NBER WORKING PAPER SERIES

LIQUIDITY DEPENDENCE AND THE WAXING AND WANING OF CENTRAL BANK BALANCE SHEETS

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Working Paper 31050
http://www.nber.org/papers/w31050

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2023, Revised December 2024

Rajan thanks the Fama-Miller Center at the Booth School and the Hoover Institution for research support. Steffen is grateful for financial support from the BMWi and DLR. We are grateful to Gara Afonso, Ryan Banerjee, Richard Berner, Wenxin Du, Michael Fleming, Charles Goodhart, Sam Hanson, Florian Heider, Martin Hiti, Raj Iyer, Anil Kashyap, Gabriele La Spada, Lorie Logan, Stephan Luck, Thorsten Martin, Thomas Mertens, Emanuel Moench, Laura Nicolae, Bill Nelson, Jose-Luis Peydro, Charlie Plosser, Jon Pogach, Rodney Ramacharan, Ricardo Reis, Asani Sarkar, Andrei Shleifer, Jeremy Stein, Paul Tucker, Bruce Tuckman, Quentin Vandeweyer, attendees at the Federal Reserve Bank of Kansas Jackson Hole Economic Symposium in August 2022 on “Reassessing Constraints on the Economy and Policy”, and seminar participants at various central banks, conferences, policy think-tanks and universities, for helpful comments. An early draft of this paper was named “Liquidity Dependence: Why Shrinking Central Bank Balance Sheets is an Uphill Task”. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 31050
March 2023, Revised December 2024
JEL No. G21

ABSTRACT

When the Federal Reserve (Fed) expanded its balance sheet via quantitative easing (QE), commercial banks typically financed reserve holdings with uninsured demandable deposits. They also issued credit lines to corporations. In the aggregate, these bank-issued claims on liquidity did not shrink commensurately when the Fed halted QE and turned to quantitative tightening (QT). Consequently, banks that increased liquidity risk exposure – especially small and regional banks – became vulnerable to liquidity shocks, necessitating further liquidity provision by the Fed. The evidence suggests that the expansion and shrinkage of central bank balance sheets has led to liquidity dependence of banks on central banks.

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Should the reduction of the size of a central bank's balance sheet be an entirely benign process "like watching paint dry", as senior Federal Reserve (Fed) officials put it?[2] The central bank will either let bonds held as assets on its balance sheet mature or sell them, thus extinguishing reserves, its liabilities. While bond prices may have to adjust to draw in sufficient private replacement demand, and the swap of bonds for reserves with the private sector may enhance the term premium, these possible price adjustments seem natural consequences to the rebalancing of portfolios, reversing in part the price effects at the time of expansion of central bank balance sheets.

Yet, after the Fed embarked on quantitative tightening (QT) in 2017, that is, a shrinkage of reserves, financial markets in the United States experienced two episodes of significant liquidity stress: in September 2019 and again in March 2020 (by when the Fed had already restarted injecting reserves). The former episode – which led to an intra-day spike in repo market rates – was attributed, in part, to significant reserve flows into the Treasury's Fed account leaving the private sector short and, in part, to the uneven distribution of reserves across banks (see Copeland, Duffie and Yang (2021) or D'Avernas and Vandeweyer (2021), for instance). Copeland, Duffie and Yang (2021) show that reserves hoarding by banks, suggesting an anticipated shortage of reserves manifested in delayed intraday interbank payments, was evident in data at least two weeks prior to the eventual repo rate spike. The March 2020 episode, which also spread across days, is attributed to the panic surrounding the COVID-19 outbreak that led to a "dash for cash", starting with corporations – both non-financial and financial – that drew heavily on lines of credit provided by commercial banks (Kashyap (2020), Acharya, Engle, Jager and Steffen (2023), and Acharya, Gopal, Jager and Steffen (2024)).

Once again, in March 2023, after a massive expansion of the Fed's balance sheet during the pandemic and a subsequent modest balance-sheet shrinkage (though accompanied by large interest-rate hikes), mid-size and regional US banks suffered runs or significant outflows of uninsured deposits, especially of corporate transaction deposits. Those that failed included Silicon Valley Bank [SVB]), Signature Bank and First Republic Bank, but at least 22 banks had runs (see Cipriani, Eisenbach, and Kovner (2024)). This episode, which lasted for several weeks, has been largely attributed to inadequate bank risk management and supervisory laxity (see Barr (2023)). Notwithstanding proximate causes for financial fragility, we ask whether the prior expansion and

[2] Former Federal Reserve Chair Janet Yellen citing Fed President Pat Harker, https://www.federalreserve.gov/mediacenter/files/fomcpresconf20170614.pdf

then shrinkage of the Fed's balance sheet left the private financial sector more vulnerable to such liquidity disruptions.

When the central bank expands its balance sheet during quantitative easing (QE) by buying securities, it can either buy them from commercial banks or the "public" such as non-bank financial institutions, family offices, and high net-worth individuals. Figure 1 (from Leonard, Martin and Potter (2017)) is illustrative. In Panel A, the central bank buys securities from banks. In this case, there is no expansion of the commercial bank balance sheet, as the central bank simply swaps reserves for securities with the banks.

In Panel B, the "public", which typically cannot hold reserves directly, deposits the payment in the commercial bank. Banks now hold reserves and (typically) owe wholesale demandable bank deposits to the public. In this case, bank balance sheets expand one for one with the expansion of the central bank balance sheet. The public may spend their deposits on corporate issuances, and corporations may in turn save the proceeds in transaction deposit accounts at banks, without altering the basic picture. Furthermore, individual banks can subsequently alter their capital structure, moving away from wholesale deposits towards other liabilities.

Similarly, when the central bank shrinks its balance sheet through QT, it could sell securities to banks (no change in bank balance sheet size) or to non-banks (leading to a shrinkage in bank balance sheets). Given these different mechanisms via which QE and QT can operate, we ask what happens to commercial bank balance sheets when the central bank balance sheet first waxes then wanes, and whether this could be a source of liquidity stress. We focus on the waxing and waning of the Fed balance sheet during the 2008Q4 to 2021Q4 period, but extend the descriptive analysis to 2023Q1, and also study the events of March 2023.

We find that during the QE episodes, commercial banks expand their balance sheets, issuing demand deposits, especially uninsured ones which are prone to runs. They also reduce their time deposits, and write more corporate credit lines, which are typically drawn down under aggregate corporate stress. Thus overall claims on bank liquidity increase. Importantly, they do not fall significantly when QE ended in October 2014 or when the Fed started QT starts in October 2017. Instead, *Claims to Potential Liquidity,* measured as the ratio of demandable claims (uninsured demandable deposits and outstanding credit lines) to liquidity (reserves plus holdings of assets eligible for repo transactions at the Fed), increased steeply over these periods. In sum, at the aggregate level over these episodes, we find commercial bank balance sheets wax but do not wane with the waxing and waning of the central bank's balance sheet.

To establish more firmly that commercial banks drive this process, we turn to the cross-section of banks to ascertain the causal impact of reserves on each bank's demandable claims. To identify plausibly exogenous changes in a given bank's reserves, we instrument the bank's reserves with the change in aggregate bank reserves multiplied by the bank's historical reserves "beta" on aggregate bank reserves (where a bank's beta is simply the past four-quarter average of its share of aggregate bank reserves). We find that during the periods of QE, banks that exogenously obtain more reserves tend to increase both uninsured demand deposits and issue credit lines, while simultaneously shrinking time deposits. Importantly, banks do not reliably shrink uninsured demand deposits or credit lines when they lose reserves as QE ends and QT begins. The panel analysis also helps rule out (via time fixed-effects) confounding factors such as GDP growth and the level of interest rates which can affect deposit growth, as well as helps control for time-varying bank-level characteristics.

We then explore bank-level pricing of liquidity. Banks that have a greater concern about liquidity risk should nudge term deposit rate spreads higher so that they can reduce their dependence on demand deposits. Therefore, a proxy for the price of liquidity at the bank level is the spread between term deposit interest rates and savings deposit interest rates. We find that during periods of QE, banks with greater (instrumented) reserves tend to *reduce* the term spread. Interestingly again, we find that these behaviors do not reliably reverse in the period between when the first sequence of QE ends in October 2014 and when the central bank resumes expanding its balance sheet again in September 2019. Put differently, banks that lose reserves post QE and during QT do not raise term spreads to raise the maturity of their deposits.

In other words, when the central bank expands its balance sheet during QE, commercial banks also alter their commitments, a simple but important fact that has not been fully appreciated. Reserve-rich commercial banks seem to engage in a search for yield both through their liabilities (issuing more money-like liabilities and reducing term liabilities) and their off-balance sheet commitments (issuing more lines of credit) that are not simply reversed or do not shrink fast enough in QT relative to the loss of reserves.

One possibility that might account for the asymmetric bank behavior between QE and QT is that banks feel confident they will retain their access to liquidity during QT if they substitute lost reserves with bonds that are eligible collateral for repo transactions. Of course, to the extent that repos must be conducted with other banks, banks will all be reliant on a diminishing pool of ultimate liquidity, that is, reserves. So, in a situation where every bank wants to transform repo-eligible financial securities into reserves (a "dash for cash"), there will be too little to satisfy all and banks with more demandable claims will experience financial fragility, effectively resulting in an aggregate bank run. If inter-bank markets cease working due to hoarding by well-managed surplus banks (see Acharya and Rajan (2024), Copeland, Duffie, and Yang (2024)), while the fear of stigma prevents banks from accessing reserves from Fed windows, then the dash for cash could lead to spikes in collateralized borrowing rates in the repo markets, and if unaddressed by Fed intervention, fire sales and distress.[3]

Indeed, it turns out that there is considerable cross-sectional dispersion in liquidity risk exposure – as proxied for by the ratio of uninsured demand deposits and undrawn lines of credit to reserves and repo-eligible securities – across banks. Specifically, we document that the ratcheting-up of liquidity risk exposure between 2010 and 2021 is driven especially by small banks not subject to liquidity coverage ratio (LCR) requirement. In contrast, the largest banks, subject to the most stringent LCR requirement, show a significant decline in exposure since 2012. Furthermore, we find that the distribution of this ratio across banks (largely driven by small banks) steadily shifts to the right, i.e., the ratio moves to higher levels, through the different episodes of QE, continuing its momentum post QE and during pre-pandemic QT, and ends up with a significantly fatter right tail of banks by the time of COVID-19's onset. Liquidity exposure becomes concentrated.

Finally, we study two episodes of financial fragility, the first around the COVID-19 outbreak in March 2020 and the second around the bank runs and uninsured deposit outflows in March 2023. Both followed episodes of QT, with the second also preceded by rate hikes.[4] In both

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[3] Note that there is often, at least in early stages of financial stress, stigma associated with borrowing from the Fed at the discount window. The Standing Repo Facility (SRF), allowing financial institutions to borrow additional reserves from the Fed, was not operational before 2021, and the fact that the Fed had to create a new lending facility in 2023 suggests the SRF was not fully effective.

[4] We do not empirically analyze the repo rate spike of September 2019 given its short-lived nature and lack of publicly available data at daily frequency. While the accumulation of reserves in the Treasury account and the uneven distribution of remaining reserves across banks were possibly the proximate causes of the Treasury repo rate spike in September 2019, Fed studies earlier in that year suggested the banking system had ample reserves (see Logan (2019)). Our evidence suggests that the shrinkage of aggregate reserves *without a commensurate decline in aggregate claims to liquidity* was a deeper catalyst. At a minimum, by leaving the system vulnerable, it likely amplified other channels (also see Copeland et al. (2024)).

cases, smaller banks with more liquidity exposure became more dependent on emergency liquidity assistance from the Fed or Federal Home Loan Banks (FHLBs).

In sum, we have three key findings. QE leads to more uninsured demandable deposits, undrawn lines of credit, and fewer time deposits in the banks that accrue reserves. Second, in the time-series, as QE stops and QT gets under way, these uninsured demand deposits and credit lines do not necessarily shrink with reserves in a commensurate manner. In the cross-section of banks, claims on reserves do not remain where the reserves are, which can exacerbate liquidity stress if shocks materialize and surplus banks are unwilling to lend reserves, creating ex-post liquidity dependence of illiquid banks on the central bank. Indeed, and third, we find evidence of such dependence for liquidity-stretched smaller banks in two episodes of financial fragility.

The shortage of reserves relative to claims can never cause a liquidity problem if the Fed will always lend reserves at short notice to any degree desired – that is, it operates an infinitely elastic balance sheet – and banks have no qualms borrowing. If interbank markets for reserves have ceased operating, an additional requirement is that the Fed should lend to specific liquidity-stressed entities, though unintended gaps or accidents could emerge. Furthermore, if the system is short in aggregate, the Fed may have to supply reserves on a more permanent basis to avoid frequent illiquidity episodes. One cost of such intervention is that the commercial banking system might issue yet more claims, and the central bank finds may find it hard to wean the system's dependence even if the economy's macro-economic priorities would require a different path.

The rest of the paper is as follows. Section 2 introduces the data we use. Section 3 presents aggregate time-series analysis linking quantities of reserves, deposits (and their various types) and credit lines. Section 4 then further analyzes these patterns using bank-level panel data to establish a plausibly causal effect of QE on these commercial banking quantities. Section 5 documents the ratcheting-up of bank-specific liquidity risk, its drivers, and ensuing financial fragility. Section 6 discusses implications for policy. Section 7 concludes with some directions for future research.

2. Data

We now describe the data sets we employ for our primary tests on how QE and QT affect commercial bank balance sheets (Sections 3 and 4). Data employed in bank fragility tests are described along with the tests in Section 5. Descriptive summary statistics of all variables of interest are in the Online Appendix Table A1.

2.1. Time-series

From the Federal Reserve Economic Data (FRED) database, we collect aggregate data on central bank reserves with the banking system (H6 release) and bank deposits (H6 and H8 release), as well as the time-series of outstanding off-balance-sheet credit lines to corporations (FDIC-sourced) and the U.S. Gross Domestic Product (GDP).[5] We use monthly data for aggregate time-series figures and quarterly data for regression tables in order to be consistent with the frequency of FDIC call reports. We focus on the period of 2008Q4-2021Q4 for the aggregate regression analysis of QE and QT. However, in some of our descriptive charts, we also use earlier data to see trends prior to QE, and use data from 2022Q1 to 2023Q4 to analyze recent bank fragility.

2.2. Panel with Individual Banks

We employ the following cross-section and time-series data for US banks during 2008Q4-2021Q4.

Bank-level reserves: Reserves are calculated as cash and balances due to a bank from the Federal Reserve Banks, based on the bank balance-sheet data from FDIC Call Reports, specifically item RCFD0090, or as item RCON0090 if the former is missing.

Bank-level deposits: We use FDIC's Summary of Deposits – Branch Office Deposits data to obtain branch-level deposits to construct our deposit instrument. For each bank in the Call Reports data, we use the Federal Financial Institutions Examination Council's (FFIEC) relationships table to link the bank to the Bank Holding Company (BHC), supplemented with RSSDHCR mapping of the Summary of Deposits. While the analysis of bank reserves, deposits, off-balance sheet unused credit lines and deposit rates is at the depository level in the panel tests, the analysis of credit line originations is at the BHC level.

An important part of our analysis focuses on uninsured demandable deposits of banks. Using FDIC Call Reports data, we first break down deposits into their uninsured-demandable, uninsured-time, insured-demandable, and insured-time components. *Total Uninsured Deposits* are computed as the sum of total foreign deposits and domestic deposit accounts with balances over \$100,000 before 2006Q1, non-retirement accounts with balances above \$100,000 and retirement accounts with balances above \$100,000 for the time period of 2006Q1-2009Q2, and all deposits

[5] Fed reserves can be held (i) in the Government Treasury Account and (ii) by non-banks via the Reverse Repo Facility. For instance, in August 2022, the Fed's liabilities of around \$9 trillion corresponded to roughly \$4 trillion reserves with the banking system, \$1 trillion in the U.S. Government Treasury Account or with agencies and market utilities, \$2 trillion in reverse repos of non-banks (which was small before the pandemic QE), and \$2 trillion currency-in-circulation. Given our focus on the banking system, we will refer to the reserves it holds as "aggregate reserves".

over $250,000 after 2009Q2 (reflecting the temporary increase in deposit insurance limit later made permanent), reported in schedule RC-O.[6] *Uninsured Time Deposits* are time deposits above $100,000 till 2010Q1 and above $250,000 after 2010Q1 plus foreign interest bearing deposits.[7] *Insured Time Deposits* and *Total Insured Deposits* are time deposits and total deposits which fall below the corresponding deposit insurance limits. We then compute *Uninsured Demandable Deposits* as the difference between Total Uninsured Deposits and Uninsured Time Deposits, and by extension, *Insured Demandable Deposits* as the difference between Total Insured and Insured Time Deposits.[8] Given this construction, demandable deposits strictly speaking are "non-time" deposits, and include savings and money market deposits in addition to transaction accounts, which is appropriate given they entail immediacy.[9] Non-interest bearing foreign deposits will count as uninsured demand deposits.[10]

We obtain deposit rate data from S&P Global's *RateWatch*, including weekly branch-level deposit rate data of different product types, along with product size and maturity information. For our deposit rate analysis, we use the average 3-month Certificate of Deposit (CD), 12-month CD, 18-month CD and 24-month CD rates, and Savings account rates, aggregated to the bank-quarter level and focus on the time period of 2008Q4-2021Q4.

Bank-level credit lines issuance: We obtain data on the origination of credit lines by U.S. non-financial firms from *Refinitiv LoanConnector*. These data include the name of the company contracting the line as well as the relevant contract terms. LoanConnector also includes the company credit rating at line origination. To obtain lender information, we use the Schwert (2018) link-file to map lenders in LoanConnector to the ultimate parent level (extending the file to the

[6] Note that Call Reports fields RCONF-051 & 052 reflect this change only in 2009Q2, while the deposit insurance limits were raised from $100,000 to $250,000 in October 2008 (2008Q4).

[7] While deposit insurance limit was raised in 2008Q4, the Call Reports items RCON2604 (Time Deposits Accounts with balance over $100,000) changed to RCONJ473 (Time Deposits Accounts with balances between $100-250k) and RCONJ474 (Time Deposits Accounts with balances over $250k) only in 2010Q1, in schedule RC-E.

[8] We do not adjust for the FDIC's Transaction Account Guarantee (TAG) Program's implicit insurance of all non-interest-bearing transaction accounts of balances over $250,000 when we compute Uninsured Domestic Deposits. Hence, Uninsured Demandable Deposits include temporarily insured transaction deposits and Insured Demandable Deposits do not include those deposits. The Program operated during October 14, 2008 to December 31, 2010, and was then replaced with a similar program (by the Dodd Frank Act) that expired on December 31, 2012.

[9] Note also that the construction of uninsured demandable deposit measures is based on other reported fields in Call Reports. It leads to some bank-quarters having negative amounts for these deposits. We truncate these negative amounts to zero in our analysis, but also verify that all our results are robust to starting the analysis in 2010 by when such negative amounts are rare (given the overall surge in uninsured deposits starting in 2009).

[10] Note that we do not use item RCON5597 which records "Estimated Amount of Uninsured Deposits in Domestic Offices of the Bank" to compute total uninsured deposits as it is missing for 65% of bank-quarter observations of our sample. Where available, it does not differ materially from our calculations of uninsured deposits.

end of 2021) and obtain their respective CRSP/Compustat identifier (GVKEY). Finally, we use the GVKEY-RSSD mapping provided by the Federal Reserve Bank of New York to obtain call report identifiers (RSSD) for BHCs. While we employ credit lines data starting in 2008Q4, due to a recent change in data vendor and associated data format changes we have not yet been able to update the data past 2021Q4.

3. The Aggregate Time-series: Bank reserves, deposits and credit lines

3.1. Descriptive evidence

In Figure 2, we plot reserves, deposits, and undrawn credit lines aggregated over all US commercial banks using data from the Federal Reserve's Flow of Funds for the period 2008Q4 to 2021Q4. In Panel A, we plot them as percentages of GDP. The vertical lines correspond to the beginning of the different Federal Reserve QE and QT programs: (1) Nov 2008 (QE I), (2) Nov 2010 (QE II), (3) Nov 2012 (QE III), (4) Oct 2014 (QE halted without actively reducing balance sheet size), (5) October 2017 (QT or active balance sheet reduction), (6) Sept 2019 (Repo-market "spike" and subsequent reserve expansion, followed by Pandemic-induced QE starting March 2020, which for simplicity we collectively refer to as "Pandemic QE"), and (7) March 2022, Fed rate hikes (with pandemic QT starting in June 2022).

Central bank reserves expanded from the start of QE I in November 2008 to the end of QE III in Sep 2014 from less than 5% of GDP to more than 15% of GDP. There was some stabilization, even decline, in reserves when each phase of QE ended and before the next phase began. At the same time, bank deposits grew from below 50% to over 60% of GDP, again with some stabilization when each phase of QE ended and before the next one began. Undrawn outstanding credit lines decreased initially, from \$2.37 trillion in Q4 2007 to \$1.89 trillion in Q4 2011, largely due to concerted drawdowns by corporations during and following the global financial crisis (see Ivashina and Scharfstein (2010) and Acharya and Mora (2015)). However, they too increased from November 2010 (the start of the QE II) from about 12% to over 15% of GDP by Sep 2014. Importantly, while reserves dropped by more than half between the end of QE in Oct 2014 and the end of the first QT in September 2019, both deposits as well as credit lines remained remarkably flat. This highlights the pattern that neither of these claims on bank liquidity reversed their QE I-III increase when the central bank balance sheet shrank.

When reserves increased from about 7% to more than 17% of GDP during the pandemic QE period, bank deposits jumped again from 60% to almost 80% of GDP and credit lines also increased from 15% to over 17% of GDP. From 2022, however, reserves, deposits and outstanding credit lines all started declining sharply (relative to the GDP) once the Fed started raising rates, ended QE and switched to QT. Banks first lost deposits to money market funds, perhaps reflecting the deposits channel of monetary policy wherein banks do not raise deposit rates commensurate with Fed rate hikes in order to squeeze sticky depositors (Drechsler, Savov and Schnabl (2017)), but from March 2023, depositors started fleeing mid-size and regional banks (see Caglio, Dlugosz, and Rezende (2023)).

Next, we split deposits into demand deposits and time deposits in Panel B.[11] Overall, the figure suggests a positive correlation between demand deposits and reserves as well as a negative correlation between time deposits and reserves during the QE I-III periods as well as the pandemic QE period. While reserves relative to GDP almost quadrupled over the 2009 to 2021 period, time deposits declined from about 23.4% of GDP to just about 6.3% of GDP. Demand deposits (both uninsured and insured), on the other hand, increased from 40% to about 80% of GDP over the same period. This shift from time to demand deposits may be because the money premium associated with demand deposits made them cheaper to issue than time deposits, which improves accounting profitability (ROE) – effectively, a search for yield on the liability side. Interestingly, the decline in time deposits flattens out whenever the Fed ceases QE, suggesting that QE tends to push banks to increase the "demandability" of bank claims.

Focusing on uninsured and insured demandable deposits separately, we observe that while both rose in a similar way during QE I-III, and also stayed flat post QE III, uninsured deposits, which are likely held by non-bank institutions, grew and fell faster respectively during the pandemic QE and QT. Panel C, which excludes foreign deposits, shows that while the share of US-based (domestic) insured demandable deposits in overall (domestic) deposits during 2001Q1 to 2021Q4 remained stable over the entire period around 40%, the share of uninsured demandable deposits, after remaining relatively flat at 18% between 2001 and 2009, rose sharply from then to peak at 47% during 2021.[12] Thus, the bulk of the effects of QE are seen in the rise in the quantum and share of uninsured demand deposits (and the fall in time deposits).

[11] Note that due to the aforementioned discrepancy in the dates on which Call Reports reflect the change in the definition of Total Uninsured Deposits (2009Q2) and Uninsured Time Deposits (2010Q1), we see a temporary blip up in Insured Demandable Deposits and a blip down in Uninsured Demandable Deposits during 2009Q2-2010Q1. Also, the sudden rise in Insured Time Deposits (and the corresponding fall in Uninsured Time Deposits) in 2010Q1 reflects the change in definition in Call Reports.

[12] The patterns in Panel C are robust to including foreign deposits.

To see that this does not reflect a general increase in household demand for deposits (which would typically be for insured deposits), we plot in Panel D the aggregate ratio of US household deposits to financial assets from the Flow of Funds for the period Oct 1987-Dec 2023. While the ratio declined dramatically from 22.5% in Oct 1987 to 10% at beginning of 2000, and did rise to 15% by the collapse of Lehman Brothers, it has remained relatively stable thereafter in the 12.5% to 15% range during the 2008Q4 to 2021Q4 period. Together, Panels C and D suggest a turning point in the growth of uninsured demandable deposits around the Fed's embarking on QE, and indicate that this turning point is not coincident with an increase in household deposits share or with a rise in insured demandable deposit share of overall deposits.

In the rest of this section, we turn to time-series regressions on aggregate quantities of bank deposits, credit lines and reserves, and offer econometric support for the descriptive patterns we have identified.

3.2. Time-series Regressions: Quantities of bank reserves, deposits and credit lines

We estimate the following ordinary least squares (OLS) regression:

$$\Delta Y_t = \alpha \Delta X_t + \beta X_{t-4} + \varepsilon_t, \qquad (1)$$

where $\Delta Y_t = Y_t - Y_{t-4}$ is either the change in Ln(*Deposits*) or Ln(*Credit Lines*) or the change in the *Deposits* or *Credit Lines*, with the change taken over the past year, i.e., four quarters back, to control for any seasonality, and $\Delta X_t = X_t - X_{t-4}$ is respectively either the change in Ln(*Reserves*) or the change in *Reserves*. As in the descriptive analysis, we also split deposits into demand and time deposits in some estimations. Standard errors reported in parentheses are adjusted for autocorrelation in the residuals up to 4 quarters. We include the four-quarter lag of Ln(*Reserves*) or *Reserves* to allow for a lagged impact of reserves.

In Table 1, we present estimates of model (1) for the 2008Q4 to 2021Q4 period. Columns (1) to (4) respectively use quarterly changes in the natural logarithm of *Deposits, Demand Deposits, Time Deposits,* and (undrawn) *Credit Lines* over the same quarter in the previous year as the dependent variable. The results suggest that the growth in *Reserves* is positively correlated with the growth in *Deposits, Demand Deposits*, as well as *Credit Lines*, and negatively correlated with the growth in *Time Deposits*. Our point estimates suggest that an increase in *Reserves* by 10% over the last 12 months is associated with an increase in *Deposits* of about 1.4%, *Demand Deposits* of 1.9%, and *Credit Lines* of 0.8%, but with a reduction in *Time Deposits* of 3.6%, consistent with demand and time deposits moving in opposite directions to reserves as we saw in Panel B of Figure

2. Importantly, this suggests that banks do not just issue deposits to finance reserves, but they shift toward issuing more demandable claims as reserves increase.

The correlation with lagged *Ln*(*Reserves*) is statistically significant, relatively smaller than the coefficient on changes in reserves for overall deposits (and statistically insignificant for demand and time deposits) but relatively larger in magnitude for credit lines, suggesting that changes in reserves take some time to translate into additional deposits and especially credit lines (or alternatively, that there is some momentum from past changes in reserves). With the exception of the credit lines coefficient, our estimates are robust to excluding this lagged variable (see Online Appendix Table A2)

In columns (5) to (8), we use arithmetic changes in *Deposits* or *Credit Lines* (instead of log changes) as dependent variables, since the coefficients are easier to interpret. The point estimate in column (5) suggests that for the aggregate banking system, deposit liabilities change in levels almost one for one with reserves. Such a relationship would arise if on the margin banks finance an expansion in their holdings of reserves largely through deposits. Equivalently, it is consistent with the Fed injecting reserves by buying assets from non-banks, who then deposit the proceeds with banks. Of course, this requires that after receiving deposits banks do not rebalance their capital structure away from deposits. Since the new assets (reserves) have zero risk weights, banks have no need to issue additional capital if the leverage ratio does not bind, and since the asset is very liquid, they have no need to rebalance assets to meet liquidity ratios. Columns (6) and (7) imply that demand deposits increase substantially more than one for one with reserves, because time deposits in fact shrink. Column (8) indicates changes in reserves are positively correlated with changes in outstanding credit lines.

In Table 2, we break the dependent variable, namely deposits, into insured and uninsured. Once again, columns (1)-(4) has the variables in log changes and columns (5)-(8) are in arithmetic changes. While uninsured deposits are statistically related to reserves (columns (1) and (5)), insured deposits are not (columns (2) and (6)). Within demand deposits, the coefficient estimates for uninsured demandable deposits (see columns (3) and (7)) is 15-60% greater than that of insured demandable deposits (see columns (4) and (8)). These results are overall in line with the descriptive patterns seen in Figure 2, Panel B.

Collectively, these correlations suggest that an increase in central bank reserves is associated with an increase in uninsured, especially demandable, deposits as well as credit lines.

This is suggestive of banks trying to minimize the cost of holding reserves by financing with uninsured demandable deposits, and earning fees by issuing demandable claims such as credit lines. Of course, this search for yield by issuing liquidity claims may be quite safe if the bank has sufficient reserves to meet claims, or if aggregate liquidity is plentiful. It can turn awry if not.

Aggregate time-series analysis is not conducive to inference about the causal impact of reserves on variables of interest, especially when we examine different episodes of central bank activity, since we run into issues of statistical power given the small number of observations within each episode. Time-series analysis also cannot adequately rule out confounding effects from economy-wide factors such as the level of economic activity and interest rates, as well as the consequent change in household financial assets, which directly affect deposit creation and deposit demand in the economy. We, therefore, turn to panel tests with a cross-section of banks.

4. The Panel Tests: Bank reserves, deposits and credit lines

4.1. Central bank reserves and bank choices (quantities and rates).

In our panel tests, we focus on individual banks and how their reserve holdings affect their uninsured demandable deposits and credit lines (which create liquidity risk), as well as time deposits (which help us understand bank deposit maturity choice). We first describe the methodology underlying our panel tests.

4.2. Methodology

While the aggregate stock of bank reserves is set by the central bank and therefore is likely to be exogenous to total bank deposits, the stock of reserves at an individual bank could be *endogenous* to that bank's deposit funding. For instance, there could be reverse causality from deposits to reserves. Conversely, a bank that has had adverse performance may experience weaker deposit inflows (or even deposit outflows) and a relative fall in reserves but may also try to attract reserves to meet withdrawals. Banks may also be subject to liquidity regulations. Since such regulations are relaxed if a bank chooses time deposits over demand deposits, liquidity-constrained banks may seek reserves at the same time as they seek time deposits – inducing a positive correlation we need to correct for. Also, large banks that have access to equity and bond markets may raise a part of their funding from non-deposit sources, which would increase reserves but simultaneously not increase deposits.

To allay such endogeneity concerns which can bias the estimated relationships of interest, we employ a 2-stage least squares (2-SLS) specification, instrumenting the change in bank-level reserves in the first stage to obtain the impact of a plausibly exogenous change in bank-level reserves on bank-level variables of interest. We employ a *Reserve Instrument*, z_{it}^{R1}, computed as the product of the most recent change in aggregate bank reserves and the bank's reserve share:

$$\ln\left(\frac{Aggregate\ bank\ reserves_t}{Aggregate\ bank\ reserves_{t-1}}\right) \times \frac{1}{4}\sum_{k=1}^{4} Bank\ i's\ share\ of\ aggregate\ bank\ reserves_{t-k}. \quad (3a)$$

The first component, the growth in aggregate banking system reserves, is plausibly not driven by an individual bank's circumstances, but in the aggregate by the Fed's monetary stance. Given the nature of Fed's QE operations, this component is large in magnitude at the inception of QE I and pandemic QE relative to other quarters. This variability lends exactly the kind of statistical and economic power to the instrument that an econometrician ideally wishes for. However, the power of the instrument is weaker during post QE III and QT period as Fed did not dramatically shrink reserves in a particular quarter, something we will have to contend with in the results to follow.[13]

Turning to the second component, banks will differ in their propensity to attract reserves. Some banks will be at the center of networks of customers with surplus deposits, which will position them best to attract reserves. In particular during QE, non-banks may tender financial assets to the central bank, placing the associated deposits received in payment with their relationship bank or prime broker. Given they are likely to attract reserves because of their activity, network centricity, or relationships, banks with a more "reserve-intensive" past are likely to attract more incremental reserves today if the central bank expands its aggregate stock. These more persistent underlying factors would cause a bank to have a pre-determined higher reserve share but because it can rebalance its balance sheet, this need not affect its structure of liquidity claims other than through the deliberate choices it makes. For instance, Kashyap, Rajan, and Stein (2002)

[13] An alternate instrument uses the growth in the overall Fed balance sheet as the first component, while retaining the second component:

$$\ln\left(\frac{Fed\ Assets_t}{Fed\ Assets_{t-1}}\right) \times \frac{1}{4}\sum_{k=1}^{4} Bank\ i's\ share\ of\ aggregate\ bank\ reserves_{t-k}. \quad (3b)$$

The rationale for using the overall balance-sheet growth of the Fed rather than the growth in aggregate bank reserves might be that aggregate banking reserves are a residual from the Fed's choice of balance sheet size and the economy's demand for cash in circulation (and in recent years, the overnight reverse repo facility for money market funds). However, bank "reserve betas" with respect to this alternate instrument do not necessarily add up to one in the cross-section. Our results are robust to employing both instruments together and separately (Online Appendix B).

argue that banks can best utilize a stock of reserves by writing both demandable deposit claims as well as credit lines against it – maximizing the effective yield of the reserves.

With this rationale, the second component of the instrument, *Bank i's lagged share of aggregate bank reserves*, can be interpreted as a bank's "reserve beta," which is calculated by dividing the bank-level reserves by aggregate bank reserves. We average this share over the past 4 quarters to deal with possible seasonality or noise in bank-level reserves, as well as to reduce the impact of any endogenous reserve adjustment by the bank (assuming that such adjustment is transitory and uncorrelated or weakly correlated from one quarter to the next). The quarterly share of a bank in aggregate bank reserves is persistent with a Kendall-bias adjusted autocorrelation of 0.74 on average across banks (standard deviation across banks being 1.50).

4.3. Impact of reserves on quantities of deposits

We then estimate a 2-stage least square specification. The first-stage is estimated as

$$\Delta Ln(Reserves)_{it} = \gamma_1 z_{it}^{R1} + \gamma_3 Ln(Reserves_{it-5}) + \mu X_{it-1} + \delta_t + \vartheta_{it} \quad (4)$$

$where\ \Delta \boldsymbol{Y}_{it} = Y_{it} - Y_{it-4}$, and X_{it-1} represents bank controls lagged by one quarter which are bank size (measured as *Ln(Assets)*), profitability (*Net Income-to-Assets*), and capitalization (*Equity-to-Assets*), as well as a *Primary Dealer* indicator that identifies banks that are primary dealers.[14] Finally, δ_t represents (quarter) time-fixed effects which soak up any aggregate temporal change in conditions.

We will typically report estimates for the overall period (column (1)), the QE I-III plus post pandemic QE period (column (2)), QE I-III periods (column (3)), and for the post QE III and QT period (column (4)). To ensure we do not have too many gaps in the panel analysis, we include the period Aug-Oct 2010 (between QE I and QE II) and Sep 2011-Aug 2012 (between QE II and QE III) as part of the QE period, even though these were periods in between phases of QE. Excluding these interim periods between successive QE programs does not change the results qualitatively. The pandemic QT period seems qualitatively different because balance sheet contraction was preceded by the sharp rise in inflation, accompanied by higher interest rates, and followed by bank runs within a year of its commencement. We analyze only the runs later in the paper.

[14] We verify in Online Appendix Table A6 that these time-varying controls are *not* correlated with our reserves instrument, i.e., there is no "bad controls" problem in the second stage. We also verify in Online Appendix Tables A7 and A8 that our results are robust to timing the controls at the beginning of each sub-period as well as excluding the controls altogether, respectively.

The first-stage results are presented in Table 3 Panel A. We find that the *relevance* criteria are met as the first-stage correlation between the instrument and the endogenous variable, viz., the log change in reserves of a bank, is estimated to be positive and significant across all time-series sub-samples of our regressions. We also report the F-statistic and the Kleibergen and Paap (2006) Wald F-Statistic as the robustness tests for instrument *weakness*.[15] We find that the F-statistics are well above the thumb rule of 40 for each sub-sample of regressions and meet the Stock and Yogo (2005) thresholds for instrumental variable bias of 10% except for the sub-sample of post QE III and QT period. The Kleibergen-Paap F-statistics marginally improve when we reduce the number of clustered standard errors to just bank-level clustering (as the number of quarters in the post QE III and QT period is only 20), which we report in the Online Appendix Table A5.

In the second stage, we regress the change in deposits, $\Delta Ln(Deposits)$, against instrumented $\Delta Ln(Reserves)$, including other independent variables included in the first stage:

$$\Delta Ln(Deposits)_{it} = \beta_1 Instr\ \Delta Ln(Reserves)_{it} + \beta_2 Ln(Reserves)_{it-5} + \mu X_{it-1} + \tau_t + \varepsilon_{it} \quad (5)$$

where X_{it-1} represents time-varying bank controls lagged by one quarter as in equation (4). Quarter time-fixed effects τ_t absorb any aggregate trends in deposit growth such as due to fluctuations in economic activity or increases in household financial assets.

In Table 3 Panel B.1, we present OLS estimates, and in Panel B.2, instrumental variable (IV) estimates, for the impact of reserves on uninsured demandable deposits. For parsimony, we do not report estimated coefficients of the control variables including the fifth lag of log reserves.

The coefficient estimates for our main variable of interest, the change in log reserves, are positive and significant in the OLS estimates for the overall period and all sub-periods. In the IV estimates, the instrumented change in log reserves is indeed positively and significantly correlated with the change in log uninsured demandable deposits in the overall sample (column (1)), the QE periods (column (2)), and QE I-III periods (column (3)), but for the post QE III and QT period (column (4)) it is negative and statistically insignificant.

The positive IV coefficient during QE periods suggests that banks that receive QE-injected reserves increase their uninsured demand deposits. This is consistent with the Fed buying bonds from non-banks which typically then hold flighty uninsured transaction or money market deposits

[15] Cragg and Donald (1993) Wald F-statistics are not useful as standard errors are clustered two-ways by bank and quarter.

at banks (unlike sticky, typically retail, insured deposits). Since reserves shrink during the post QE III and QT period, the statistically insignificant IV coefficient during these periods supports the time-series finding that uninsured demandable deposits do not (reliably) shrink after having risen during QE periods, and the negative sign in fact implies that if anything they (noisily) keep rising.

In terms of magnitudes, an exogenous 10 percent year-on-year increase in a bank's reserves leads to a 2.05 percent rise in its uninsured demandable deposits in the overall time period, and 1.96 percent rise in the QE periods. The statistically significant IV magnitudes in Panel B.2 are almost an order of magnitude greater than those observed in the OLS estimation in Panel B.1, suggesting there is some bank-level endogeneity that shrinks the magnitude of the OLS estimate. The IV estimate is of the same order of magnitude as the simple time-series estimate based on aggregate data (Table 2, Panel A, Column 3).

Panel C presents results on time deposits. While the OLS estimates (Panel C.1) suggest a positive relation between reserves and time deposits, the IV estimates (Panel C.2) imply a negative relation in the overall and QE periods (Columns 1-3), suggesting that there is indeed some endogeneity in individual bank reserves that the IV estimates address. This IV estimate is consistent in sign with our aggregate time-series results and about half the magnitude (see Table 1, Panel A, Column 3). Based on the estimates, an exogenous 10 percent year-on-year increase in a bank's reserves leads to approximately a 1.6-1.8 percent *decrease* in the bank's time deposits in the overall and the QE periods. Finally, there is a statistically insignificant, albeit large-in-magnitude, positive coefficient in the Post QE III and QT period (C.2 Column 4).

Overall, Table 3 suggests that there is a maturity-shortening of deposits at the bank level during QE periods, as a bank's uninsured transaction, money market, and savings (all clubbed together as demandable) deposits increase with an influx of reserves, while longer-maturity time deposits decrease. This maturity-shortening, however, does not reverse when the central bank stops injecting or reduces aggregate reserves during the post QE III and QT period. The differential effect for demand and time deposits suggests that it is not just that deposit financing passively grows with reserves; there seems to be an active move by banks to substitute term financing with demandable financing.

Could it be that this transformation is simply because lower interest rates accompany QE (Drechsler, Savov and Schnabl, 2017)? Importantly, we have shown that the maturity-shortening of deposits within quarter is greater at banks that typically received QE-injected reserves, so there is a cross-sectional dimension to this, different from the time series that we control for.[16] More generally, the value of our panel tests is precisely to rule out confounding possibilities that make the aggregate time-series regressions hard to interpret. For instance, the desire for time deposits may shrink during times of low interest rates, especially if QE is accompanied by forward guidance that rates will remain "low for long." Since we identify greater rotation towards demandable deposits away from time deposits during QE for banks that are more reserve intensive, controlling for such time fixed-effects, this suggests an active bank preference rather than a passive one.

There may be something special about the smallest banks, who dominate our sample. Large banks, by contrast, dominate activity. We check in Online Appendix C whether our estimates are broadly similar when we limit our sample to the top 100 banks by asset size as of 2014 Q3. This includes 8 banks greater than $250 billion in assets, 28 banks in $50-$250 billion in assets, and the rest below $50 billion.[17] Indeed, by and large the magnitude of the coefficient estimates on instrumented reserves are similar for the top 100 banks in explaining both uninsured demand deposits and time deposits, though statistical significance is lower in some sub-periods due to the smaller sample of banks.

4.4. Impact of bank-level reserves and deposits on deposit rates

In Table A3 of the Online Appendix, we show (following Lopez-Salido and Vissing Jorgensen (2022)) that the price of aggregate liquidity, measured as the Effective Federal Funds Rate (EFFR) minus Interest on Excess Reserves (IOR), is reduced by aggregate reserves outstanding but increased by claims on aggregate liquidity, that is, by deposits and credit lines outstanding. Aggregate analysis, as we have just noted, has the obvious problem that we cannot control for all time-varying factors. Therefore, one way to get further insights into the financing of reserves by commercial banks with uninsured demandable rather than time deposits is to examine the relative pricing of these deposits *across* banks, correcting for time fixed effects. Our intent is to see whether banks with more (exogenous) reserves tend to offer a lower spread for term

[16] Furthermore, if we do control for a bank's deposit "beta" (Drechsler, Savov and Schnabl, 2021), that is, for how much a bank's deposit rate changes in relation to changes in the Federal Funds rate, we do not see a qualitative change in estimates for the first stage or the second stage of our panel tests in Table 3 (see Online Appendix Table A9). The deposit betas are from Philipp Schnabl's website at https://pages.stern.nyu.edu/~pschnabl/data/data_deposit_beta.htm (last update: April 2023).

[17] While standard errors are clustered at the bank-quarter level for the full sample, limiting the sample to top 100 banks allows for clustering only at the bank level, (refer to Appendix C)

deposits, that is, they prefer shrinking deposit maturity and foregoing the liquidity protection term deposits offer.

Specifically, we focus in our cross-sectional deposit-rate tests on the spread between time-deposit rates (in particular, rates on 3-, 12-, 18- and 24-month Certificates of Deposits where the depositor is locked in for the term by high withdrawal penalties) and money market savings rates (henceforth MM savings rates). A narrowing of the difference between the two as a bank's reserves grow, coupled with a reduction in the quantum of time deposits, would suggest the bank's unwillingness to pay more for term protection, a form of liability side search for yield.

Formally, we employ a 2-SLS specification by instrumenting bank-level reserves and bank-level deposits in the first stage. We have already discussed our instruments for reserves. Deposit rates might be jointly determined with bank-level deposits as well – for example, a bank seeing an outflow of term deposits may raise term deposit rates, and this could show up as a negative correlation between deposits and spreads. To correct for such endogeneity, our instrument for deposits focuses on the counties the bank is present in and the growth in deposits there. Specifically, the instrument is $z_{it}^{D} = \ln\left(\sum_{c \in Ci,t} w_{ict} \cdot \frac{Dep_{c,t}}{Dep_{c,t-1}} \right)$ where $w_{ict} = \frac{Dep_{c,t-1}}{\sum_{c' \in C_{i,t}} Dep_{c',t-1}}$ is the bank-specific weight accorded to county c the bank operates in time t, and $\frac{Dep_{c,t}}{Dep_{c,t-1}}$ is the growth rate in aggregate deposits in that county over the past period. The bank-specific weight is determined as the level of aggregate deposits in that county at time *t-1* divided by the sum of aggregate deposits over all the counties the bank has a presence in. In other words, our deposit instrument for a bank is the overall deposit growth rates of the counties the bank has a presence in, weighted by their relative aggregate deposit size last period among all the counties the bank has a presence in.

Implicitly, we assume the deposit growth rates in the larger counties (in terms of aggregate deposits) that the bank has a presence in will drive the growth rate in its own deposits, else the correlation of the instrument with deposits will be weak, and the instrument will fail the standard weak instrument tests. The exclusion restriction is that the bank's presence in those counties, the relative size of deposit banking in those counties, and the growth of deposits in those counties, are factors that do not determine the bank's deposit spreads, other than through the size and growth of its own deposits. We also control for bank and quarter fixed effects, which helps absorb bank- and quarter-level time-invariant variation in our first and second-stage regressions.

Formally, we estimate the following model in the first stage:

$$Ln(Deposits)_{it} = \gamma_{11} Deposit\ Instrument_{it} + \gamma_{12}. Reserves\ Instrument_{it} + \mu X_{it-1} + \rho_i + \delta_t + \mu_{it} \quad (6)$$

$$Ln(Reserves)_{it} = \gamma_{21} Deposit\ Instrument_{it} + \gamma_{22}. Reserves\ Instrument_{it} + \mu X_{it-1} + \rho_i + \delta_t + \mu_{it} \quad (7)$$

where *i* represents bank, *t* represents quarterly data, ρ_i represents bank-fixed effects, and δ_t represents (quarter) time-fixed effects. All regressions include bank-time-varying controls lagged by one quarter (X_{it-1}). The first-stage results are presented in Table 4 Panel A. Confirming the relevance criteria, we find that the first-stage correlation between the instrument and the relevant endogenous variables (*Ln(Reserves)* or *Ln(Deposits)*) is positive and significant across all sub-samples of our regressions, except *Ln(Reserves)* with the reserves instrument in the Post QE-QT period (column (4) – we will return to this in the next section). The specification is also robust to Hansen-J test for overidentifying restrictions. As robustness tests for instrument weakness, we also report the F-statistic and the Kleibergen-Paap Wald F-statistic. We find these statistics are well above the thumb-rule of 40 for each sub-sample of regressions and meet the Stock-Yogo thresholds bias of 10% except, once again, for the sub-sample of post QE III and QT period.

In the second stage, we regress deposit spreads against instrumented *Ln(Deposits)* and *Ln(Reserves)*; in particular, we estimate

$$Deposit\ Rate\ Spread_{it} = \beta_1 Instr\ Ln(Deposits)_{it} + \beta_2\ Instr\ Ln(Reserves)_{it} + \mu X_{it-1} + \pi_i + \tau_t + \varepsilon_{it} \quad (8)$$

where *i* represents bank *i*, *t* represents the quarterly date, X_{it-1} again represents bank-time varying controls lagged by one quarter as in the first-stage, π_i represents bank-fixed effects and τ_t represents (quarter) time-fixed effects. *Deposit Rate Spread* refers to the *3-, 12-, 18-, or 24-month Certificate of Deposit (CD) Rate to MM Savings Rate Spread*. The primary coefficient of interest in model (8) is β_2, and the hypothesis is that it is negative because an exogenous increase in bank reserves induces a preference in banks for a shorter maturity of deposits, whence they reduce time deposit spreads.

Table 4, Panels B presents the second-stage of the 2-SLS regression results (corresponding OLS results are in the Online Appendix Table A10). Within each panel, subpanels 1-4 correspond sequentially to estimates for the overall time period and individual QE/QT periods.

We see that for the overall sample of banks and the overall time period (subpanel B.1), the coefficients on *Ln(Reserves)* are always negative as expected and statistically significant. The coefficient magnitude is smaller by a factor of 2 to 4 for the 12-month CD spread relative to the other CD maturities (there may be more noise in the 12-month CD spread across banks, because some banks treat it as a short-term CD with minimal loss of interest if the CD is withdrawn prematurely, while others treat it as a long-term CD with substantial penalty for early withdrawal). In terms of economic magnitude, a one standard deviation increase in the instrumented log reserves (demeaned for bank and time fixed effects) translates into a 48 basis points narrower 18-month CD to MM Savings Rate Spread, which is about 1.16 times the standard deviation of the (demeaned) 18-month CD to MM Savings Rate Spread. We note here that the unreported coefficients on *Ln(Total Deposits)* are positive but insignificant.

Examining estimates for the individual time periods (subpanels B.2-4), we find that relative to the overall sample period, the negative effect of reserves on the term spread for deposits is similar in magnitude for all of the QE periods (subpanel B.2) and the QE I-III periods alone (subpanel B.3). Interestingly however, pricing in the Post QE III/QT period (subpanel B.4) becomes much noisier, with the coefficients on *Ln(Reserves)* turning positive for three of the four maturities. Hence, similar to the estimates from quantities, the cross-sectional bank pricing of liquidity turns noisy with the shrinkage in reserves, instead of simply reversing. Of course, we should note the weakness of our instrument in this sub-period.

4.5. Impact of Reserves on Origination of Credit Lines

As discussed earlier, banks can also create demandable claims on liquidity through the provision of credit lines. There has been a significant increase since 2010 (post Global Financial Crisis and its aftermath) in credit lines as a percentage of GDP, as shown in Figure 2 earlier. Credit line usage has also evolved into an important source of liquidity management for corporations. In the early stages of the pandemic, there was a dash for cash (Kashyap, 2020) and credit lines were substantially drawn down in March 2020 (see e.g. Acharya and Steffen (2020) and Acharya, Engle, Jager and Steffen (2024)). Despite this unprecedented usage, the amount of undrawn outstanding credit lines increased much beyond the pre-pandemic levels by the end of 2021.

In this sub-section, we provide corroborating evidence using panel data that banks with higher exogenous reserves originate more credit lines. To investigate the effect of an exogenous change in reserves on the origination of credit lines across banks, we re-compute the instrument for reserves at the BHC level, since data on bank participation in the syndicates that offer credit lines are at the BHC level. Table 5, Panel A confirms that the instrument meets the relevance criteria as well as passes the instrument weakness threshold for the overall period (Column 1) and the QE periods (Columns 2 and 3). However, the instrument is statistically insignificant in explaining reserves during the post QE III and QT period as well as fails to cross the instrument weakness threshold (Column 4). We will return to this issue in the next section.

For the second stage, we estimate at the BHC (*i*) -quarter (*t*) level:

$$\Delta Ln(Credit\ Lines)_{it} = \beta_1 \Delta Ln(Reserves)_{it} + \beta_2 Ln(Reserves)_{it-5} + \mu X_{it-1} + \tau_t + \varepsilon_{it} \quad (9)$$

where X_{it-1} represents bank-time-varying controls lagged by one quarter, τ_t is a quarter-time fixed effect, again to control for aggregate growth trends induced by fluctuations in economic activity. $Credit\ Lines_{it}$ is the total amount of lines of credit to IG-rated corporations (Table 5, Panel B) and Non-IG rated corporations (Table 5, Panel C) originated by BHC *i* in quarter *t.* Standard errors in parentheses are clustered at the quarter level. Both panels show the OLS estimates as well as the IV ones.

A possible concern with OLS estimates is (again) that of endogeneity. Banks that need more central bank reserves, for example, due to an increase in liquidity risk, may also cut back on new credit lines to reduce risk. This can result in a negative correlation, or dampen the otherwise positive correlation, between reserves and credit lines. Indeed, the OLS estimates reported in Panels B.1 and C.1 suggest that an increase in reserves is often associated with a *decrease* in the amount of credit lines that are originated, though the coefficients are not uniformly statistically significant.

The IV estimates reported in Panels B.2 and C.2 correct for endogeneity. They indicate that during the overall and QE periods, an exogenous 10% increase in a bank's reserve growth leads to an *increase* in the origination of lines of credit to investment-grade firms by about 2.23 percent and non-investment-grade firms by 2.28 percent for the overall period.

For both types of firms, the coefficient estimate on reserves is not statistically significant only for the post QE III/QT period, and indeed has a negative sign for IG firms.[18] It may well be, however, that the first stage is simply not well-identified for the post QE III/QT period at BHC level (which shrinks the cross-section appreciably), rendering difficult any statistical inference in the second stage.

4.6. Implications

Overall, that reserves-recipient BHCs expand outstanding credit lines during QE (Table 5) is consistent with their preference for taking on liquidity risk, as seen also in the bank-level increase of uninsured demandable deposits (Table 3) and decrease of deposit maturity (Table 4). The evidence on off balance sheet liabilities growing during QE also assuages concerns that these effects of QE on liquidity risk-taking by the banking sector (Tables 3 and 4) are simply due to some mechanical balance sheet effect. While the absence of precise coefficient estimates for the post QE III/QT period suggest that banks simply do not reverse their claims, our reserve instruments in this period are not always strong (Tables 4 and 5). We now examine bank balance sheets more closely to understand what might be going on.

5. Financial Fragility in Moving from QE to QT.

QE is not simply an expansion of reserves, taking the nature of claims on liquidity on the banking sector as static. Were it so, any increase in central bank balance sheet size by injecting reserves would always enhance financial stability. In contrast, the liquidity dependence view (see Acharya and Rajan (2024)) suggests that banks write new liquidity claims when the central bank issues reserves that it does not intend to withdraw quickly. Furthermore, banks don't not always shrink these claims commensurately when the central bank switches from expanding to shrinking its balance sheet (as for example, in 2017-19), creating an aggregate liquidity mismatch.[19]

[18] In a related finding, Carletti et al. (2021) exploit a tax change in Italy that induced households to switch from bank bonds to deposits and find that banks experiencing a greater inflow of retail deposits expand the supply of credit lines and term loans to low-risk credits.

[19] The increase in demand for reserves is described in a Federal Reserve survey of senior loan officers in November 2022: "*the majority of respondents from domestic banks reported that their bank's lowest comfortable level of reserves (LCLOR) had increased [since the end of 2019]…; most of the group reported the change being an increase by more than 20 percent…A large majority of respondents reported that their bank always preferred to hold additional reserves above their bank's LCLOR*." (see Senior Financial Officer Survey Results, November 2022, Board of Governors of the Federal Reserve System, p 2).

We now examine these developments across banks more carefully. In an episode of aggregate liquidity shortage, bank specific vulnerabilities will get accentuated and therefore it is important to understand where the liquidity mismatches are the largest. Our analysis here should be thought of as illustrative of vulnerabilities built up across bank characteristics during central bank balance sheet expansions and contractions, rather than an exhaustive or causal analysis.

5.1. Ratcheting-up of liquidity risk at some banks

5.1.1. Growth in uninsured demandable deposits and its variation by bank size

Banks of different sizes are regulated differently. As noted by Yankov (2020), liquidity coverage ratio (LCR) regulations were applied rigorously to large banks with size above $250 billion in assets, moderately to mid-size banks between $50 billion and $250 billion in assets, and mildly to small banks below $ 50 billion in assets.[20] These partitions were known ahead of time, and the regulation implemented in a phased manner during 2014 to 2017. Partitioning banks according to asset size in 2014Q3, we plot value-weighted ratios, i.e., they are the aggregate of the numerator across banks in a partition, divided by the aggregate of the denominator.

Figure 3, Panel A shows that uninsured demandable deposits to bank assets follows an upward trend during 2008Q4-2021Q4, from 16.5% to 39.2% for the largest banks, 14.1% to 35.8% for mid-size banks, and 10.2% to 33.8% for the small banks. The largest proportional increase in uninsured demandable deposits seems to take place for the small banks, the ones not subject to the LCR regulations. Importantly, the ratio was stable for the largest banks, rose for the smallest banks, and fell for the medium sized banks during the Post-QE + QT period of 2014-19. It did fall for all banks during the pandemic-QT in 2022-23 as policy rates were also raised sharply (culminating with bank runs or sharp deposit outflows starting in 2023Q1). Perhaps more accentuated is the ratio of uninsured demand deposits to bank reserves (see Online Appendix Figure A1 Panel A), which really explodes for the smallest banks during 2014-2019, and again around the initiation of QT in 2022. The differential behavior across banks in how claims on liquidity and reserves respond to declines in aggregate reserves in Post-QE/QT periods may explain why the reserves instrument is weak over these periods.

[20] LCR regulation imposes a minimum requirement on the amount of unencumbered high-quality liquid assets (HQLA) that would allow banks to service a supervisory 30-day liquidity stress scenario. In particular, HQLA should exceed 30-day net outflow under the stress scenario, in its most stringent implementation.

Even if commercial banks find issuing liquidity claims worthwhile, why do they not shrink their issuance of claims on liquidity whenever the central bank withdraws reserves from the system (as in 2014-2019)? One possibility is that banks feel confident in their access to liquidity because they substitute lost reserves during QT with bonds that are eligible collateral for repo transactions. Eligible securities are, of course, not cash, though they may give holders the illusion of ready access to reserves. In a dash for cash, everyone will want to borrow reserves, and few will want to lend them, exacerbating demand relative to supply. So substituting reserves with eligible securities does not eliminate exposure to liquidity stress, and may indeed exacerbate it if banks become overconfident about their access to reserves.

In Figure 3 Panel B we calculate a bank's ratio of uninsured demandable deposits to its potential liquidity, the latter being measured as its reserves plus eligible assets, where eligible assets are those that qualify as collateral for borrowing reserves from the Fed (at any time during our sample period). Such collateral is also commonly posted and accepted for repo market transactions. Uninsured demandable deposits relative to potential liquidity fell during 2008Q4-2021Q4 from a multiple of 1.29 to 1.15 for the largest banks, and marginally rose from 0.97 to 0.98 for mid-size banks; for the small banks, however, it rose from 0.68 to 1.45. So there is important cross-size variation in the ratcheting-up of liquidity risk in the banking sector. By 2021, small banks, which traditionally used to hold more insured deposits and liquid assets, seem to have swapped position with the largest banks in being the most exposed to unbacked uninsured deposits (especially so given their limited access to wholesale funding and public bond and equity markets). As a side note, Silicon Valley Bank was a small bank by our measure till 2019.[21]

Pandemic QT, when rates also moved up rapidly, is particularly interesting. Initially, from 2022Q1 to 2022Q4, the uninsured demandable deposit multiple rose for the largest, the mid-size, and the small banks to 1.34, 1.09 and 1.7, respectively. But with the onset of banking stress in the first quarter of 2023, and the rapid movement in deposits, the ratio fell to 1.09, 0.88 and 1.34 in 2023Q4, respectively, a particularly substantial fall for the small banks.

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[21] Ruan and Vij (2024), focusing on a 2018 regulatory cap on the size of Wells Fargo bank, document that it led to a growth of uninsured deposits at smaller, less regulated banks, especially during the COVID-19 aftermath. Subsequently, these banks faced deposit outflows around the SVB stress in 2023. Their finding is consistent with facts we document, though the relative rise of uninsured demandable deposits at small banks is seen in data even pre-2018 (and especially so relative to their potential liquidity).

5.1.2. Claims to potential liquidity: a composite measure of liquidity risk

Recognizing credit lines are also claims on liquidity, we compute *Claims to Potential Liquidity* as the ratio of uninsured demandable deposits and outstanding credit lines to reserves plus eligible assets.[22] Note that since the field for Off Balance Sheet Unused Credit Lines (RCFDJ457) only appears 2010Q1 onwards, our analysis of the Claims to Liquidity Ratio starts in 2010Q1. In Figure 4, Panel A shows that for the aggregate commercial banking balance sheet, claims to potential liquidity had come down to 1.6 by the end of QE III, rose again to peak at 1.9 around the liquidity stresses of September 2019 and the end of pre-pandemic QT, falling again to 1.5 during pandemic-QE, but then rising again to 1.8 by the time of banking stress of 2023 (and falling thereafter), reflecting well its movement in tandem with the waxing and waning of Fed balance sheet.

Figure 4 Panel B mirrors Figure 3 Panel B in showing the cross-section of the ratcheting-up of this measure of liquidity exposure from 2010Q1 to 2023Q1, emphasizing that it is most pronounced again for the small banks.[23] We will see that the rise in outstanding credit lines, a component of this measure, is an important vulnerability during the dash for cash at the time of COVID outbreak.

Finally, Figure 4 Panel C shows how the distribution of Claims to Potential Liquidity evolves, with a density plot separately for QE I-III, post QE III, and QT (2017Q4-2019Q3) periods, in each case bunching all values greater than or equal to 6 as a single point of mass at 6. It is clear that Claims to Potential Liquidity ends up in September 2019 (end of pre-pandemic QT) with a significantly fatter right tail at values greater than or equal to 6. In other words, by September 2019, in addition to the system having a larger ratio of Claims to Potential Liquidity, there was an increase in dispersion among banks in such Claims.

As aggregate reserves started shrinking during QT, reserve-deficient banks were now effectively reliant on repo markets to obtain reserves from surplus banks by pledging eligible

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[22] There are other bank liabilities and assets that could also be considered. For instance, funds borrowed from the Federal Reserve plus other funds borrowed (e.g., from Federal Home Loan Banks) could also signal fragility that has been addressed by official backstops rather than privately; subordinated debt borrowings could matter if there is a nexus of solvency and liquidity issues; finally, Federal funds sold and reverse repos could also be sources of potential liquidity for banks given their short-term nature. Results that follow are robust to including these in alternate definitions of *claims to potential liquidity* (see Online Appendix Figure A1 and Table A13).

[23] Interestingly, uninsured demandable deposits drive most of the variation in the ratio for small banks. In size-weighted terms, these deposits at small banks grew by 2022Q1 to more than 300% of their 2010Q1 level, while their holdings of eligible assets (Treasury and Agency securities) grew by less than 200% over the same period.

assets, failing which they had to go to the Fed. As Acharya and Rajan (2024) explain, such interdependence can render the system fragile and illiquid. Treasury repo rates could spike up if surplus banks hoard liquidity, and with the overall system being tight, there may have been incentive for them to do so.[24] Similarly, the onset of the pandemic might not have caused the dash for cash on corporate credit lines in March 2020 if the system had not already seen a significant tightening of reserves relative to demandable claims on liquidity.

5.2. Liquidity risk seeking as a form of search for yield by banks

Why do banks seek liquidity risk? Meiselman, Nagel and Purnanandam (2023) show that banks with high accounting returns on equity (ROE) had higher systematic tail risk during the Global Financial Crisis (GFC). They show ROE has strong predictive power for materialization of such tail risk both during the 2007-09 global financial crisis as well as the 2023 banking sector stress. Since bank top management has high-powered incentives to generate ROE, this may also incentivize them to reach for yield by taking liquidity risks in normal times, that is, reduce funding costs with uninsured demandable deposits and generate higher fee premia by writing credit commitments, in return for a small probability of a really bad outcome when massive drawdowns are realized (see, for example, Rajan (2006)). The post-GFC regulations such as more stringent capital requirements (e.g., stress tests) and the LCR requirement were meant to curb this kind of risk-taking, but these regulations apply more to large banks than small banks, and supervision post GFC has also been uneven except for the very large banks, as suggested by Barr (2023).

Figure 5 relates the log of bank Return On Equity (ROE, measured as Income before Tax divided by Total Book Equity) to the log of *Claims to Potential Liquidity*, at quarterly frequency over the period 2010Q1 to 2021Q4, controlling for bank and time fixed effects, and separately for mid-size and small banks (left plots) and large banks (right plots).[25] Given the time-series evolution in ratcheting-up of liquidity risk (as seen in Figures 3 and 4), Panel A shows the bin-scatter for QE I-III period of 2010Q1 to 2014Q3, Panel B for the post QE-III and QT period of 2014Q4 to 2019Q3, and Panel C shows it for the pandemic QE period of 2019Q4 to 2021Q4.

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[24] Such hoarding might be an attempt to signal their "fortress" balance sheet with high reserves, a consequence of regulatory requirements to hold liquidity (Copeland, Duffie and Yang (2021), D'Avernas and Vandeweyer (2021)), or the fear of supervisory stigma from having to access the Fed for intra-day reserves (Nelson (2019, 2022)).

[25] Conclusions we draw are all robust to examining the relationship between bank ROE and claims to potential liquidity, i.e., without taking logs (see Online Appendix Figure A2).

The left plots show that while liquidity risk is positively and significantly associated with ROE for mid-size and small banks across all three periods, the economic magnitude of the relationship is small, with a unit increase in *Claims to Potential Liquidity* being associated with an increase in bank ROE by around 1-6 basis points. In contrast, the right plots show that liquidity risk is not statistically significantly associated with ROE for large banks during two of three periods (perhaps due to lack of statistical power from there being only eight banks in this sample of banks subject to the most stringent LCR). However, during QE and especially during post QE-III and QT (when the aggregate price of liquidity risk would have risen), the economic magnitude of the relationship is large, and statistically significant in the latter. Conversely, during pandemic QE when the system is flooded with liquidity and the relationship might have attenuated, the coefficient estimate is negative.

The bottom line, therefore, is that for banks below 250 billion in assets (which typically have lower profitability overall), there appear to be gains in accounting profitability from taking on liquidity risk across all QE and QT periods, though gains seem to be small. For large banks, the gains are especially large post-QE and in QT when aggregate liquidity becomes tighter. That leads to the critical question: Does any of this individual liquidity risk taking matter when aggregate liquidity shortages emerge?

5.3. Consequences of ratcheting-up of bank liquidity risk

We investigate two episodes of plausible aggregate liquidity shortage, the COVID-19 outbreak of March 2020 and runs on banks by uninsured depositors in March 2023. We have shown that the individual bank's response (and the aggregate systemic response) to the Fed's QE and QT set up the mismatch between claims on liquidity and available liquidity that would potentially be troubling in case of an aggregate shock. These mismatches were high as we have seen (Figure 4 panel A) just before the onset of the pandemic, and before the bank runs in March 2023, especially for small banks (Figure 4 panel B). We now show that smaller banks with higher liquidity risk exposure suffered greater stock price falls, claim drawdowns, and greater resort to Fed liquidity facilities during these episodes.

5.3.1. COVID-19 outbreak (March 2020)

We first examine bank returns during March 2020, i.e., at the onset of the COVID-19 pandemic, when the financial system experienced intense liquidity stress. Panel A of Figure 6 shows the time-series from Jan 1 to June 30, 2020 of the stock return difference between banks split into those with high and those with low *Claims to Potential Liquidity* ratio (median split) measured as of December 31, 2019. The stock prices of banks with an above-median ratio dropped, on average, 7.5 percentage points more by third week of March 2020 compared to banks with a below-median ratio. The decline is particularly sharp from March 1, 2020 onward, as awareness of the likely impact of the pandemic dawned, and until March 23, 2020, when a series of liquidity interventions by the Federal Reserve Bank stemmed the market decline including of bank stock prices (Acharya, Engle, Jager and Steffen, 2024). While the differential stock return narrows somewhat thereafter, it remained close to –4.0% even at end of June 2020.

To tease out the effects for smaller banks, and for the different components of *Claims to Potential Liquidity* (though the small number of observations makes this analysis only suggestive), we compute the total return on the stock of a BHC minus the cumulative stock market (S&P500). In Table 6 column 1, the dependent variable is this excess return from Jan 1st to Feb 28th. As explanatory variables, we include our measure of liquidity risk exposure, *Claims to Potential Liquidity* (logged to ensure that inference is not driven by extreme outliers) and a set of BHC-level control variables at the end of 2019, consisting of Net Income/Assets, Equity/Assets, Non-Performing Loans to Loans ratio, Loans/Assets and the Primary Dealer Indicator. The coefficient on *Claims to Potential Liquidity*, is positive. Since there were no relevant news surprises over this period, all we take away is there was no pre-trend in stock prices.

In columns (2)-(4), the dependent variable is the cumulative excess return from March 1 2020 to March 23rd 2020, the period when credit line drawdowns increased. The various claims to liquidity, both directly and interacted with bank size indicator (which is one if book assets are below or equal to $250bln in 2019Q4), are the primary explanatory variables of interest. Estimates suggest that during 1st-23rd March 2020, bank returns appear negatively but not significantly correlated with claims (whether overall, credit lines, or deposits), and negatively but again not significantly correlated with the smaller bank size indicator. Returns are, however, economically as well as statistically significantly more negative for smaller banks with credit line exposure (column 3).

With all the caveats associated with a small number of observations, this makes sense. At the outbreak of Covid, liquidity stress came from a drawdown in credit lines, as firms rushed to assure themselves of liquidity before banks tightened conditions for drawdowns. Supportive of this, in Figure 6 panel B, we plot the realized *Gross Drawdowns* (measured as the change in outstanding corporate credit lines for a bank in FDIC Call Reports during Q1 2020 relative to total assets) against the log of *Credit Lines to Potential Liquidity* ratio of banks. The scatter plot as well as the fitted regression line show a clear positive association – banks that had written more credit lines relative to potential liquidity experienced more drawdowns. This must have particularly affected the stock price of small and medium banks that had written them as they would have had to find immediate costly sources of liquidity to meet these demands and because these drawdowns encumbered bank capital (see Acharya, Engle, Jager and Steffen (2024)). Because there were no associated fears of bank insolvency, uninsured demand deposit exposure at these banks was not as much a worry for market participants (column 4), which is perhaps why we find overall liquidity exposure at smaller banks has large negative but noisy effects (column 2).[26]

How about borrowing from the Fed and allied authorities? We plot in Figure 7 Panel A quarterly data on "Other Borrowings" (relative to assets), which include discount window borrowing from the Fed as well as advances from the Federal Home Loan Banks (FHLBs) for the period 2019Q1 to 2023Q1. Panel A shows that Other Borrowings were high following the COVID-19 outbreak in 2020, especially for smaller banks, consistent with discount window borrowings from the Fed, but started declining from 2020Q2 until 2022Q1 when tightening started again. Large banks were uniformly less reliant than small banks on these facilities from 2019 Q3.

We can delve deeper. There usually is stigma associated with discount window borrowing, so banks undertake it only if liquidity stressed. The dependent variable in columns (5)-(7) of Table 6 is an indicator if a bank borrowed from the Fed's discount window during 2020Q1-Q4. The coefficient estimates on all direct measures of claims to potential liquidity are negative, suggesting large banks that write them do not have to approach the discount window because they have other sources of liquidity (e.g., repo borrowing) or offsetting claims on liquidity during stressed times as in Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2007) (e.g., if credit line drawdowns on smaller banks are redeposited with large banks). By contrast, we find that relative to large banks, smaller banks are significantly more likely to approach the discount window, especially if they have written more claims to liquidity. Interestingly, even though there were no

[26] Indeed, as documented by Li, Strahan and Zhang (2020), many (e.g., the highest-rated) firms that drew down credit lines from the largest banks did so for precautionary reasons rather than liquidity needs and simply redeposited credit line drawdowns with their banks, transforming a possibly revocable promise (credit line) to an irrevocable one (deposit).

significant uninsured deposit drawdowns, we find that smaller banks that have uninsured deposit exposure (column (7)) also approached the discount window, perhaps with a precautionary motive.

Because of the early and unprecedentedly large Fed intervention, and perhaps because large banks were better-capitalized and more solvent than during the global financial crisis, the dash for cash did not turn into a full-scale panic. The events of March 2020 remained simply a warning of what could happen. We turn next to the bank runs of March 2023.

5.3.2. Mid-sized bank runs and regional banking stress (March 2023)

Figure 2 Panel B shows a steep, almost vertical, increase in commercial bank reserves and deposits in 2020Q1 with the QE initiated at the onset of the COVID-19 pandemic, while Figure 4 Panel B shows *Claims to Potential Liquidity* ratcheting up till early 2023. Did the pandemic QE and the growth in liquidity exposure set the stage for the banking stress that followed in March 2023?

In March 2023, a mid-size bank, Silicon Valley Bank (SVB) Financial Group, with over $200 billion in assets, became distressed. SVB had gained 140 billion dollars in deposits during the Pandemic QE period of 2019Q4 - 2022Q1, over 90% being uninsured deposits. However, as has been our recurring theme, reserves did not stay where the demandable deposits were. Instead, SVB had invested mostly in a long-dated Treasury portfolio and the rest in loans to tech-sector startups that were also its depositors in a large measure. The pace of its expansion was so rapid that both total assets and deposits more than tripled during the Q1 2020 to Q4 2022 period. When interest rates were raised sharply in 2022-23, long duration asset values fell. The resulting value erosion of SVB's bond portfolio and tech sector losses induced a net outflow of $25 billion of deposits between 2022 Q2-2022Q4. This accelerated to a full-fledged run as large depositors, such as tech-sector venture-capital firms, sensed insolvency. After a significant loss of deposits in March 2023, the bank failed on March 10, 2023 and was put under FDIC receivership. At least 22 banks experienced runs at that time (see Cipriani, Eisenbach, and Kovner (2024)). The runs ended after unprecedented intervention by the Fed, the FDIC, and the Treasury, including a new Fed Bank Term Funding Program (BFTP), lending by the Federal Home Loan Banks, and the invoking of the systemic risk exception to bail out all uninsured depositors in the failed banks. The FDIC incurred losses exceeding $30 billion to date in the process (Gruenberg (2023)).

While some banks were likely insolvent and many poorly supervised, did their outcomes turn out to be emblematic of small- and medium-sized banks in general, especially given the ratcheting up of liquidity risk at small banks seen in Figures 3 and 4? Table 7 answers this question econometrically, also employing bank-level control variables in the cross-sectional regressions. It is especially important in this period to separate liquidity risk effects from potential concerns of solvency. Hence, we verify that the results are robust to controlling for each bank's mark-to-market losses using balance sheets and the methodology of Jiang et al. (2023) to compute losses, allowing for the effect of losses to vary by bank size groups (Online Appendix Table A11 Panel B).

In column 1, the dependent variable is the bank's pre event excess return (over the period Jan 3-Feb 28 2023). As we can see from the positive but economically small coefficient estimate on *Claims to Potential Liquidity*, there is no pre-trend. Columns (2)-(4) examine excess stock returns of banks over the period 1st March to 13th March 2023, which represents the peak period of bank runs on small and mid-sized banks, with a range of dependent variables that allow for the effect of liquidity risk (and its components) to be size-dependent. Coefficient estimates suggest once again there is indeed a divergence between large banks and smaller ones. In particular, interacting claims to potential liquidity with an indicator if the bank's 2022Q4 asset size is below $250 billion shows that the adverse stock market effects are relatively much larger for mid-size and small banks relative to similar large banks. Importantly, it is uninsured deposits to potential liquidity (and also claims to potential liquidity, of which it is the major component) which drive the effect. In particular, if we vary the claims to potential liquidity ratio from the 25th to the 75th percentile of its distribution, the adverse stock market return implied by the coefficient estimates is 2.78 p.p. lower for small and mid-size banks relative to that for similarly exposed large banks**.** Interestingly, because the concerns in March 2023 were centered around the solvency of banks stemming from illiquidity, not around corporate needs to drawdown credit lines, credit lines outstanding seem to play less of a role.[27]

Turning to quarterly change in uninsured demandable deposits in Columns (5)-(7), higher exposure to liquidity risk does result in drawdowns of deposits from 2022Q1 to 2023Q1, especially at smaller banks. The magnitude of the effect is particularly pronounced for banks that have high uninsured deposits to potential liquidity exposure. For large banks, the change is positive, consistent with a flight-to-quality of uninsured deposits to the largest banks (see, for instance, Caglio, Dlugosz, and Rezende (2023)). While the latter may in part be due to their too-big-to-fail

[27] In Online Appendix Table A11 Panel A we exclude delisting returns of the failed banks (Signature Bank and Silicon Valley Banks) and also run a cross-section with Change in Ln(Uninsured Demandable Deposits) and Change in Ln(Other Borrowed Money) over 2022Q4-2023Q1. Results are robust to these changes.

status, we showed earlier in Figure 4 that these banks, on average, brought down their *Claims to Potential Liquidity* substantially since 2008Q3, perhaps because of more binding LCR requirements, besides being better-capitalized than the rest because of their systemic status.

Finally, a significant consequence of all this was again the liquidity dependence of smaller banks on the Fed. Returning to Figure 7 Panel A, we see that Other Borrowed Money sky-rocketed for small and medium banks, growing steadily as the Fed started tightening in March 2022. In contrast, their borrowing in the private market, as evidenced by Fed Funds Borrowed in Figure 7 Panel B, stayed low during the crisis. Private borrowing by large banks increased significantly in 2023q1, suggesting they continued to be able to access private markets. Comparing the magnitudes across the panels, while large banks had approximately equal reliance on public and private funds during 2023Q1, for small (mid-size) banks the reliance on public funds was about eight (seven) times that on private funds. This suggests that the Fed and Home Loan Banks, not private markets, emerged as the marginal source of liquidity for small and mid-size banks, confirming their liquidity dependence.

The estimates in Table 7 Columns (8)-(10) highlight this liquidity dependence of smaller banks on the authorities (unfortunately, details of discount window borrowing will be released only with a two-year lag). The (log) quarterly change in Other Borrowings from 2022Q1 to 2023Q1 is significantly greater for smaller banks with greater (log) claims to potential liquidity. Once again, these data suggests that unlike at the time of COVID outbreak, this dependence is driven by banks with uninsured demandable deposits exposure (column 10) and less so by those with outstanding credit lines (column 9).

In sum then, our analysis of where liquidity exposures build up in the system, and then how they play out in the face of aggregate liquidity shocks in March 2020 and March 2023, suggest liquidity exposure is not entirely benign. At the very least, it suggests a dependence on Fed liquidity support. Of course, we do not have compelling explanations about why liquidity risk exposure builds up in parts of the banking system other than the lack of regulation coupled with the agency incentive to search for yield. There could also be organizational behavior explanations. For instance, if units are set up by banks to write lines of credit, it may be hard for them to withdraw committed lines, or disband units, when reserves shrink. The need to maintain corporate relationships may be a related reason why banks may be reluctant to cut back on liquidity claims. Silicon Valley Bank, for instance, maintained uninsured transaction deposit accounts for tech companies (see, for example, Chang, Cheng and Hong (2023)). Until the shortage of aggregate liquidity makes itself felt through disruptions, individual banks may not realize, or have an incentive to ignore, a tightening of aggregate conditions. Such behavior may be especially pronounced and rational if banks believe the Fed will always come to the rescue. Indeed, since the Fed has repeatedly come to the rescue and reaffirmed the liquidity put, it is hard to assess the counterfactual.

6. Discussion: Other Explanations and Policy Implications.

6.1. Other Explanations

A possible explanation of our finding that banks expand their balance sheets at the same time as the Fed does is that it is not causal. Instead, as Lopez-Salido and Vissing-Jorgensen (2022) argue, the value of household assets increased during QE, and the rise in deposits could be a natural consequence if the households maintained a constant deposit to asset ratio. The fact that uninsured demand deposits expand disproportionately with reserves during QE (see Figure 2 Panel B), and uninsured deposits are typically not held by households suggests this cannot be the entire story.[28] It is also not clear why, if banks passively accommodated deposit flows, they would push time deposit rates lower (as we have documented) or issue credit lines when flush with reserves.

6.2. Policy Implications

Turning to policy, clearly a primary function of a central bank is to provide emergency temporary liquidity support to maintain financial stability. Indeed, the shortage of reserves relative to claims can never be a problem if the Federal Reserve can lend reserves at short notice to the degree desired to all who desire it, and have eligible collateral to borrow.[29]

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[28] A more direct way to test our explanation is to re-estimate Table 1 Panel A controlling for the change in household financial assets. However, since household financial assets also contain deposits, which is the dependent variable, we include the change in household financial assets minus deposits (or insured deposits, which are typically held by households) to rule out a mechanical correlation in the time-series, and to capture the effect of household financial assets alone. Formally, if $D_t = \alpha \text{Reserves}_t + \gamma(HA_t^{OtherThanDeposits} + D_t) + \varepsilon_t$ is the true model, then we can recover γ by estimating $D_t = \frac{\alpha}{1-\gamma}\text{Reserves}_t + \frac{\gamma}{1-\gamma}HA_t^{OtherThanDeposits} + \pi_t$. We find in Online Appendix Table A4 that the coefficient on household assets less deposits is not statistically significant, while the coefficient estimate on reserves increases.

[29] The costs of repeated emergency liquidity infusion include distortions in the price of liquidity, windfall gains to those who have access to central bank-provided liquidity or who can game or time central bank liquidity intervention, and distortions in private sector credit and investment when the private sector knows the central bank will be available whenever liquidity bets go sour. See Acharya, Shin and Yorulmazer (2011), Diamond and Rajan (2012), or Farhi and Tirole (2012) on the theoretical modeling of such collective moral hazards.

Our concern is that Fed balance-sheet expansion followed by contraction can create a large and persistent mismatch. The problem then is not just temporary intra-day demand-supply mismatches for reserves (which undoubtedly will increase) but that the entire banking system will have a higher stock of claims on potential liquidity issued by banks – that is, the aggregate bank balance sheet is more levered with demandable claims and fewer supporting reserves. By raising the risk of dash-for-cash episodes, including the possibility the Fed may intervene too little, too late, and not reach the right places, the persistent mismatch may serve as an overhang to activity (see Acharya and Rajan (2024)). Unless all participants are confident of repeated, adequate, and timely Fed intervention, seemingly the best way for the Fed to eliminate the overhang of liquidity risk is through a durable infusion of additional reserves into the market, that is, a central bank balance sheet expansion. But such an intervention then raises the specter of further liquidity dependence, our key concern, as commercial banks issue further claims on liquidity in response.

In other words, unless Fed's balance sheet expansion is quickly and predictably reversed, commercial bank responses will demand a bigger central bank balance sheet for longer. However, temporary intervention may not alleviate concerns unless banks dial down liquidity mismatches. The Fed may be trapped into accommodating liquidity dependence of banks. There are other consequences; if the central bank is forced to resume QE in a time of above-target inflation, it may send confusing signals to the market. Fresh QE may also foster irresponsible fiscal policy if government finances are already strained, as seems currently the case in industrial economies.

Our findings have implications for monetary policy. By buying long-term bonds from the market using reserves, the Federal Reserve expects to compress the yield on long-term financing, thereby facilitating the financing of long-term projects (also known as "portfolio rebalancing"). However, we find that banks have been shortening the maturity of their liabilities over the period of QE, making it harder for them to finance long-term loans without incurring costly asset/liability maturity mismatches. In other words, the maturity-shortening effect of QE on the bank's liability side may limit any maturity-lengthening effects of QE on the bank asset side, dampening the effectiveness of the portfolio-rebalancing channel (see Greenlaw et al., 2018, and Fabo et al., 2021 for more questions on the effectiveness of QE).[30]

[30] We show in Online Appendix Table A12 that an exogenous increase in bank's reserves affects its loan growth adversely, echoing the findings of Diamond, Jiang and Ma (2021), who document a restraining effect of quantitative easing on non-reserve assets of banks, and of Altavilla, Rostagno and Schumacher (2023), who find that only the non-borrowed portion of reserves (i.e., reserves not funded with deposits) is positively related to bank loans.

7. Further Research and Conclusion.

Our work suggests that stress may build when the elasticity of liquidity claims to reserves is much higher during QE than QT, leaving large liquidity mismatches – our Claims to Liquidity can be a useful measure both in the aggregate and in subsets of banks of impending aggregate tightness. However, large changes in monetary policy interest rates can also have an independent effect on deposit (and reserve) withdrawals from banks. And, of course, depositor panics may have to be offset by Fed-cum-Treasury solvency and liquidity interventions. Arguably, we have seen all this since the pandemic QT started in 2022. After the mini-panic of March 2023, subsequent QT seems to have eaten into money market reserve holdings rather than bank reserve holdings, perhaps because of generous Fed lender of last resort support to banks. Our primary insight that we need to incorporate private bank behavior to understand the financial stability implications of the waxing and waning of central bank balance sheet size will likely hold up.

Policy measures should also ensure the flow of liquidity between banks to mitigate liquidity stress when it materializes. In particular, supervisors should be particularly wary of ratcheting up implicit liquidity requirements (see Nelson (2019, 2022)) as the fear of such supervisory action in response to a bank's intra-day overdrafts can accentuate the phenomenon of reserve hoarding by surplus banks (Bank of England (2022), Copeland, Duffie, and Yang (2021)).

Finally, our evidence is based entirely around the balance-sheet decisions of the Federal Reserve. What about other systems? In recent work, Angeloni et al. (2024) document that the positive relation of banking sector reserves to uninsured demandable deposits that we documented for the US holds up also for the Eurozone countries. Using available data from balance-sheets of stress-tested and systemically important banks since 2010, they also show that in the Eurozone too, "small" banks (based on below median assets on average over the sample period 2010-23) grew their transactions deposits faster than the "large" banks (above median assets). Large banks also reduced their transaction deposits more once reserves decreased. Are drivers of these patterns in Europe similar to those we documented for the US banks, and what compensating regulations have allowed European banks to fare better during the recent period of rate hike and QT? Du, Forbes and Luzzetti (2024) finds only a modest impact of QT in seven advanced economies on overnight funding spreads though, as we argue, the US banking turmoil of March 2023 was in part a consequence of QT. Once the dust has settled, more data will be available to help us understand all this. More research is clearly warranted.

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Figure 1. Quantitative Easing, Quantitative Tightening, and Commercial Bank Balance Sheets

The figure below shows how the Federal Reserve's balance sheet expansion during quantitative easing (QE) affects commercial bank balance sheets.

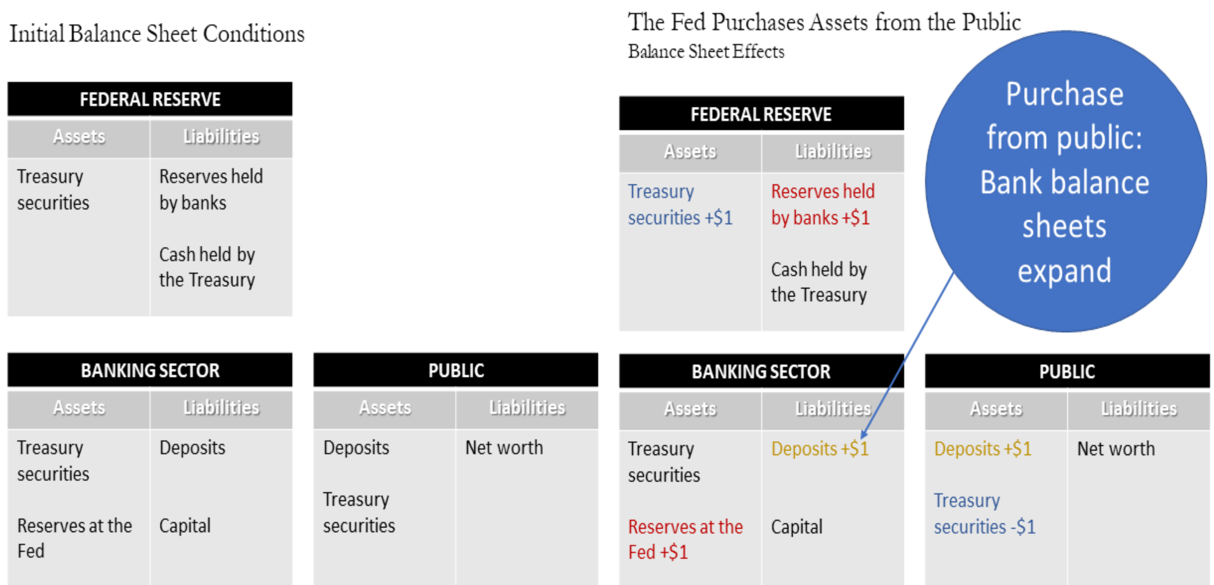
Panel A: QE – Purchase from Banks

Panel A shows the Fed purchasing securities from banks, with banks effectively swapping eligible securities for reserves. In this case, commercial bank balance sheets do not expand with the expansion of the Fed balance sheet.

Source: "How the Fed Changes the Size of its Balance Sheet" (Leonard, Martin and Potter, *Liberty Street Economics,* 2017)

Panel B: QE – Purchase from Non-banks/public

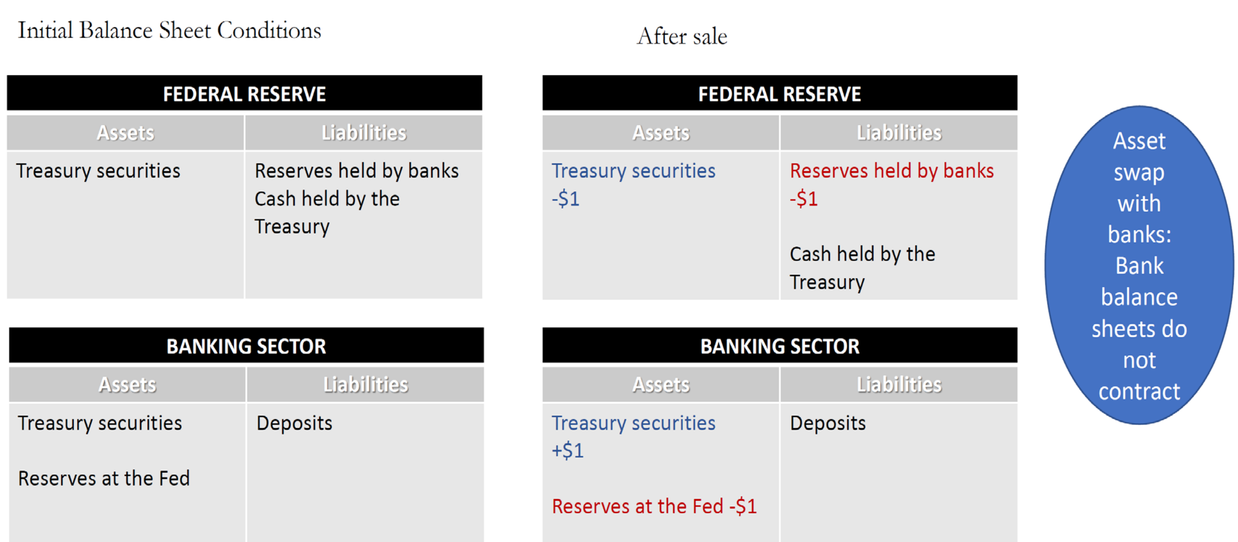
Panel B shows the Fed purchasing eligible securities directly from non-banks/public. In this case, commercial bank balance sheets expand with the expansion of the Fed balance sheet as the non-banks deposit the Fed payment in the bank.



Source: "How the Fed Changes the Size of its Balance Sheet" (Leonard, Martin and Potter, *Liberty Street Economics*, 2017)

Panel C: QT – Asset Sale to Banks, No Contraction in Bank Balance Sheets

Panel C shows the asset swap with banks during quantitative tightening (QT). As Fed balance sheet shrinks, commercial bank deposits do not shrink in this case.



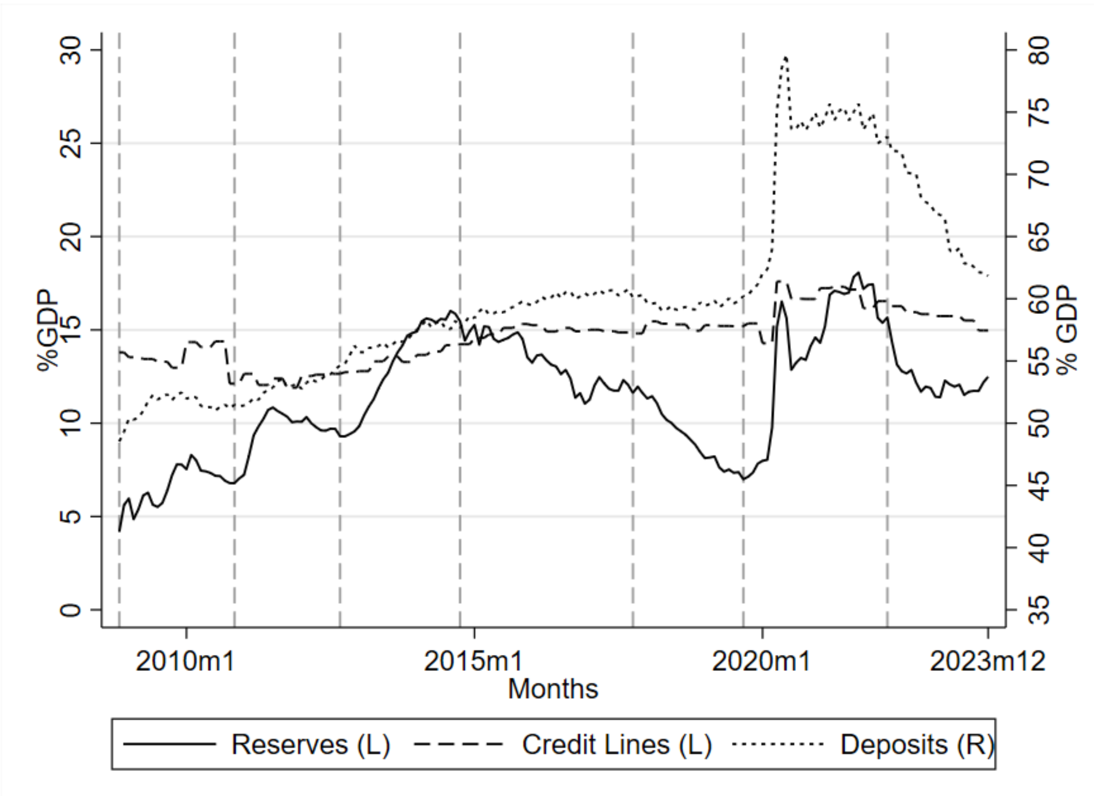
Source: "How the Fed Changes the Size of its Balance Sheet" (Leonard, Martin and Potter, *Liberty Street Economics*, 2017)

Figure 2. Time-Series of Aggregate Reserves, Deposits, and Credit Lines

The panels plot credit lines (left y-axis), deposits (right y-axis) and reserves (left y-axis) as a percentage of gross domestic product (GDP) for all commercial banks using data from the Federal Reserve's Financial Accounts of the United States (Flow of Funds).

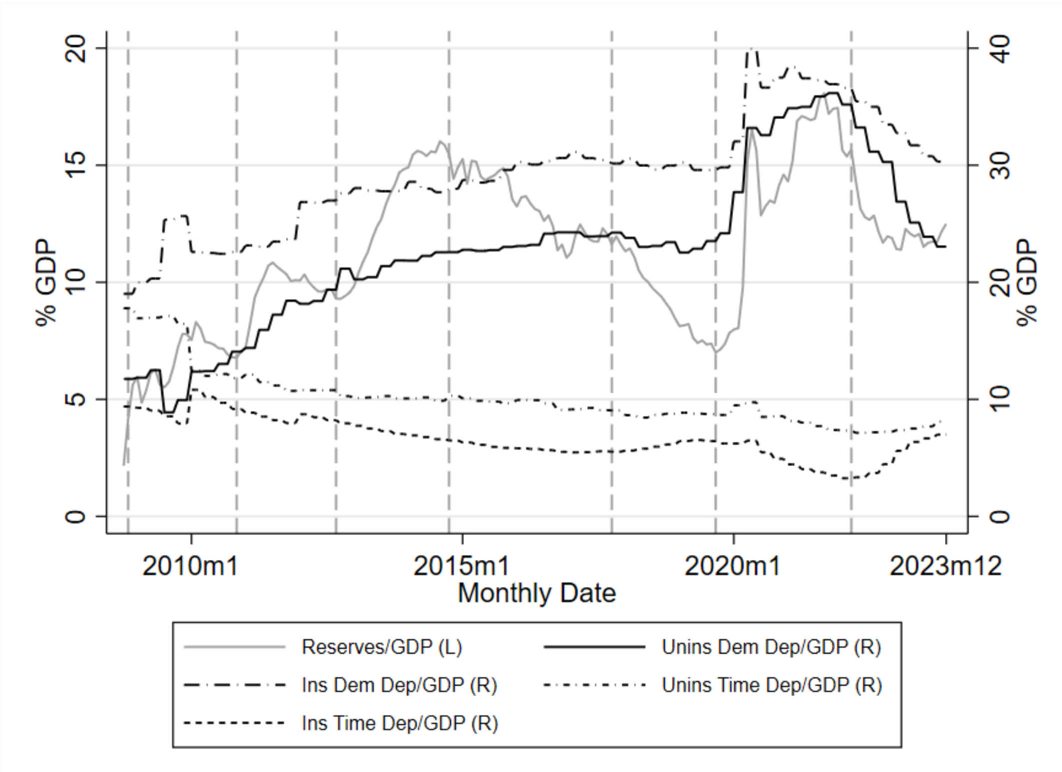
Panel A. Credit Lines, Deposits, and Reserves as percentage of GDP

The vertical lines correspond to the beginning of the different Federal Reserve QE / QT phases: (1) Nov 2008 (QE I), (2) Nov 2010 (QE II), (3) Nov 2012 (QE III), (4) Oct 2014 (Post QE III), (5) QT period, (6) Sept 2019 (Pandemic QE) (7) March 2022 (Pandemic QT).



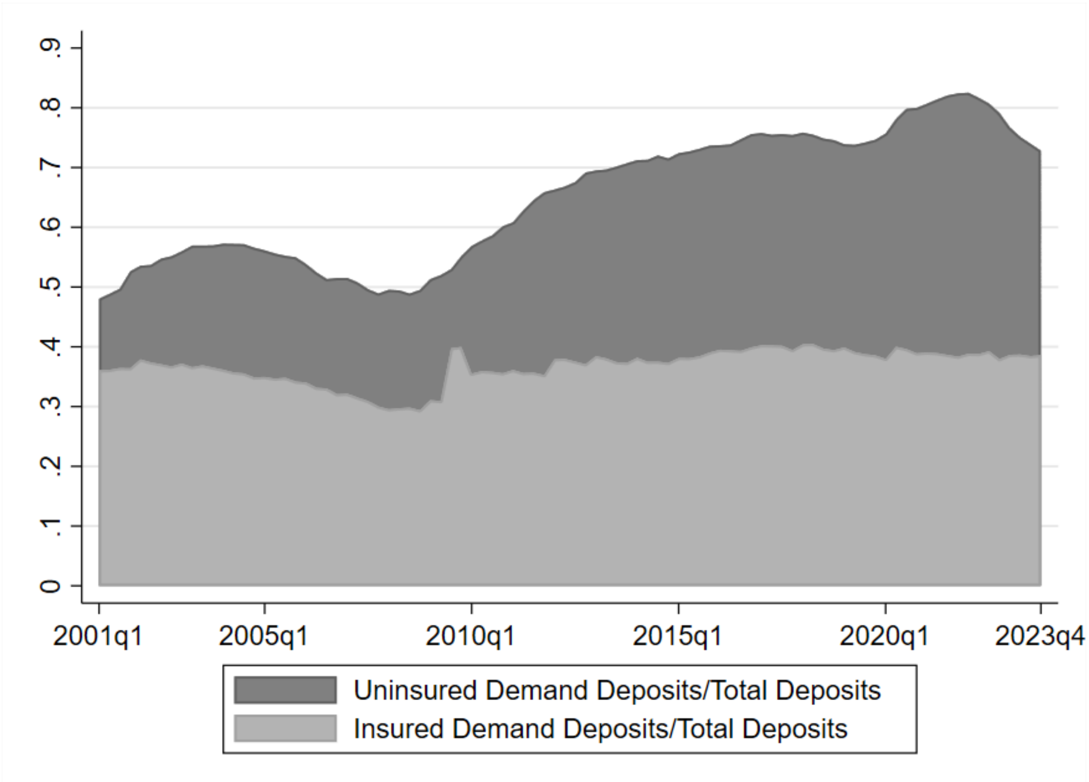
Panel B. Uninsured and Insured Demand and Time Deposits, and Reserves as percentage of GDP

We plot demandable (demand, savings, and money market deposits) and time deposits partitioned into insured and uninsured deposits using FDIC's Call Reports Data for the period 2008Q4-2023Q4. Computation of Insured and Uninsured Domestic Deposits are based on call report schedule RC-O. Insured domestic deposits are defined as deposits lying below the FDIC deposit insurance thresholds of $100,000 before 2006Q1, non-retirement accounts below $100,000 and retirement accounts below $250,000 between 2006Q1-2009Q2 and $250,000 after 2009Q2. Split of time deposits into Insured vs. Uninsured Deposits are based on the aforementioned deposit insurance thresholds ($100k before 2010Q1 and $250k thereafter) in schedule RC-E. Demandable Domestic Insured and Uninsured deposits are estimated by taking the difference between Total Domestic Insured/Uninsured Deposits and Domestic Insured/Uninsured Time Deposits respectively. Uninsured demandable deposits are domestic uninsured demand deposits plus non-interest-bearing foreign deposits. Uninsured time deposits are domestic uninsured time deposits plus interest-bearing foreign deposits.



Panel C: Share of Uninsured and Insured Demandable Deposits to Total Deposits

We plot the share of Domestic Uninsured Demandable Deposits and Domestic Insured Demandable Deposits to total domestic deposits estimated using US Call Reports annually for the time period 2001-2023. Foreign deposits are excluded from this chart.



Panel D: Ratio of Deposits to Household Financial Assets

We plot the ratio of aggregate US household deposits to household financial assets (series BOGZ1FL194090005Q) from Flow of Funds for the period Oct 1987-Dec 2023.

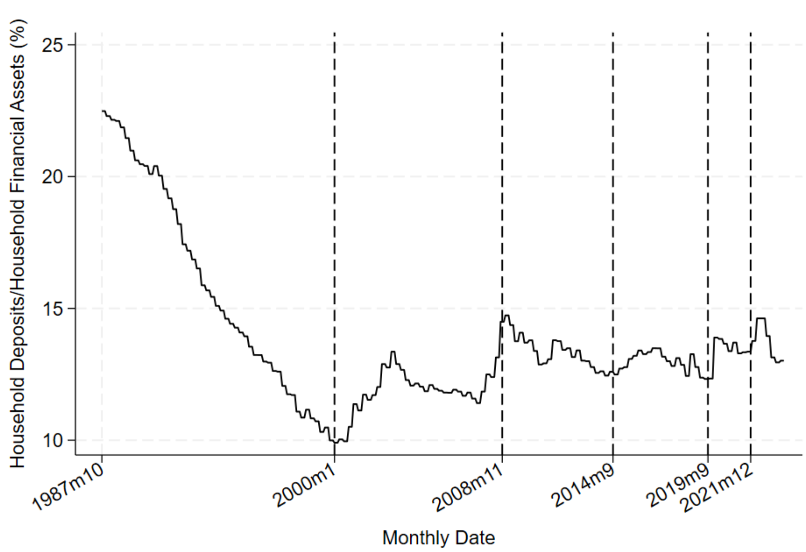
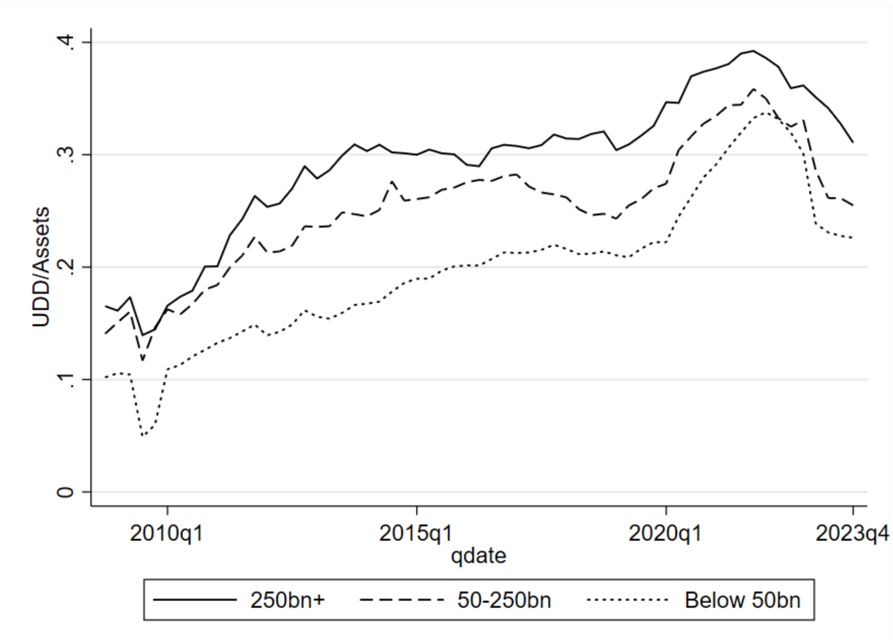


Figure 3: The Rise in Uninsured Demandable Deposits

Panel A: Uninsured Demandable Deposits/Assets

We plot the ratio of aggregate uninsured demandable deposits to aggregate book assets of banks that fall within the size buckets of (i) Bank Assets above $250bn (ii) Bank Assets between $50-250bn and (iii) Bank Assets below $50bn, with Bank Assets measured in 2014Q3. Uninsured demandable deposits are defined as the difference between Total Uninsured Deposits and Uninsured Time Deposits plus Non-interest Bearing Foreign Deposits. Bank Assets refer to Total Book Assets. Bank Reserves refer to balances due at Federal Reserve Banks. Eligible assets consist of Treasury and Agency securities that were eligible for swap against reserves in at least one Quantitative Easing round between 2008Q4-2021Q4. The sample ranges 2008Q4 to 2023Q4. All data is sourced from FDIC's Call Reports.



Panel B: Uninsured Demandable Deposits/(Reserves + Eligible Assets)

Panel B plots the ratio of aggregate uninsured demandable deposits to the aggregate sum of bank reserves and eligible assets of banks within the aforementioned size buckets.

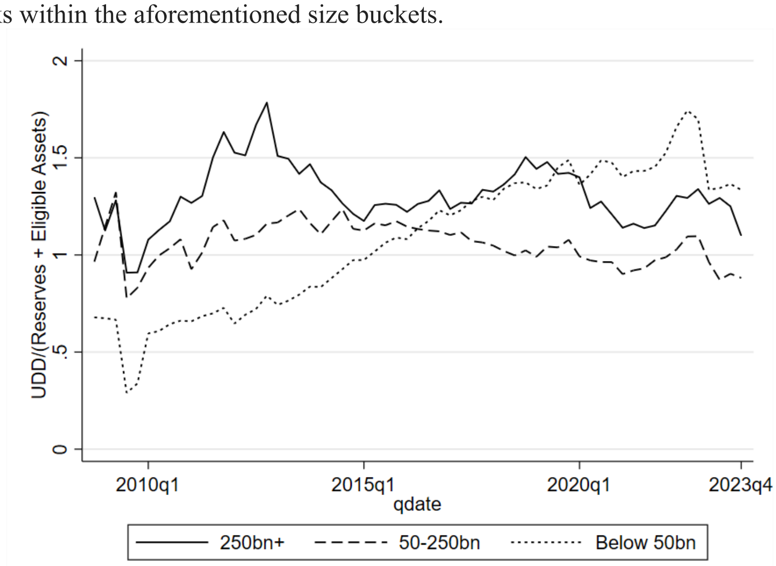
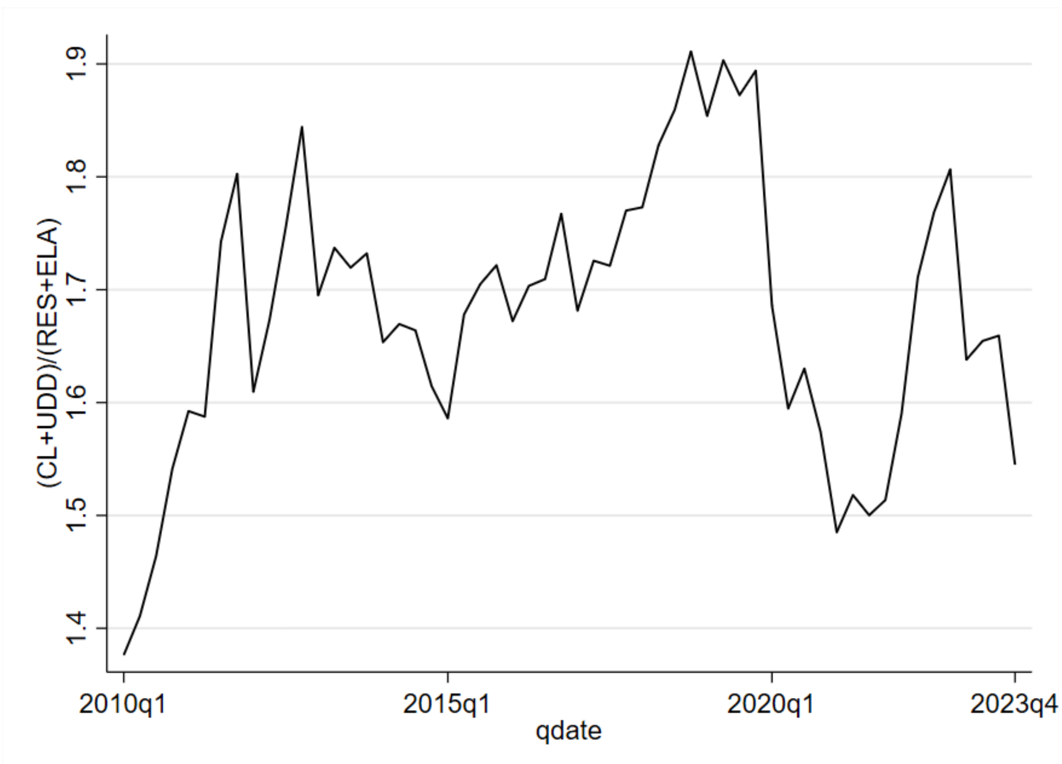


Figure 4. Claims toPotential Liquidity: (Credit Lines + Uninsured Demandable Deposits)/(Reserves + Eligible Assets)

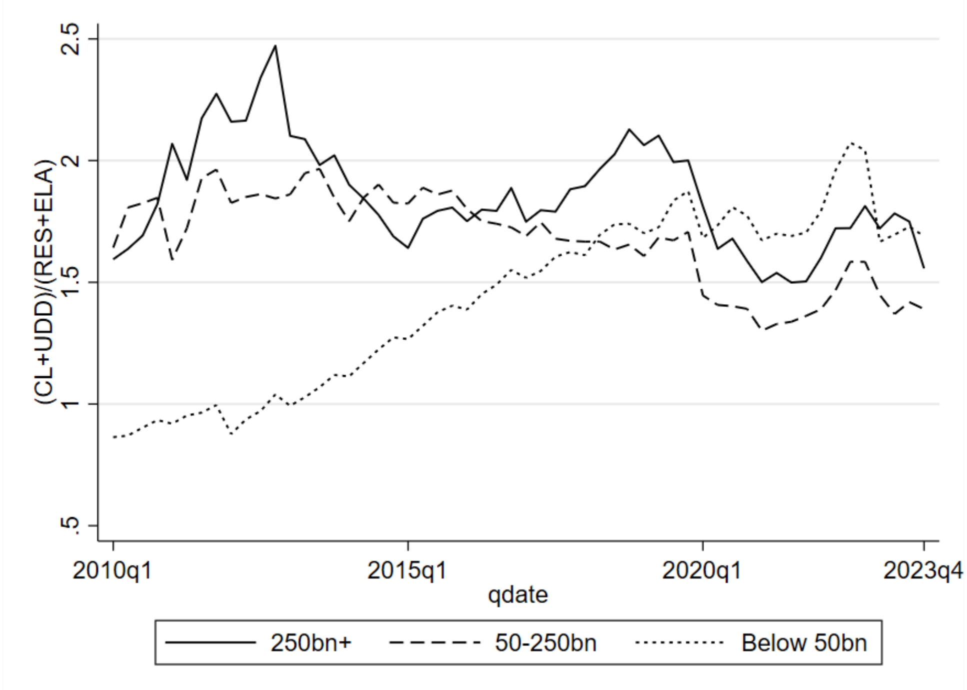
We plot the time-series of *Claims to Potential Liquidity,* which is the ratio of the sum of aggregate undrawn credit lines and uninsured demandable deposits to the sum of reserves and eligible assets between 2010Q1-2023Q4, with data (field) obtained for each component from Call Reports: Off-balance sheet unused loans or credit lines (RCFDJ457); Uninsured demandable deposits, obtained by subtracting time deposits of more than $250,000 ($100,000 before 2010Q1) from total uninsured deposits, the latter being estimated from schedule RC-O of Call Reports, to which we add non-interest bearing foreign deposits. Reserves are from RCFD0090 (RCON0090 if missing), and Eligible assets consist of Treasury and Agency securities that were eligible for swap with the Fed for reserves in at least one quantitative easing round between 2008Q4-2023Q1. We set the value of reserves and credit lines to zero for a given quarter if they are missing. All data are from FDIC's Call Reports.

Panel A: Claims to Potential Liquidity for the aggregate banking sector



Panel B: Claims to Potential Liquidity by bank size categories

We plot Claims to Potential Liquidity aggregated within bank size categories of (i) Bank Assets above $250bn (ii) Bank Assets between $50-250 bn, and (iii) Bank Assets below $50bn, banks classified by assets as of 2014Q3.



Panel C: Density of Claims to Potential Liquidity, for different QE and QT periods

Panel C plots the density of distribution of the ratio in different QE and QT periods. QEI-III refers to the period 2010Q1-2014Q3, Post QE-III period refers to 2014Q4-2017Q3, and QT period refers to 2017Q4-2019Q3.

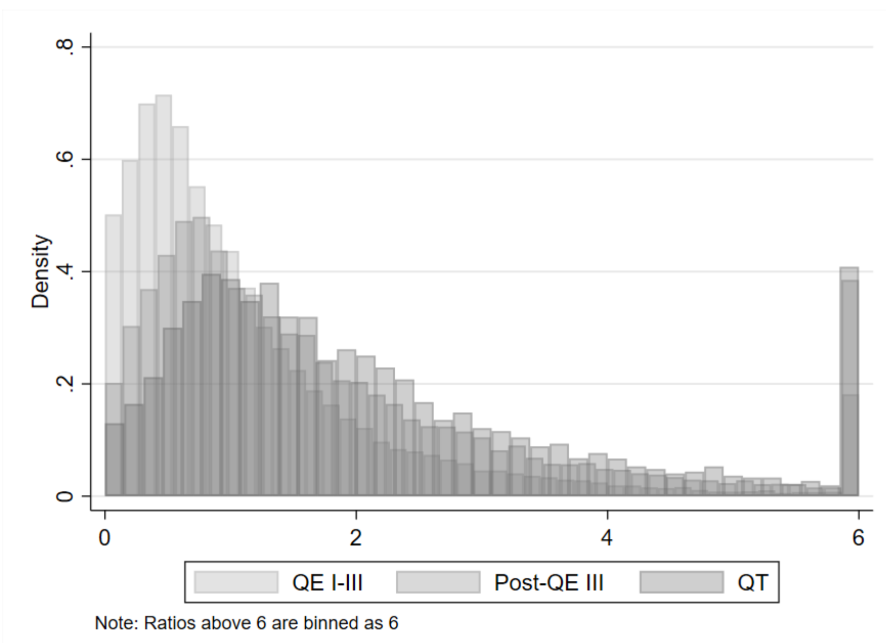


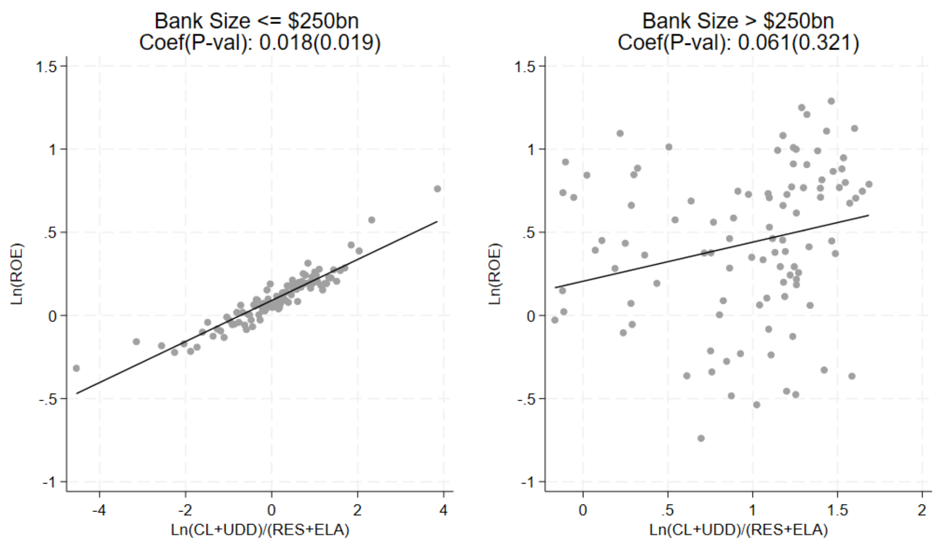
Figure 5. Return on Equity and Claims to Potential Liquidity Ratio by Bank Size

The panels are bin-scatter plots of log of bank Return on Equity (ROE) on the log of Claims to Potential Liquidity ratio for different bank size sub samples. The Claims to Potential Liquidity ratio is defined as the sum of off-balance sheet credit lines and uninsured demandable deposits divided by the sum of reserves and eligible assets (as in Figure 4). We scale the Claims ratio with its Standard Deviation in every sub-sample. ROE is the ratio of Income before Tax to Total Bank Book Equity. Data are sourced from FDIC Call Reports. We control for bank and time fixed effects.

The left plot is for smaller banks i.e. banks with assets less than $250 billion in 2014Q3. The right panel is for large banks with more than $250 billion in assets.

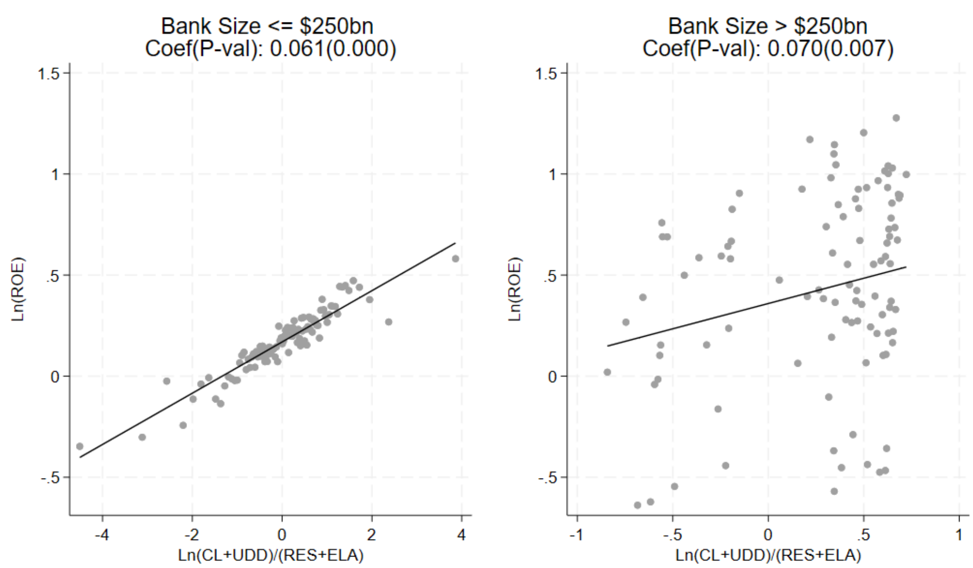
Panel A: QE-I-III

Panel A plots data for 2010Q1-2014Q3 (QE-I-III).



Panel B: Post-QE + QT

Panel B plots data for 2014Q4-2019Q3 (Post QE III + QT).



Panel C: Pandemic QE

Panel C plots data for 2019Q4-2021Q4 (Pandemic QE).

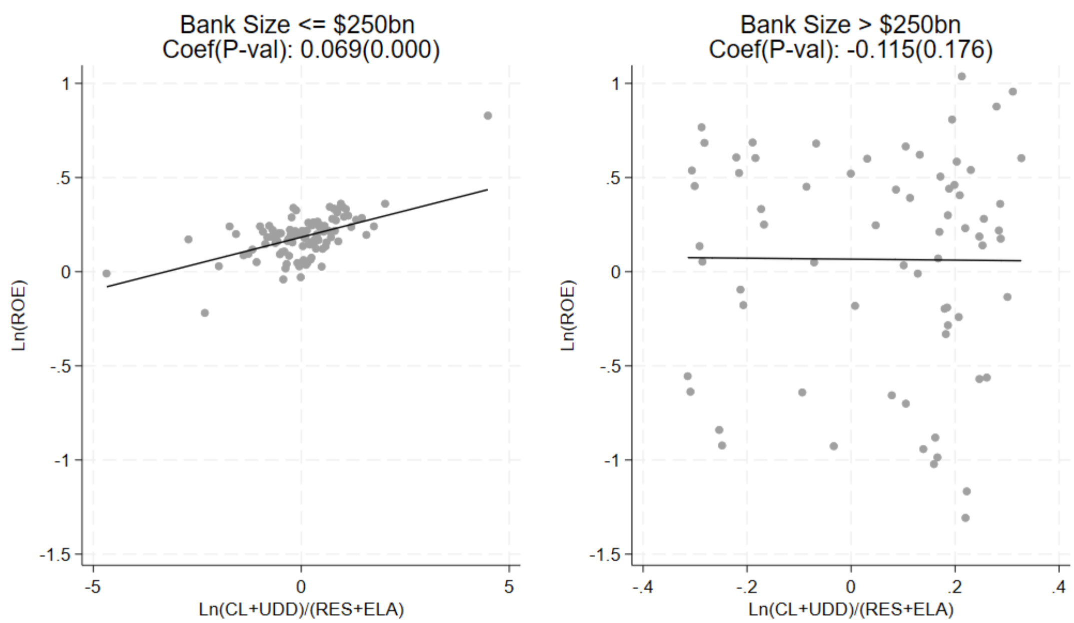
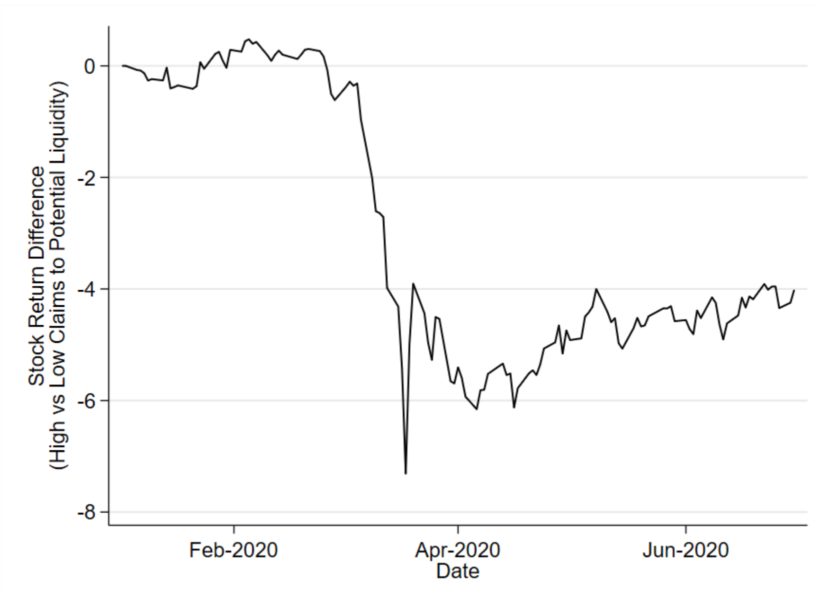


Figure 6. Liquidity Risk and Fragility: The COVID Shock

Panel A. Implications for bank stock returns (1st January to 30th June, 2020)

Panel A shows the difference in stock return performance (in percentage points) between banks with high vs. low *Claims on Potential Liquidity* ratio over the 1st January to 30th June 2020 period. We measure *Claims to Potential Liquidity* ratio as (Undrawn Credit Lines + Uninsured Demandable Deposits)/(Eligible Assets + Reserves) as of December 31, 2019 and use a median split to distinguish between the two groups of banks. Stock returns data are from CRSP.



Panel B. Gross drawdowns of credit lines (Q1 2020)

Panel B plots *Gross Drawdowns* of credit lines to bank assets over the Q1 2020 period against the log *Credit Lines to Potential Liquidity* ratio defined as ln (Undrawn Credit Lines)/(Eligible Assets + Reserves) in 2019Q4. Gross Drawdowns are from Refinitiv LoanConnector.

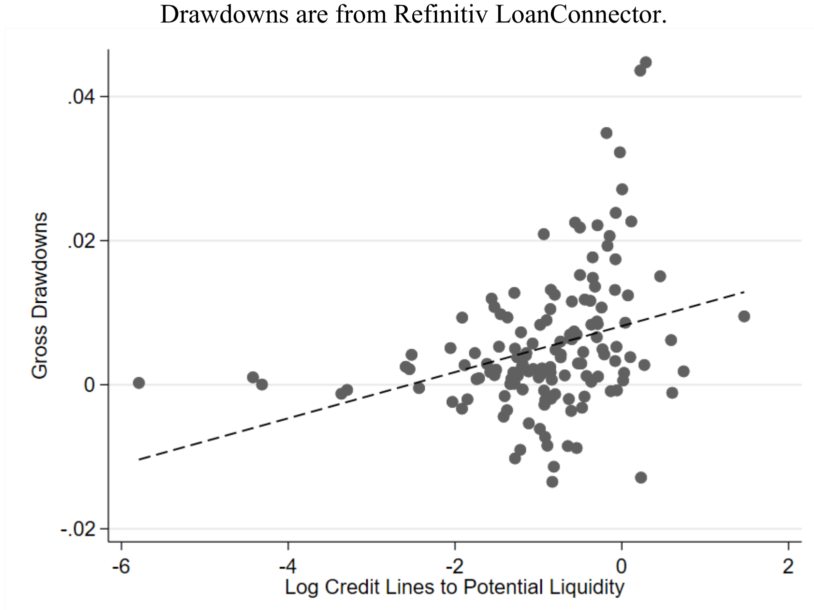
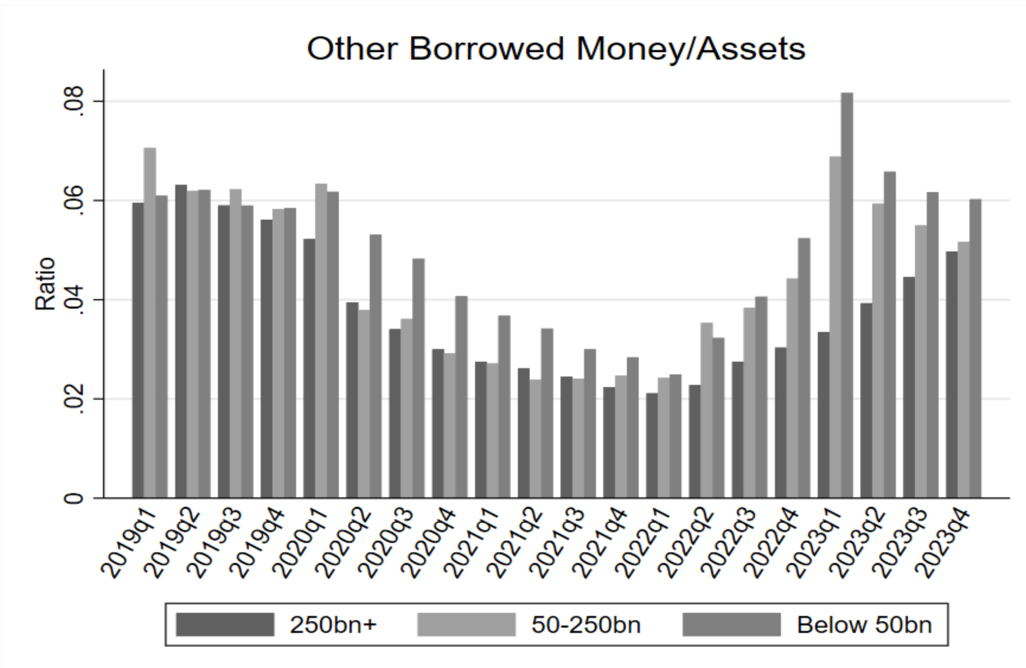


Figure 7: Dependence of Banks on Official Liquidity During 2019 to 2023

Panel A

Panel A plots the bank size-wise bar charts of "Other Borrowed Money" (RCFD3190) deflated by bank assets for the time period 2019Q1-2023Q4. Other Borrowed Money includes Federal Home Loan Bank (FHLB) Advances and borrowings made from the Federal Reserve Bank. The bank-size groups are based on asset size in 2014Q3



Panel B

Panel B plots the bank size-wise summary bar-charts of "Fed Funds Borrowed" (RCONB993+RCFDB995) deflated by Assets in 2019Q4. Fed Funds Borrowed include inter-bank secured (including repo) and unsecured transactions.

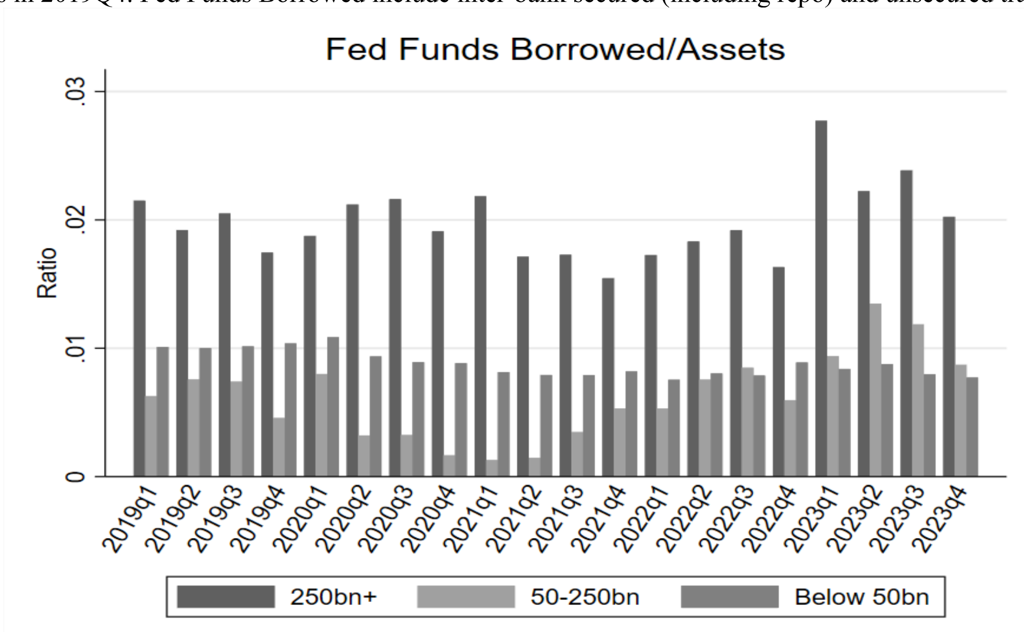


Table 1. Aggregate Deposits and Credit Lines vs Reserves (Time-Series)

This table reports the results from time-series regression of changes in deposits or credit lines on changes in reserves. The variables in Columns (1) to (4) are changes in the natural logarithm of total deposits (1), demand deposits (2), time deposits (3) and credit lines (4) as dependent variables. Columns (5) to (8) uses changes in the levels of the same variables. All data are from the Federal Reserve Economic Database (FRED). Standard errors (Newey-West) account for auto-correlation up to 4 quarters and are reported in parentheses. The sample ranges from 2008Q4-2021Q4. * p<0.1, ** p<0.05, *** p<0.01

	(1) ΔLn(Deposits)	(2) ΔLn(Demandable Deposits)	(3) ΔLn(Time Deposits)	(4) ΔLn(Credit Lines)	(5) Δ Deposits	(6) ΔDemandable Deposits	(7) ΔTime Deposits	(8) ΔCredit Lines
ΔLn(Reserves)	0.143***	0.191***	-0.362***	0.0815**				
	(0.0384)	(0.0563)	(0.105)	(0.0309)				
$Ln(Reserves)_{t-4}$	0.0490***	0.0110	-0.00475	0.0889***				
	(0.0140)	(0.0220)	(0.0792)	(0.0329)				
ΔReserves					1.011***	1.376***	-0.277***	0.149***
					(0.250)	(0.327)	(0.0627)	(0.0414)
$Reserves_{t-4}$					0.328***	0.342***	0.0795	0.147***
					(0.0724)	(0.0836)	(0.0693)	(0.0403)
Constant	-0.318***	-0.00782	0.0370	-0.621**	-90.77	-17.77	-168.2	-164.5*
	(0.106)	(0.166)	(0.606)	(0.254)	(178.1)	(160.7)	(158.5)	(91.83)
N	49	49	49	49	49	49	49	49
R-Sq	0.63	0.63	0.57	0.23	0.67	0.69	0.59	0.42
S.E.(# Lags)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)

Table 2. Aggregate Uninsured and Insured Deposits vs Reserves (Time-Series)

We report the results from time-series regression of changes in deposits of different types on changes in reserves. Computation of Insured and Uninsured Domestic Deposits are based on the FDIC Call Report schedule RC-O. Insured deposits are defined as deposits lying below the FDIC deposit insurance thresholds of $100,000 before 2006Q1, non-retirement accounts below $100,000 and retirement accounts below $250,000 between 2006Q1-2009Q2, and $250,000 after 2009Q2. Split of Time Deposits into Insured vs. Uninsured Deposits are based on the aforementioned deposit insurance thresholds ($100k before 2010Q1 and $250k thereafter) in schedule RC-E. Demandable Insured and Uninsured Domestic Deposits are estimated by taking the difference between Total Insured/Uninsured Domestic Deposits and Insured/Uninsured Time Deposits respectively. Uninsured demandable deposits are obtained by adding non-interest-bearing foreign deposits to uninsured domestic demand deposits. Uninsured time deposits are obtained by adding interest-bearing foreign deposits to uninsured domestic time deposits. Columns (1) to (4) use changes in the natural logarithm of uninsured deposits (1), insured deposits (2), uninsured demandable (3) and insured demandable deposit (4) as dependent variables. Columns (5) to (8) uses changes in the level of the same variables. Standard errors (Newey-West) account for auto-correlation up to 4 quarters and are reported in parentheses. The sample ranges from 2008Q4-2021Q4. * p<0.1, ** p<0.05, *** p<0.01

	(1) ΔLn(Uninsured Deposits)	(2) ΔLn(Insured Deposits)	(3) ΔLn(Uninsured Demandable Deposits)	(4) ΔLn(Insured Demandable Deposits)	(5) ΔUninsured Deposits	(6) ΔInsured Deposits	(7) ΔUninsured Demandable Deposits	(8) ΔInsured Demandable Deposits
ΔLn(Reserves)	0.174***	0.0490	0.163*	0.140**				
	(0.0482)	(0.0514)	(0.0908)	(0.0631)				
$Ln(Reserves)_{t-4}$	0.0921	-0.0188	-0.0399	-0.00274				
	(0.0630)	(0.0330)	(0.0943)	(0.0445)				
ΔReserves					0.728***	0.263	0.740***	0.479***
					(0.148)	(0.158)	(0.161)	(0.160)
$Reserves_{t-4}$					0.268*	0.00354	0.128	0.0809
					(0.141)	(0.0894)	(0.0999)	(0.0859)
Constant	-0.640	0.198	0.410	0.0870	-221.3	346.7	96.05	174.9
	(0.484)	(0.256)	(0.724)	(0.346)	(329.1)	(217.6)	(225.2)	(207.4)
N	49	49	49	49	49	49	49	49
R-sq	0.28	0.12	0.20	0.27	0.55	0.19	0.59	0.42
S.E.(# Lags)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)	Newey-West (4)

Table 3: Effect of Reserves on Deposit Quantities – First Stage, OLS and Second Stage
The table shows the first stage, the OLS and the second-stage of 2SLS IV regressions of Δ*Ln(Deposits)* (the dependent variable) against Δ*Ln(Reserves).* Deposit and reserve data are sourced from FDIC's Call Reports. *Reserves* are cash and balances due from Federal Reserve Banks at the consolidated bank-level (RCFD0090). We supplement the *Reserves* variable with the field at depository institution level (RCON0090) if the former field is missing. Panel A shows the first-stage of Δ*Ln(Reserves)* instrumented by reserve instrument (z^{R1}_{it}): *Growth in Aggregate Reserves in quarter t × Lagged Share in Reserves, averaged over previous 4 quarters.*

All specifications control for Time-FE, lagged Ln(assets), Equity-Capital Ratio, Net Income/Assets, indicator for Primary Dealers and Ln(Reserves) lagged by five quarters. Columns (1) represent the regressions on the overall sample ranging 2008 Q4 – 2021 Q4. Columns (2) represent QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Columns (3) represent the QEI-III period: 2008Q4 - 2014Q3. Columns (4) show results for the Post QE III and QT period 2014Q4 - 2019Q3. Standard errors are two-way clustered at the bank and time level. Newey-West SE adjusted for autocorrelation up to 4 quarters are also reported for OLS. Stock & Yogo (S&Y) weak ID test critical values with 10% maximal IV size for the first-stage are reported below the F-stats. * p<0.1, ** p<0.05, *** p<0.01

Panel A: First Stage

	(1)	(2)	(3)	(4)
	ΔLn(Reserves)			
Ln(Reserves_t/Reserves_t-1) × Lagged Share in Agg. Reserves over 4Q	13.14***	12.54***	12.67***	25.87**
	(0.722)	(0.594)	(0.606)	(12.30)
N	81892	51062	43236	30830
Kleibergen-Paap F-stat	1039.24	3341.34	614.27	4.41
F-stat	132358415.9	578625.9	193052.1	28.30
S&Y 10% maximal IV size	16.38	16.38	16.38	16.38
Period	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT
	2008Q4-2021Q4	2008Q4-2014Q3, 2019Q4-2021Q4	2008Q4-2014Q3	2014Q4-2019Q3

Panels B and C: Second Stage

Computation of Insured and Uninsured Domestic Deposits are based on call report schedule RC-O. Insured deposits are defined as deposits lying below the FDIC deposit insurance thresholds of $100,000 before 2006Q1, non-retirement accounts below $100,000 and retirement accounts below $250,000 between 2006Q1-2009Q2, and $250,000 after 2009Q2. Split of Time Deposits into Insured vs. Uninsured Domestic Deposits are based on the aforementioned deposit insurance thresholds ($100k before 2010Q1 and $250k thereafter) in schedule RC-E. Demandable Insured and Uninsured Domestic Deposits are estimated by taking the difference between Total Insured/Uninsured Domestic Deposits and Insured/Uninsured Domestic Time Deposits respectively. Uninsured demandable deposits are obtained by adding non-interest-bearing foreign deposits to uninsured domestic demand deposits. Uninsured time deposits are obtained by adding interest-bearing foreign deposits to uninsured domestic time deposits.

Panel B: ΔLn(Uninsured Demandable Deposits)

	(1)	(2)	(3)	(4)
Panel B.1: OLS				
ΔLn(Reserves)	0.0284***	0.0262***	0.0264***	0.0345***
	(0.00255)	(0.00335)	(0.00381)	(0.00254)
Newey-West s.e.	(0.00177)	(0.00239)	(0.00267)	(0.00205)
N	73882	42556	34923	31326
Panel B.2: IV				
ΔLn(Reserves)	0.205***	0.196***	0.197***	-0.253
	(0.0177)	(0.0148)	(0.0161)	(0.464)
N	72431	42536	34911	29895
Period	Overall 2008Q4-2021Q4	QE I-III + Pandemic QE 2008Q4-2014Q3, 2019Q4-2021Q4	QE I-III 2008Q4-2014Q3	Post QE III + QT 2014Q4-2019Q3

Panel C: ΔLn(Time Deposits)

In Panel C, the dependent variable is Δ*Ln*(*Time Deposits)* or (RCON6648+RCON2604 before 2009Q4) and (RCON6648 + RCONJ473 + RCONJ474 after 2009Q4).

	(1)	(2)	(3)	(4)
Panel C.1: OLS				
ΔLn(Reserves)	0.0137***	0.0133***	0.0130***	0.0160***
	(0.00131)	(0.00174)	(0.00189)	(0.00125)
Newey-West s.e.	(0.00119)	(0.00153)	(0.00162)	(0.00129)
N	82616	50430	42733	31946
Panel C.2: IV				
ΔLn(Reserves)	-0.171***	-0.145***	-0.158***	0.690
	(0.0459)	(0.0441)	(0.0334)	(0.646)
N	81106	50555	42853	32612
Period	Overall 2008Q4-2021Q4	QE I-III + Pandemic QE 2008Q4-2014Q3, 2019Q4-2021Q4	QE I-III 2008Q4-2014Q3	Post QE III + QT 2014Q4-2019Q3

Table 4: Effect of Reserves on CD Spreads: First Stage and Second Stage

The table shows the first stage (Panel A) and the second stage (Panel B) of 2SLS IV regressions of *3, 12, 18 and 24-month CD – Money Market (MM) savings spread* against bank-level *Ln(Reserves).* Panel A shows the first stage of *Ln(Reserves)* and *Ln(Deposits)* instrumented respectively by *Growth in Aggregate Reserves × Lagged Share in Reserves averaged over previous 4 quarters* ($z^{R1}{}_{it}$) and *Deposit Growth Instrument* ($z^{D}{}_{it}$), with bank-level controls. Note Total Deposits contain domestic and foreign deposits at the bank-level. Bank-level variables are sourced from *FDIC's Call Reports* data. *Reserves* are cash and balances due from Federal Reserve Banks at the consolidated bank level (RCFD0090). We supplement the *Reserve* variable with the field at depository institution level (RCON0090) if the former field is missing. All specifications control for lagged Ln(Assets), Equity/Assets Ratio, Net Income/Assets, and Primary Dealer indicator, along bank and time fixed effects. Standard errors are two-way clustered at the bank and time level. Stock & Yogo (S&Y) weak ID test critical values with 10% maximal IV size for the first-stage are reported below the F-stats. The sample period is 2008Q4 – 2021Q4. * p<0.1, ** p<0.05, *** p<0.01

Panel A: First Stage

	(1) Ln(Reserves)	(2) Ln(Reserves)	(3) Ln(Reserves)	(4) Ln(Reserves)	(5) Ln(Total Deposits)	(6) Ln(Total Deposits)	(7) Ln(Total Deposits)	(8) Ln(Total Deposits)
Deposit Growth Instrument	0.0775***	0.0500	0.0782	0.119***	0.0271***	0.0212**	0.0239**	0.0193***
	(0.0262)	(0.0444)	(0.0485)	(0.0254)	(0.00425)	(0.00833)	(0.00932)	(0.00557)
Ln(Reserves_t/Reserves_t-1) # Lagged Share in Agg. Reserves over 4Q	10.90***	10.52***	10.52***	-29.58	-0.0413	0.152	0.438	13.55
	(1.329)	(1.332)	(1.513)	(34.22)	(0.583)	(0.917)	(0.961)	(12.27)
N	81966	51170	43351	30796	122050	51804	43835	32058
Kleibergen-Paap F-stat	1932.7	31.96	58.19	2600.8	107.22	31.96	58.19	36947.7
F-stat	142.46	1173.5	917.3	0.66	11586.1	9547.5	6172.1	0.66
S&Y IV 10% maximal IV size	7.03	7.03	7.03	7.03	7.03	7.03	7.03	7.03
Hansen-J p-val	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Period	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT
	2008Q4-2021Q4	2008Q4-2014Q3 2019Q4-2021Q4	2008Q4-2014Q3	2014Q4-2019Q3	2008Q4-2021Q4	2008Q4-2014Q3 2019Q4-2021Q4	2008Q4-2014Q3	2014Q4-2019Q3

Panels B: Second Stage

	(1) 3 month CD Rate - MM Savings Rate	(2) 12 month CD Rate - MM Savings Rate	(3) 18 month CD Rate - MM Savings Rate	(4) 24 month CD Rate - MM Savings Rate
Panel B.1 - Overall Period: 2008Q4 – 2021Q4				
Ln(Reserves)	-0.177***	-0.0731**	-0.280***	-0.138**
	(0.0452)	(0.0343)	(0.103)	(0.0538)
N	58950	63432	52761	62513
Panel B.2 - QE I-III + Pandemic QE: 2008Q4 – 2014Q3 & 2019Q4 – 2021Q4				
Ln(Reserves)	-0.164***	-0.0558*	-0.228*	-0.114**
	(0.0441)	(0.0278)	(0.112)	(0.0543)
N	37872	40491	33661	39863
Panel B.3 - QE I-III: 2008Q4 – 2014Q3				
Ln(Reserves)	-0.167***	-0.0505	-0.230**	-0.117**
	(0.0375)	(0.0302)	(0.109)	(0.0504)
N	33180	35311	29287	34716
Panel B.4 – Post QE III + QT: 2014Q4-2019Q3				
Ln(Reserves)	0.526	0.0289	-0.240	0.288
	(0.402)	(0.707)	(0.573)	(0.676)
N	21001	22860	19024	22571

Table 5. Effect of Reserves on Credit Line Originations: First Stage and Second Stage

The table shows OLS and the second-stage of 2SLS IV regressions of the change in the amount of originated credit lines Δ*Ln(Credit Lines)* of IG-rated and Non-IG rated firms in the U.S. as the dependent variable against change in reserve holdings aggregated to the BHC level. Change is the contemporaneous level minus the level lagged by 4 quarters. Reserve data is sourced from FDIC's Call Reports, credit line originations from the Refinitiv LoanConnector database. *Reserves* are cash and balances due from Federal Reserve Banks at the consolidated bank-level (RCFD0090). We supplement the *Reserves* variable with the field at depository institution level (RCON0090) if the former field is missing. Columns (1) represent the regressions on the overall sample ranging 2008 Q4 – 2021 Q4. Columns (2) represent QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Columns (3) represent the QEI-III period: 2008Q4 - 2014Q3. Columns (4) show results for the Post QE III and QT period: 2014Q4 - 2019Q3. We report the second stage where Δ*Ln(Reserves)* is instrumented by the BHC-level reserve instrument (z^{R1}_{it}): *Growth in Aggregate Reserves × Average Lagged Share of the BHC in Reserves over the previous 4 quarters.* All specifications control for Time-FE, lagged Ln(assets), Equity-Capital Ratio, Net Income/Assets, indicator for Primary Dealers and Ln(Reserves) lagged by five quarters. Standard errors are clustered at the time level. Stock & Yogo (S&Y) weak ID test critical values with 10% (15%) maximal IV size for the first-stage are reported below the F-stats. * p<0.1, ** p<0.05, *** p<0.01

Panel A: First Stage

Panel A presents the first-stage results for both the IG (A.1) and Non-IG (A.2) sub-samples.

Panel A.1: IG Firms	(1)	(2)	(3)	(4)
	ΔLn(Reserves)			
z^{R1}_{it}	4.676***	4.857***	4.822***	7.055
	(0.979)	(1.080)	(1.177)	(22.82)
N	1189	724	543	465
F-stat	17.82	17.74	16.07	3.887
Kleibergen-Paap F-Stat	12.646	11.999	9.726	0.002
S&Y 10% (15%) Max. IV size	16.38 (8.96)	16.38 (8.96)	16.38 (8.96)	16.38 (8.96)
Panel A.2: Non-IG Firms	(1)	(2)	(3)	(4)
	ΔLn(Reserves)			
z^{R1}_{it}	5.967***	6.197***	6.206***	16.81
	(0.294)	(0.378)	(0.477)	(24.44)
N	1312	792	603	520
F-stat	170.3	196.2	163.3	5.217
Kleibergen-Paap F-Stat	224.762	150.27	86.797	0.496
S&Y 10% (15%) Max. IV size	16.38 (8.96)	16.38 (8.96)	16.38 (8.96)	16.38 (8.96)
Period	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT
	2008 Q4 – 2021 Q4	2008Q4 – 2014Q3 & 2019Q4 – 2021Q4	2008Q4 – 2014Q3	2014Q4-2019Q3

Panels B and C: Second Stage

Panel B: IG-rated firms

Panel B.1: OLS	(1)	(2)	(3)	(4)
		ΔLn(Credit Lines)		
ΔLn(Reserves)	-0.0493**	-0.0484	-0.0290	-0.0442
	(0.0206)	(0.0348)	(0.0370)	(0.0874)
N	1718	649	486	430
Panel B.2: IV	(1)	(2)	(3)	(4)
		ΔLn(Credit Lines)		
ΔLn(Reserves)	0.223***	0.197***	0.192***	-29.44
	(0.0581)	(0.0652)	(0.0552)	(618.8)
N	1079	649	486	430
Period	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT
	2008 Q1 - 2021 Q4	2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	2008Q4 - 2014Q3	2014Q4-2019Q3

Panel C: Non-IG rated firms

Panel C.1: OLS	(1)	(2)	(3)	(4)
		ΔLn(Credit Lines)		
ΔLn(Reserves)	-0.0417	-0.0636*	-0.0606*	0.0450
	(0.0295)	(0.0313)	(0.0344)	(0.0755)
N	1223	731	562	492
Panel C.2: IV	(1)	(2)	(3)	(4)
		ΔLn(Credit Lines)		
ΔLn(Reserves)	0.228**	0.226**	0.237**	1.217
	(0.101)	(0.0991)	(0.0979)	(2.155)
N	1223	731	562	492
Period	Overall	QE I-III + Pandemic QE	QE I-III	Post QE III + QT
	2008 Q1 - 2021 Q4	2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	2008Q4 - 2014Q3	2014Q4-2019Q3

Table 6. Claims to Liquidity and Fragility: March 2020 – COVID Shock

This dependent variables in this table are U.S. *banks' excess stock returns* over the 1/1/2020 – 2/28/2020 period (column 1) and the 3/1/2020 – 3/23/2020 period (columns (2)-(4)) and indicator variables if a bank uses the discount window (DW) over the period 2020Q1-Q4 (columns (5)-(7)). The explanatory variables are the log of *Claims to Potential Liquidity* ratio (=(Off Balance Sheet Unused Credit Lines + Uninsured Demandable Deposits)/(Eligible Assets + Reserves)) as of December 31, 2019, or the log of *Unused Credit Lines to Potential Liquidity* ratio (= (Off Balance Sheet Unused Credit Lines)/(Eligible Assets + Reserves)), or the log of *Uninsured Demandable Deposits to Potential Liquidity* ratio (= (Uninsured Demandable Deposits)/(Eligible Assets + Reserves)). *Excess Return* over a period is measured as cumulative stock return at the BHC level net of S&P 500 return over the same period estimated from CRSP data. Discount Window data is sourced from www.federalreserve.gov/regreform/discount-window.htm. Bank-level data from Call Reports is aggregated to the BHC level using FFIEC relationship table. Bank Reserves refer to balances due at Federal Reserve Banks. Eligible assets consist of Treasury and Agency securities that were eligible for swap with the Fed for reserves in at least one Quantitative Easing round between 2008Q4-2021Q4. Off balance sheet (BS) unused credit lines refers to field RCFDJ457 in Call Reports. We control for equity/assets, the log of total assets, the non-performing loans to loans ratio, loans/assets, primary dealer indicator and net income/assets in 2019Q4. Standard errors are in parentheses. The regressions also include size indicators and interactions of various claims to potential liquidity ratios with the size indicators, which are equal to one if bank assets in 2019Q4 are less than $250bn. * p<0.1, ** p<0.05, *** p<0.01

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pre-Covid Return		Excess Returns			1(DW/Assets)	
	(1/1/2020-2/28/2020)		(3/1/2020-3/23/20)			(2020Q1-Q4)	
Ln(Claims to Potential Liquidity)	0.015***	-0.0342			-0.308**		
	(0.005)	(0.0249)			(0.157)		
1{Bank Assets<=$250bn}		-0.0379	-0.0331	-0.0307	0.263***	0.538***	0.359***
		(0.0322)	(0.0371)	(0.0314)	(0.100)	(0.192)	(0.128)
1{Bank Assets<=$250bn} # Ln(Claims to Potential Liquidity)		0.0181			0.306*		
		(0.0240)			(0.157)		
Ln(Unused Credit Lines to Potential Liquidity)			-0.000740			-0.0986**	
			(0.00715)			(0.0470)	
1{Bank Assets<=$250bn} # Ln(Unused Credit Lines to Potential Liquidity)			-0.0183**			0.0995**	
			(0.00829)			(0.0470)	
Ln(Unins. Dem. Deposits to Potential Liquidity)				-0.0517			-0.406**
				(0.0315)			(0.178)
1{Bank Assets<=$250bn} # Ln(Unins. Dem. Deposits to Potential Liquidity)				0.0371			0.404**
				(0.0309)			(0.179)
N	309	310	304	309	3711	3457	3574
R^2	0.275	0.132	0.165	0.133	0.182	0.183	0.181

Table 7: Claims to Liquidity and Fragility: March 2023 – The SVB Episode

The dependent variables are Excess returns (col (1)- (4)), Change in Ln Uninsured Demandable Deposit (col (5)- (7)) and Change in Ln Other Borrowed Money balances (col(8)-(10)). Explanatory variables include banks' claims to potential liquidity, and additionally, size indicators and interactions of claims to potential liquidity ratios with the size indicators (equal to one if bank assets in 2022Q4 <=$250bn). Excess returns are estimated as the bank's cumulative return over a period net of the S&P 500 return over the indicated period. Columns (5)-(10) use quarterly changes in the dependent variables fort the time-period 2022Q1-2023Q1. Uninsured Demandable Deposits are estimated from schedule RC-O of call reports by subtracting uninsured time deposits from total uninsured deposits and adding non-interest-bearing foreign deposits. Other borrowed money is from Call Reports (RCFD 3190) and includes FHLB advances and other borrowings made by banks for liquidity needs. *Claims to Potential Liquidity* ratio is the (Off Balance Sheet Unused Credit Lines + Uninsured Demandable Deposits)/(Reserves + Eligible Assets). *Unused Credit Lines to Potential Liquidity* ratio is (Off Balance Sheet Credit Lines)/(Reserves + Eligible Assets). *Uninsured Dem. Deposits to Potential Liquidity* ratio is (Uninsured Demandable Deposits)/(Reserves + Eligible Assets). All specifications control for lagged Equity/Assets ratio, the log of total assets, Net Income/Assets, the NPL/Loans-Ratio, Loans/Assets and a Primary Dealer indicator. Columns (5)-(10) control for Time-FE. Standard errors are in parentheses and clustered by BHC. * p<0.1, ** p<0.05, *** p<0.01

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Excess Returns				ΔLn(Uninsured Dem. Deposits)			ΔLn(Other Borrowed Money)		
	01/03-02/28/23	03/01-03/13/23			2022Q1-2023Q1					
Ln(Claims to Potential Liquidity)	0.00961**	0.0392			0.127***			-0.527***		
	(0.00466)	(0.0275)			(0.0436)			(0.178)		
1{Bank Assets <=$250bn}		-0.0892**	-0.134***	-0.0993**	0.000567	-0.0976**	-0.0397	0.0835	0.445***	0.224**
		(0.0427)	(0.0478)	(0.0429)	(0.0426)	(0.0446)	(0.0419)	(0.129)	(0.100)	(0.0940)
1{Bank Assets <=$250bn} # Ln(Claims to Potential Liquidity)		-0.0544*			-0.139***			0.528***		
		(0.0280)			(0.0436)			(0.177)		
Ln(Unused Credit Lines to Potential Liquidity)			0.0103			0.0307***			-0.0656	
			(0.00880)			(0.0100)			(0.0614)	
1{Bank Assets <=$250bn} # Ln(Unused Credit Lines to Potential Liquidity)			-0.00831			-0.0301***			0.0681	
			(0.0100)			(0.00977)			(0.0615)	
Ln(Unins. Dem Deposits to Potential Liquidity)				0.0541**			0.121*			-0.566***
				(0.0274)			(0.0671)			(0.217)
1{Bank Assets <=$250bn} # Ln(Uninss. Dem Deposits to Potential Liquidity)				-0.0709**			-0.137**			0.567***
				(0.0280)			(0.0672)			(0.217)
N	307	306	301	305	13690	13024	13690	7320	7048	7287
R^2	0.130	0.378	0.375	0.381	0.0491	0.0408	0.0512	0.0180	0.0186	0.0181