beta_{NI} Net\ income/Assets_{ist-1} + \beta_{ROA} ROA\ volatility_{ist-4,t-1} + \beta_{TA} Trading\ assets_{ist-1} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \quad (2)$$

We focus on the variables that are specific to the framework developed in the previous section. We expect a negative sign on *Loan growth* and a positive sign on *Deposit volatility*. We see in Panel B of Table 2 that *Loan growth* has a negative coefficient in all the regressions. The coefficient is not significant for large banks, but the sample size for large banks is a small fraction of the sample size for other banks or for the whole sample. Note, however, that the coefficient for large banks is of the same magnitude as the coefficient for other banks. Turning next to *Deposit volatility*, we see that *Deposit volatility* has a positive significant coefficient for the whole sample period and for the pre-GFC period, but not for the post-GFC period. The

coefficient is insignificantly negative for large banks for the pre-GFC period and insignificantly positive for the post-GFC period. It follows that we find support for our prediction of a negative relation between holdings of liquid assets and lending opportunities. The evidence on the precautionary motive for deposits is consistent with such a motive for the pre-GFC period, but not for the post-GFC period.

Another concern with Panel A of Table 2 is the concern that aggregate reserves have to be held by banks. We address this issue by looking separately at cash holdings, which are mostly reserves, and non-cash holdings. With the investment motive, we expect non-cash holdings to be lower when a bank has better lending opportunities. We estimate the regressions of Panel A of Table 2 separately for cash holdings of liquid assets and non-cash holdings of liquid assets in Panel C of Table 2. We see that the coefficient on *Loans-to-assets* is negative in all regressions, except for regressions using cash holdings for large banks in the pre-crisis period. We find further that the coefficient is higher in absolute value for non-cash liquid assets. When it comes to demand deposits, we see that the coefficient on *Demand deposits-to-assets* is positive for the cash holdings regressions and negative for the non-cash holdings regressions. This is consistent with the precautionary motive applying to cash holdings of liquid assets but not to non-cash holdings. Lastly, the negative coefficient on *Equity-to-assets* observed in Panel A of Table 2 seems to be due to a negative relation between equity and holdings of non-cash liquid assets.

We now estimate regressions using changes that are in the spirit of Almeida et al. (2004). These regressions assess how changes in the use of bank resources are allocated to liquid assets and relate contemporaneous changes in the dollar amount of liquid assets to contemporaneous changes in loans and assets. With these regressions, changes in the dollar amounts of liquid assets and loans do not have a mechanical relation since both could grow as a bank's balance sheet grows. We scale the dollar changes in these and other bank balance sheet variables by lagged total assets to circumvent issues with non-stationarity, outliers, and inflation that could arise when using variables expressed in dollar terms. We also control for net income, scaled by lagged assets, for contemporaneous changes in ROA volatility, and changes in the indicator for trading assets. As in Panel A, we have state-quarter and bank fixed effects. We estimate the following model:

$$\Delta Liquid\ assets_{ist}/Assets_{ist-1} = \beta_L \Delta Loans_{ist}/Assets_{ist-1} + \beta_A \Delta Assets_{ist}/Assets_{ist-1} + \beta_{ROA} \Delta ROA\ volatility_{ist} + \beta_{NA} Net\ income_{ist}/Assets_{ist-1} + \beta_{TA} \Delta Trading\ assets_{ist} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \quad (3)$$

In this model, the dependent variable is the change in liquid assets for bank *i* from state *s* from *t-1* to *t* normalized by assets at *t-1*. The regressors are constructed in the same way. It is important to note that model (3) is not a differenced version of model (1) and that the regression coefficients from model (3) are not directly comparable to the regression coefficients from model (1). First, model (1) uses lagged values of the explanatory variables, so that a differenced version would have lagged changes instead of contemporaneous changes. Second, model (1) focuses on the equivalent of portfolio weights, whereas model (3) focuses on dollar changes. To see the difference, note that for the LAR to stay constant when assets increase, holdings of liquid assets have to increase as assets increase. Therefore, an increase in holdings of liquid assets does not imply that the LAR increases. The LAR only increases if holdings of liquid assets increase more than assets.

We show in Panel D of Table 2 estimates of model (3). As in Panel A, we find significant negative coefficients on *ΔLoans/Assets*. In other words, when loans increase, liquid assets typically fall. We find that *ΔAssets/Assets* always has a positive significant coefficient. These coefficients suggest that if resources flow into a bank, a substantial share of these resources will be held as liquid assets. It is noteworthy that the adjusted R-squareds are much lower for these change regressions, but the adjusted R-squareds for the post-GFC period are quite large compared to the adjusted R-squareds for the pre-GFC period.

We show additional regression estimates in the Internet Appendix. We add lagged changes to the regressions of Panel D. Doing so leads to two conclusions. First, the results we show in Panel D do not change. Second, the coefficients on the lagged changes are generally small in absolute value and typically insignificant for large banks. The adjusted R-squareds are essentially unchanged when we add the lagged changes. Second, we estimate the regressions of Panel D, adding *ΔCommitments/Assets* and

ΔDerivatives/Assets. The coefficients on changes in loans, assets, and net income are not meaningfully different from the coefficients for the same variables in Panel D.

We also use a different specification for changes. Instead of using dollar changes, we use growth rates as in Chakraborty, Goldstein, and MacKinlay (2018). The results using that approach are similar to the results using the dollar change specifications. In these regressions, a given growth rate of assets is associated with a higher growth rate in liquid assets. Such a result is opposite to results in the liquid asset holdings literature for non-financial firms or from predictions of models for transaction holdings of liquid assets. It is consistent with Figure 4 when a bank experiences an increase in balance sheet size but no change in the demand for loans.

The evidence in this section strongly supports the investment motive hypothesis of liquid asset holdings for banks in that we find a negative relation between liquid assets holdings and lagged loans-to-assets, between liquid assets holdings and lagged lending opportunities, and between changes in liquid asset holdings and changes in loans-to-assets. We find that these results hold for non-cash liquid asset holdings as well as for cash holdings.

5.2. Holdings of liquid assets and exogenous variation in loans and deposits

A concern with the results reported in Table 2 is that loans and deposits are both chosen by banks. That concern is especially acute in Panel D of Table 2 because it uses contemporaneous changes for all variables. In this section, we investigate this relation further using exogenous variation in loans and deposits. This approach addresses concerns about the joint determination of liquid asset holdings and loans and about potential omitted variables. We also allow for exogenous variation in deposits. Our investment hypothesis predicts that banks use additional resources from deposits for investment in liquid assets absent good opportunities to underwrite loans.

In this section, we instrument the change in loans from *t-1* to *t* (normalized by assets at *t-1*) with a Bartik-like instrumental variable (Bartik, 1991; Blanchard and Katz, 1992; Goldsmith-Pinkham, Sorkin, and Swift, 2020). Bartik-like instruments have been used before in banking, for example, in Schiantarelli,

Stacchini, and Strahan (2020), Greenstone, Mas, and Nguyen (2020), and Diamond, Jiang, and Ma (2021). The approach uses as an instrument for loan changes at a bank the (predetermined) exposure of that bank to each type of loan times the aggregate loan changes for each type of loan for the type of bank at the national level. We distinguish between three types of banks: small, medium, and large. We proceed in the same way for the change in total deposits, i.e., the sum of the change in demand deposits and other deposits (normalized by assets at *t-1*), which we denote by *ΔDeposits/Assets*.

Specifically, our Bartik instrument for the change in loans is constructed as follows:

$$Bartik_{cts} = \sum_k w_{cks} g_{kts} \qquad (4)$$

where *s* denotes the size group (based on total assets in constant 2018 dollars) to which bank *c* belongs: Small ($2B – $10B), Medium (>$10B-$50B), and Large (>$50B); w_{cks} is bank *c*'s share of loan type *k* in bank *c*'s portfolio (loans type *k*/total loans) as of the first available quarter as of the beginning of the decade or as of the most recent date between the beginning of the mid-decade and the beginning of the decade. We focus on the following loan types (*k*): commercial and industrial (C&I) loans, real estate (RE) loans, personal loans, and other loans. When instrumenting the change in loans, g_{kts} is computed as the aggregate dollar change in loans of type *k*, scaled by lagged aggregate assets, where aggregate numbers are computed across all banks in size bucket *s.*

We use a similar approach to construct our Bartik instrument for the change in deposits. Specifically, our Bartik instrument for changes in deposits is constructed using Equation (4) above, where w_{cks} is bank *c*'s initial share of total bank funding of deposit type *k (*demand deposits or other deposits) as of the first available quarter as of the beginning of the decade. g_{kts} is the aggregate dollar change in deposits of type *k*, scaled by lagged aggregate assets, where aggregate numbers are computed across all banks in size bucket *s.*

We report the results in Table 3. The regressions use bank fixed effects, but not state-time fixed effects since the Bartik estimate has a common time-varying component for all banks. We add changes in the fed

funds rate, the default spread (measured as the yield difference between BBB-rated and AAA-rated corporate bonds), the composite leading indicator, the interest rate on reserves, and the ratio of aggregate reserves to aggregate bank assets to control for macroeconomic conditions. We first show the first-stage regressions where we regress *ΔLoans/Assets* on our Bartik instrument for the change in loans, our Bartik instrument for the change in deposits, the change in the other bank characteristics we use in the regressions of Panel D of Table 2, and the variables that control for macroeconomic conditions. We report the first-stage results for *ΔLoans/Assets* for the full sample period and the pre-GFC and post-GFC periods in Columns (1) through (3). In Columns (4) through (6), we estimate the same regressions, but now the dependent variable is *ΔDeposits/Assets*. We find that the Bartik instrument for *ΔLoans/Assets* has a positive and significant coefficient for each regression. The regression coefficient on the Bartik instrument for the change in deposits is positive and significant in each regression.

Columns (1) through (6) of Table 3 show strong first-stage results, so that our Bartik instruments are relevant. Consequently, the first stage captures the impact of differential exposures of banks to loan types on a bank's loans and the impact of differential exposures to deposit types on a bank's deposits. These differential exposures are not affected by the aggregate variables as they are observed before the changes in the aggregate variables. The additional control variables capture changes in macroeconomic conditions, so that these changes can affect holdings of liquid assets directly rather than potentially through their impact on the instruments. It is useful to note that the addition of the control variables that proxy for macroeconomic conditions has only a trivial impact on the coefficients on instrumented loans and instrumented deposits.

We now turn in Columns (7) through (9) to the second-stage results. Again, these models have bank fixed effects. We find a strong negative coefficient on the instrumented *ΔLoans/Assets* for all three periods and a strong positive coefficient on the instrumented *ΔDeposits/Assets* for all three periods. The Sanderson-

Windmeijer (2016) multivariate *F*-test of excluded instruments rejects the null of weak instruments strongly for the whole sample period and the pre-GFC sample period, but not as strongly for the post-GFC period.[5]

In this section, we instrument changes in loans and changes in deposits using Bartik-like instruments. We show that the negative relation between changes in loans and changes in liquid asset holdings as well as the positive relation between changes in deposits and changes in liquid asset holdings when we use these instruments.

5.3. Do banks with low holdings of liquid assets invest more in such assets following an increase in deposits?

Our framework implies that banks that have not exhausted their valuable lending opportunities will use an increase in deposits to fund more loans. In contrast, banks that have exhausted their lending opportunities will invest an increase in deposits in other assets, such as liquid assets. We proceed as in Section 5.2. using the Bartik-like instrument for the change in loans and the change in deposits. In this section, however, we are interested in whether banks with low liquid assets behave differently. If banks with low liquid assets are somehow liquidity-constrained banks, we would expect them to use additional deposits to invest more in liquid assets. Alternatively, if banks with low liquid assets are simply banks that have good lending opportunities, we would expect them to not invest more in liquid assets out of additional deposits. If banks with low holdings of liquid assets do not increase their holdings of liquid assets when their deposits increase, this would be consistent with the investment motive but not with the view that these banks are constrained in their holdings of liquid assets and that their holdings of liquid assets are abnormally low.

We consider a bank to have low liquid asset holdings if it has liquid asset holdings in the bottom decile of liquid asset holdings of banks in a given year. We add an indicator variable for whether a bank has low liquid asset holdings to our regressions in Table 3, together with an interaction of that variable with the instrumented *ΔLoans/Assets* and *ΔDeposits/Assets*. The results of the second-stage regressions are in Table

[5] Based on the Stock and Yogo (2005) weak ID F-test critical values.

4. The coefficient on the indicator variable is negative and significant, so that banks with low liquidity overall tend to increase liquid assets less. Such a result is inconsistent with the view that banks with low liquidity aim to increase their liquidity to exit the low liquidity state. We then see that the interaction of the indicator variable with *ΔDeposits/Assets* is negative and significant for all three periods. It follows that banks with low holdings of liquid assets put less of an increase in deposits in liquid assets than other banks. This result is inconsistent with the view that banks with low holdings of liquid assets are somehow liquidity-constrained and work at exiting their low liquidity state. Instead, it is consistent with the investment view of liquid asset holdings, which is that banks that have valuable lending opportunities have low liquid asset holdings and invest additional funds from deposits less in liquid asset holdings than banks that have less valuable lending opportunities. We also show that, as we would expect, banks with low liquidity fund less of their loans through a decrease in liquid asset holdings since the coefficient on the interaction of *ΔLoans/Assets* with the low liquid asset holdings indicator is positive and significant for all three periods.

Our evidence shows that a low LAR is not evidence that a bank is liquidity-constrained. Instead, some banks have low holdings of liquid assets because it is optimal for them to invest more in loans as these investments are more profitable. Other banks have more liquid assets and they invest more in liquid assets as their deposits increase because they do not have as valuable lending opportunities. The evidence in this section supports the investment view of liquid asset holdings.

6. The post-GFC period.

After the GFC, a massive gap develops between the LAR of large banks and the LAR of small and medium banks. Before the GFC, large banks hold fewer liquid assets than small or medium banks. Immediately after the GFC, the LAR of large, medium, and small banks evolves similarly. However, eventually, the LAR of large banks keeps increasing while the LAR of small and medium banks falls. As a result of this evolution, immediately before the COVID crisis, the LAR of large banks (with assets in excess of $50 billion) is 8.98 percentage points higher than the LAR of medium banks and 7.80 percentage points higher than the LAR of small banks. As a result, the LAR difference at the end of 2019 is the reverse of

what it was at the start of our sample in 1984 when the LAR of small banks was 8.22 percentage points higher than the LAR of large banks. We investigate the causes of this reversal in this section.

Going beyond the data in Figure 2, we assess whether there is a change in regime from before the GFC to after the GFC. A simple way to conduct this analysis is to examine whether our liquid asset holdings regression model estimated on the pre-GFC period predicts liquid asset holdings after the GFC. We first conduct this analysis for the sample as a whole. We estimate our regression model over 1984-2006 with our baseline set controls used in Panel A of Table 2. We do not use fixed effects, but add the Fed funds rate, the default spread, and the composite leading indicator. The adjusted R-squared of the model is 61.1%, so that the model captures a fair amount of the variation in the LAR. Panel A of Figure 5 shows the predicted equally-weighted LAR using our model versus the actual equally-weighted LAR over 2010-2020. The model does reasonably well in that it captures the evolution of the equally-weighted LAR for the sample. The model underpredicts the actual average LAR by 1.7 percentage points, and the standard deviation of the prediction error is 0.88%.

In Panel B of Figure 5, we show the results for large vs. other banks, where large banks have assets greater than $50 billion in 2018 dollars and other banks have assets less than $50 billion. Though the model underpredicts the holdings of liquid assets, it tracks the holdings of liquid assets of the other banks relatively well as the average error is 1.19 percentage points. In contrast, the average error for large banks is large, at 5.74 percentage points. The prediction error for other banks actually falls over time until the end of 2019 as it is 1.44 percentage points for the first five years and 0.98 percentage points for the last five years. The opposite is the case for large banks as the prediction error is 1.57 percentage points in 2010 and 7.56 percentage points in 2019. The large prediction errors for the period 2010-2020 for large banks suggest that the divergence of liquid asset holdings of large vs. other banks post-GFC is due to a regime change rather than to changes in bank characteristics from before to after the GFC. As shown in the Internet Appendix, we reach the same conclusion if we estimate models separately for other banks and large banks.

What can explain the regime change we document from before the GFC to after the GFC? Within our framework, a regime change like the one we observe requires a decrease in the demand for loans for large

banks relative to other banks, an increase in the supply of deposits for large banks relative to other banks, and/or an increase in the benefits from liquid asset holdings for large banks relative to other banks. There are at least five possible changes that could help explain the regime change:

1) **Increase in aggregate reserves due to quantitative easing.** The Fed expanded its balance sheet massively after the collapse of Lehman and kept doing so through several quantitative easing programs. With quantitative easing, the banking system has to hold the reserves created through purchases of assets by the Fed. Keeping everything else the same, an increase in holdings of reserves would increase liquid assets through an increase in the reserves held at the Fed. However, for reserve increases to explain the change in regime, it should be that quantitative easing led to greater increases in reserves for large banks.
2) **Capital depletion hypothesis**. Large banks invested more in mortgage-related securities that suffered losses during the GFC (Erel, Nadauld, and Stulz, 2014). As a result, they were more likely to be capital constrained or at risk of being capital constrained. To alleviate capital pressures, large banks could increase liquid asset holdings and decrease loans.
3) **Deposit inflows hypothesis.** During the GFC, some of the largest banks experienced deposit inflows because of a flight to quality (Acharya and Mora, 2015). Lending opportunities fell or did not increase commensurately. As a result, large banks had funds to invest that they could not invest in loans.
4) **Change in capital requirements**. Formal capital requirements increased more for large banks and especially for the largest banks (Walter, 2019). Other than the leverage ratio, the increase in risk-based capital requirements favored holdings of liquid assets compared to holdings of loans, and the increase was larger for large banks. As a result, making loans became more expensive for large banks compared to other banks. However, in addition to increases in capital requirements, stress tests became part of the capital requirements since banks had to pass those tests. These tests might further have made it more advantageous for large banks to hold more liquid assets.

5) **Introduction of liquidity requirements**. Before the GFC, banks had no liquidity requirement. After the GFC, the Basle III accord of 2010 introduced liquidity requirements. The main requirement for US banks during our sample period is the Liquidity Coverage Ratio (LCR), which was finalized in 2014. The LCR applies to bank holding companies with assets in excess of $250 billion starting in 2015 and to bank holding companies with assets in excess of $50 billion starting in 2016. However, some liquidity regulations apply to these bank holding companies already in 2015. In addition, the US introduced liquidity stress tests for the largest banks.
6) **Changes in regulation of derivatives**. Large banks have large positions in derivatives from their trading activities. With Dodd-Frank and related legislation, banks were subject to more collateral requirements on their derivatives trading. Non-cash liquid assets can be used as collateral, so that they became more advantageous.

The Fed balance sheet extension can help explain the increase of reserve holdings by banks. However, it fails to explain why banks increased non-reserve liquid asset holdings as much as they did. Non-cash liquid assets-to-assets for the banking system were higher by 7.1 percentage points at the end of 2020 than at the end of 2009, while cash liquid assets-to-assets, which include reserves, were higher by 6.7 percentage points. The capital depletion hypothesis could plausibly explain why holdings of liquid assets increase sharply during the GFC, but it does not really explain why liquid assets keep increasing throughout the post-GFC period. With the capital depletion hypothesis, we would expect liquid assets to fall as banks rebuild their capital positions. While liquid asset holdings decrease for the other banks, they increase for large banks. A similar argument holds for the increase in deposits. We would expect deposits resulting from a flight to safety to flow out of banks when economic conditions return to a more normal state.

Bank regulatory requirements in the US were affected by two major regulatory changes. The first regulatory change was the Basle III Accord, which was published in November 2010. The second regulatory change was the passage of Dodd-Frank in July 2010. The implementation of the critical provisions of these

regulatory changes for capital requirements and liquidity requirements took time. However, banks started taking steps to meet the expected requirements before they became effective.[6]

Large banks experience significant capital requirement increases relative to other banks.[7] Within large banks, the increase in capital requirements is larger for banks that exceed the $250 billion of assets threshold. First, the largest banks are subject to a surcharge for being globally systemically important banks, a total loss-absorbing capacity requirement, and a supplementary leverage ratio. Second, banks with assets in excess of $50 billion are subject to enhanced supervision and to various stress tests (including liquidity stress scenarios) that require them to have sufficient capital and liquidity to pass these tests. The larger the portfolio of loans with performance dependent on the business cycle, the harder it is for banks to pass these tests. The difference in capital requirements between banks that are subject to enhanced supervision and other banks can be large, but this difference is not fully observable as the outcomes of the stress tests depend on decisions by bank supervisors that are not transparent at the bank level.

Before the GFC, there were no liquidity requirements for banks. These requirements were introduced in the Basel III accord in 2010 and implemented by countries in the following years. In the US, the LCR requirement for banks became effective on January 1, 2015. The final version of the LCR applied to bank holding companies with assets in excess of $250 billion starting from January 1, 2015, but with full implementation in 2017. Banking organizations with assets greater than $50 billion were subject to a modified LCR starting in 2016. As part of enhanced supervision, these banking organizations were subject to regulation YY, which required these banking organizations to have a liquidity risk management framework and to conduct liquidity stress tests. On May 24, 2018, Congress adopted the Economic Growth, Regulatory Relief, and Consumer Protection Act (EGRRCPA). This Act led to regulatory relief for banks with assets lower than $250 billion as of November 1, 2019. Effectively, the threshold for enhanced supervision became $100 billion.

[6] For instance, JPMorgan Chase took steps to decrease its risk-weighted assets to meet Basel III requirements in 2011 (Zeissler, Ikeda, and Metrick, 2019).
[7] See Davis Polk, U.S. Basel III Final Rule: A visual memorandum, April 30, 2015, for a detailed summary of the changes in capital requirements resulting from Basel III.

To isolate the evolution of the LAR for banks depending on how they were affected by the regulatory changes, we show in Figure 6 the evolution of the equally-weighted LAR for four size groups. We focus on a sample for which the regulatory changes were relatively clear and where the size groups are not affected by entrants. The sample we use excludes trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. The results in the earlier sections hold for this more restrictive sample. We sort banks into size groups at the end of 2009 and only use the banks that are in the sample at the end of 2009. As a result, our figure shows the evolution of the equally-weighted LAR for a constant sample of banks. We do not adjust the size thresholds for inflation as we are focused on differences in LAR across regulatory thresholds. With this sample, we see that at the start of 2010, the largest banks have the lowest LAR and the smallest banks have the largest LAR. At the end of the sample period, the ranking has switched. We also see that the equally-weighted LAR of the largest banks increases until roughly early 2015 and then stays fairly stable. The equally-weighted LAR of the medium banks increases first to reach a peak at the end of 2012 and then falls, so that it is lower in December 2019 than in 2010. The equally-weighted LAR of the large banks with assets between $50 billion and $250 billion increases by 3.60 percentage points from the first quarter of 2010 to the first quarter of 2015, while the equally-weighted LAR of the largest banks increases by 9 percentage points. This evidence is supportive of the view that the LAR of banks increases in response to the prospect of regulatory changes in proportion to the anticipated impact of these changes and that the LAR of banks most affected by these changes stays relatively stable after banks have adjusted to the anticipated changes.

A more formal examination of the impact of the regulatory changes faces some important obstacles. First, as discussed, this is not a situation where banks have one liquidity policy until the changes are implemented and another one when the changes are implemented. Banks get ready for the implementation of new regulations. The second obstacle is that the introduction of liquidity requirements is just one of many regulatory changes. It was not the change on which bank CEOs focused. They focused much more on the

increase in capital requirements and the stress tests.[8] Even within capital requirements, the changes do not just include an increase in the minimum amount of various types of regulatory capital banks have to hold. Risk-based capital depends on a bank's risk-weighted assets, but the regulatory reforms changed how risk-weighted capital is computed. Third, it is not clear when the banks thought that they knew enough about the regulatory changes to fully adjust their policies. Fourth, the banks most affected by the regulatory changes are the largest banks, but there are few of those. After excluding foreign banks and trust banks, there are seven banks with assets in excess of $250 billion. Fifth, the complexity of the changes makes it impossible for researchers to attempt to measure capital requirements and the LCR liquidity requirement.[9] Sixth, these various changes took place while the Federal Reserve was implementing various forms of quantitative easing.

The general principles of post-GFC regulations were known in 2010. By 2013, both the capital requirement changes and the details of the liquidity requirements were generally known. The Federal Reserve published key documents that year.[10] The final version of the LCR was published in 2014. Capital requirements and liquidity requirements were implemented over time. We show results where we take 2013 to be the treatment year. We show and discuss results where we take 2014 to be the treatment year and show these results in the internet appendix.

We now turn to a more detailed examination of whether the regulatory reforms affected 1) the LAR, 2) non-reserves liquid assets to assets, 3) reserves (at the Fed) to assets, 4) risk-weighted assets to assets (RWA), 5) Tier 1 equity to assets, and 6) loans to assets. As discussed in Section 4, we would expect the regulatory reforms to increase the LAR for banks that have a low LAR because they have good loans

[8] For instance, we reviewed the CEO's letter to shareholders for JP Morgan Chase for 2013 and 2014. There is almost no discussion of the LCR, but considerable discussion of the various new capital requirements and changes in capital requirements.

[9] In its 2014 letter to the shareholders, the CEO of JPMorgan Chase states that the bank has 27 different capital requirements and more than 500 requirements for liquidity (see page 23 of the Annual Report for 2014 of JPMorgan Chase Co.).

[10] See Basel Regulatory Framework, Recent Updates, Board of Governors of the Federal Reserve System, https://www.federalreserve.gov/supervisionreg/basel/basel-default.htm.

opportunities. For such banks, the increase in LAR should be accompanied by a decrease in loans. We would also expect Tier 1 to increase for banks that have a low Tier 1 ratio. We have no predictions for the other ratios. For instance, the change in the calculation of RWA increased RWA, but some banks were explicit that they wanted to decrease RWA to decrease their capital requirements. It is reasonable to conclude that the regulatory changes affected the largest banks, i.e., those with assets in excess of $250 billion, faster and to a larger extent. In particular, these banks had to adjust quickly to the changes to the new requirements to also comply with the CCAR stress tests and have the ability to make payouts. We, therefore, consider two groups of treated banks. The first group consists of banks with assets in excess of $250 billion. The second group consists of banks with assets between $50 billion and $250 billion. The non-treated banks are the banks with assets below $50 billion. The treatment year (*t=1*) is 2013. We classify banks into size groups based on their status the year before treatment (*t-1*, as of the end of 2011). We estimate the regressions over the period 2010 to 2015.

We show the estimation results in Table 5. We include interactions between indicators for our treatment groups, *Large banks >$250B* and *Large Banks $50-$250B*, respectively, and an indicator, *Post*, that equals one starting in the year 2013. We also include interactions with *Pre*, an indicator equal to one for 2011. The table has three panels because we have three different approaches to take into account bank characteristics. All regressions use bank fixed effects and time fixed effects.[11] Panel A uses no controls. Panel B uses controls observed in the year 2011 and interacts these controls with the *Post* indicator variable. This indicator variable takes a value of 1 for each year starting in the treatment year. Finally, Panel C uses controls measured in year *t*-1 for each year. The controls are those in Panel A of Table 3. An obvious concern with the use of controls in Panel C is that these controls could be affected by treatment. The Panel on which we put the most weight is Panel B, which addresses this concern by using pre-treatment controls interacted with *Post*.

[11] State-time fixed effects do not make sense for the largest banks as they are global in nature.

Irrespective of the controls, there appears to be a large treatment effect for LAR for the largest banks. In Panel B, the LAR of the largest banks increases by 7.5 percentage points. The treatment effect for the large banks, i.e., those with assets between $50 billion and $250 billion, is less than half the treatment effect for the largest banks in both Panel A and Panel B (but still significant at the 10% level). Such an outcome is the expected outcome given the differential effects of the regulatory changes on the largest banks and the large banks. Turning next to the components of LAR, there is no significant increase in non-reserve liquid assets for the largest banks, but there is one for the large banks. For reserves, the significance of the coefficients appears to depend on what controls we use. The coefficient is significant for both groups of treated banks in Panel A, but for neither group in Panel B. Turning to Tier 1 equity, it increases for the largest banks in Panel A and Panel C, but not in Panel B. Tier 1 equity does not seem to be affected by treatment for the large banks. RWA-to-assets falls for both types of treated banks in Panel B, but only for the large banks in Panel C. Lastly, we find that loans fall for the largest banks but not for the large banks in Panel B, but not in Panels A and C.

The evidence is Table 5 supports the hypothesis that the change in LAR is in part caused by the regulatory changes. In Figure 7, we check whether the parallel trends assumption holds for our analysis of the treatment effect for the LAR. We report results based on the specification in Panel B of Table 5, which uses controls observed in the year 2011 and interacts these controls with the *Post* indicator variable. We find that the parallel trends assumption holds irrespective of how we deal with controls. We then explore the sensitivity of our results to changing the treatment year (t=1). If we use 2014, the results are largely similar with three important differences. First, the treatment effect is much stronger for non-reserve liquid assets than in Table 5. Second, the negative treatment effect on loans holds across specifications, but the *Pre* indicator variables in the regression for loans are negative. Third, the parallel trends assumption holds marginally for LAR.

The results shown so far estimate a treatment effect without taking into account the extent to which a bank will have to change its LAR as a result of the LCR or of the change in capital requirements. Further, these results cannot distinguish between the effect of the capital requirement changes and the effect of the

LCR. Remember that an increase in capital requirements can be met by a bank that becomes capital-constrained as a result of either a capital raise or a reduction in risk-weighted assets (if the constraint applies to risk-based capital), or a reduction in assets (if the constraint applies to the leverage ratio). Risk-weighted assets can be decreased by replacing risky assets with safe assets. The liquid assets are safe assets, so reducing loans and increasing liquid assets results in a decrease in required risk-based capital. We find that the largest banks increase Tier 1 capital and decrease risk-weighted assets. We cannot tell whether the increase in LAR for these banks is the result of an attempt to reduce their capital requirement or the result of having to increase LAR to meet the LCR requirement. If the LAR is increased because of the LCR requirement, we would expect the LAR to increase more for banks with a low LAR. If the LAR is increased because of the increase in capital requirements, we would expect the LAR to increase more for banks with a low Tier 1 ratio. We test these hypotheses in Table 6.

In Table 6, we add to the regressions of Table 5 for LAR triple interactions with an indicator variable *Low*. Regressions in Columns (1) through (4) have no controls. Regressions in Columns (5) through (8) have controls observed in the year 2011 and their interactions with *Post*. Finally, regressions in Columns (9) through (12) have controls measured in year *t*-1 for each year, but they are not interacted with *Post*. All regressions have bank and time fixed effects. The standard errors are clustered at the bank level. In Column (1), we interact *Post* × *Large* > *$250* with an indicator variable that takes value 1 if a bank has a LAR below the median for the banks with assets greater than $250 billion in 2011. We proceed in the same way for *Post* × *Large* > *$50*, where the group of banks is defined as banks with assets greater than $50 billion and lower than $250 billion. We find that the triple interactions have insignificant coefficients. In Columns (5) and (9), we repeat the estimation of Column (1) but with controls. We find similar results. In Columns (2), (6), and (10), we repeat the estimation but define the indicator variable *Low* to take value one if a bank's LAR is in the lowest quartile of its group. In this case, the triple interaction is significant for the largest banks in Columns (2) and (6) and marginally significant in Column (10).

We now turn to the regressions that examine the impact of the change in capital requirements for the LAR. We would expect a bank with a low Tier 1 ratio to decrease capital requirements by reducing risk-

weighted assets. Since the increase in capital requirements is stronger for the largest banks, we would expect a larger treatment effect for the largest banks. We define the indicator variable *Low* to take value 1 for a bank if its Tier 1 ratio is below the median or in the lowest quartile of the distribution for the bank's size group. The results are supportive of the effect of the increase in capital requirements on LAR. The coefficient on the triple interaction for the largest banks is positive and significant in all regressions except for the regression in Column (4) where the t-statistic is 1.61. Further, in Column (3), the coefficient for the large banks is significant as well. As expected, however, the coefficient on the triple interaction is always the largest for the largest banks. A caveat with the results is that the triple interaction of the *Low* indicator variable with *Pre* x *Large > $250* has a positive and significant coefficient, though the coefficient is much smaller. A plausible explanation for this is that the largest banks started building up capital immediately after the adoption of Basel III.

The results of Table 5 indicate that the regulatory changes led to an increase in LAR. Table 5 does not make it possible to reach a conclusion as to whether the increase is caused by the LCR or by increases in capital requirements. Table 6 suggests that both the LCR and the increase in capital requirements led to an increase in LAR. Consequently, the increase in LAR for the largest banks can be attributed at least in part to regulatory changes. When we repeat the analysis using 2014 as the treatment year, the triple interaction with *Low LAR* is not significant, but the triple interaction with *Low Tier 1* is stronger.

7. Conclusion

In this paper, we investigate the determinants of liquid asset holdings for banks and the evolution of these assets over our sample period from 1984 to 2020. Liquid asset holdings by banks are important both for the stability of the financial system and for economic growth. If liquid asset holdings of banks are too low, the financial system lacks resilience. If liquid asset holdings are too high, economic growth suffers because banks make too few loans. Despite the considerable importance of bank liquid asset holdings, there is almost no empirical literature on the determinants of these holdings. While there is a considerable literature on the determinants of liquid asset holdings for non-financial firms, we show that this literature

is not helpful to understand the determinants of liquid asset holdings for banks. We provide a simple theory of liquid asset holdings for banks where banks with better lending opportunities hold fewer liquid assets. We provide empirical evidence that is strongly supportive of that prediction. We also predict that increases in deposits that are not accompanied by increases in lending opportunities lead banks to hold more liquid assets. We also find supportive evidence for that prediction.

Before the GFC, bank liquid asset holdings were decreasing, and large banks held fewer liquid assets than other banks. The opposite is true after the GFC. Aggregate holdings of liquid assets keep increasing after the GFC. Further, from 2012 onwards, the large banks keep increasing liquid asset holdings while the other banks decrease them. As a result of this evolution, large banks hold more liquid assets than other banks after the GFC and this gap in liquid asset holdings grows until the end of our sample period. The increase in liquid asset holdings is particularly dramatic for the largest banks, which are those with assets in excess of $250 billion. We show that this evolution can be explained, at least in part, by the post-GFC regulatory changes. After the GFC, capital requirements increased and liquidity requirements were introduced. Importantly, both the increase in capital requirements and the introduction of liquidity requirements increased liquid asset holdings. The reason for the role of the capital requirements is that liquid assets have low risk and hence low capital requirements, so that higher capital requirements on riskier assets make it more advantageous for banks to hold liquid assets. These changes were more important for the largest banks and least important for the smallest banks. We find that liquid asset holdings increased sharply for the largest banks but decreased for the smaller banks after 2012. We find some evidence that the extremely large holdings of liquid assets of the largest banks, which result from the post-GFC regulatory changes, come at the cost of a decrease in their lending activity.

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Table 1. Determinants of liquid asset holdings of non-financial firms and banks

The table shows results from regressions of liquid asset holdings for non-financial firms and for banks. Our sample of non-financial firms consists of firms incorporated in the US (excluding financials, SIC codes 6000-6999, and utilities, SIC codes 4900-4999) with assets exceeding $10 billion (in constant 2018 dollars). We exclude firms with negative sales. The sample of public banks consists of publicly listed US-chartered commercial banks with assets that exceed $10 billion. The dependent variable is the liquid asset ratio (*LAR*). For non-financial firms, *LAR* is cash and short-term investments, scaled by assets. For banks, *LAR* is the sum of cash holdings and non-cash liquid assets, scaled by total assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. Controls include *Log(assets)*, the natural log of book value of assets; *Leverage*, total debt, scaled by assets; *Market-to-book*, the book value of assets minus book value of equity plus market value of equity, scaled by the book value of assets; *Dividend payout*, an indicator equal to one if the firm pays dividends during the year and zero otherwise; *Cash flow-to-assets*, earnings after interest expense, taxes, and dividends, but before depreciation, scaled by assets; *Capex-to-assets*, capital expenditures, scaled by assets; *Acquisitions-to-assets*, Acquisition activity, scaled by assets, and *ROA volatility*, the standard deviation of return on assets (ROA) over the prior four quarters. In column (7), we replace *Leverage* with *Equity-to-assets*. The sample period is 1984-2006, and *t*-statistics based on standard errors clustered at the firm level are in parentheses. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	LAR	LAR	LAR	LAR	LAR	LAR	LAR
	Non-financials			Banks			
Log(assets)$_{t-1}$	-0.001	-0.018**	-0.028***	-0.045***	-0.029***	-0.018	-0.014
	(-0.39)	(-2.28)	(-3.23)	(-5.42)	(-4.34)	(-1.24)	(-0.94)
Leverage$_{t-1}$	-0.124***	-0.071***	-0.051***	0.184**	0.118**	0.147**	
	(-5.58)	(-3.76)	(-2.80)	(2.43)	(2.11)	(2.57)	
Market-to-book$_{t-1}$	0.033***	0.003	0.010**	-0.042	-0.007	0.031	0.056
	(6.19)	(0.68)	(2.54)	(-0.93)	(-0.21)	(0.90)	(1.41)
Dividend payout$_{t-1}$	-0.054***	-0.015**	-0.014**	-0.009	-0.020**	-0.019**	-0.018**
	(-6.40)	(-2.31)	(-2.34)	(-0.81)	(-2.45)	(-2.54)	(-2.41)
Cash flow-to-assets$_{t-1}$	0.001	0.128***	0.052	-1.348	-0.029	1.011	0.703
	(0.02)	(4.61)	(1.59)	(-0.72)	(-0.03)	(1.01)	(0.70)
Capex-to-assets$_{t-1}$	-0.156*	-0.120***	-0.128**	6.963	0.268	3.866	5.807
	(-1.76)	(-4.12)	(-2.43)	(0.72)	(0.08)	(0.91)	(1.14)
Acquisitions-to-assets$_{t-1}$	-0.083***	-0.055***	-0.038**	1.616	-0.195	0.167	0.711
	(-3.17)	(-2.88)	(-2.11)	(0.69)	(-0.15)	(0.14)	(0.50)
ROA volatility$_{t-1}$	0.171***	0.098**	0.092**	-1.036	0.870	2.384*	2.187
	(3.02)	(2.50)	(2.40)	(-0.44)	(0.96)	(1.72)	(1.49)
Equity-to-assets$_{t-1}$							-0.281
							(-1.13)
Constant	0.096***	0.276***	0.251***	0.986***	0.717***	0.500**	0.473*
	(2.82)	(3.43)	(2.86)	(7.47)	(6.13)	(2.13)	(1.91)
Observations	11,210	11,210	11,210	5,015	5,015	5,015	5,015
Adjusted R^2	0.334	0.728	0.753	0.190	0.717	0.740	0.730
Firm fixed effects	No	Yes	Yes	No	Yes	Yes	Yes
Time fixed effects	Yes	No	Yes	Yes	No	Yes	Yes

Table 2. Determinants of liquid asset holdings of banks

The table shows results from regressions of liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). In Panels A and B, the dependent variable is the liquid asset ratio, *LAR*-the sum of cash holdings and non-cash liquid assets, scaled by total assets. In Panel C, the dependent variables are *Cash*, cash holdings, scaled by assets, and *Non-cash liquid assets-to-assets*. In Panel D, the dependent variable is *ΔLiquid assets-to-assets* – the change in liquid assets for bank *i* from *t-1* to *t* normalized by assets at *t-1*. The sample period is 1984-2020. Columns (1)-(3) of Panels A and B show results using three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. In columns (4)-(7), we show results separately for large banks (>$50B) and other banks (<$50B in assets) for the pre-crisis and post-crisis periods, respectively. Regressors include *Log(assets)*, the natural log of book value of assets; *Loans-to-assets*, total loans-to-assets; *Demand deposits-to-assets,* demand deposits-to-assets; *Other deposits-to-assets,* total deposits minus demand deposits, scaled by assets; *Equity-to-assets*, equity-to-assets; *Net income-to-assets; ROA volatility*, the standard deviation of return on assets (ROA) over the prior four quarters, and *Trading assets*, an indicator equal to one for banks with trading assets as of the prior quarter-end. In Panel B, regressors include *Loan growth* – lagged eight-quarter average growth for loans, and *Deposit volatility*, the standard deviation of deposits-to-assets over the prior four quarters. Controls in Panel D include *Net income$_t$-to-assets$_{t-1}$;* all other controls are measured as changes from *t-1* to *t* normalized by assets at *t-1*, except for *ΔROA volatility*, and *ΔTrading assets*, which are measured as changes from *t-1* to *t*. We report *t*-statistics based on standard errors clustered at the bank level in parentheses. Bank and state-year fixed effects are included in all modes. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Determinants of LAR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	LAR	LAR	LAR	LAR	LAR	LAR	LAR
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
Log(assets)$_{t-1}$	-0.004	-0.005	-0.018***	-0.005	0.005	-0.019***	0.001
	(-0.82)	(-1.14)	(-2.96)	(-0.85)	(0.23)	(-2.92)	(0.04)
Loans-to-assets$_{t-1}$	-0.509***	-0.444***	-0.602***	-0.463***	-0.208	-0.595***	-0.519***
	(-17.23)	(-15.40)	(-15.20)	(-15.41)	(-1.48)	(-14.32)	(-9.04)
Demand deposits-to-assets$_{t-1}$	0.098	-0.046	0.077*	-0.048	0.265**	0.034	-0.135
	(1.57)	(-0.95)	(1.67)	(-0.93)	(2.59)	(0.70)	(-0.75)
Other deposits-to-assets$_{t-1}$	0.001	-0.037	0.056	-0.042	0.036	0.022	0.037
	(0.03)	(-1.36)	(1.38)	(-1.37)	(0.46)	(0.49)	(0.41)
Equity-to-assets$_{t-1}$	-0.338***	-0.343***	-0.323***	-0.353***	-0.136	-0.246**	-0.505**
	(-4.96)	(-5.51)	(-3.23)	(-5.51)	(-0.81)	(-2.41)	(-2.42)
Net income-to-assets$_{t-1}$	0.028	0.709*	-1.143***	0.578	4.205***	-1.190***	-0.488
	(0.10)	(1.94)	(-2.95)	(1.55)	(3.28)	(-2.98)	(-0.32)
ROA volatility$_{t-1}$	-0.785*	-0.314	0.450	-0.673	1.378	0.641	2.014
	(-1.65)	(-0.63)	(0.63)	(-1.37)	(0.83)	(0.91)	(0.93)
Trading assets$_{t-1}$	-0.008**	-0.007**	-0.002	-0.007**	-0.019**	-0.003	0.012
	(-2.44)	(-2.09)	(-0.56)	(-2.19)	(-2.39)	(-0.57)	(1.46)
Intercept	0.621***	0.641***	0.876***	0.648***	0.180	0.908***	0.570
	(8.60)	(7.95)	(8.66)	(7.08)	(0.37)	(8.17)	(1.09)
Observations	47,322	29,656	13,921	27,779	1,508	12,325	1,367
Adjusted R^2	0.815	0.825	0.893	0.829	0.756	0.892	0.920
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Determinants of liquid asset holdings of banks – continued

Panel B. Determinants of LAR: Loan growth and deposit volatility							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	LAR	LAR	LAR	LAR	LAR	LAR	LAR
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
Log(assets)$_{t-1}$	-0.003	0.001	-0.027***	0.003	0.012	-0.025**	0.014
	(-0.41)	(0.20)	(-2.86)	(0.53)	(0.78)	(-2.44)	(0.29)
Loan growth$_{t-8,t-1}$	-0.114***	-0.098**	-0.137**	-0.092*	-0.108	-0.138**	-0.109
	(-3.00)	(-2.12)	(-2.16)	(-1.89)	(-0.83)	(-2.15)	(-0.48)
Deposit volatility$_{t-1}$	0.168***	0.227***	-0.189*	0.233***	-0.200	-0.203*	0.209
	(2.91)	(3.62)	(-1.83)	(3.55)	(-0.96)	(-1.73)	(1.04)
Net income-to-assets$_{t-1}$	-0.468	-0.148	-2.127***	-0.369	3.876***	-1.863***	-0.169
	(-1.16)	(-0.28)	(-3.60)	(-0.68)	(3.14)	(-2.96)	(-0.08)
ROA volatility$_{t-1}$	-0.378	-0.826	3.118***	-1.336*	1.879	3.497***	1.548
	(-0.58)	(-1.15)	(3.02)	(-1.79)	(1.07)	(3.19)	(0.58)
Trading assets$_{t-1}$	-0.010**	-0.003	-0.010	-0.003	-0.014	-0.012	0.059***
	(-2.22)	(-0.62)	(-1.31)	(-0.69)	(-1.24)	(-1.51)	(2.82)
Intercept	0.268**	0.209**	0.646***	0.180*	-0.051	0.595***	-0.058
	(2.50)	(2.22)	(4.37)	(1.81)	(-0.17)	(3.84)	(-0.07)
Observations	47,207	29,616	13,873	27,739	1,508	12,277	1,367
Adjusted R^2	0.715	0.752	0.830	0.754	0.740	0.829	0.886
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Determinants of liquid asset holdings of banks – continued

Panel C. Determinants of cash-holdings and non-cash liquid asset holdings														
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable:	Cash	Non-cash	Cash	Non-cash	Cash	Non-cash	Cash		Non-cash		Cash		Non-cash	
Sample period:	1984-2020		1984-2006		2010-2020		1984-2006				2010-2020			
							Other	Large	Other	Large	Other	Large	Other	Large
Log(assets)$_{t-1}$	-0.002	-0.001	-0.001	-0.004	-0.015**	-0.002	0.002	0.003	-0.006	0.002	-0.012*	-0.003	-0.007	0.004
	(-0.70)	(-0.29)	(-0.38)	(-0.83)	(-2.32)	(-0.36)	(0.58)	(0.19)	(-1.16)	(0.13)	(-1.76)	(-0.11)	(-1.37)	(0.25)
Loans-to-assets$_{t-1}$	-0.136***	-0.373***	-0.112***	-0.332***	-0.191***	-0.411***	-0.103***	0.005	-0.360***	-0.214**	-0.173***	-0.307***	-0.422***	-0.211***
	(-5.42)	(-12.79)	(-4.62)	(-12.04)	(-5.06)	(-8.74)	(-3.92)	(0.10)	(-12.69)	(-2.15)	(-4.07)	(-4.75)	(-8.28)	(-3.73)
Demand deposits-to-assets$_{t-1}$	0.205***	-0.107**	0.127***	-0.172***	0.103**	-0.026	0.145***	0.074	-0.194***	0.192**	0.102*	0.025	-0.067	-0.160**
	(4.46)	(-2.20)	(3.21)	(-3.20)	(2.04)	(-0.63)	(3.29)	(0.68)	(-3.31)	(2.11)	(1.76)	(0.14)	(-1.51)	(-2.29)
Other deposits-to-assets$_{t-1}$	0.034*	-0.033	0.000	-0.037	0.090**	-0.034	0.007	0.013	-0.049	0.023	0.092*	0.006	-0.069**	0.031
	(1.70)	(-1.63)	(0.03)	(-1.39)	(2.09)	(-0.97)	(0.40)	(0.31)	(-1.62)	(0.36)	(1.84)	(0.06)	(-2.02)	(0.57)
Equity-to-assets$_{t-1}$	-0.079	-0.258***	-0.103	-0.239***	-0.062	-0.262***	-0.089	0.069	-0.262***	-0.205	-0.016	-0.363	-0.229***	-0.142
	(-1.17)	(-3.31)	(-1.56)	(-3.24)	(-0.72)	(-3.24)	(-1.35)	(0.83)	(-3.52)	(-1.45)	(-0.20)	(-1.21)	(-2.77)	(-0.95)
Net income-to-assets$_{t-1}$	-0.794***	0.813***	-0.129	0.827**	-2.201***	1.058**	-0.236	1.079*	0.799**	3.126***	-2.314***	-0.618	1.124**	0.129
	(-3.44)	(3.03)	(-0.49)	(2.51)	(-4.36)	(2.49)	(-0.88)	(1.70)	(2.37)	(2.85)	(-4.26)	(-0.41)	(2.53)	(0.10)
ROA volatility$_{t-1}$	-0.349	-0.435	-0.385	0.074	-0.316	0.766	-0.546	0.976	-0.124	0.402	0.139	1.397	0.502	0.617
	(-1.02)	(-0.90)	(-1.11)	(0.15)	(-0.47)	(1.10)	(-1.58)	(1.04)	(-0.24)	(0.39)	(0.21)	(0.57)	(0.69)	(0.25)
Trading assets$_{t-1}$	-0.003	-0.005	-0.003	-0.003	0.005	-0.007	-0.004	0.007*	-0.004	-0.027***	0.002	0.013	-0.005	-0.001
	(-1.04)	(-1.30)	(-0.98)	(-0.83)	(1.29)	(-1.46)	(-1.16)	(1.71)	(-0.97)	(-3.58)	(0.59)	(0.82)	(-0.98)	(-0.12)
Intercept	0.166***	0.455***	0.159***	0.482***	0.383***	0.493***	0.100*	-0.012	0.549***	0.192	0.299**	0.377	0.609***	0.193
	(3.08)	(6.22)	(2.91)	(5.53)	(3.28)	(4.57)	(1.96)	(-0.03)	(5.83)	(0.63)	(2.54)	(0.62)	(5.98)	(0.55)
Observations	47,322	47,320	29,656	29,654	13,921	13,921	27,779	1,508	27,777	1,508	12,325	1,367	12,325	1,367
Adjuster R^2	0.705	0.790	0.704	0.819	0.825	0.857	0.708	0.808	0.825	0.818	0.819	0.855	0.863	0.900
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Determinants of liquid asset holdings of banks – continued

Panel D. Determinants of changes in liquid asset holdings							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	*ΔLiquid assets$_t$-to-assets$_{t-1}$*						
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
ΔLoans$_t$/assets$_{t-1}$	-0.419***	-0.324***	-0.725***	-0.329***	-0.158*	-0.715***	-1.006***
	(-20.12)	(-14.01)	(-16.60)	(-13.83)	(-1.87)	(-16.01)	(-21.27)
ΔAssets$_t$/assets$_{t-1}$	0.469***	0.414***	0.659***	0.420***	0.269***	0.652***	0.835***
	(30.85)	(24.19)	(22.72)	(23.66)	(4.76)	(21.79)	(25.22)
Net income$_t$/assets$_{t-1}$	0.142	0.447***	-0.551***	0.462***	0.941	-0.503***	-1.397**
	(1.50)	(3.10)	(-3.60)	(3.16)	(1.05)	(-3.05)	(-2.12)
ΔROA volatility$_{t-1,t}$	0.281	0.402*	0.291	0.411*	0.647	0.412	-3.236**
	(1.61)	(1.78)	(0.98)	(1.69)	(1.18)	(1.46)	(-2.31)
ΔTrading indicator$_{t-1,t}$	-0.000	0.000	-0.002	0.000	-0.003	-0.003	0.005
	(-0.07)	(0.18)	(-1.04)	(0.22)	(-0.90)	(-1.14)	(0.46)
Intercept	-0.000	-0.001***	0.002***	-0.001***	-0.003	0.002***	0.006***
	(-0.33)	(-3.53)	(5.63)	(-3.38)	(-1.37)	(4.54)	(2.99)
Observations	47,248	29,600	13,907	27,725	1,507	12,312	1,366
Adjusted R^2	0.512	0.468	0.706	0.469	0.435	0.718	0.674
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3. Exogenous variation in loans and deposits and bank holdings of liquid assets

The table shows first- and second-stage results from 2SLS regressions of liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). We instrument *ΔLoans-to-assets*$_{t-1}$ and *(ΔDeposits-to-assets*$_{t-1}$*)* using Bartik-like instruments. The approach uses as an instrument for loan (deposit) changes at a bank the predetermined exposure of that bank to each of four loan types (two deposit types) times the aggregate loan (deposit) changes for each type of loan (deposits) for banks of the same type at the national level. We distinguish between three types of banks: small, medium, and large; four loan types: Commercial and industrial (C&I) loans, real estate (RE) loans, personal loans, and other loans; and two deposit types: demand deposits and other deposits. When instrumenting *ΔLoans*$_t$*-to-assets*$_{t-1}$ *(ΔDeposits-to-assets*$_{t-1}$*)*, we use the aggregate $ change in each loan (deposit) type, scaled by lagged aggregate assets, where we aggregate across all banks in group size *s*. We show first-stage results in columns (1)-(6) and second-stage results using *ΔLiquid assets-to-assets* as the dependent variable in columns (7)-(9). The sample period is 1984-2020 and we show results for three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. Regressors include *Net income*$_t$*-to-assets*$_{t-1}$; *ΔROA volatility; ΔTrading assets; ΔFed funds rate; ΔDefault spread; ΔComposite leading indicator; ΔInterest on excess reserves*, and *ΔAggregate reserves-to-assets.* We report *t*-statistics based on standard errors clustered at the bank level in parentheses. We report the Sanderson-Windmeijer multivariate *F*-test of excluded instruments. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 3. Exogenous variation in loans and deposits and bank holdings of liquid assets – continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	*ΔLoans$_t$-to-assets$_{t-1}$*			*ΔDeposits$_t$-to-assets$_{t-1}$*			*ΔLiquid assets$_t$-to-assets$_{t-1}$*		
	First-stage			First-stage			Second-stage		
Sample period:	1984-2020	1984-2006	2010-2020	1984-2020	1984-2006	2010-2020	1984-2020	1984-2006	2010-2020
ΔLoans$_t$/assets$_{t-1}$ (Instrumented)[A]							-0.306***	-0.248***	-0.280***
							(-5.78)	(-3.69)	(-2.92)
ΔDeposits$_t$ /assets$_{t-1}$ (Instrumented)[B]							0.520***	0.460***	0.648***
							(21.99)	(14.81)	(12.29)
Bartik instrument:ΔLoans	0.267***	0.399***	0.295***	-0.728***	-0.888***	-0.477***			
	(4.32)	(3.59)	(4.51)	(-12.40)	(-8.61)	(-6.44)			
Bartik instrument:ΔDeposits	0.044**	0.043	-0.040	0.452***	0.491***	0.337***			
	(2.27)	(1.42)	(-1.29)	(18.42)	(14.77)	(8.34)			
Net income$_t$/assets$_{t-1}$	3.585***	4.403***	1.687***	3.423***	4.606***	1.383**	0.336*	0.634**	-0.312
	(11.97)	(8.35)	(3.55)	(10.79)	(8.27)	(2.43)	(1.73)	(2.21)	(-1.12)
ΔROA volatility$_{t-1,t}$	0.268	0.198	-0.176	0.608**	0.665**	-0.681	-0.278**	-0.273*	0.292
	(1.28)	(0.84)	(-0.37)	(2.46)	(2.36)	(-1.18)	(-2.06)	(-1.72)	(0.97)
ΔTrading indicator$_{t-1,t}$	-0.001	-0.002	0.002	-0.002	-0.003*	0.002	-0.001	-0.001	-0.006*
	(-0.76)	(-1.23)	(0.69)	(-1.04)	(-1.65)	(0.37)	(-1.22)	(-0.87)	(-1.96)
ΔFed funds rate$_{t-1,t}$	0.001**	0.002***	0.024***	-0.003***	-0.002***	0.025***	-0.001**	-0.001**	-0.004
	(1.97)	(2.73)	(5.31)	(-4.57)	(-3.33)	(4.40)	(-1.97)	(-2.16)	(-0.88)
ΔDefault spread$_{t-1,t}$	1.231***	1.912***	0.406	1.133***	2.207***	-0.014	0.417***	0.747***	-0.168
	(8.01)	(6.34)	(1.53)	(5.96)	(6.49)	(-0.04)	(3.94)	(3.65)	(-1.01)
ΔComposite leading indicator$_{t-1,t}$	-0.003***	-0.003***	-0.007***	-0.001**	-0.003***	-0.006***	0.001***	0.002***	0.001
	(-5.87)	(-4.41)	(-8.53)	(-2.35)	(-3.06)	(-5.78)	(3.59)	(4.27)	(0.76)
ΔInterest on excess reserves$_{t-1,t}$	-1.400***		-3.303***	-1.581***		-3.541***	-0.119		0.604
	(-7.54)		(-9.29)	(-7.47)		(-8.68)	(-0.89)		(1.24)
ΔAggregate reserves$_t$-to-assets$_{t-1}$	-0.259***	3.583***	-0.106**	-0.066*	5.639***	0.037	0.097***	1.103**	0.058**
	(-9.28)	(5.22)	(-2.27)	(-1.81)	(7.89)	(0.63)	(4.48)	(2.35)	(2.00)
Observations	47,582	29,983	13,837	47,582	29,983	13,837	47,581	29,982	13,837
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	No	No	No	No	No	No	No
SW F-test of excl. instrument [A]							*71.57*	*53.32*	*17.39*
SW F-test of excl. instrument [B]							*529.22*	*325.47*	*30.07*

Table 4. Low levels of liquid asset holdings and exogenous variation in loans and bank holdings of liquid assets

The table shows second-stage results from 2SLS regressions of changes in deposits and in liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). We instrument *ΔLoans-to-assets$_{t-1}$* and *(ΔDeposits-to-assets$_{t-1}$)* using Bartik-like instruments. The approach uses as an instrument for loan (deposit) changes at a bank the predetermined exposure of that bank to each of four loan types (two deposit types) times the aggregate loan (deposit) changes for each type of loan (deposits) for banks of the same type at the national level. We distinguish between three types of banks: small, medium, and large; four loan types: Commercial and industrial (C&I) loans, real estate (RE) loans, personal loans, and other loans; and two deposit types: demand deposits and other deposits. When instrumenting *ΔLoans$_t$-to-assets$_{t-1}$ (ΔDeposits-to-assets$_{t-1}$)*, we use the aggregate $ change in each loan (deposit) type, scaled by lagged aggregate assets, where we aggregate across all banks in group size s. The table shows results from interactions between the instrumented *ΔLoans-to-assets$_{t-1}$* and *ΔDeposits-to-assets$_{t-1}$* and *Low LAR*, an indicator equal to one for banks with an *LAR* in the bottom decile of the distribution in a year. The sample period is 1984-2020 and we show results using three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. Regressors include *Net income$_t$-to-assets$_{t-1}$*; *ΔROA volatility; ΔTrading assets; ΔFed funds rate; ΔDefault spread; ΔComposite leading indicator; ΔInterest on excess reserves*, and *ΔAggregate reserves-to-assets.* We report *t*-statistics based on standard errors clustered at the bank level in parentheses. We report *p*-values from *F*-tests of the sum of the coefficients *ΔLoans (ΔDeposits)* x *Low LAR+ ΔLoans (ΔDeposits*) = 0 and the Sanderson-Windmeijer multivariate F-test of excluded instruments. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
Dependent variable:	*ΔLiquid assets$_t$-to-assets$_{t-1}$*		
	1984-2020	1984-2006	2010-2020
ΔLoans$_t$/assets$_{t-1}$ (Instrumented) [A]	-0.554***	-0.510***	-0.525***
	(-9.46)	(-5.66)	(-7.27)
ΔDeposits$_t$/assets$_{t-1}$ (Instrumented)[B]	0.605***	0.559***	0.716***
	(24.00)	(14.34)	(16.52)
ΔLoans$_t$/assets$_{t-1}$ x *Low LAR [A']*	0.566***	0.530***	0.522***
	(8.74)	(5.33)	(5.88)
ΔDeposits$_t$/assets$_{t-1}$ x *Low LAR [B']*	-0.533***	-0.411***	-0.656***
	(-9.08)	(-4.87)	(-7.31)
Low LAR	-0.010***	-0.013***	-0.004**
	(-5.70)	(-4.53)	(-2.25)
Net income$_t$/assets$_{t-1}$	0.930***	1.262***	0.090
	(5.43)	(4.44)	(0.44)
ΔROA volatility$_{t-1,t}$	-0.309**	-0.352**	0.180
	(-2.32)	(-2.18)	(0.65)
ΔTrading indicator$_{t-1,t}$	-0.001	-0.001	-0.005**
	(-1.15)	(-0.72)	(-2.12)
ΔFed funds rate$_{t-1,t}$	-0.000	-0.000	0.003
	(-0.30)	(-0.01)	(1.11)
ΔDefault spread$_{t-1,t}$	0.527***	0.905***	-0.209
	(4.98)	(4.14)	(-1.42)
ΔComposite leading indicator$_{t-1,t}$	0.000	0.001***	-0.001
	(1.42)	(2.89)	(-1.27)
ΔInterest on excess reserves$_{t,t-1}$	-0.281**		-0.000
	(-2.01)		(-0.00)
ΔAggregate reserves$_t$-to-assets$_{t-1}$	0.045**	1.026**	0.058**
	(2.21)	(2.20)	(2.34)
Observations	47,619	30,012	13,869
Bank fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No
p-value [A+A']=0	0.722	0.574	0.956
p-value [B+B']=0	0.187	0.072	0.514
SW F-test of excl. instrument [A]	*119.58*	*70.17*	*38.39*
SW F-test of excl. instrument [B]	*452.97*	*199.72*	*85.14*

Table 5. Difference-in-differences regressions around the adoption of the LCR Rule

The table shows results from regressions for the [-2,+3] window around the treatment year (t=1) of 2013. The sample consists of US-chartered commercial banks with assets that exceed $2B billion (in constant 2018 dollars). We exclude trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. Dependent variables are *LAR* – the sum of cash holdings and non-cash liquid assets, scaled by total assets; *Non-reserve liquid assets* – total liquid assets net of reserves, scaled by total assets; Reserves–cash and due from Fed, scaled by total assets; *Tier 1 capital ratio*–the total Tier 1 capital, scaled by risk-weighted assets; *RWA-to-assets*–risk-weighted assets, scaled by assets, and *Loans-to-assets*. We have two groups of treated banks, sorted by size as of *t-1* (2011): *Large >$250B,* banks with assets in excess of $250B (in constant 2018 dollars) and *Large $50-$250B*, banks with assets between $50B and $250B. The control group includes banks with assets below $50B. *Post* is an indicator variable equal to one starting in 2013. *Pre* is an indicator equal to one for 2011 and zero otherwise. Regressors include *Log(assets)*, the natural log of book value of assets; *Demand deposits-to-assets,* demand deposits-to-assets; *Other deposits-to-assets,* total deposits minus demand deposits, scaled by assets; *Equity-to-assets*, equity-to-assets; *Net income-to-assets; ROA volatility*, the standard deviation of return on assets (ROA) over the prior four quarters, and *Trading assets*, an indicator equal to one for banks with trading assets as of the prior quarter-end. Panel A shows results without controls. Panel B shows results using interactions between regressors measured as of *t-1* and *Post*. Panel C shows results using lagged regressors. We report *t*-statistics based on standard errors clustered at the bank level in parentheses. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. No controls.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	LAR	Non-reserve liquid assets	Reserves	Tier 1 capital	RWA-to-assets	Loans-to-assets
Pre x *Large >$250B*	-0.004	-0.007*	0.003	-0.002	0.006	0.002
	(-0.60)	(-1.79)	(0.53)	(-1.12)	(0.61)	(0.30)
Pre x *Large $50-$250B*	0.000	-0.007*	0.007	-0.001	0.017**	0.005
	(0.05)	(-1.89)	(1.03)	(-0.45)	(2.03)	(1.22)
Post x *Large >$250B*	0.068***	0.013	0.055**	0.011**	-0.029	-0.022
	(4.00)	(1.03)	(2.48)	(1.99)	(-1.56)	(-1.41)
Post x *Large $50-$250B*	0.033***	0.018**	0.015**	0.004	-0.026	0.002
	(2.69)	(2.08)	(2.04)	(0.64)	(-1.60)	(0.09)
Large >$250B	-0.004	-0.007*	0.003	-0.002	0.006	0.002
	(-0.60)	(-1.79)	(0.53)	(-1.12)	(0.61)	(0.30)
Intercept	0.221***	0.178***	0.043***	0.135***	0.718***	0.634***
	(549.17)	(599.81)	(118.41)	(764.47)	(1,416.64)	(1,192.20)
Observations	5,673	5,673	5,673	5,669	5,673	5,673
Adjusted R^2	0.860	0.867	0.727	0.611	0.818	0.899
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. Difference-in-differences regressions around the adoption of the LCR Rule. Continued.

Panel B. Regressors (as of *t-1*) interacted with *Post*.						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	LAR	Non-reserve liquid assets	Reserves	Tier 1 capital	RWA-to-assets	Loans-to-assets
Pre x *Large >$250B*	-0.004	-0.007*	0.003	-0.001	0.004	0.002
	(-0.53)	(-1.68)	(0.53)	(-0.83)	(0.45)	(0.29)
Pre x *Large $50-$250B*	0.001	-0.006*	0.007	-0.000	0.015*	0.005
	(0.13)	(-1.70)	(1.03)	(-0.12)	(1.85)	(1.18)
Post x *Large >$250B*	0.075***	0.041	0.035	0.013	-0.083**	-0.050*
	(2.69)	(1.47)	(1.44)	(0.91)	(-2.48)	(-1.76)
Post x *Large $50-$250B*	0.033*	0.031**	0.003	0.014	-0.058**	-0.019
	(1.77)	(2.23)	(0.21)	(1.30)	(-2.46)	(-0.86)
Post x *Log(assets)$_{t-1}$*	0.002	-0.001	0.003	-0.000	0.007	0.002
	(0.40)	(-0.22)	(0.88)	(-0.01)	(0.96)	(0.44)
Post x *Loans-to-assets$_{t-1}$*	0.102***	0.060**	0.041**	0.061**	-0.067	
	(3.21)	(2.25)	(2.07)	(2.58)	(-1.57)	
Post x *Demand deposits-to-assets$_{t-1}$*	0.104	0.233***	-0.129***	0.014	-0.214**	-0.203**
	(1.36)	(3.14)	(-2.71)	(0.37)	(-2.35)	(-2.16)
Post x *Other deposits-to-assets$_{t-1}$*	0.033	0.058*	-0.025	0.015	-0.112**	-0.081*
	(0.82)	(1.79)	(-0.87)	(0.69)	(-2.10)	(-1.73)
Post x *Equity-to-assets$_{t-1}$*	-0.045	0.106	-0.151*	-0.613***	0.484*	0.251*
	(-0.38)	(1.07)	(-1.74)	(-3.27)	(1.74)	(1.78)
Post x *Net income-to-assets$_{t-1}$*	-3.318*	-3.196**	-0.123	-0.392	3.135*	2.702
	(-1.91)	(-2.09)	(-0.14)	(-0.50)	(1.67)	(1.44)
Post x *ROA volatility$_{t-1}$*	-1.688	-0.075	-1.613	-2.037	4.586	1.747
	(-0.68)	(-0.04)	(-0.95)	(-1.05)	(1.27)	(0.66)
Post x *Trading assets indicator$_{t-1}$*	-0.003	-0.004	0.001	0.005	-0.011	0.002
	(-0.25)	(-0.39)	(0.17)	(1.28)	(-0.84)	(0.16)
Intercept	0.168***	0.140***	0.028	0.145***	0.701***	0.629***
	(3.35)	(3.22)	(0.83)	(5.02)	(10.86)	(13.21)
Observations	4,964	4,964	4,964	4,960	4,964	4,964
Adjusted R^2	0.861	0.871	0.716	0.650	0.833	0.902
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. Difference-in-differences regressions around the adoption of the LCR Rule. Continued.

Panel C. Lagged Regressors.						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	LAR	Non-reserve liquid assets	Reserves	Tier 1 capital	RWA-to-assets	Loans-to-assets
Pre x *Large >$250B*	-0.006	-0.008**	0.002	-0.003**	0.006	0.002
	(-1.21)	(-2.09)	(0.43)	(-2.03)	(0.87)	(0.33)
Pre x *Large $50-$250B*	0.004	-0.005	0.009	-0.002	0.012*	0.006
	(0.64)	(-1.58)	(1.36)	(-1.05)	(1.78)	(1.25)
Post x *Large >$250B*	0.055***	0.004	0.052**	0.009*	-0.018	-0.022
	(4.62)	(0.28)	(2.41)	(1.96)	(-1.27)	(-1.39)
Post x *Large $50-$250B*	0.034***	0.020***	0.014*	0.009	-0.031*	-0.003
	(2.84)	(2.71)	(1.96)	(1.53)	(-1.86)	(-0.17)
Log(assets)$_{t-1}$	-0.008	0.005	-0.013	-0.012	0.030**	0.053***
	(-1.12)	(0.58)	(-1.57)	(-1.49)	(2.32)	(4.77)
Loans-to-assets$_{t-1}$	-0.528***	-0.438***	-0.090***	-0.172***	0.605***	
	(-12.18)	(-10.27)	(-3.56)	(-4.42)	(10.65)	
Demand deposits-to-assets$_{t-1}$	0.099	0.111	-0.012	-0.067	0.139	0.103
	(1.21)	(1.57)	(-0.19)	(-0.76)	(1.10)	(0.95)
Other deposits-to-assets$_{t-1}$	-0.001	0.007	-0.008	-0.017	0.072	0.161***
	(-0.02)	(0.16)	(-0.21)	(-0.39)	(0.95)	(2.63)
Equity-to-assets$_{t-1}$	-0.281**	-0.128	-0.152*	0.628***	0.150	0.022
	(-2.53)	(-1.16)	(-1.67)	(3.55)	(0.76)	(0.15)
Net income-to-assets$_{t-1}$	-1.208**	1.110**	-2.318***	0.438	-0.779	0.604
	(-2.39)	(2.37)	(-2.83)	(0.62)	(-1.50)	(1.01)
ROA volatility$_{t-1}$	-0.473	-0.247	-0.226	1.720**	-2.428***	-2.062**
	(-0.69)	(-0.40)	(-0.34)	(2.14)	(-2.62)	(-2.03)
Trading assets indicator$_{t-1}$	-0.005	-0.009	0.004	-0.013*	0.019	0.011
	(-1.01)	(-1.54)	(1.15)	(-1.72)	(1.59)	(1.35)
Intercept	0.705***	0.381***	0.324**	0.382***	-0.208	-0.329*
	(6.42)	(2.87)	(2.25)	(2.88)	(-0.96)	(-1.86)
Observations	5,636	5,636	5,636	5,632	5,636	5,636
Adjusted R^2	0.913	0.910	0.747	0.722	0.882	0.908
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 6. Difference-in-differences regressions around the adoption of the LCR Rule.

The table shows results from regressions for the [-2,+3] window around the treatment year (t=1) of 2013. The sample consists of US-chartered commercial banks with assets that exceed $2B billion (in constant 2018 dollars). We exclude trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. The dependent variable is *LAR* – the sum of cash holdings and non-cash liquid assets, scaled by total assets. We have two groups of treated banks, sorted by size as of *t-1* (2011): *Large >$250B,* banks with assets in excess of $250 billion (in constant 2018 dollars) and *Large $50-$250B*, banks with assets between $50 billion and $250 billion. *Low* is an indicator equal to one for banks with *LAR (Tier 1 capital)* below the median or in the bottom quartile in its size group as of *t-1*. The control group includes banks with assets below $50B. *Post* is an indicator variable equal to one starting in 2013. *Pre* is an indicator equal to one for 2011 and zero otherwise. Regressors (omitted to conserve space) include *Log(assets)*; *Demand deposits-to-assets*; *Other deposits-to-assets*; *Equity-to-assets*; *Net income-to-assets; ROA volatility*, and *Trading assets*. Columns (1)-(4) show results without controls. Columns (5)-(8) show results using interactions between regressors measured as of *t-1* and *Post*. Columns (9)-(12) show results using lagged regressors. We report *t*-statistics based on standard errors clustered at the bank level in parentheses. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable							LAR					
Low indicator:	*LAR Median*	*LAR Quartile*	*Tier 1 Median*	*Tier 1 Quartile*	*LAR Median*	*LAR Quartile*	*Tier 1 Median*	*Tier 1 Quartile*	*LAR Median*	*LAR Quartile*	*Tier 1 Median*	*Tier 1 Quartile*
Pre x *Large >$250* x *Low*	0.015	0.019	0.023**	0.026***	0.014	0.018	0.022**	0.025***	0.012	0.015*	0.020***	0.021***
	(1.15)	(1.55)	(2.04)	(2.75)	(1.07)	(1.51)	(1.97)	(2.72)	(1.20)	(1.68)	(2.81)	(2.73)
Pre x *Large >$50* x *Low*	-0.015	-0.022	0.001	-0.008	-0.016	-0.022	0.000	-0.008	-0.010	-0.014	-0.004	-0.007
	(-0.92)	(-1.19)	(0.05)	(-0.61)	(-0.97)	(-1.19)	(0.02)	(-0.63)	(-0.83)	(-1.31)	(-0.28)	(-0.69)
Post x *Large >$250* x *Low*	0.032	0.057***	0.062***	0.045	0.032	0.067***	0.074***	0.070**	0.014	0.029*	0.043***	0.040*
	(1.27)	(4.73)	(3.74)	(1.61)	(1.12)	(3.39)	(3.51)	(2.12)	(0.72)	(1.68)	(2.96)	(1.95)
Post x *Large >$50* x *Low*	-0.006	-0.034	0.036*	0.030	-0.014	-0.034	0.022	0.020	-0.031	-0.048	0.012	0.008
	(-0.24)	(-0.98)	(1.77)	(1.22)	(-0.53)	(-1.07)	(0.85)	(0.76)	(-1.27)	(-1.63)	(0.48)	(0.39)
Post x *Low*	0.023***	0.023***	0.010	-0.000	0.016	0.014*	-0.002	-0.018**	0.020***	0.022***	0.004	0.003
	(3.28)	(3.37)	(1.41)	(-0.03)	(1.61)	(1.75)	(-0.27)	(-2.07)	(4.25)	(4.20)	(0.82)	(0.61)
Pre x *Low*	-0.010**	-0.017***	-0.005	-0.001	-0.009*	-0.016***	-0.004	-0.001	-0.009**	-0.011**	-0.004	-0.002
	(-2.14)	(-2.77)	(-1.04)	(-0.26)	(-1.94)	(-2.69)	(-0.89)	(-0.21)	(-2.53)	(-2.30)	(-1.07)	(-0.54)
Pre x *Large >$250*	-0.012	-0.009	-0.015**	-0.012**	-0.011	-0.008	-0.015*	-0.012*	-0.012	-0.010	-0.016***	-0.013***
	(-0.96)	(-0.94)	(-1.98)	(-2.06)	(-0.87)	(-0.88)	(-1.87)	(-1.97)	(-1.27)	(-1.39)	(-3.72)	(-3.31)
Pre x *Large >$50*	0.008	0.006	0.000	0.003	0.009	0.006	0.001	0.003	0.009	0.007	0.006	0.006
	(0.65)	(0.65)	(0.02)	(0.24)	(0.72)	(0.71)	(0.07)	(0.28)	(0.86)	(0.97)	(0.50)	(0.73)
Post x *Large >$250*	0.052***	0.048***	0.037***	0.053***	0.050*	0.054**	0.038	0.054*	0.048***	0.044***	0.034***	0.042***
	(3.69)	(4.45)	(4.35)	(2.70)	(1.76)	(2.25)	(1.51)	(1.92)	(5.03)	(6.10)	(5.71)	(4.66)
Post x *Large >$50*	0.036**	0.041***	0.015	0.026*	0.039*	0.043**	0.023	0.030	0.049***	0.046***	0.028	0.032**
	(2.44)	(3.38)	(0.91)	(1.82)	(1.82)	(2.31)	(0.91)	(1.37)	(2.64)	(3.60)	(1.26)	(2.10)
Observations	5,673	5,673	5,673	5,673	4,964	4,964	4,964	4,964	5,636	5,636	5,636	5,636
Adjusted R^2	0.864	0.864	0.862	0.861	0.863	0.863	0.862	0.862	0.916	0.916	0.914	0.914
Bank and time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls interacted with Post	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No

Figure 1. Aggregate liquid asset holdings and loans.

The figure shows the aggregate liquid assets-to-assets ratio (*LAR*), the *Loans-to-assets* ratio, and the components of the *LAR*: *Cash-to-assets* and *Non-cash LAR* for US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). The aggregate *LAR* (*Loans-to-assets*) is computed by summing liquid assets (loans) for all banks in the sample and dividing them by the sum of assets for all banks. Liquid assets represent the sum of cash holdings and non-cash liquid assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We obtain the data from the quarterly Reports of Condition and Income "Call Reports" (Form FFIEC 031) from 1984-2020.

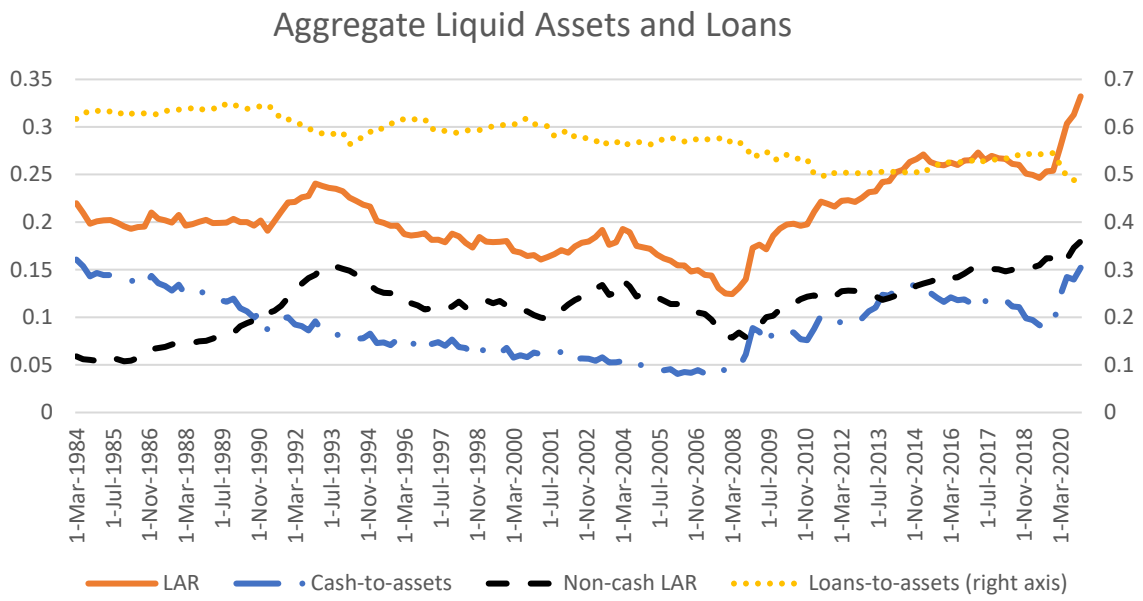
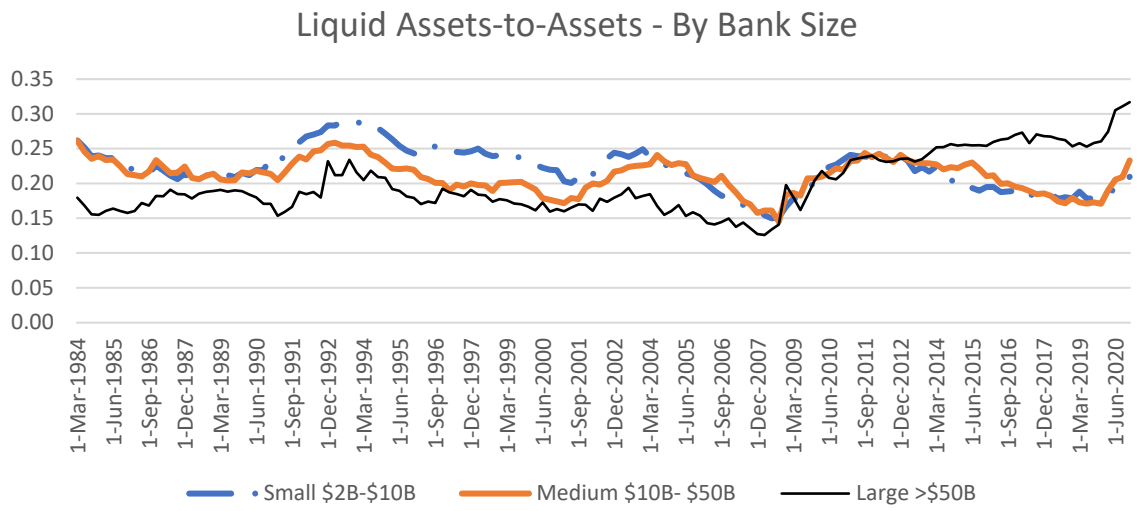


Figure 2. Average Liquid Asset Ratio (LAR) and Loans-to-Assets Ratio by Bank Size.

The figure shows the equally-weighted average liquid assets-to-assets, *LAR* (Panel A) and loans-to-assets ratio (Panel B) by bank size. The sample consists of US-chartered commercial banks with assets that exceed $2billion (in constant 2018 dollars). We define large banks to be banks with assets in excess of $50 billion dollars in 2018 dollars. Medium banks have assets between $10 billion and $50 billion. Small banks have assets between $2 billion and $10 billion. Liquid assets represent the sum of cash holdings and non-cash liquid assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We obtain the data from the quarterly Reports of Condition and Income "Call Reports" (Form FFIEC 031) from 1984-2020.

Panel A. LAR



Panel B. Loans-to-assets

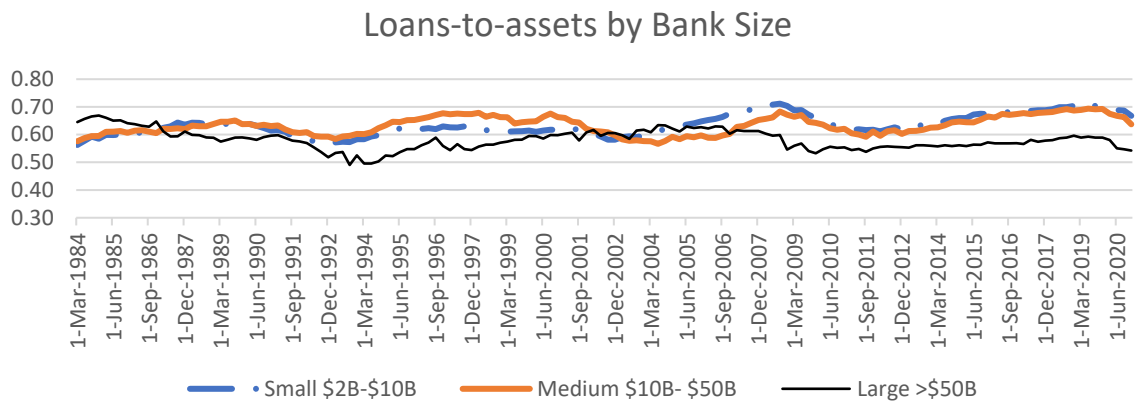
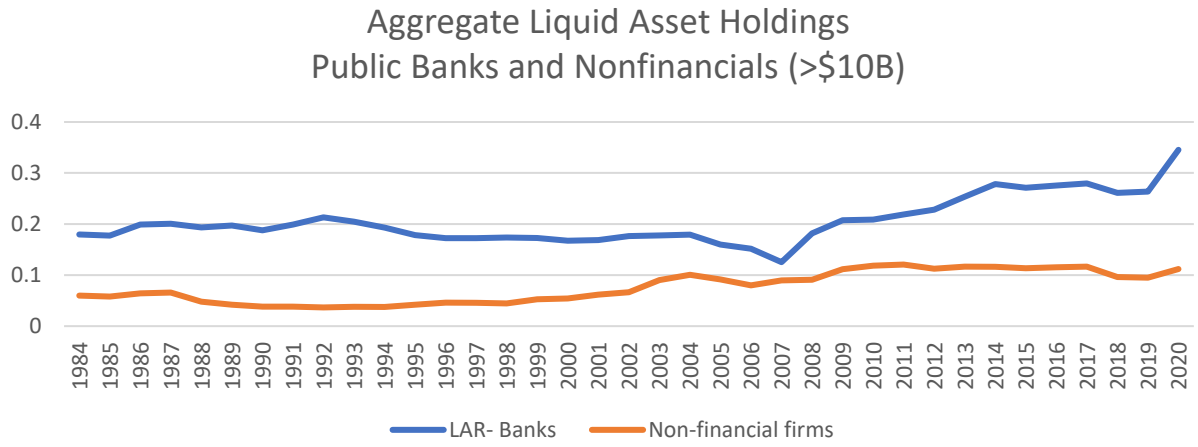


Figure 3. Aggregate liquid asset holdings of public banks and non-financial firms.

The figure shows the aggregate (Panel A) and equally-weighted average (Panel B) liquid assets-to-assets ratio (*LAR*) for banks and non-financial firms. Our sample of non-financial firms consists of firms incorporated in the US (excluding financials, SIC codes 6000-6999, and utilities, SIC codes 4900-4999) with assets exceeding $10 billion (in constant 2018 dollars). The sample of public banks consists of publicly listed US-chartered commercial banks with assets that exceed $10 billion. The aggregate *LAR* is computed by summing liquid assets for all banks (non-financial firms) in the sample and dividing them by the sum of assets for all banks (non-financial firms). For non-financial firms, *LAR* is cash and short-term investments, scaled by assets. For banks, *LAR* is the sum of cash holdings and non-cash liquid assets, scaled by total assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC.

Panel A. Aggregate liquid asset holdings.



Panel B. Equally-weighted average liquid asset holdings.

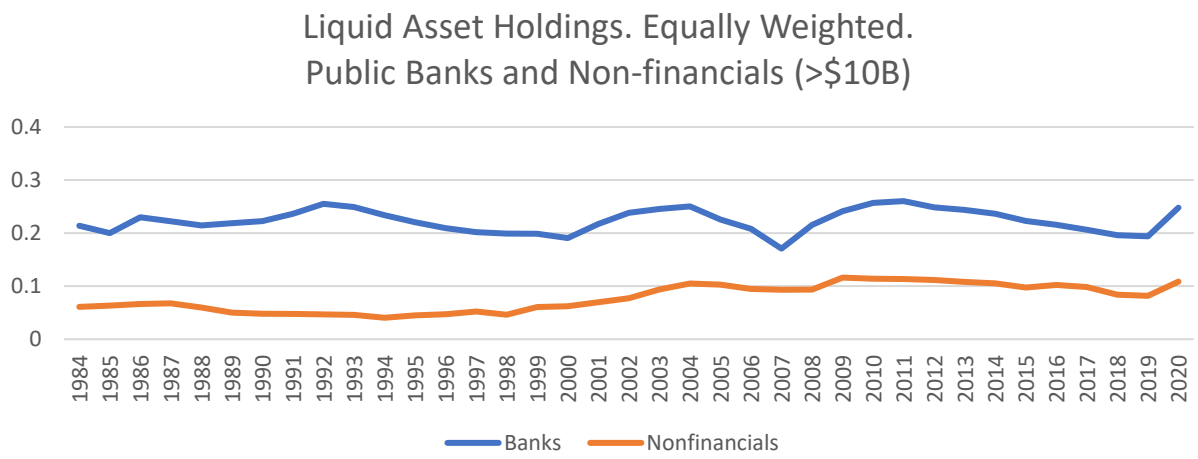
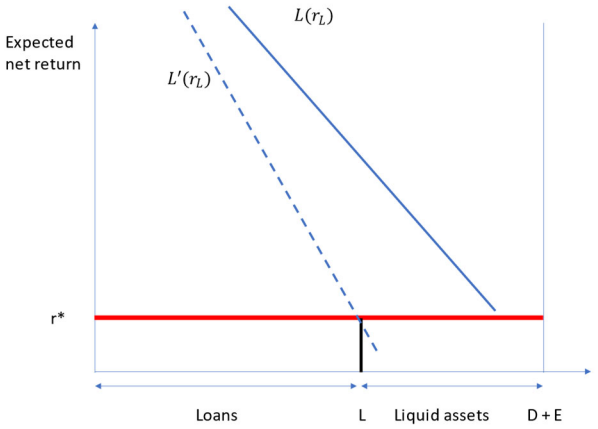


Figure 4. Equilibrium holdings of liquid assets.

The size of the bank balance sheet is fixed at the sum of deposits (D) and equity (E). The market for loans is imperfectly competitive so that the demand for loans L(r_L) falls with the expected net return on loans r_L., i.e., L'(r_L) < 0. The bank sets the level of loans where the marginal revenue of loans, L'(r_L), equals the net expected return on liquid assets. The net expected return on liquid assets is equal to r* when the marginal holdings of liquid assets have no risk management benefit, which is the continuous red line. The amount of loans is L. The amount of liquid assets is (D + E) – L. In Panel A, there is no risk management benefit of liquid assets. In Panel B, there is such a benefit. In Panel C, there is an exogenous increase in deposits. In Panel D, the liquidity requirement immobilizes an amount of liquid assets equal to (D+E) – LCR. Following the introduction of the LCR, the amount of liquid asset holdings increases from (D+E) – L to (D+E) – L*. The amount of loans falls from L to L*.

Panel A.



Panel B.

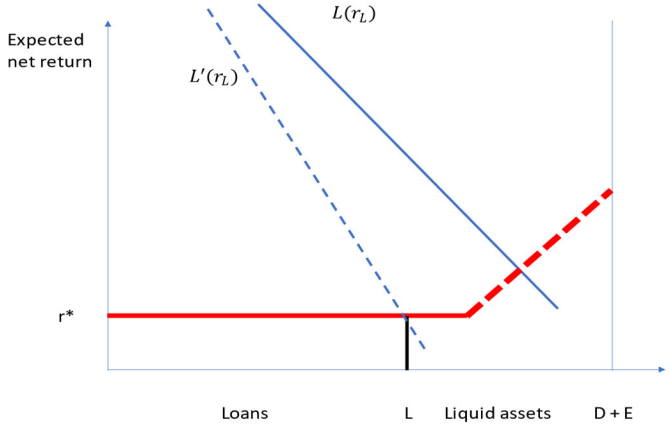
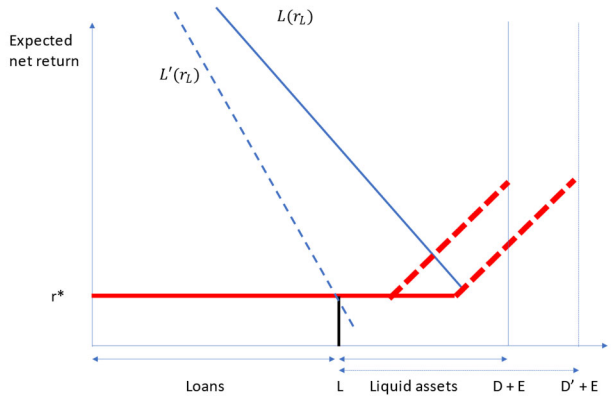


Figure 4. Equilibrium holdings of liquid assets – continued

Panel C.



Panel D.

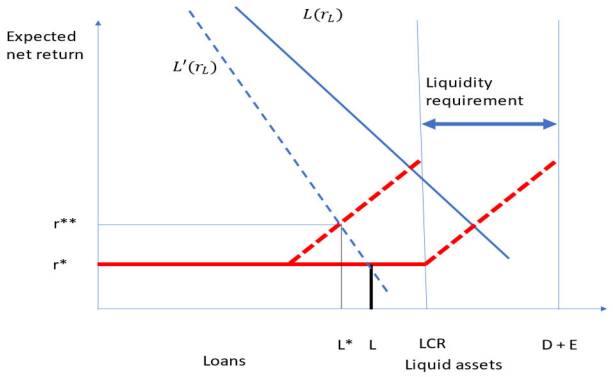
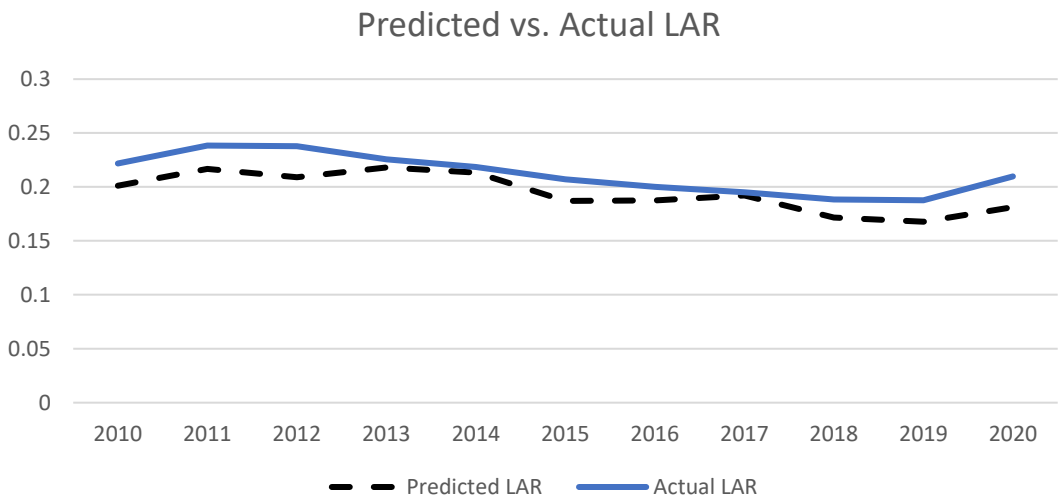


Figure 5. Average LAR versus predicted LAR

The figure shows the predicted versus actual average *LAR* by year. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). To compute the predicted *LAR*, we first estimate regressions of liquid asset holdings for banks (*LAR*) over the 1984-2006 sample with no fixed effects. Regressors include *Log(assets)*; *Loans-to-assets*; *Demand deposits-to-assets*; *Other deposits-to-assets*; *Equity-to-assets*; *Net income-to-assets*; *ROA volatility; Trading assets; Fed funds rate*, *the default spread*, and the *composite leading indicator. Predicted LAR* is estimated by applying the coefficients from these regressions to the values of the explanatory variables in each year from 2010 to 2020. The figure reports the equally-weighted averages of the predicted and actual LAR. Panel A shows the evolution for the full sample of banks, while Panel B shows the evolution by bank size. Large banks are those with assets in excess of $50 billion, and other banks are those with assets <$50B. All variables are defined in the Appendix.

Panel A. Full sample



Panel B. By bank size

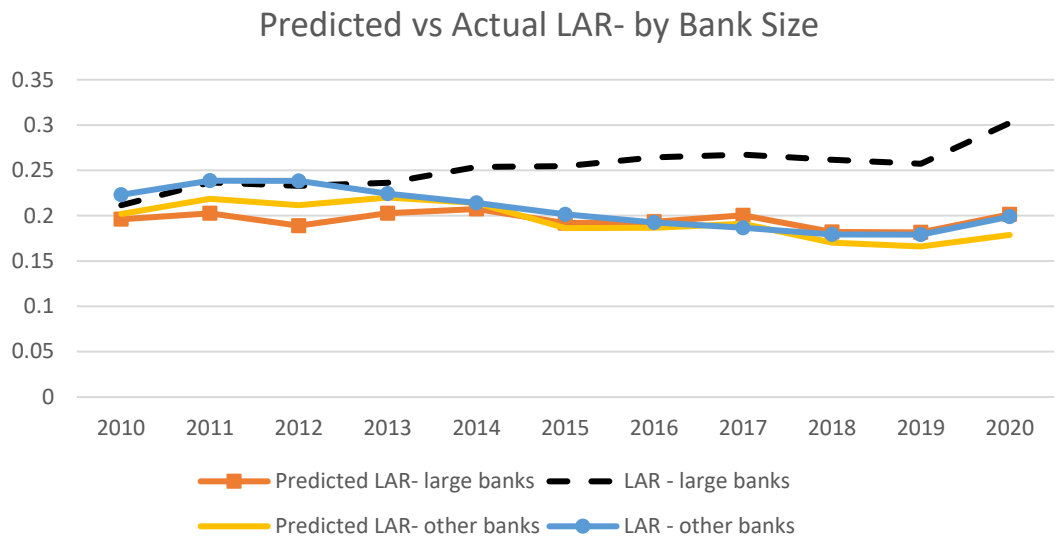


Figure 6. LAR by Bank Size.

The figure shows the evolution of the LAR for the banks directly affected by the LCR, those with assets in excess of $250 billion, for the banks subject to enhanced supervision, namely those with assets in excess of $50 billion, and for the other banks (<$50B). The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). We exclude trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. We sort banks into size groups at the end of 2009 and only use the banks that are in the sample at the end of 2009.

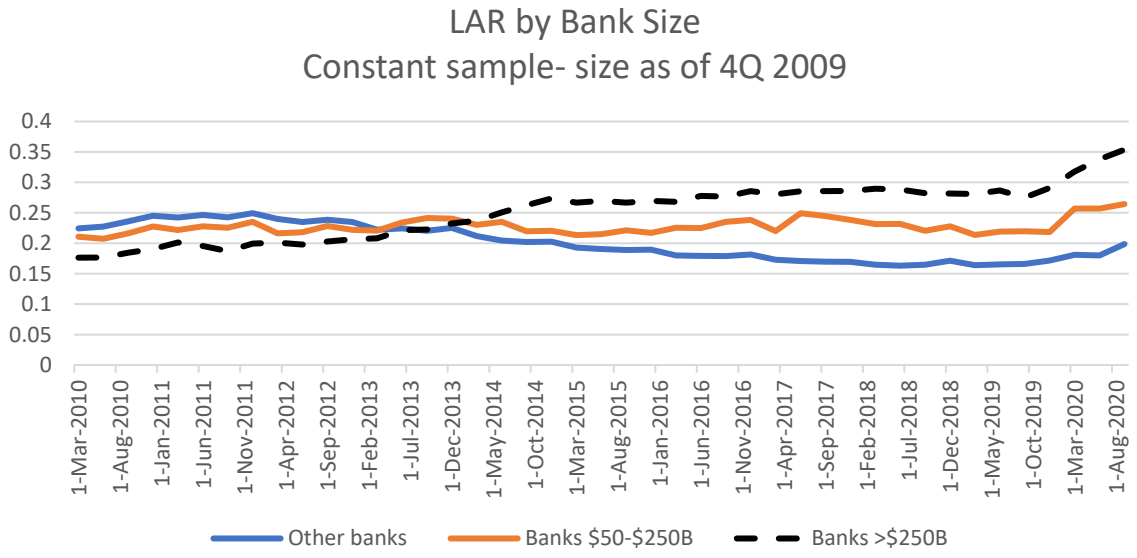
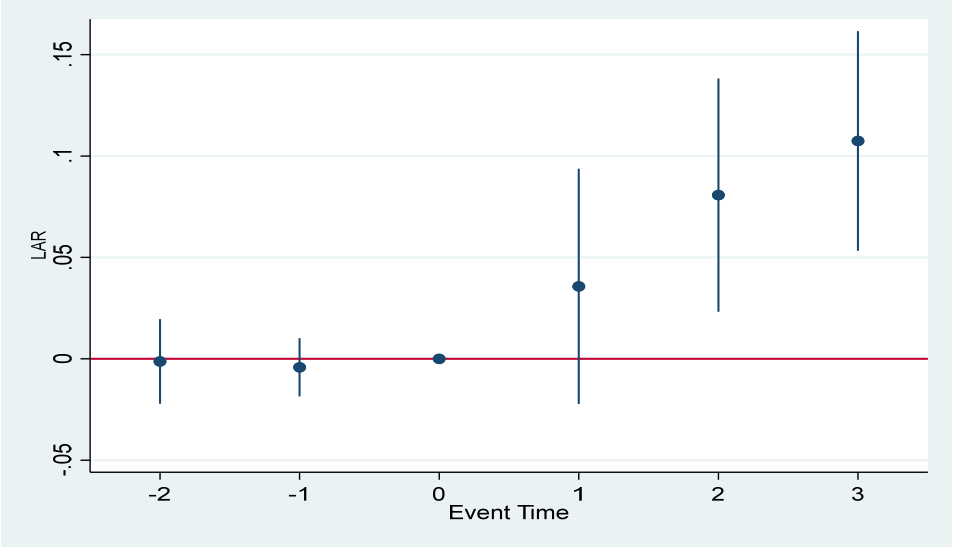


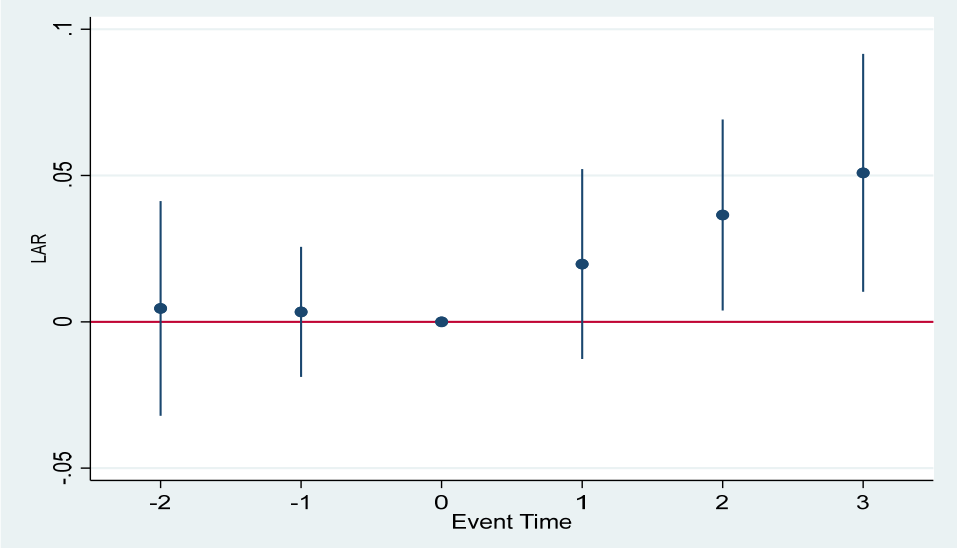
Figure 7. Tests of the parallel trends assumption.

This figure plots the coefficients on the interaction terms between the timing indicators (*t-2*,…, *t=3*) and indicators for our treatment groups: Large >$250B (Panel A) and Large $50-$250B (Panel B) from regressions of LAR including the same regressors as in Table 5 (Panel B). Banks are ranked by size as of *t-1* (2011). We estimate regressions for the [-2,+3] window around the treatment year (*t=1*) of 2013.The control group includes banks with assets below <$50B. The sample of banks consists of US-chartered commercial banks with assets that exceed $2B billion (in constant 2018 dollars). We exclude trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. The solid dots represent the point estimates, and the lines represent the 95% confidence interval.

Panel A. Treatment Group: Large banks >$250B



Panel B. Treatment Group: Large banks $50B-$250B



Appendix. Variable definitions

Variable name	Definition
Acquisitions-to-assets	Acquisition activity, scaled by assets. Source: COMPUSTAT.
Aggregate reserves	Total reserves of depository institutions (series TOTRESNS), scaled by total assets of commercial banks (TLAACBM027NBOG). Source FRB St. Louis FRED database
Capex-to-assets	Capital expenditures, scaled by assets. Source: COMPUSTAT.
Cash holdings	Vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks.
Cash flow-to-assets	Cash flow-to-assets. Cash flows is earnings after interest expense, taxes, and dividends, but before depreciation. For banks, it is computed as net income plus depreciation. Source: COMPUSTAT.
C&I loans-to-assets	Commercial and industrial loans divided by total assets.
Composite leading indicator	Amplitude adjusted Composite Leading Indicator, seasonally adjusted. Source: FRB St. Louis FRED database.
Default spread	Difference between Moody's seasoned Baa and Aaa corporate bond yield, not seasonally adjusted. Source: FRB St. Louis FRED database.
Demand deposits-to-assets	Total demand deposits.
Deposits-to-assets	Total deposits divided by total assets.
Deposit volatility	The standard deviation of deposits-to-assets over the prior four quarters.
Derivatives	Total gross notional amount of interest rate, equity, foreign exchange, and commodity derivate contracts held for trading, scaled by total assets.
Dividend payout	Indicator equal to one if a firm (bank) pays a common dividend in the year and zero otherwise. Source: COMPUSTAT.
Equity-to-assets	Total book value of equity divided by total assets.
Fed funds rate	The effective Federal Funds Rate. Source: FRB St. Louis FRED database.
Interest on excess reserves	The interest rate on excess reserves as determined by the Board of Governors. Source: FRB St. Louis FRED database .
Large >$50B	Indicator variable for banks with assets greater than $50B (constant 2018 US$).
Large >$250B	Indicator variable for banks with assets greater than $250B that are subject to the Liquidity Coverage Ratio (LCR) rule.
Large public banks	Publicly traded banks with assets greater than $10 billion in constant 2018 US$. We classify banks as public if stock price data are available for the bank or for its bank holding company. For public multibank holding companies, a public bank is the largest entity in the holding company structure.

Appendix. Variable definitions – continued

Variable name	Definition
LAR	Total liquid assets, scaled by total assets. Liquid assets represent the sum of cash holdings, US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC.
Leverage	Long-term debt plus debt in current liabilities divided by book value of assets.
Loan growth	Average loan growth over the prior eight quarters.
Loans-to-assets	Loans divided by total assets.
Log (assets)	The natural logarithm of total assets ($000s).
Market-to-book	Book value of assets minus book value of equity plus market value of equity, scaled by the book value of assets. Source: CRSP/COMPUSTAT.
Net income-to-assets	Net income, scaled by total assets.
Non-cash liquid assets-to-assets	Non-cash liquid assets, scaled by total assets. Non-cash liquid assets represent the sum of US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC.
Personal loans-to-assets	Loans to individuals scaled by total assets.
RE loans-to-assets	Loans secured by real estate divided by total assets.
Reserves-to-assets	Balances due from Federal Reserve Banks, scaled by total assets.
ROA volatility	The standard deviation of return on assets (ROA) over the prior four quarters.
Small	Indicator variable for banks with assets between $2B and $10B (constant 2018 US$).
Trading assets	An indicator equal to one for banks with trading assets as of the prior quarter-end.
Tier 1 capital	Tier 1 capital, scaled by risk-weighted assets.
Unused commitments	Sum of credit lines secured by 1-4 family homes, secured and unsecured commercial RE credit lines, commitments related to securities underwriting, commercial letters of credit, and other credit lines.
US Treasuries	The sum of the amortized cost held-to-maturity US Treasury securities and the fair value of available for sale US Treasuries
Wholesale funding	The sum of large time deposits, deposits booked in foreign offices, subordinated debt and debentures, gross fed funds purchased, repos, and other borrowed money.