Liquidity Dependence:

Why Shrinking Central Bank Balance Sheets is an Uphill Task[1]

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Abstract

When the Federal Reserve (Fed) expanded its balance sheet via quantitative easing (QE), commercial banks financed reserve holdings with deposits and reduced their average maturity. They also issued lines of credit to corporations. However, when the Fed halted its balance-sheet expansion in 2014 and even reversed it during quantitative tightening (QT) starting in 2017, there was no commensurate shrinkage of these claims on liquidity. Consequently, the past expansion of the Fed's balance sheet appears to have left the financial sector more sensitive to potential liquidity shocks when the Fed started shrinking its balance sheet, necessitating Fed liquidity provision in September 2019 and again in March 2020. The banks most exposed to liquidity claims suffered the most drawdowns and the largest stock price declines in March 2020. This evidence suggests that the shrinkage of central bank balance sheets must be handled with utmost care as it may involve tradeoffs between monetary policy and financial stability.
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Will the current reduction of the size of central bank balance sheets be an entirely benign process? 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. Yet, when the Federal Reserve embarked the last time around on quantitative tightening (QT), 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 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). The latter episode is attributed to the panic surrounding the COVID-19 outbreak. Notwithstanding the relevance of these proximate causes, we ask whether the prior expansion and then shrinkage of the Fed's balance sheet had left the private financial sector more vulnerable to such disruptions.

Acharya and Rajan (2022) argue that when the central bank expands its balance sheet, commercial banks, which (typically) have to hold the reserves the central bank issues to finance its asset purchases, tend to finance them with demandable deposits.[2] In part, the desire of banks to match the maturity of assets and liabilities moves them to issue such claims. In part, their enhanced holding of reserves gives banks the confidence they can service any enhanced deposit withdrawals. This is especially the case when reserves are in large supply, for example, during quantitative easing (QE). The reserve holdings become a backstop for commercial banks to issue other fee-generating claims on liquidity, such as lines of credit and other off-balance-sheet commitments to provide financing, that are typically not called upon at the same time as deposits (see Kashyap, Rajan, and Stein (2002)).[3] However, in periods of stress when many claims on liquidity are drawn

[2] Some of this is mechanical to start with. If primarily non-banks sell their bonds to the central bank (which is empirically the case), then they deposit their payment in their commercial bank, which now holds reserves and owes wholesale demandable bank deposits to the non-banks (see also Leonard, Martin and Potter (2017)). Without any indirect or multiplier effects via the bank balance-sheets, there is a one for one expansion of the banking sector balance-sheet. What makes it less mechanical is that banks can subsequently alter their capital structure, moving away from these wholesale deposits towards longer-term liabilities. We find they do the opposite.

[3] Implicit in deposit withdrawals or credit line drawdowns being an amplifier during a bank's stress is the notion that reserves used to service these liquidity claims do not recycle back in the same measure to the bank; in other words, that there are "net" withdrawals of reserves on the stressed bank (as documented, for example, by Acharya and Mora (2015) for the global financial crisis, and as modeled by Acharya and Rajan (2022)).

upon, there is far less "spare" liquidity in the system than might be suggested by the increase in bank holdings of reserves.

What does the evidence say? We first document that during the initial period of Fed balance sheet expansion – Quantitative Easing (QE) I from Nov 2008 to June 2010, QE II from November 2010 to June 2011, and QE III from September 2012 to October 2014, as well as during the pandemic QE from March 2020, demand deposits issued and credit lines written by the commercial banks increase, while time deposits decrease. Importantly, bank-written claims on liquidity do not fall significantly when QE ends or when the process of actively shrinking the Fed's balance sheet during quantitative tightening (QT) starts in October 2017; instead, the ratio of demandable claims to reserves increases steeply over these periods. We refer to this phenomenon – whereby the banking system acquires more on- and off-balance-sheet demandable claims during QE that are not simply reversed with QT – as "liquidity dependence", since it necessitates even greater central bank balance sheet support in the future.

Liquidity claims also affect the aggregate pricing of liquidity. We build on the work of Lopez-Salido and Vissing-Jorgensen (2022) by showing that the Effective Fed Funds Rate less the Interest on Excess Reserves, a measure of the price of liquidity, is influenced not just by aggregate reserves and aggregate commercial bank demandable deposits, but also aggregate lines of credit. This reinforces the point that aggregate claims on liquidity need to be accounted for before we can judge how much spare liquidity the system has.

Of course, we need stronger evidence to conclude commercial banks drive this process. For instance, Lopez-Salido and Vissing-Jorgensen (2022) argue that household financial assets grew along with quantitative easing, and the rise in deposits was simply a consequence of household allocations of their increased assets to deposits. However, as mentioned above, QE is associated with a shortening of the maturity of bank deposits. There is also an expansion of uninsured demand deposits of banks (which typically are not held by households). This suggests banks do play an active role. Nevertheless, we turn to the cross-section of banks over time to obtain firmer evidence on the causal impact of reserves on the banking sector's demandable claims. Using instrumental variable analysis, we find that during the periods of QE, banks that exogenously obtain more reserves tend to increase both demand deposits and issue credit lines, while simultaneously shrinking time deposits. Importantly, they do not reliably shrink 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, household financial assets growth, and the level of interest rates, as well as helps control for time-varying bank-level characteristics.

What about bank-level pricing of liquidity? Banks that have a greater need for liquidity would tend to 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 how much higher the spread between term deposit interest rates and savings deposit interest rates are at the bank. We find that during periods of QE, banks with greater (exogenous or instrumented) reserves tend to reduce the term spread, consistent with the spread reflecting their need for liquidity. Interestingly again, we find that these patterns do not reliably persist in the period between when the first sequence of QE ends in October 2014 and when the central bank resumes expanding its balance sheet in September 2019. Put differently, banks that lose reserves do not raise term spreads. We see a similar behavior with a measure of the price of liquidity based on fees for lines of credit.

What might account for this behavior? One possibility is that banks feel confident in their access to liquidity during QT because 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 (because there is stigma associated with borrowing from the Fed at the discount window, and the Standing Repo Facility (SRF) allowing financial institutions to borrow additional reserves from the Fed was not operational before 2021), banks will all be reliant on a diminishing pool of ultimate liquidity, viz. reserves. So, in a situation where every bank wants to transform eligible assets into reserves (a "dash for cash"), there will be too little to satisfy all.

It turns out that the ratio of demandable claims (demand deposits and outstanding credit lines) to "liquid" assets (reserves plus assets eligible for repo with Fed) also increases during QT. Furthermore, the distribution of this ratio 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 QT, and ends up with a significantly fatter right tail. For instance, the ratio for the bank holding company (BHC) at the 90th percentile in early 2010 was at 12 but had reached more than twice the level to over 30 for the 90th percentile BHC in September 2019. This suggests that not only were aggregate liquidity claims rising relative to reserves and eligible assets as the Fed implemented QT, but the dispersion among banks was also increasing. As Acharya and Rajan (2022) explain, this makes the banking system extremely dependent on "surplus reserves" banks, and if these banks hoard liquidity in times of need, the banking system becomes fragile.

In sum, 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 – though Fed studies earlier in that year suggested the banking system had ample reserves, even accounting for unexpected variations such as in the Treasury's Fed account (see Logan (2019)). Our evidence suggests that the shrinkage of aggregate reserves *without a commensurate decline in aggregate claims on liquidity* was the likely deeper cause, or at a minimum it amplified other channels, since it left the system vulnerable and eventually dependent on further liquidity provision by the Fed.

Similarly, the onset of the pandemic may not have caused the *dash for cash* in March 2020 (Kashyap, 2020) if the system had not already seen a significant shrinking of reserves relative to claims on liquidity. Indeed, we find that during the unexpected liquidity shock in March 2020, the higher the prior liquidity claims a bank had issued relative to reserves and eligible assets, the greater the drawdowns it experienced, and the greater its stock price declined. Interestingly, our calculations suggest banks do not on average make significant earnings from issuing claims on liquidity, even though, as we see, the liquidity risk they accumulate can have consequences when the unexpected occurs. It does seem there is an element of "picking up pennies in front of a steamroller" in bank behavior at such times.

Our arguments matter for policy. If claims on liquidity are entirely exogenous to the stock of reserves, then the solution to any liquidity stress is simply to inject and maintain even more reserves. For instance, Copeland, Duffie and Yang (2021) argue that the Fed had reduced reserves significantly below needs in 2019. They recommend a higher sustained level. This is indeed reasonable advice in the short run, but our analysis suggests a higher level of reserves leads to a ratcheting up of bank-issued claims on liquidity. In other words, the supply of reserves creates its own demand for reserves over time, increasing the required size of the Fed's balance sheet.

This is not worrisome if there is no cost to Fed balance sheet expansion. Clearly, a primary function of a central bank is to provide emergency liquidity support of the kind provided most recently by the Bank of England during the pension crisis in October 2022. However, unless this balance sheet expansion is quickly and predictably reversed, commercial bank responses will increase the need for a bigger central bank balance sheet for longer, as well as possibly larger future emergency liquidity infusions if the central bank attempts to shrink its balance sheet. While the costs of emergency liquidity infusion are now well-known[4], there are multiple costs of longer-term central bank balance sheet expansion; first, it makes QT harder as banks become liquidity dependent; second, if the central bank is forced to reverse QT in a time of high inflation, it may send confusing signals to the market; and third, it may foster irresponsible fiscal policy if government finances become more strained, as seems currently the case in industrial economies.

Our findings have implications for monetary policy as well as financial stability. On the monetary policy side, one of the channels through which QE is intended to work is "portfolio rebalancing". Essentially, 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. However, our evidence suggests banks in aggregate do not seem to be taking advantage of the compression in term spreads. Instead, banks have been shortening the maturity of their liabilities over the period of QE (both in the aggregate time-series and the panel of banks), making it harder 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 offset any maturity-lengthening effects of QE on the bank asset side, dampening the effectiveness of the "portfolio rebalancing" channel. This may partly explain why it has been somewhat challenging to identify the real effects of quantitative easing (Greenlaw et al., 2018, and Fabo et al., 2021).[5]

From a financial stability perspective, the obvious takeaway is that QE could incentivize an accumulation of liquidity risk in some banks that QT could exacerbate. Our description of commercial bank behavior could also modulate important theoretical arguments. For instance, Greenwood, Hanson and Stein (2016) suggest that central banks should issue more reserves in order to reduce the "money-ness" of demandable claims. This will induce commercial banks to issue longer-term claims instead of demand deposits, thus reducing banking sector risk. The argument works best if reserves are held by non-banks. However, if they are held by banks, we

[4] The costs of emergency liquidity infusion are 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, as well as 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 hazard.

[5] Indeed, we show in the Online Appendix Table A10 that an exogenous increase in bank's reserves affects its loan growth adversely, echoing the findings of Diamond, Jiang and Ma (2021) who also document a restraining effect of quantitative easing on non-reserve assets of banks.

have seen that commercial banks, in aggregate and individually, not only issue demand deposits to finance reserves, but also shorten the maturity of their deposits in response to an expansion in reserves. Thus reserve issuance may elicit an endogenous bank response that may make the system more, rather than less, prone to liquidity risk.

Overall, since (i) quantitative easing may not have as powerful an effect on economic activity as suggested by theories that ignore the claims on liquidity written by the banking sector, and (ii) central bank balance sheet expansion may be harder to reverse than earlier thought, our work suggests careful reconsideration of the merits of quantitative easing. When policy rates hit the zero lower bound, it may be appropriate to leave it to the fiscal authorities to stimulate activity unless the central bank thinks the costs of a larger balance sheet for longer are small.

The rest of the paper is as follows. Section 2 introduces the data we employ in our aggregate and bank-level analyses. Section 3 presents the aggregate patterns and time-series analysis linking reserves, deposits and their maturity structure, and credit lines, as well as of the pricing of liquidity in the inter-bank reserves market. Sections 4 and 5 then analyze these patterns using bank-level panel data on deposit and credit line amounts, and deposit rates and credit line fees, respectively. Section 6 documents how the distribution across banks of the ratio of demandable claims to liquid assets has evolved over time and relates this to recent episodes of liquidity stress. It also examines how much banks earn from taking on liquidity risk. Section 7 discusses implications for policy and concludes with some directions for future research.

2. Data

We describe below the data sets we employ for our aggregate time-series, as well as for panel tests with a cross-section of banks. Descriptive summary statistics of all primary variables of interest are in the Online Appendix Table A1.

2.1. Time-series

From the Federal Reserve Economic Data (FRED) database, we collect 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).[6] We

[6] 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 reserves it holds as "aggregate reserves".

also obtain the effective federal fund rate (EFFR), interest on excess reserves (IOR), and U.S. Gross Domestic Product (GDP) from FRED. Wherever possible, we use monthly data, else quarterly data (for credit lines). The time-series data span the 2009 to 2021 period.

2.2. Panel with Cross-section of Banks

Bank-level deposits: We use FDIC's Summary of Deposits – Branch Office Deposits data to obtain branch-level deposit values, Call Reports of the FDIC for bank balance sheet data for the time period 2001Q1-2021Q4, including bank-level reserves (defined as cash and balances due from Federal Reserve Banks). We use the FFIEC's Relationships table to link the bank to the Bank Holding Company for each bank in the Call Reports data. While the analysis of bank reserves, deposits and deposit rates is at the depository level in the panel tests, the analysis of credit lines and their fees is at the bank holding company level. We obtain deposit rate data from S&P Global's *RateWatch* deposits database with the sample period 2001Q1-2022Q2. *RateWatch* provides 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.

Bank-level credit lines issuance and fees: 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, *i.e.*, the credit line amount, the commitment fee for the undrawn credit line, as well as the credit spread over LIBOR for each dollar drawn. LoanConnector also includes the company credit rating at line origination. To obtain lender information, we use the Schwert (2020) link-file to map lenders in LoanConnector to the ultimate parent level (extending the file to the 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 bank holding companies (BHC).

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

3.1. Descriptive evidence

In Figure 1, we plot reserves, deposits, and undrawn credit lines aggregated over all commercial banks using data from the Federal Reserve's Flow of Funds for the 2008 to 2021 period. In Panel

A, we plot them as percentages of GDP. The vertical lines correspond to the beginning of the different Federal Reserve Quantitative Easing (QE) / Quantitative Tightening (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 (Quantitative Tightening or active balance sheet reduction), and (6) Sept 2019 (Repo-market "spike" and liquidity infusion, followed by Pandemic-induced QE starting March 2020, which for simplicity we collectively refer to as "Pandemic QE").

[Figure 1]

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 about 50% to 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)). 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 after QE was halted in Oct 2014 and during the first QT period until September 2019, both credit lines, as well as deposits, 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. However, 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.

This descriptive evidence already highlights the asymmetric effect of an expansion vis-à-vis shrinkage of the central bank balance sheet on commercial bank demandable claims. From a financial stability standpoint, it is interesting to ask how large deposits and outstanding credit lines are relative to aggregate reserves with the banking system, essentially what are the ratios of the claims on liquidity to the only asset that can be used for final settlement. In Panel B, we plot credit lines (left y-axis) and deposits (right y-axis) as multiples of central bank reserves. At the beginning of each QE period (QE I-III as well as the pandemic QE), credit lines and deposits drop as a multiple of reserves as the latter expand relatively more during these periods. In contrast, when the Fed started normalizing and shrinking its balance-sheet size after October 2014, both credit lines and deposits more than doubled relative to central bank reserves. Interestingly, right after the end of each of the first two QE periods and until the beginning of the next QE period, credit lines and deposits had started rising relative to reserves. This may be because commercial bank demandable claims react to higher reserves with a lag. However, that the ratios continue increasing for years after QE III ceased, including sharply through QT when the Fed shrank reserves, suggests this cannot just be lagged bank reactions. By September 2019, the ratios are almost at the same level for both deposits and credit lines as in 2008 before QE began.

In other words, a shrinkage of the Fed balance-sheet during QT by a magnitude much smaller than the expansion undertaken during QE (reserves were about $1.4 trillion in beginning of Sep 2019) led to the claims on liquidity relative to available reserves rising significantly. Copeland, Duffie, and Yang (2021), focusing on delayed payments and possible reserve hoarding by banks, argue that reserves may have been inadequate in September 2019. Our evidence, suggesting an increase in the outstanding claims banks had written on liquidity relative to available reserves, hints at why banks might have been especially eager to conserve their scarce reserves when markets were disrupted.

We then split deposits into demand deposits and time deposits.[7] In Panel C, we plot demand deposits, time deposits and reserves all as percentages of GDP. 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 all but lost their importance, declining from about 25% of GDP to just about 5% of GDP. Demand deposits, on the other hand, increased from 30% to about 80% of GDP over the same period. This shift from time to demand deposits suggests a substantial shortening of the maturity of deposit contracts during QE periods. Interestingly, the decline in time deposits flattens out whenever the Fed ceases QE (indeed reverses slightly during QT), yet another piece of evidence suggesting that QE tends to push banks to increase the "demandability" of bank claims.

In Panel D, we plot time deposits and demand deposits as multiples of central bank reserves. Like overall deposits in Panel B, demand deposits fall as a multiple of reserves at the

[7] Demand deposits are demand and other liquid deposits from the H.6 release. Time deposits are the sum of small- and large-time deposits from the H.6 and H.8 releases.

beginning of each QE period but eventually rise by the end of the QE period and continue to rise as a multiple of reserves after the end of QE III and during QT. Time deposits, in contrast, exhibit a secular decline over the QE periods, flattening after QE ends and rising only in the QT period.

One possibility suggested by Lopez-Salido and Vissing-Jorgensen (2022) is that reserves could also increase the size of household assets (for example, because QE has a multiplier effect on economic activity) and such increases will necessitate a portfolio allocation to safe assets such as insured deposits. Put differently, the correlation between aggregate reserves and aggregate deposits may simply be because of the indirect effects of QE in enhancing household financial wealth, and not because of any direct effects of QE on bank financing choices. Of course, as we explain in the introduction, if the central bank purchases bonds from non-banks, reserves and deposits would rise together simply by virtue of the non-banks depositing the receipts from bond sales in their banks. This would happen mechanically with QE even if the value of household financial assets were constant[8]. But Panels C and D suggest that banks are not simply absorbing deposits passively – they seem to be shortening maturities of their borrowing as reserves pile up, probably because demand deposits are cheaper than time deposits, and rising reserves offer a liquidity cushion with which to pay off any depositors that demand payment. This would not happen if households were simply looking to allocate rising financial assets to time and demand deposits according to prior (that is, pre-QE) portfolio weights.

Indeed, a significant fraction of the correlated rise between reserves and deposits may not be because of households. In Figure 1E, which otherwise mirrors Figure 1A, we divide deposits into insured and uninsured deposits, both demand and time. Insured deposits typically belong to households while larger uninsured deposits typically belong to non-bank institutions. As is clear from Figure 1E, the patterns in Figures 1A-D are driven primarily – and robustly, only – by uninsured demand deposits (especially the correlated growth of reserves and deposits during the QE periods). Interestingly, a closer look at the resumption of QE from September 2019 to December 2021 reveals that while there is a surge in insured deposits with the onset of the pandemic (these were probably due to fiscal transfers to households that were redeposited in banks), eventually only the stock of uninsured demand deposits rose in tandem. Once again, this suggests that the rise in deposits, especially uninsured demand deposits, with the increase in

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[8] We show this in appendix table A2, regressing change in deposits against change in household financial assets net of deposits.

reserves during QE is not merely a passive accumulation by banks of the portfolio allocations of rising household financial assets to deposits. The most correlated deposit flows seem unlikely to come from households, and as we will see later, banks that accumulate reserves actively push away time deposits in favor of demand deposits.

In the rest of this section, we turn to time-series regressions, both on aggregate quantities and prices, and econometrically confirm the descriptive patterns we have identified.

3.2. Time-series Regressions

3.2.1. Quantities: Bank deposits, credit lines, and reserves

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

$$\Delta Y_t = \alpha \Delta X_t + \beta X_{t-12} + \varepsilon_t, \qquad (1)$$

where $\Delta Y_t = Y_t - Y_{t-12}$ 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 to control for any calendar effects, and $\Delta X_t = X_t - X_{t-12}$ 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. Data are at monthly frequency when examining deposits and quarterly for credit lines. Standard errors reported in parentheses are adjusted for autocorrelation in the residuals up to 12 months or 4 quarters.

[Table 1]

In Table 1 Panel A, we present estimates of model (1) for the 2009 to 2021 period. Columns (1) to (4) respectively use changes in the natural logarithm of *Deposits, Demand Deposits, Time Deposits,* and (undrawn) *Credit Lines* over the previous 12-months 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 1.8%, and *Credit Lines* of 0.8%, but with a reduction in *Time Deposits* of 2.4%, consistent with demand and time deposits moving in opposite directions with reserves as we saw in Panel C of Figure 1. 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 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).

In columns (5) to (8), we use changes in *Deposits* or *Credit Lines* (instead of log changes) as dependent variables. The results are qualitatively similar. The point estimate in column (5) suggests that for the aggregate banking system, deposit liabilities change in levels almost one for one with reserves – consistent with the theory in Acharya and Rajan (2022). 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 more than one for one with reserves, and time deposits in fact shrink. Column (8) indicates changes in reserves are positively correlated with changes in outstanding credit lines.

In Panel B, we control for the change in household financial assets minus deposits (or insured deposits). We subtract deposits to rule out a mechanical effect in the time-series whereby household financial assets, which include deposits, are positively related to deposits. In Columns (1) and (2), we find that the effect of reserves on overall deposits remains significant, even though its magnitude is about 40% smaller than in Panel A, Column (1). In Columns (3) and (4), we examine the effect of reserves on demand deposits. Relative to Panel A, Column (2), the coefficient estimate is largely unchanged by household financial assets minus deposits (or insured deposits), both statistically and in economic magnitudes.

Collectively, these estimates suggest that an increase in reserves, or equivalently, in the size of the central bank balance sheet, is associated with an increase in demandable claims on the commercial banking system. This should imply that reserves have both direct and indirect effects on the price of liquidity when injected into the banking system. On the one hand, the direct impact of reserve injection, holding all else equal, should reduce the price of liquidity; on the other hand, the indirect impact of reserves injection is to increase demandable claims on banks, which should raise the price of liquidity. In effect, the overall impact of reserve expansion on the price of liquidity may be more muted than an analysis that ignores the issuance of demandable claims. To illustrate this point, we turn to time-series evidence on the price of liquidity in the market for reserves.

3.2.2. Price of liquidity

The effective fed funds rate (*EFFR*) is how much suppliers of liquidity will receive in the Fed Funds market. The interest on excess reserves (*IOR*) reflects the price the Fed would like to set in this market. The difference (possibly negative) is a measure of the price of liquidity, adjusting for the prevailing policy rate. Our initial regressions follow the "demand for reserves" approach outlined in Lopez-Salido and Vissing-Jorgensen [LS-VJ] (2022), but augmented for outstanding bank credit lines as another demand on liquidity that could affect its price:[9]

$$EFFR - IOR_t = \gamma + \alpha\, Ln(Reserves)_t + \beta\, Ln(Deposits)_t + \gamma Ln(Credit\ Line)_t + \varepsilon_t \qquad (2)$$

We estimate it using OLS on quarterly data to match the frequency of data on outstanding credit lines, and following LS-VJ (2022), rearrange equation (2) as

$$EFFR - IOR_t = \frac{\gamma}{\alpha} + \alpha\left[Ln(Reserves)_t + \frac{\beta}{\alpha}\, Ln(Deposits)_t + \frac{\gamma}{\alpha} Ln(Credit\ Line)_t\right] + \varepsilon_t$$

where $Ln(Reserves)_t + \frac{\beta}{\alpha}\, Ln(Deposits)_t + \frac{\gamma}{\alpha} Ln(Credit\ Line)_t$ represents the "deposits- and credit-lines-adjusted" reserves. Figure 2 shows a scatter plot of *EFFR-IOR* on *Ln(Reserves)* in Panel A. Panel B reflects adjustment due to deposits and credit lines. Once we adjust reserves by bank deposits and credit lines (Panel B), a strong negative relationship between the amount of reserves and the price of liquidity emerges.

[Figure 2]

There are, however, well-known problems with regressions in levels. We therefore estimate versions of specification (2) but in log changes which has the advantage of absorbing confounding variation that may simply shift the levels of both dependent and explanatory variables:

$$\Delta EFFR - IOR_t = \alpha\, \Delta Ln(Reserves)_t + \beta\, \Delta Ln(Deposits)_t + \gamma \Delta Ln(Credit\ Line)_t + \varepsilon_t$$

The results from OLS estimation using monthly data (when credit lines are not included) or quarterly data (when credit lines are included) are reported in Table 2 Panel A. Standard errors reported in parentheses are adjusted for autocorrelation in the residuals up to 4 quarters.

[Table 2]

[9] The literature offers several approaches to estimating the so-called "aggregate reserves demand" of banks (see, e.g., Hamilton (1996), Carpenter and Demiralp (2006), and Afonso, Giannone, La Spada and Williams (2022)).

In column (1), we only include Δ*Ln(Reserves)* as the explanatory variable and find that in differences, unlike in levels, there is a statistically significant negative correlation between *EFFR-IOR* and reserves over time. Column (2) suggests a positive correlation of deposits with the price of liquidity, with the coefficient on deposits more than twice the magnitude of that on reserves. This provides preliminary support for our hypothesis that demandable bank claims mute the impact of reserves injection on the price of liquidity.

Importantly, because changes in deposits are positively correlated with changes in reserves, this regression suggests we are not simply picking up some common component, since they have diametrically opposite correlations with the price of liquidity. This is further supported when we split deposits into demand and time deposits in column (3) and document that most of the effect from deposits in column (2) is driven by demand rather than time deposits. In particular, the coefficient on demand deposits is about twice the magnitude of the coefficient on reserves, and the opposite is true for time deposits (the coefficient is negative but essentially zero), which underscores the fact that it is the demandable nature of bank liabilities that primarily dampens the impact of reserves on the price of liquidity.

We then use changes in undrawn credit lines measured as Δ*Ln(Credit Lines)* from FRED data in column (4) and find that its coefficient is also positive as in the case of deposits but about half the magnitude. Next, we obtain quarterly data on credit lines usage of U.S. firms from Capital IQ, and in column (5), add Δ*Ln(Usage)*. Δ*EFFR-IOR* loads negatively on usage, suggesting that as usage increases, outstanding undrawn credit lines fall, and this reduces the demand – in turn, the price of – liquidity. Once again, this suggests the demandability of credit lines leads their outstanding (undrawn) amount to be positively associated with the price of liquidity.

Finally, in column (6) we include all the explanatory variables. The coefficients of Δ*Ln(Demand Deposits)*, Δ*Ln(Credit Lines)* and Δ*Ln(Usage)* remain significant and economically meaningful. Importantly, the coefficient on Δ*Ln(Reserves)* in all specifications (columns 1-6) is negative, large in magnitude, and statistically significant.

In Panel B, we separate the data on deposits and reserves into those for the overall banking system, for US banks only, and for foreign banks (overall minus US banks) only, and estimate the specification of Panel A with reserves only and with reserves and deposits (or separately demandable deposits in the case of US banks). Throughout in columns (1)-(5), we find that as in Panel A, bank reserves have a negative and significant coefficient estimate. This is the case not only for the reserves held by US banks but also for Fed reserves held by foreign banks, the latter being consistent with the evidence in Anderson et al. (2021) that global banks play an important intermediation function between the Fed and money market funds who do not have access to interest on reserves. While in column (4), the magnitude of the effect of US bank reserves is smaller than foreign bank reserves, in column (5) when demandable US bank deposits are included, the magnitude is in fact larger. Unsurprisingly, the coefficient on 4 bank deposits is insignificant in affecting the price of liquidity as they face regulatory constraints in raising such deposits and hold a relatively small stock. Overall, this is supportive of the view that while foreign bank holdings of Fed reserves do matter for the price of liquidity, both deposits and reserves of US banks also play a significant role in the determination of this price.[10]

While the correlations thus far are interesting, aggregate time-series analysis is not conducive to analyzing the causal impact of reserves on variables of interest, especially as we examine different phases of central bank activity, since we run into issues of statistical power given the small number of observations within each phase. Time-series analysis also cannot adequately rule out confounding effects from economy-wide factors such as the level of economic activity, the consequent change in household financial assets, and interest rates, which directly affect deposit creation and deposit demand in the economy. We, therefore, turn to panel tests with a cross-section of banks (at a depository- or bank-holding-company level).

4. Central bank reserves and bank deposits and credit lines (quantities).

Since we use bank-level Call Reports data for the subsequent tests, we confirm in the Online Appendix Figure A1 that deposits paint the same picture aggregated up as we saw based on the flow-of-funds (FRED) data. They do.[11] Consistent with the aggregate FRED data in Figure 1 (Panels C-D), we find that the share of time deposits in the bank-level Call Reports data has been

[10] One concern may be that the Fed's provision of reserves to the financial system following the collapse of Lehman Brothers in September 2008 and the Treasury repo rate spike of September 2019 was a direct response – among other things – to the elevated *EFFR*, which create potential endogeneity issues in "reserves demand" estimation. In the Online Appendix Table A3, we verify that our conclusions are robust to focusing on the period from Q3 2009 to Q2 2019, a period over which the alteration of aggregate reserves by the Fed was most likely unrelated to the state of the inter-bank markets, in particular, to *EFFR-IOR*.

[11] This decomposition within demand deposits available in the Call Reports data is not available in the aggregate flow-of-funds (FRED) data that we used in time-series tests. Note also that whenever we refer to "demand" deposits in our cross-section tests, we mean demand deposits excluding MM and non-MM savings deposits; the distinction will usually be clear from the context.

falling since the beginning of QE I and did not reverse after the end of QE III; the reversal is observed only after late 2017. In contrast, the shares of savings and other demand deposits have been rising. Given this divergence between demandable and time deposits, also observed in our time-series regression analysis of Tables 1 and 2, we do not analyze bank deposits as a whole in the panel tests but instead focus on its two components – demandable and time – individually.

4.1. Methodology

An immediate concern is that 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 bank-level stock of reserves could be *endogenous* to the 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 seek reserves to meet withdrawals. Banks may also be subject to regulations such as the Liquidity Coverage Ratio (LCR). Because LCR is relaxed if a bank chooses time deposits over demand deposits, constrained banks may seek reserves at the same time as they seek time deposits – inducing a positive correlation we need to correct for. Large banks that have access to equity and bond markets may raise a part of their funding from non-deposit sources, which would imply an increase in reserves that is not coincident with an increase in 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 an exogenous change in bank-level reserves on bank-level deposits. Our bank-level *Reserve Instrument*, z_{it}^{R}, is the product of two components: the most recent change in aggregate reserves times the bank's recent share of reserves:

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

The growth in aggregate reserves is plausibly not driven by an individual bank's circumstances, but by the Fed's monetary stance. As to the second component, banks will differ in their propensity to use reserves. Kashyap, Rajan, and Stein (2002) argue that banks can use their reserve holdings best if they can write multiple diversified commitments against them, earning a fee on each – the same pool of low-yielding reserves backs many potential calls on them. Some banks will find it easier to write these multiple commitments, for instance because of the nature of their steady clientele. In network theories of banks, banks at the center of networks tend to be best positioned to use reserves for the benefit of the network. Such centricity could also be determined by relationships. During QE, non-banks may tender assets, placing the associated reserves with their relationship bank. Some banks may have stronger non-bank relationships than others. Given they are likely to attract reserves because of their activity, 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. This would cause them to hold relatively higher reserve shares but will not affect their liability structure directly.

This then leads to the second component of the instrument, *Bank i's lagged share of aggregate reserves*. It is calculated by dividing the bank-level *Reserves* by aggregate bank reserves. We average the 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 adjustment of reserves of the bank (assuming that such adjustment is transient and uncorrelated or weakly correlated from one quarter to the next). Effectively, we assume that a bank's lagged share in reserves captures some persistent characteristic such as some banks being able to write a multitude of claims on reserves (not just deposits but also syndicated lines of credit), or being money-center banks or primary dealers or having strong non-bank relationships. Results from alternative instrument choices are in the Online Appendix Tables B1 and B2.

4.2. Impact of reserves on quantities of deposits

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

$$\Delta Ln(Reserves)_{it} = \gamma_1 Reserves\ Instrument_{it} + \gamma_2 Ln(Reserves_{it-5}) + \mu X_{it-1} + \delta_t + \vartheta_{it}$$

(4)

$where\ \Delta(Y)_{it} = Y_{it} - Y_{it-4}$, and X_{it-1} represents bank controls lagged by one quarter which are size (measured as *Ln(Assets)*), profitability (*Net Income-to-Assets*), and capitalization (*Equity-to-Assets*), as well as a dummy variable *Primary Dealer Indicator* that identifies banks that are primary dealers. Finally, δ_t represents (quarter) time-fixed effects which soak up any aggregate change in conditions ensuring the effect of the instrument is only via the cross-section. Note that we assume $Ln(Reserves_{it-5})$ to be exogenous to $\Delta Ln(Deposits)_{it}$ given the 5-quarter lag. For all our panel tests, we 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 them does not change the results qualitatively.

In the first-stage estimation, we find that $\Delta Ln(Reserves)$ has a positive and strong correlation with the *Reserves Instrument* for the overall period, the QE periods, as well as the post QE III and QT period. The first-stage results and F-statistics are reported in Online Appendix Table A4 and satisfy the usual criteria for rejecting the null hypothesis of a weak instrument, again for the overall period as well as the sub-periods.

In the second stage, we regress the change in deposits, $\Delta Ln(Deposits)$, against instrumented $\Delta Ln(Reserves)$ and $Ln(Reserves)_{it-5}$ as independent variables:

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

where X_{it-1} represents 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 A.1, we present OLS estimates, and in Panel A.2, instrumental variable (IV) estimates, for the impact of reserves on demandable deposits. For parsimony, we do not report estimated coefficients on the 5-quarter-lagged reserves. The coefficients on 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 demandable deposits in the overall sample (column (1)), the QE periods (column (2)), and QE I-III periods (column (3)), but is insignificant for the Post QE III/QT period (column (4)). Since reserves shrink on average during these latter periods, the lack of a significant IV coefficient suggests demandable deposits do not shrink.

[Table 3]

In terms of magnitudes, an exogenous 10 percent year-on-year increase in a bank's reserves leads to a 1.35 percent rise in its demandable deposits in the overall sample, and 1.22 percent rise in the QE periods. Consistent with there being some bank-level endogeneity that causes reserves to rise when deposits are shrinking, the statistically significant IV magnitudes in Panel A.2 are greater than those observed in the OLS estimation (Panel A.1). Interestingly, however, the panel IV estimate is of the same order of magnitude as the simple time-series estimate based on aggregate data (Table 1, Column 2). Thus the causal effect of reserves on demandable deposits is similar in the panel as in the aggregate OLS regressions in Table 1.

Panel B presents results on time deposits. While the OLS estimates (Panel B.1) suggest a positive relation between reserves and time deposits, the IV estimates (Panel B.2) imply a negative relation consistent with our time-series results (Table 1, Column 3). This again suggests that there is indeed some endogeneity that the IV estimates address. Turning to magnitudes, an exogenous 10 percent year-on-year increase in a bank's reserves leads to approximately a 1.6 percent *decrease* in the bank's time deposits in the overall sample period (column (1)) as well as during the QE periods (columns (2) and (3)). However, during the Post QE III/QT period (column (4)), the effect of reserves on time deposits becomes positive but is statistically insignificant.

Finally, in Panels C and D we confirm respectively that exogenous change to bank reserves increases demand deposits but leads to shrinkage of time deposits, even if we restrict attention solely to their uninsured components. This is an important test as bank financing of QE-enhanced reserves is likely to operate via uninsured deposits from non-banks (as the Fed buys bonds from them) rather than sticky or relatively inelastic insured deposits. As discussed earlier, this test also helps rule out the concern that the effect of reserves we estimate is due primarily to QE having raised household financial assets that in turn raise household demand for insured deposits.

Overall, Table 3 suggests that there is a maturity-shortening of deposits at the bank level during QE periods, as a bank's demand and savings 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/QT periods. The differential effect for demand and time deposits suggests that it is not just that deposit financing passively grow with reserves; there seems to be an active move by banks to substitute term financing with demandable financing.

One value of our panel tests is 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 quantitative easing is accompanied by forward guidance that rates will remain "low for long". Since we identify rotation towards demandable deposits away from time deposits for individual reserve-intensive banks after controlling for such time fixed-effects, we can be confident that this rotation is in fact an active bank preference rather than a passive one. We will add to this confidence when we examine bank pricing of term deposits.

Finally, the substitution of demand deposits for term deposits also suggests the implementation of the Liquidity Coverage Ratio (LCR) in 2015 is not the primary causal factor behind our results. The LCR would push banks to favor time deposits, which require significantly lower liquid assets to be maintained under the LCR Guidelines, over demand deposits.

4.3. 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 1 earlier. Indeed, we find in raw data that bank-holding-company-level growth in demandable deposits correlates in a robust positive manner with the growth in outstanding credit lines, both during QE as well as QT. Credit line usage has also evolved into an important source of liquidity management for corporations. During the Pandemic QE, 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 and Steffen (2021)). Despite this unprecedented usage, the amount of undrawn outstanding credit lines increased even beyond the pre-pandemic levels by the end of 2021.

Furthermore, credit line issuances are particularly important for investment-grade rated as well as unrated firms, as shown by Colla et al. (2013) and in Figure A5 in our Online Appendix. Finally, Berg et al. (2021) show that investment-grade rated and unrated firms issue credit lines for corporate borrowing and liquidity management purposes, while non-investment grade rated firms issue credit lines in combination with term loans for transaction purposes (e.g., mergers and acquisitions, leveraged buyouts, or dividend recapitalizations). Given these considerations, we focus our analysis on credit line originations by banks to investment-grade and unrated firms.[12]

4.3.1 Credit line originations

In this sub-section, we provide corroborating evidence in the panel 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 bank holding company (BHC) level, since data on bank participation in the syndicates that offer credit lines are at the BHC level. We estimate the following regressions at the BHC (i) -quarter (t) level:

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[12] Results for sub-investment grade firms suggest that IV estimates are qualitatively similar, and in fact quantitatively larger, compared to those for investment-grade and unrated firms (see Online Appendix Table A11).

$$\Delta Ln(Credit\ Lines)_{it} = \beta_1 \Delta Ln(Reserves)_{it} + \beta_2 Ln(Reserves)_{it-5} + \mu X_{it-1} + \tau_t + \varepsilon_{it} \quad (6)$$

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 investment-grade and unrated corporations originated by bank holding company *i* in quarter *t.* Standard errors reported in parentheses are clustered at the quarter level.[13]

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 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, when we estimate the regressions outlined in equation (6), reporting the OLS estimates in Table 6 Panel A, we find that an increase in reserves is associated with a *decrease* in the amount of credit lines that are originated. An IV estimate would correct for possible endogeneity driving the OLS estimate.

Turning to the IV estimates, we report the first-stage results in the Online Appendix Table A5, which show a positive and statistically significant relationship between Δ*Ln(Reserves)* and the instrument for reserves in the Overall and QE periods, and F-statistics pass the usual criteria too. This is, however, not so for the QT period at BHC level (unlike at bank level in the Online Appendix Table A4); the coefficient is positive but insignificant and the F-statistic low too.

[Table 4]

The IV estimate is reported in Table 6 Panel B. As before, column (1) shows the results for the overall, column (2) for the QE I-III and Pandemic QE, column (3) for the QE I-III, and column (4) for the post QE III and QT periods, respectively. We find that during the overall and quantitative easing periods, an exogenous 10% increase in a bank's reserves leads to an *increase* in the origination of lines of credit to investment-grade and unrated firms by about 0.9 percent. So the instrumenting of reserves changes the sign of the effect from the OLS. Such a positive statistically significant relationship between reserves and credit line amounts is, however, missing in the quantitative tightening period, with the coefficient turning insignificant and standard errors

[13] In this test, we only cluster at the time (not the bank level). The universe of bank holding companies originating credit lines is small within our sample period, particularly during the QE/post-QE/QT sub-periods, which results in fewer clusters as compared to the universe of banks that are depositories.

significantly higher. It may well be that the first stage is simply not well-identified at BHC level for post QE III/QT period, rendering difficult any statistical inference in the second stage.

5. Central bank reserves and bank pricing of deposits and credit lines.

One way to get further insights into the issuance of claims on liquidity by commercial banks is to examine their pricing across banks. As econometricians operating outside the Fed, we do not have inter-bank data in order to determine a variant of *EFFR-IOR* at the bank- or bank-holding-company level; hence, we must examine alternative measures of the price of liquidity. In particular, we identify measures of the price of liquidity using bank-level deposit rates and bank-holding-company level fees charged for credit lines. While we have already established the aggregate price of liquidity varies over time, the intent in this section is to examine whether banks with more exogenous reserves tend to price lower the claims on liquidity that they issue. In that sense, we are estimating off the cross-section of banks, accounting for the prevailing aggregate price of liquidity at any point of time.

We start by examining bank deposit rates. Checking accounts typically have close-to-zero rates given the transactional convenience they offer. Hence, 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 reserves grow, coupled with a reduction in the quantum of time deposits, would suggest a bank preference for shorter maturity deposits as its reserves increase, i.e., the bank is not willing to pay more for term protection, and indeed reduces the issuance of term deposits.[14]

5.1 Impact of bank-level reserves and deposits on deposit rates

We now investigate how an exogenous increase in bank-level reserves and deposits affects the CD to savings rate spread across banks, controlling for bank- and time- fixed effects. With these fixed effects, we also address stationarity issues relating to the explanatory variables being

[14] The results that follow are similar if we replace money market savings rates with non-money market savings rates as shown in the Online Appendix Table A9. Figures A3 and A4 also show that the time-series of the average spread between CDs of different maturities and various demandable deposit rates co-move. Indeed, these spreads move with the spread between the effective federal funds rate and the target federal funds rate (*EFFR-TFFR*) and the spread between the effective federal funds rate and the interest on excess reserves (*EFFR-IOR*), validating our focus on them as bank-level proxies for the price of liquidity.

in level terms. We employ a 2-SLS specification by instrumenting bank-level reserves and bank-level deposits in the first stage.

We have already discussed our instrument 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 $z_{it}^{D} = \ln\left(\sum_{c \in Ci,t} w_{ict} \cdot \frac{Dep_{c,t}}{Dep_{c,t-1}}\right)$ where $w_{ict} = \frac{Dep_{c,t-1}}{\sum_{c' \in C_{i,t}} Dep_{c',t-1}}$. w_{ict} 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. Note that as the FDIC's Summary of Deposits data only contains total deposits by bank branch, we cannot estimate the deposit instrument using demandable deposits.

Implicitly, we assume the deposit growth rates in the larger (in terms of aggregate deposits) counties that 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 *F*-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. In Online Appendix Tables B4 and B5, we test the robustness of our results with alternative instruments for deposits that are based on different assumptions of exogeneity.

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

$$Ln(Deposits)_{it} = \gamma_{11} Deposit\ Instrument_{it} + \gamma_{12} Reserves\ Instrument_{it} + \mu X_{it-1} + \rho_i + \delta_t + \mu_{it} \quad (7)$$

$$Ln(Reserves)_{it} = \gamma_{21} Deposit\ Instrument_{it} + \gamma_{22} Reserves\ Instrument_{it} + \mu X_{it-1}$$

$$+ \rho_i + \delta_t + \mu_{it} \tag{8}$$

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}). In interest of space, the first-stage results are relegated to the Online Appendix Table A6. By way of brief summary, *Ln(Deposits)* has a positive and significant correlation with the *Deposit Instrument* and *Ln(Reserves)* has a positive and significant correlation with the *Reserves Instrument.*

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

$$Deposit\ Rate\ Spread_{it} = \beta_1 Ln(Deposits)_{it} + \beta_2 Ln(Reserves)_{it} + \mu X_{it-1} + \pi_i + \tau_t + \varepsilon_{it} \tag{9}$$

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 is β_2 from model (9), the hypothesis being that it is negative, i.e., an exogenous injection of reserves induces a preference in banks for a shorter maturity of deposits, whence they reduce time deposit spreads.

Table 5, Panel A presents the second-stage of the 2-SLS regression results for the overall sample period (corresponding OLS results are in the Online Appendix Table A8). We see that except for the 12-month CD spread, the coefficients on *Ln(Reserves)* are negative and statistically significant as expected (and always negative). 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 46 basis points narrower 18-month CD to MM Savings Rate Spread, which is about 1.12 times the standard deviation of the (demeaned) 18-month CD to MM Savings Rate Spread. Note that the coefficient on *Ln(Total Deposits)* is positive but insignificant.

[Table 5]

Panels B-D replicate the analysis for individual time periods and find that relative to the overall sample period, the negative effect of reserves on the term spread for deposits is stronger for all of the QE periods (Panel B) and similar during the QE I-III periods (Panel C). Interestingly, pricing in the Post QE III/QT period (panel D) becomes much noisier, with the coefficients on

Ln(Reserves) turning positive and those on *Ln(Total Deposits)* turning negative for some maturities, which may in part be linked to the lack of a well-identified first stage while instrumenting reserves in the post QE III plus QT period. With that caveat in mind, we conclude that on par with their behavior on quantities and liquidity pricing in aggregate, the cross-sectional bank pricing behavior of liquidity in term deposit spreads does not simply reverse with the shrinkage in reserves, instead it turns noisy.

5.2. *Impact of bank-level reserves and credit lines on the pricing of credit lines*

Lastly, we turn to the pricing of credit lines across banks. The prior literature on credit lines emphasizes three components as particularly relevant in the pricing of credit lines: (1) the all-in-spread-undrawn (*AISU*), which is the commitment fee charged for each dollar committed but not drawn; (2) the all-in-spread-drawn (*AISD*), which is the credit spread above LIBOR paid on each dollar drawn; and, (3) the *AISD/AISU-ratio*. The *AISD/AISU-ratio* is a measure of the cost of drawing on a promised credit line relative to the cost of obtaining the promise. A reduction in this ratio reflects a bank's preference to supply immediacy by selling claims on reserves. In situations of tight liquidity, banks are likely to hike the premium they demand for those who want liquidity insurance, but will likely increase the cost of actually drawing down even more. So the *AISD/AISU-ratio* is likely to go up in situations of tight liquidity when the bank does not really want drawdowns.

Indeed, Berg et al. (2016) show that the *AISD/AISU-ratio* is negatively related to usage rates as borrowers, particularly investment-grade and unrated firms, with contracts that have a high *AISD/AISU-ratio* pay a relatively low fee for obtaining the credit line but relatively high spread once the credit line is drawn down (also see Thakor and Udell (1987) and Shockley and Thakor (1997)). Furthermore, they find that in the sample of large syndicated loan borrowers, investment-grade and unrated firms are similar to each other in terms of credit quality and demand for liquidity. Finally, investment grade firms are likely to draw down only in the face of systemic (or high aggregate risk) events such as the onset of the COVID-19 pandemic. In contrast, below-investment grade rated firms might want to draw down under a variety of idiosyncratic circumstances. Since liquidity stress in the banking system is also likely to be primarily a systemic concern, the pricing effects of systemic liquidity in turn are most likely to be pronounced for investment grade firms where drawdowns are likely only in systemic eventualities. Hence, we focus our analysis of bank credit line fees on investment-grade and unrated firms, as we did also for the analysis of bank credit line originations (Table 4).[15]

Intuitively, more liquidity should, *ceteris paribus*, decrease the price for providing liquidity via credit lines. We estimate variants of the following:

$$AISD/AISU_{it} = \beta_1 Ln(Credit\ Lines)_{it} + \beta_2 Ln(Reserves)_{it} + \mu X_{it-1} + \pi_i + \tau_t + \varepsilon_{it} \quad (10)$$

where $AISD/AISU_{it}$ is the ratio of the all-in-spread-drawn and all-in-spread-undrawn from LoanConnector, collapsed at the BHC (*i*) and quarter (*t*) level. All regressions include bank-time-varying controls lagged by one quarter and bank (π_i) and quarter-time (τ_t) fixed effects. Standard errors are clustered at the bank and quarter level.

We estimate a 2-stage least square specification, instrumenting in the first stage BHC-level 4credit lines, measured as *Ln(Credit Lines)*, by a *Credit Line Instrument,* and BHC-level reserves, measured as *Ln(Reserves)*, by the BHC-level *Reserves Instrument* discussed earlier (Table 4). For the credit line instrument, once again we rely on specific but stable bank characteristics that may make it more prone to issue credit lines. Specifically, we use $(Ln(Credit\ Lines)_{it-1}\ x\ ELP_{t-1})$, which is a bank's lagged credit line originations times the lagged aggregate *Excess Loan Premium (ELP)* from Saunders et al. (2022). Aggregate *ELP* is regarded as an indicator of the tightness of financial conditions in the economy.[16] A high credit-line instrument for a bank suggests it is special in being able to *increase* the origination of credit lines even when overall financial conditions are tight (for instance, because it expects to attract deposits at the same time that credit lines are drawn down, see Gatev and Strahan (2006)). Therefore, higher instrumented credit lines for a bank are a proxy for its greater ability to supply credit lines, which should lead to a reduction in the price of

[15] We examine the cross-sectional correlation of the different price measures of credit lines, (1) *AISU*, (2) *AISD*, and (3) the *AISD/AISU-ratio* with the *EFFR-IOR*. Interestingly, while the *AISD/AISU-ratio* exhibits a correlation of $\rho = 0.51$ with *EFFR-IOR*, both *AISD* and *AISU* are insignificant individually – if anything, negatively correlated with the *EFFR-IOR* ratio (respectively, $\rho = -0.1$ *and* $\rho = -0.17$). Next, we investigate the correlation between *EFFR-IOR* and the *AISD/AISU-ratio* separately for investment-grade, non-investment-grade, and unrated firms. We find that the time-series correlation over the 2009 to 2021 period of the *EFFR-IOR* and the *AISD/AISU-ratio* for all credit lines originated to U.S. firms is 0.49, for credit lines originated to investment-grade rated and unrated firms is 0.45, and for credit lines originated by non-investment-grade rated firms it drops to 0.3 (and in fact, to just 0.18 after 2013). Overall, we conclude that the *AISD/AISU-ratio* is highly correlated with the *EFFR-IOR* for investment-grated and unrated firms, and will be our measure of the price of liquidity for a bank offering credit lines.

[16] Saunders et al. (2022) construct the *ELP* from secondary loan market credit spreads. The *ELP* is orthogonal to borrower default risk and can be interpreted as a price for risk in the corporate loan market above a compensation for default risk. Loan markets are particularly populated with smaller and private firms prone to market frictions, which is why an increase in the *ELP* suggests more difficulties for firms to access and roll over credit. Results from using *Excess Bond Premium* in place of *ELP* are in Online Appendix Table B3.

credit lines. In contrast, higher un-instrumented credit lines may reflect either easier ability to supply (suggesting a lower price of liquidity) or higher demand (suggesting a higher price).

We estimate the first stage of the 2-SLS as:

$$Ln(Credit\ Lines)_{it} = \gamma_{11} Credit\ Line\ Instrument_{it} + \gamma_{12} Reserves\ Instrument_{it} + \mu X_{it-1} + \rho_i + \delta_t + \mu_{it} \tag{11}$$

$$Ln(Reserves)_{it} = \gamma_{21} Credit\ Line\ Instrument_{it} + \gamma_{22} Reserves\ Instrument_{it} + \mu X_{it-1} + \rho_i + \delta_t + \mu_{it} \tag{12}$$

where *i* represents bank, *t* represents quarterly data, X_{it-1} represents bank-time varying controls lagged by one quarter, ρ_i represents bank-fixed effects, and δ_t represents (quarter) time-fixed effects.

The first-stage results are in the Online Appendix Table A7. *Ln(Credit Lines)* has a positive and significant correlation with the *Credit Line Instrument*. Similarly, *Ln(Reserves)* has a positive and significant correlation with the *Reserves Instrument.* We report the second-stage regression results in Table 6. The coefficient estimate on reserves is negative in all periods and significant, implying that higher reserves at a bank tend to drive the *AISD/AISU-ratio* lower, except in the post QE III/QT period (when the coefficient remains negative but the standard errors blow up, similarly to the case with credit line quantities in Table 4). Finally, while the coefficient estimate on the instrumented log of credit lines is always negative, it is not statistically significant.

[Table 6]

The robust bottom line is that the price of credit-line liquidity provided by banks tends to fall when the Fed expands its balance-sheet, but the effect becomes noisy when it stops expansion or shrinks. The overall symmetry between quantity and price of liquidity results across both deposits and credit lines imply that both are important demandable claims to be concerned about while assessing the likely liquidity stress for banks when the central bank shrinks its balance sheet.

6. Robustness and Discussion.

6.1 Liability-based perspective on liquidity stress

Our findings suggest it is wrong to think about QE as simply a reserve expansion, taking the nature of claims on liquidity on the banking sector as given. Under this view, an increase in central bank balance sheet size always lowers the price of liquidity and improves financial stability, so that a solution to any liquidity stress is to inject even more reserves. In contrast, our liquidity dependence view 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 shrink these claims easily. Hence, the supply of reserves creates its own additional demand via these new claims, which can come due in times of aggregate stress.

6.2. Why do banks issue demandable claims against reserves?

It is interesting to ask how much value banks gain from issuing such demandable claims. Is this the proverbial "picking pennies in front of a steamroller"? To understand the magnitude of the gain (which we refer to as *Gains from Claims*), we estimate it bank-wise when the Federal Reserve expanded its balance sheet during 2010Q1 to 2014Q3 period.

The idea behind the calculation of the *Gains from Claims* is that banks earn low, or even zero, interest on reserves, which they try to augment (i) by reducing the deposit interest burden by switching from the more expensive time deposits to cheaper demandable deposits, and (ii) by originating more credit lines on which they earn fees on unused portion as well as the drawn-down portion. For simplicity, we ignore the capital charges associated with unused credit lines as well as with credit line drawdowns (they would reduce the magnitude of our estimates). We seek to measure the gain from such activity over the quantitative easing period by examining changes in reserves, demandable and time deposits, and outstanding credit lines. Hence, we estimate average quarterly *Gains from Claims* for bank *i* using the following formula:

$$
\begin{aligned}
&Gains\ from\ Claims_i \\
&\quad = \frac{1}{4}\Bigg[(\Delta Reserves_{i,QE\to QT}\ \times\ IOR \\
&\quad - \Delta Demandable\ Deposits_{i,QE\to QT}\ \times\ Money\ Market\ Savings\ Rate\ _i \\
&\quad - \Delta Time\ Deposits_{i,QE\to QT}\ \times\ 12\ month\ CD\ Rate_i \\
&\quad + \frac{1}{1 - Drawdown\ Rate} \times\ \Delta Unused\ Credit\ Lines_{i,QE\to QT} \\
&\quad \times\ [All\ in\ Spread\ Drawn_i\ \times\ Drawdown\ Rate \\
&\quad + All\ in\ Spread\ Undrawn_i\ \times\ (1 - Drawdown\ Rate)]\Bigg]
\end{aligned}
$$

where $\Delta Y = Y_{2014Q3} - Y_{2010Q1}$ for all variables. *Reserves* are at the bank holding company (BHC) level in Table 7 Panel A and at bank level in Table 7 Panel B. For Panel A we take the BHC-specific All-in-Spread-Drawn (*AISD*) and All-in-Spread-Undrawn (*AISU*) rates from *Refinitiv DealScan* database. For Panel B we take 200 bps as *AISD* and 30 bps as *AISU* for all banks since individual *AISD* and *AISU* data are not available at the level of individual banks. Finally, we take a common drawdown rate of 20 percentage points in both panels based on average historical drawdown rates in Capital IQ data across all credit lines. We "inflate" the unused credit lines by the undrawn proportion based on this rate as the Call Reports provide the outstanding credit lines rather than their total originations.

In the first row, we show our estimate of BHC-level and depository-level *Gains from Claims* relative to median net income as the denominator. We restrict attention to banks with positive median net income values during the 2010Q1 – 2014Q3 period.

[Table 7]

We find that *Gains from Claims* account on average (median) for 2.86% (2.81%) of the net income at the BHC level, and respectively 12.7% (0.384%) at the depository-level. In other words, the contribution to net income is rather low on average and akin to "pennies", especially at the BHC level where reserves and balance-sheet optimization activities are likely managed. At the BHC level, the 90th percentile bank has a *Gains from Claims to Net Income* ratio of 6.92% whereas the depository-level 90th percentile is at 12%, indicating a significant positive skew at the depository-level, potentially because some depositories benefit from bank-holding-company level reserves management and do not keep reserves on their own balance-sheets.

Note that we include the spread between interest on reserves and deposits in our calculation. If bank accumulation of reserves is largely exogenous, then the profitability of the choices banks actually make (swapping time for demand deposits and issuing lines of credit) is even smaller. On balance, we conclude that the incentive to engage in maturity-shortening of deposits and origination of credit lines is a form of balance-sheet optimization by banks seeking to reduce the cost of holding reserves. The activity generates a modest increase in net income for the median bank but can be a source of meaningful return on equity for hyper-active and/or low-profit banks. We will see below that the activity can also contribute non-trivially, and even significantly, to liquidity risk ("steamroller") of banks, especially post-QE and during QT.

6.3 Why do commercial banks not reduce claims when reserves shrink?

Even if commercial banks find issuing liquidity claims worthwhile, why do they not shrink their issuance of claims on liquidity when the central bank withdraws reserves from the system?

6.3.1. Substituting reserves with eligible assets

One possibility is that banks feel confident in their access to liquidity because they substitute lost reserves with bonds that are eligible collateral for repo transactions. To assess this, we use Call Reports data to calculate at the BHC level a measure of *Claims to Potential Liquidity*, defined as the ratio of outstanding credit lines and demandable deposits (demand + savings) to reserves plus *eligible* assets, where eligible assets are those that qualified at some point during our sample period for exchange with the Fed for reserves. Collateral eligible to secure liquidity from the Fed also tends to be the most commonly posted and accepted for repo market transactions. In Figure 3, we plot how this ratio varies across banks and how the variation evolves over time.

[Figure 3]

Panel A shows the ratio calculated for the aggregate balance sheet of the BHCs. The ratio shows variation between 2.4 to 3.1, between 2009 and 2021, with falls during QE and rises during the post-QE III and QT periods. However, the aggregate numbers mask important across-bank variation. In Panel B, we show the time-series evolution of 10th, 25th, 50th, 75th and 90th percentile values of BHC-level ratios in each quarter. While we see an overall increase in each percentile through most of the period up until Q1 2021, what is most striking is the sharp rise of 75th and 90th percentiles, and especially during post-QE III and QT periods. For instance, the 90th percentile bank holding company (BHC) by this ratio in early 2010 was at 12 but the 90th percentile BHC in September 2019 had increased to around 30. The sharper increase at higher percentiles implies that the cross-bank distribution steadily shifts to the right over time. Panel C shows this more vividly by plotting the distribution as a histogram, separately for QE I-III, post-QE III and QT periods, in each case bunching all values greater than or equal to 20 as a single point of mass at 20. It is clear that the ratio of demandable claims to (potentially) liquid assets of BHCs ends up at September 2019 with a significantly fatter right tail, in fact with more than 20% of the mass at values greater than or equal to 20.[17]

In other words, by September 2019, in addition to the system having a larger ratio of demandable claims to reserves (Figure 1 Panel B), there was an increase in dispersion or heterogeneity among banks in demandable claims relative to reserves plus eligible assets. As reserves started shrinking during QT, reserve-deficient banks were now effectively reliant on repo

[17] We also find that the largest banks (those in the asset bucket of 90th percentile and above) see a reduction in this ratio after March 2020, while other bank-sizes continue to see an increase till 2020Q3. This suggests that the smaller banks were relatively more prone to liquidity demand shocks. The overall patterns are also robust to examining the ratio based on *uninsured* demand and savings deposits. The figures are contained in the Online Appendix Figure A2.

markets to obtain reserves from surplus banks by pledging eligible assets. As Acharya and Rajan (2022) 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. 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)).

Similarly, the onset of the pandemic may not have caused the *dash for cash* on corporate credit lines in March 2020 (Kashyap (2020), Acharya, Engle and Steffen (2021)) if the system had not already seen a significant tightening of reserves relative to potential claims on liquidity. Indeed, Panel B suggests that the dispersion of demandable claims to potentially liquid assets ratio continued rising even after the Fed resumed QE in response to the September 2019 repo rate spike, and only stabilized and came down after the massive Fed intervention in March 2020. The bottom line is that including eligible assets may not change the picture. Indeed, it shows the dispersion in demandable claims to liquid assets is at worrisome levels. Furthermore, it opens up the possibility that some banks may be "complacent" because they have eligible assets with which to borrow reserves, even though aggregate reserves are inadequate if everyone wants to borrow them.

6.3.2. Demandable claims and fragility: The COVID shock

Could our worries be overstated because we miss other sources of comfort for banks issuing demandable claims? To investigate, we consider 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 4 shows the time-series over the Jan 1 to June 30, 2020 period of the stock return difference between banks split into those with high and low *Claims to Potential Liquidity* ratio (median split) measured as of December 2019. Bank stock prices dropped, on average, about 50% from the beginning of the recognition of the pandemic and until March 23, 2020, when a series of liquidity interventions by the Federal Reserve Bank stemmed the market decline (Acharya, Engle and Steffen, 2021). Strikingly, stock prices of banks with high ratio dropped, on average, about 7 percentage points more compared to banks with low ratio.

[Figure 4]

To test this econometrically, we employ the following cross-sectional regression:

$$r_i = \alpha + \gamma\ Claims\ to\ Potential\ Liquidity_i \ + \sum \beta\ X_i + \varepsilon_i$$

We compute daily excess returns for bank holding company *i*, r_i, which we define as the log of one plus the total return on a stock minus the risk-free rate defined as the one-month daily Treasury-bill rate. *X* is a vector of control variables as in Acharya, Engle and Steffen (2021), measured at the end of 2019 and reflecting key bank portfolio exposure and performance measures (see the Online Appendix Table A12 for their description).

[Table 8]

The results are reported in Table 8. In column (1), stock returns are measured over the Jan 1 to Feb 28, 2020 period and in column (2) to (4) over the March 1 to March 23, 2000 period. Not surprisingly, we do not see much statistical explanatory power of the *Claims to Potential Liquidity* ratio for bank stock returns when we include only the January and February 2020 period suggesting parallel pre-trends. Focusing in contrast on the March 1 to March 23, 2020 period, we observe an economically and statistically significant effect (column (2)). A one-standard deviation increase in the ratio decreases stock returns by about 4.6%, which is about 10% of the unconditional mean decline in bank stock prices during this period. Interestingly, the effect is driven by unused credit lines (*Credit Lines to Potential Liquidity* ratio in column (3)) but to a lesser extent by demandable deposits (*Demandable Deposits to Potential Liquidity* ratio in column (4)). This is not surprising, as we will argue below.

To investigate the role of bank credit lines further, we present direct evidence of "dash for cash" on banks that had written substantial credit lines relative to their reserves and eligible assets. In Panel B of Figure 4, we plot the realized *Gross Drawdowns* (measured as the change in outstanding corporate credit lines during Q1 2020 relative to total assets) against the *Credit Lines to Potential Liquidity* ratio of banks. The scatter plot as well as fitted regression line (Table 8 column (5)) shows a clear positive association. A one standard deviation increase in *Credit Lines to Potential Liquidity* ratio increases *Gross Drawdowns* by about 0.24%, which is almost 50% of the unconditional increase in *Gross Drawdowns*. However, as column (6) suggests, there are no associated dashes for cash in deposits.

What explains the excess credit line drawdowns, the muted reaction on deposits, and the stock market reaction? Clearly, access to liquidity became tighter at onset of the pandemic (especially in view of its uncertain duration). Firms that had obtained credit line commitments from banks called on promises, perhaps also worried that banks that were overcommitted would tighten conditions for drawdowns. Not surprisingly, banks that had written these claims and had few reserves or eligible assets to back them up would have had to look for potentially pricier sources of liquidity, thus hurting their profits and stock price. Ex post, as a result of early and unprecedentedly large Fed intervention, and perhaps because banks were well-capitalized and solvent unlike during the global financial crisis, the dash for cash did not turn into a full-scale panic. Consequently, depositor withdrawals (by firms that were less in need of liquidity, or that were content holding deposits in case of need rather than drawing them down) were limited – a phenomenon that might have even been bolstered by firms redepositing credit line drawdowns with their banks, so they now had firmer access to liquidity. In other words, the events of March 2020 remained simply a warning of what could happen, because only one segment of claims on liquidity, that is, credit lines, was called, the Fed and Congress (through fiscal transfers to individuals and businesses) intervened massively and quickly, and bank solvency was not questioned (unlike in 2007-09).

6.3.3. Other explanations for why banks do not shrink liquidity claims

Finally, why might banks expose themselves to meaningful liquidity risk by not shrinking liquidity claims as reserves shrink? One possibility is institutional hysteresis. For instance, if units are set up by banks to write lines of credit, it may be hard to disband them when the underlying support – the growth of reserves – reverses. The need to maintain corporate and retail borrower relationships may be another reason why banks may be reluctant to cut back on writing lines of credit. As a result, some banks may continue to write claims on aggregate liquidity even though the system may increasingly be short of final liquidity. Until the shortage of aggregate liquidity makes itself felt through disruptions, individual banks may not realize, or have an incentive to ignore, tightening 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.

Could regulation explain bank behavior? There has been substantial liquidity and capital regulation put in place since the Global Financial Crisis. But if regulatory capital and/or liquidity requirements are binding, it would make sense for banks to take advantage of QT to shrink reserves (see, for example, the discussion in Stulz, Taboada, and van Dijk (2022)) and simultaneously also reduce the claims written on liquidity. That they are forced to shrink reserves (at least on average) but not claims on liquidity is hard to attribute to regulation alone.

In particular, US banks have been subject to liquidity coverage ratio (LCR) requirements since 2015, with the largest banks having to meet them on a daily basis. However, if a bank's liability structure were entirely determined by binding LCR constraints, then starting 2015 which is immediately post QE III when aggregate reserves started shrinking, banks should have increased their time deposits while shrinking demand deposits, since deposits with maturity greater than 1 month attract zero run-off rates in LCR calculation. They did not.

A somewhat related explanation is that some other balance-sheet constraint such as capital requirement or high liquidity charges for inter-bank contracts in LCR have reduced the mobility of US bank reserves within the banking system and from banks to non-banks (D'Avernas and Vandeweyer (2021)). If so, run-off rates at specific banks that exceed LCR assumptions would be more likely to trigger liquidity stress in the system, requiring Fed injection of more reserves. However, these explanations are not mutually exclusive to ours, that the financial system had endogenously become more vulnerable to unexpected liquidity shocks given the private issuance of demandable claims in response to the Fed balance sheet expansion.

7. Policy Implications and Conclusions.

Is the financial system better positioned to handle quantitative tightening today? Clearly, the starting point for QT today is different. The Fed does over 2 trillion dollars in reverse repo transactions with the non-banks (typically money market funds), the amount has been rising since March 2021 (see, e.g., Covas (2021)). To the extent that the initial shrinkage of reserves reduces these reverse repo transactions, it should have little consequence for bank-level liquidity mismatches. Our evidence suggests more concern when the aggregate reserve shrinkage starts reducing the reserve holdings of individual banks, especially if banks do not reduce – or are not required to reduce – the claims they have written on liquidity commensurately, as observed in the past QT period. In this case, central banks may need to slow the process of reserve withdrawal (QT). Financial stability and monetary objectives of central bank could then conflict. This suggests policy should focus both on reducing the extent of demandable claims written by banks during QE (vulnerability) and reducing constraints on the flow of inter-bank liquidity during QT (stress).

Policies aimed at reducing the vulnerability via writing of demandable claims require a better understanding of bank behavior. Liquidity regulation, in particular, may need to become more contingent on aggregate circumstances and more forward looking. For instance, individual banks could be required/incentivized to maintain a longer duration of deposits, especially during QE when we observe substantial duration-shortening. Similarly, capital and liquidity stress tests could factor in higher drawdowns on bank liquidity claims in aggregate risk scenarios.

If aggregate liquidity shortages precipitate systemic liquidity stress, then additional liquidity provision by central banks may resolve the problem temporarily but also strengthens the underlying behavior that led to the shortages in the first place. It is best therefore if such intervention is temporary as in the Bank of England's intervention in the pension fund liquidity crisis in October of 2022. Given the crucial role non-banks play in markets and the broader economy, a standing repo facility for non-banks (the Fed opened one primarily for primary dealers in 2021) against high quality collateral, such as the one introduced recently by the Bank of England, has merit. Of course, it is still an open question whether these facilities will suffer from stigma since they are not used frequently, much as with discount window borrowing from the Fed.

Finally, policy measures aimed at ensuring a relatively unconstrained flow of liquidity among banks would also mitigate stress at such times. 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 intra-day overdraft by a bank from the central bank can accentuate the phenomenon of reserve hoarding by surplus banks (Bank of England (2022), Copeland, Duffie, and Yang (2021)). Indeed, regulators could allow some state-contingent tolerance (e.g., +/- 5% or 10% band) in meeting liquidity requirements on a daily basis, while always insisting that requirements be met on average over (say) a fortnight. Such "reserves averaging" could also reduce surplus banks' worries about falling short while arbitraging inter-bank rates in times of stress and induce them to reallocate liquidity rather than hoard it.

There is much scope for research. Understanding the precise determinants of bank behaviors would help inform a judicious calibration of central bank policy responses. Teasing out the relation between the expansion of banking sector's demandable claims and the impediments to transmitting unconventional monetary policy to real activity is another fertile area for future analysis. Finally, our evidence is based entirely around the balance-sheet decisions of the Federal Reserve. What aspects are seen in other systems when the central bank expands its balance sheets?

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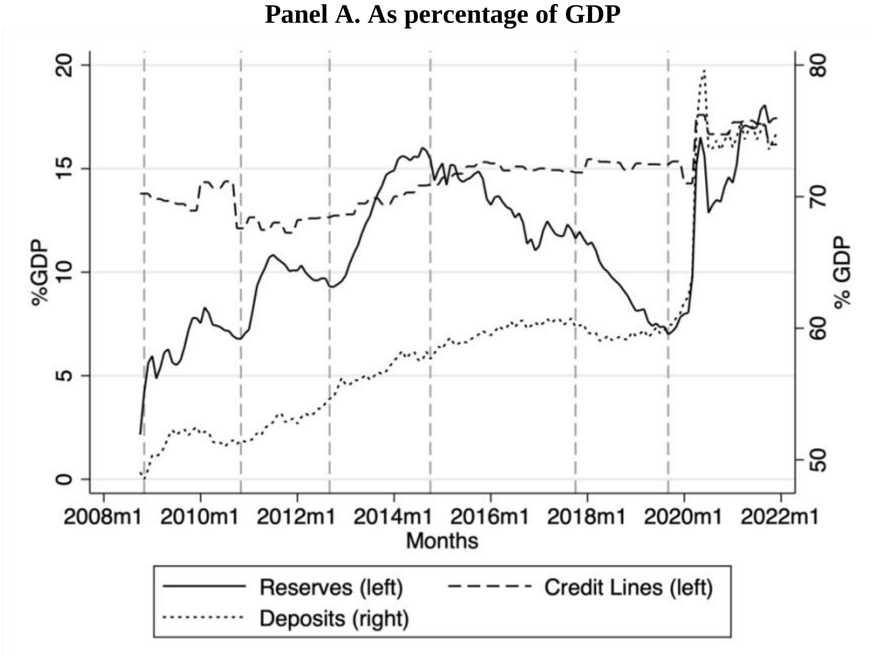
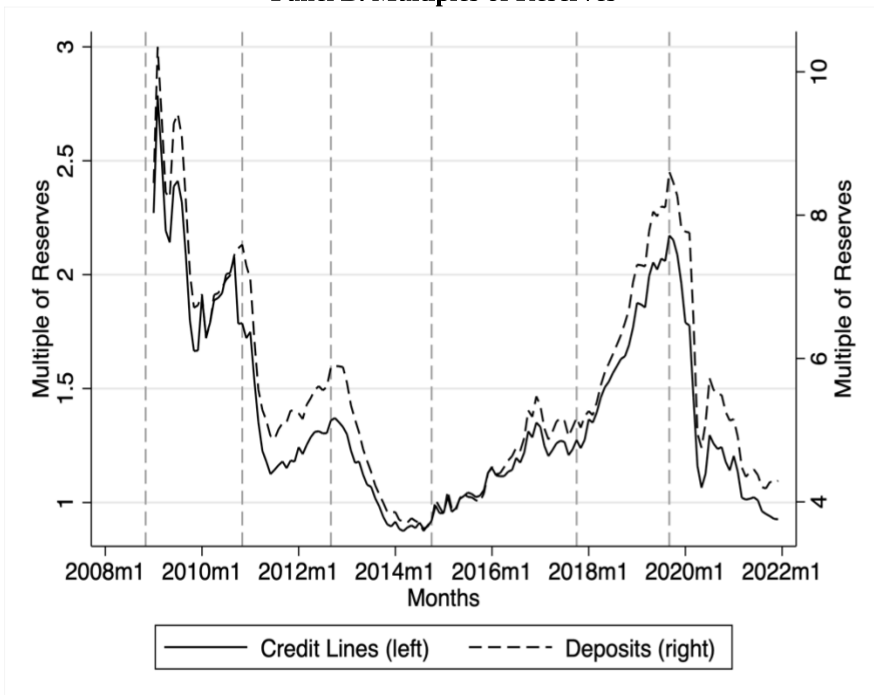
Figure 1. Time-Series of Aggregate Credit Lines, Deposits and Reserves

This figure plots the time-series of credit lines, deposits and reserves of the 2008 to 2021 period using data from the Federal Reserves' Flow of Funds. Panel A plots credit lines (left y-axis), deposits (right y-axis) and reserves (left y-axis) as percentage of gross domestic product (GDP) for all commercial banks. Panel B plots credit lines (left y-axis) and deposits (right y-axis) as multiples of central bank reserves. Panel C shows demand and other liquid deposits (right y-axis), time deposits (left y-axis) and reserves (left y-axis) all as percentage of GDP. Panel D plots time deposits (left y-axis) and demand deposits (right y-axis) as multiple of central bank reserves. Time deposits are the sum of small and large time deposits (H6 and H8 release). Demand and other liquid deposits are from the H6 release. Panel E shows the break-up of demand and time deposits into insured and uninsured time-series using FDIC's Call Reports Data. Estimation of Insured and Uninsured Domestic Deposits are based on the items in the call report schedule RC-O. Insured deposits are defined as deposits lying below the FDIC deposit insurance thresholds of $100,000 before 2008Q4 and $250,000 after 2008Q4. Uninsured deposits are domestic deposits above the aforementioned deposit insurance thresholds and all foreign deposits. Insured deposits are adjusted for the FDIC Transaction Account Guarantee (TAG) program. Split of Time Deposits into Insured vs. Uninsured Deposits are based by splits of Time Deposits by the aforementioned deposit insurance thresholds in schedule RC-E. Non-time Insured and Uninsured deposits are estimated by taking the difference of Total Insured/Uninsured Deposits and Insured/Uninsured Time Deposits respectively. Non-time Deposits are labelled as Demandable Deposits. 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).

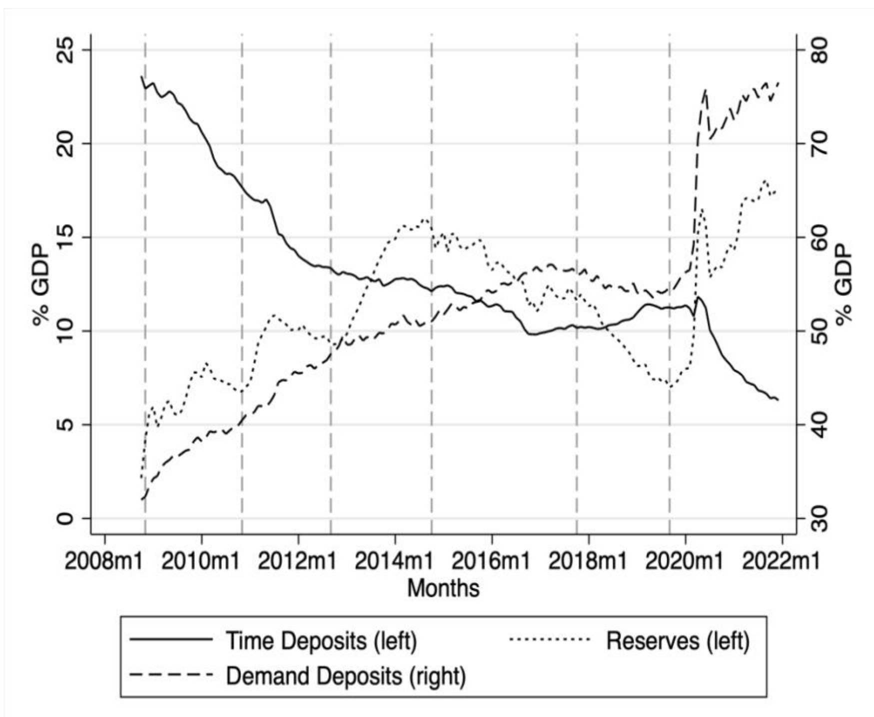
Panel A. As percentage of GDP



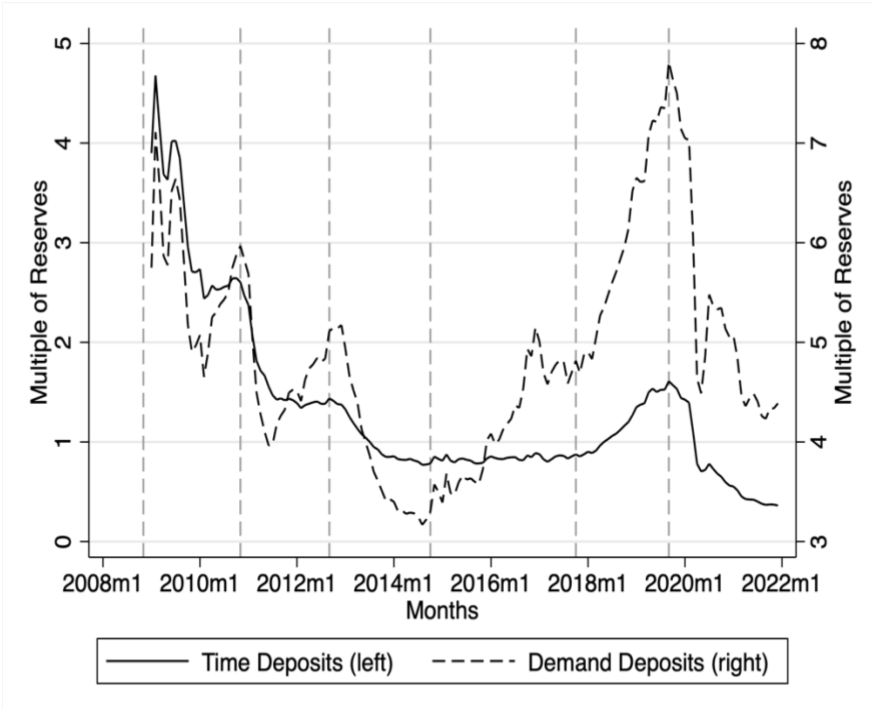
Panel B. Multiples of Reserves



Panel C. Demand (and other Liquid) Deposits and Time Deposits vs. Reserves



Panel D. Demand and Time Deposits as Multiples of Reserves



Panel E. Uninsured and Insured Demand and Time Deposits

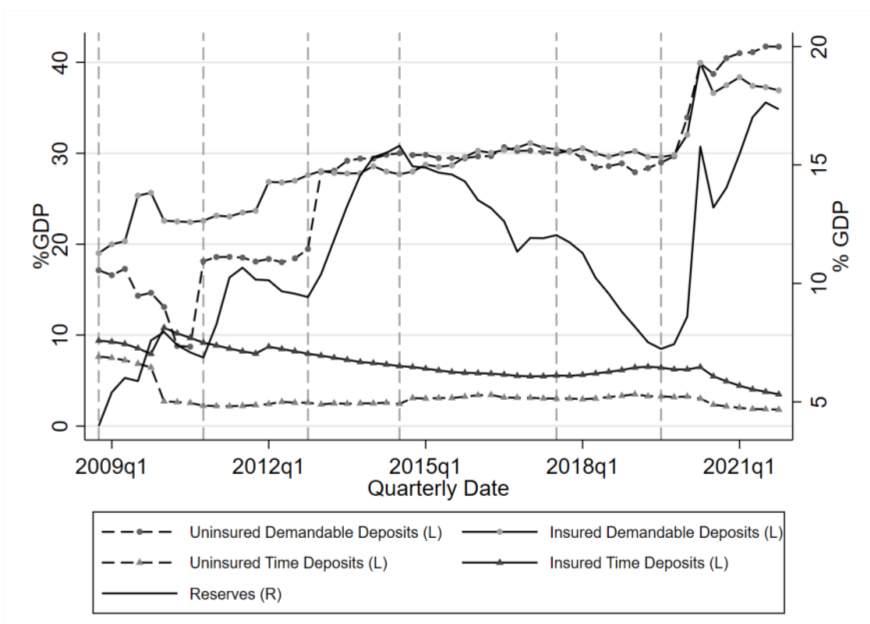
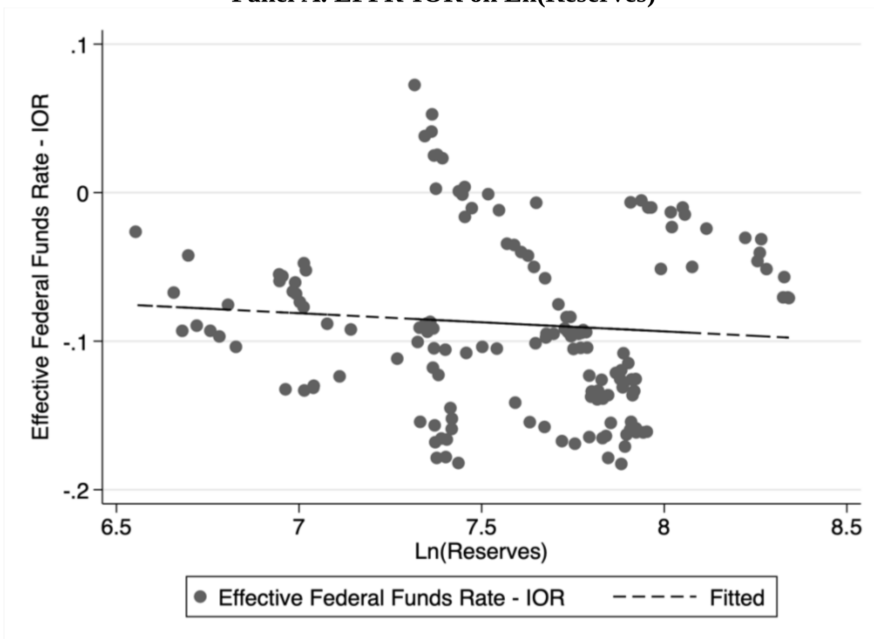


Figure 2: Aggregate Price of Liquidity (EFFR-IOR)

This figure plots the EFFR-IOR on Ln(Reserves) in Panel A, and on the deposit and credit line adjusted reserves in Panel B. All data are monthly data and obtained from the Federal Reserve Economic Data (FRED) online database.

Panel A. EFFR-IOR on Ln(Reserves)



Panel B. EFFR-IOR on Deposit & Credit Line Adjusted Reserves

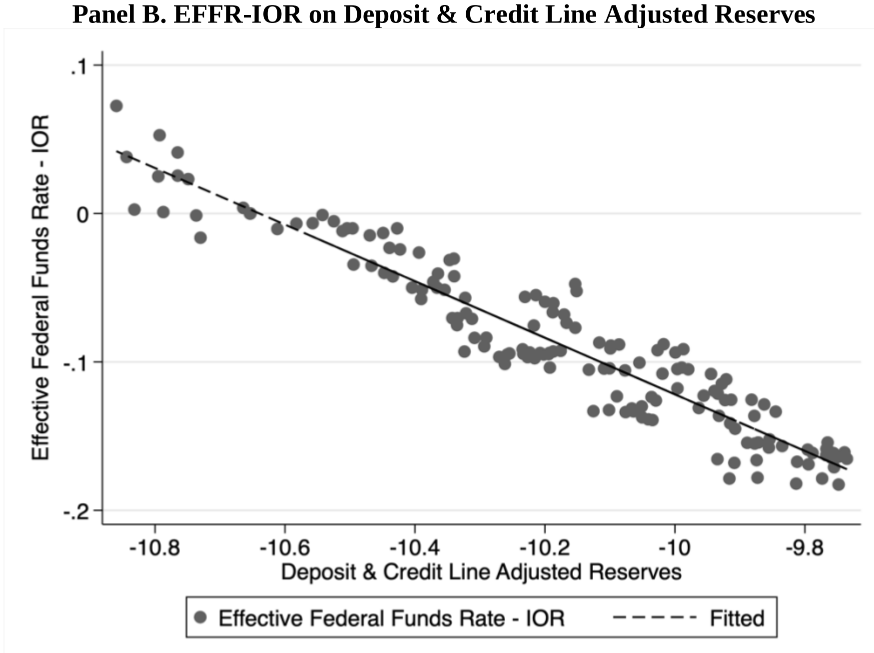
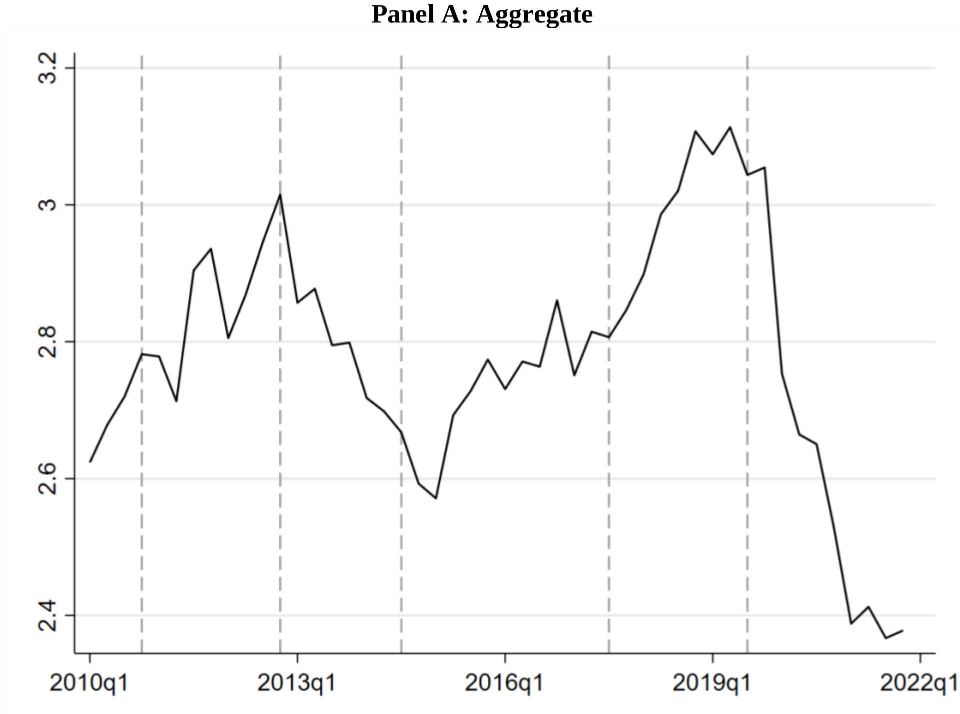


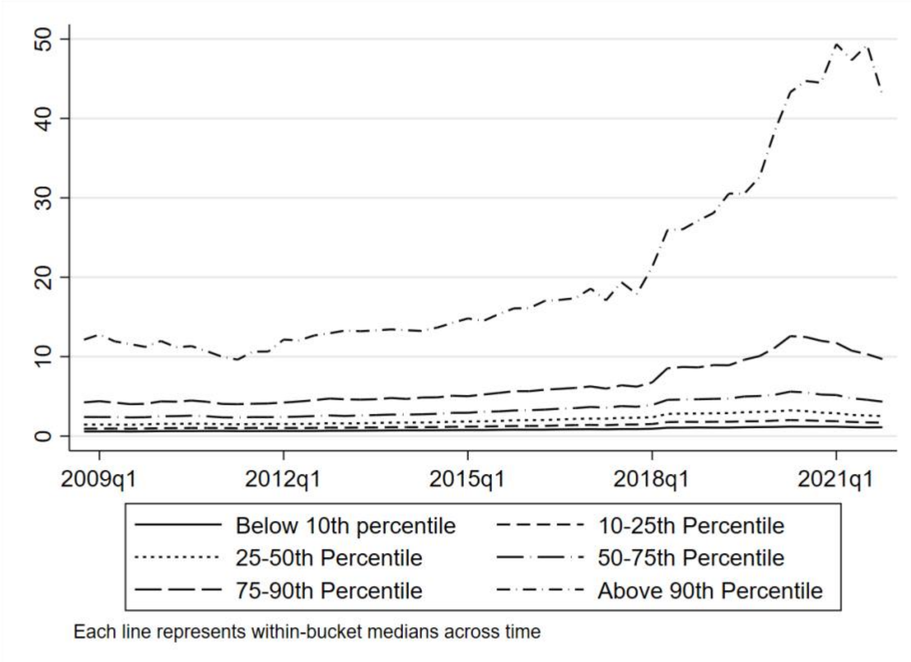
Figure 3. (Credit Lines + Demandable Deposits)/(Reserves + Eligible Assets)

This figure plots the time-series of aggregate credit lines and demandable deposits to reserves and eligible assets ratio as well as it's within-sample distribution across bank holding companies over time. Panel A plots the ratio of the sum of off-balance sheet unused loans or credit lines (RCFDJ457) and aggregate demandable deposits (RCON2210+RCON6810+RCON0352) to the sum of Reserves (RCFD0090) and assets that were eligible at any point for quantitative easing transactions. Eligible assets are estimated from Schedule RC-B of Call Reports (labelled as Eligible Assets for brevity) which is the sum of the banks' holdings of US treasuries, obligations of US Government agencies, securities issued by US States and Political Subdivisions, and agency-backed mortgage-backed securities.. Panel B plots the within-sample and by-time 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles of the demand and savings deposits to reserves and eligible assets ratio estimated at the BHC level. Panel C plots the histogram of distribution of the ratio by different QE periods. Panel D shows the distribution of the ratio by bank-size buckets. We plot the median ratio within the below 10^{th} , 10^{th}-25^{th} percentile, 25^{th}-50^{th} percentile, 50^{th}-75^{th} percentile, 75^{th}-90^{th} percentile and the above 90^{th} percentile bucket by bank assets in a given quarter. QEI-III refers to the period 2008Q4-2014Q3, Post QE-III period refers to 2014Q4-2017Q3 and QT period refers to 2017Q4-2019Q3. All data is sourced from FDIC's Call Reports and aggregated at the bank holding company level.

Panel A: Aggregate



Panel B: Distribution across time



Panel C: Histogram

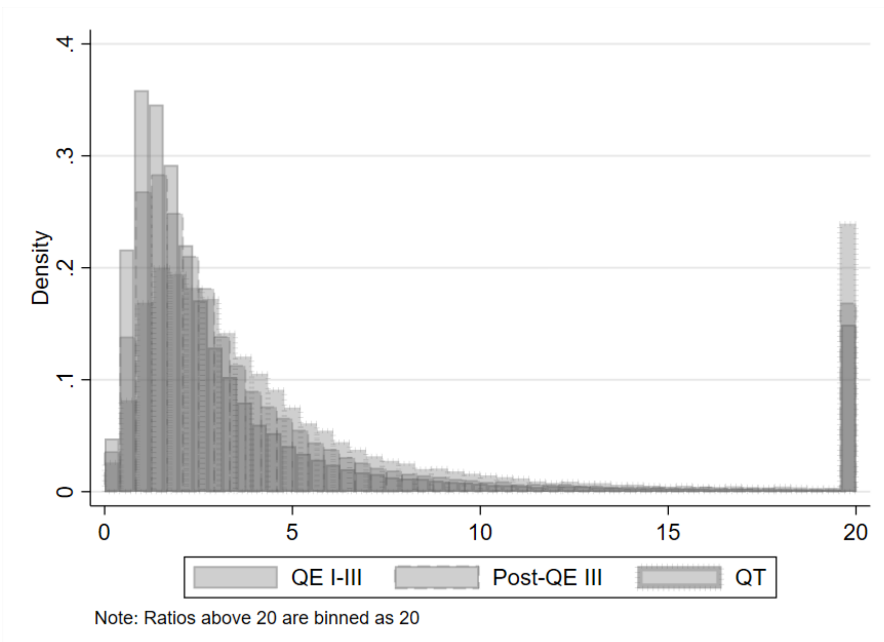
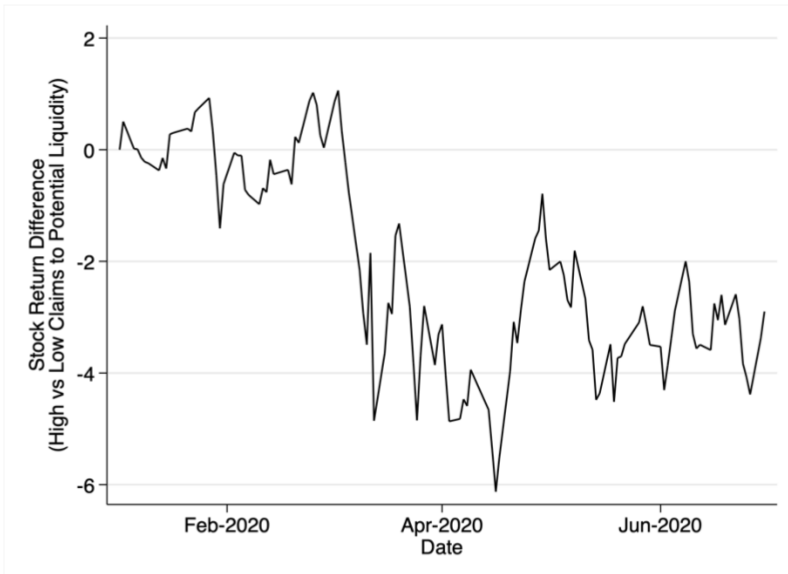


Figure 4. Demandable claims and fragility: The COVID shock

Panel A shows the differential stock return performance (in percentage points) of banks over the 1st January to 30th June 2020 period with high vs. low *Claims to Potential Liquidity* ratio. We measure *Claims to Potential Liquidity* ratio as (Undrawn Credit Lines + Demand Deposits)/(Eligible Assets + Reserves) as of December 31, 2019 and use a median split to distinguish between the two groups of banks. Panel B plots *Gross Drawdowns* relative to bank assets over the Q1 2020 period on *Credit Lines to Potential Liquidity* ratio, defined using only banks' credit line exposures as the demandable claims [(Undrawn Credit Lines)/(Eligible Assets + Reserves).

Panel A. Implications for bank stock returns (1 March – 23 March 2020)



Panel B. Implications for gross drawdowns of credit lines (Q1 2020)

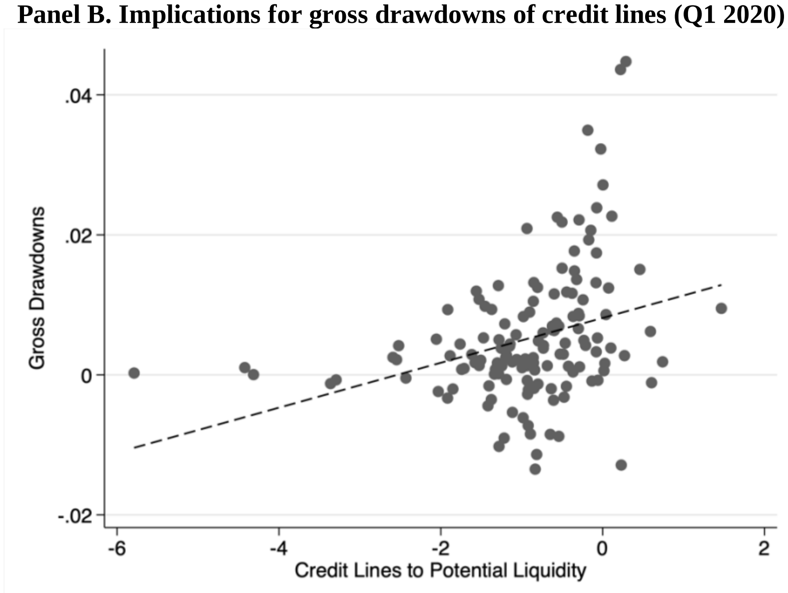


Table 1. Aggregate Deposits and Credit Lines vs Reserves (Time-Series)

This table reports the results from time-series regression of changes in deposits or credit lines on changes in reserves. Panel A Columns (1) to (4) use changes in the natural logarithm of deposits (1), demand deposits (2), time deposits (3) and credit lines (4) as dependent variables. Panel A Columns (5) to (8) uses changes in the level of the same variables. Demand deposits is the sum of demand and other liquid deposits from the H.6 release. Time deposits is the sum of small and large time deposits (H6 and H8 release). Panel B contains the results of regressing change in Ln(Deposits) against Change in Ln(Reserves) and Change in Ln(Household Financial Assets net of Deposits) as in LS-VJ (2022). All changes are calculated over a 12-month period. *Change in Ln(Reserves)* is the 12-month change in the natural logarithm of reserves, *Ln(Reserves)$_{t-12}$* is the 12-month lag of *Ln(Reserves)*. *Change in Reserves* is the 12-month change in the level of reserves and *Reserves$_{t-12}$* is the corresponding 12-month lagged variable. Standard errors (Newey-West) account for auto-correlation up to 12 months. Standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Panel A

	(1) Δ Ln(Deposits)	(2) Δ Ln(Demand Deposits)	(3) Δ Ln(Time Deposits)	(4) Δ Ln(Credit Lines)	(5) Δ Deposits	(6) Δ Demand Deposits	(7) Δ Time Deposits	(8) Δ Credit Lines
Δ Ln(Reserves)	0.137***	0.180***	-0.242**	0.0802***				
	(0.0368)	(0.0541)	(0.114)	(0.0282)				
Ln(Reserves)$_{t-12}$	0.0503***	0.0136	-0.0251	0.0882***				
	(0.0140)	(0.0227)	(0.0702)	(0.0323)				
Δ Reserves					0.999***	1.358***	-0.224**	0.147***
					(0.242)	(0.314)	(0.0932)	(0.0392)
Reserves$_{t-12}$					0.329***	0.343***	0.0726	0.146***
					(0.0691)	(0.0838)	(0.0684)	(0.0399)
Constant	-0.327***	-0.0265	0.163	-0.616**	-88.97	-15.98	-220.0	-162.4*
	(0.106)	(0.172)	(0.533)	(0.249)	(169.3)	(164.0)	(150.2)	(91.28)
Obs	147	147	147	147	147	147	147	147
R-sq	0.592	0.589	0.296	0.232	0.663	0.673	0.334	0.416

Panel B

	(1)	(2)	(5)	(6)
	ΔLn(Deposits)		ΔLn(Demand & Other Liquid Deposits)	
ΔLn(Reserves)	0.0877**	0.0865**	0.160***	0.161***
	(0.0383)	(0.0385)	(0.0394)	(0.0384)
ΔLn(Fin Assets - Deposits)	0.160		0.157	
	(0.116)		(0.147)	
ΔLn(Fin Assets – Insured Deposits)		0.159		0.125
		(0.110)		(0.148)
Constant	0.0459***	0.0457***	0.0670***	0.0688***
	(0.00870)	(0.00875)	(0.0106)	(0.0104)
Obs	146	146	146	146
R-Sq	0.457	0.462	0.597	0.593
Reg-Type	Newey-West	Newey-West	Newey-West	Newey-West
# Lags	12	12	12	12

Table 2. Aggregate Price of Liquidity (Time-Series)

This table reports the results from time-series regression of the Effective Federal Fund Rate (EFFR) minus Interest on Reserves (IOR) on reserve, deposits and credit lines. *Ln(Reserves)* is the natural logarithm of reserves from the H.6 release, *Ln(Demand Deposits)* is the natural logarithm of the sum of demand and other liquid deposits from the H.6 release. *Ln(Time Deposits)* is the sum of small and large time deposits (H6 and H8 release). *Ln(Credit Lines)* is the natural logarithm of unused (other) loan commitments from FDIC insured banks (including corporate credit lines but not credit card commitments). *Ln(Usage)* is the natural logarithm of quarterly drawn credit lines of U.S. publicly listed firms sourced from Capital IQ. Panel A reports the regression of change in EFFR-IOR on change in levels of reserves, deposits (and its constituents), and credit lines. Columns (1)-(3) use monthly data whereas columns (4)-(8) use quarterly frequency as credit lines data is available quarterly on FRED. Panel B, Columns (2) and (3) represent regressions of EFFR-IOR on *US Banks' Ln(Reserves*), calculated as the aggregate sum of cash and balances due from Federal Reserve banks (RCFD0090) and *Non-US Banks' Ln(Reserves)* calculated as the difference of *Total Reserves* in H.6. Release and the aggregate sum of RCFD0090. In Column (4) along with the previous independent variables, we regress EFFR-IOR on *US Banks' Ln(Deposits)* ,estimated as the aggregate sum of domestic deposits (RCON2200), and *Non-US Banks' Ln(Deposits)* calculated as the difference between Total Deposits of H.6 and H.8 release and aggregate sum of RCON2200. Column (5) splits deposits into demandable and time depostis. Standard errors (Newey-West) account for auto-correlation up to 12 months. * p<0.1, ** p<0.05, *** p<0.01

Panel A

	(1) Δ(EFFR-IOR)	(2) Δ(EFFR-IOR)	(3) Δ(EFFR-IOR)	(4) Δ(EFFR-IOR)	(5) Δ(EFFR-IOR)	(6) Δ(EFFR-IOR)
ΔLn(Reserves)	-0.155***	-0.188***	-0.186***	-0.161***	-0.173***	-0.220***
	(0.0319)	(0.0368)	(0.0308)	(0.0290)	(0.0313)	(0.0213)
ΔLn(Total Deposits)		0.474**				
		(0.211)				
ΔLn(Demandable Deposits)			0.344***			0.376***
			(0.125)			(0.0961)
ΔLn(Time Deposits)			-0.00215			0.0460
			(0.0612)			(0.0610)
ΔLn(Credit Lines)				0.140**	0.183***	0.170***
				(0.0523)	(0.0496)	(0.0482)
ΔLn(Usage)					-0.0157***	-0.0123*
					(0.00518)	(0.00660)
Constant	0.00173**	-0.000692	-0.000857	0.00325	0.00318	-0.00385*
	(0.000751)	(0.00120)	(0.00130)	(0.00196)	(0.00200)	(0.00210)
Obs	154	154	154	51	51	51
R-sq	0.277	0.305	0.314	0.521	0.561	0.607
Reg-Type	OLS	OLS	OLS	OLS	OLS	OLS
Standard-Error	Newey-West	Newey-West	Newey-West	Newey-West	Newey-West	Newey-West
#Lags	12	12	12	4	4	4

Panel B

	(1) ΔEFFR-IOR	(2) ΔEFFR-IOR	(3) ΔEFFR-IOR	(4) ΔEFFR-IOR	(5) ΔEFFR-IOR
ΔLn(Reserves)	-0.174***				
	(0.0327)				
ΔUS-Banks Ln(Reserves)		-0.133***		-0.0658***	-0.133***
		(0.0313)		(0.0223)	(0.0300)
ΔNon-US-Banks Ln(Reserves)			-0.116***	-0.113***	-0.118***
			(0.0303)	(0.0314)	(0.0314)
ΔUS-Banks Ln(Deposits)				-0.0484	
				(0.200)	
ΔNon-US-Banks Ln(Deposits)				-0.00621	-0.00000277
				(0.00770)	(0.00631)
ΔUS-Banks Ln(Demandable Deposits)					0.502***
					(0.184)
ΔUS-Banks Ln(Time Deposits)					0.110
					(0.0839)
Constant	0.0248***	0.0212***	0.0159*	0.0276*	-0.00935
	(0.00554)	(0.00664)	(0.00817)	(0.0157)	(0.0153)
Obs	48	48	48	46	46
R-Sq	0.690	0.498	0.474	0.754	0.780
Reg-Type	OLS	OLS	OLS	OLS	OLS
Data Frequency	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly
Standard-Error	Newey-West	Newey-West	Newey-West	Newey-West	Newey-West
# Lags	4	4	4	4	4

Table 3: Effect of Reserves on Deposit Quantities – Second Stage (just keep demandable and time deposits with controls)

The table shows OLS and the second-stage of 2SLS IV regressions of *Depoist types* as 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). Panel A uses the Ln(*Demand and Savings deposits*)(RCON2210+RCON6810+RCON0352), Panel B uses Ln(*Time Deposits)* (RCON6648 + RCONJ473 + RCONJ474) or (RCON6648+RCON2604) as the dependent variables. Panel C and D use Uninsured Time and Non-time Deposits as the dependent variable. $\Delta Y = Y_t - Y_{t-4}$. Panels C and D represent the second-stage results of uninsured non-time and time deposits. Estimation of Insured and Uninsured Domestic Deposits are based on the items in the call report schedule RC-O. Insured deposits are defined as deposits lying below the FDIC deposit insurance thresholds of $100,000 before 2008Q4 and $250,000 after 2008Q4. Uninsured deposits are domestic deposits above the aforementioned deposit insurance thresholds and all foreign deposits. Insured deposits are adjusted for the FDIC Transaction Account Guarantee (TAG) program. Split of Time Deposits into Insured vs. Uninsured Deposits are based by splits of Time Deposits by the aforementioned deposit insurance thresholds in schedule RC-E. Non-time Insured and Uninsured deposits are estimated by taking the difference of Total Insured/Uninsured Deposits and Insured/Uninsured Time Deposits respectively. 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 2001 Q1 – 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 + QT period 2014Q4 - 2019Q3. In all second-stage regressions, Δ*Ln(Reserves)* is instrumented by the reserve instrument (z^R_{it}): *Growth in Aggregate Reserves × Average Lagged Share in Reserves over the previous 4 quarters*. 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. * p<0.1, ** p<0.05, *** p<0.01

Panel A: ΔLn(Demand + Savings Deposits)

Panel A.1: OLS	(1) ΔLn(Demand + Savings Deposits)	(2) ΔLn(Demand + Savings Deposits)	(3) ΔLn(Demand + Savings Deposits)	(4) ΔLn(Demand + Savings Deposits)
ΔLn(Reserves)	0.0112***	0.0138***	0.0138***	0.0162***
	(0.00172)	(0.00258)	(0.00283)	(0.00122)
Newey-West s.e.	(0.00130)	(0.00206)	(0.00223)	(0.00102)
N	117076	50948	43149	32258
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Reg Type	OLS	OLS	OLS	OLS
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3
Panel A.2: IV	(1) ΔLn(Demand + Savings Deposits)	(2) ΔLn(Demand + Savings Deposits)	(3) ΔLn(Demand + Savings Deposits)	(4) ΔLn(Demand + Savings Deposits)
ΔLn(Reserves)	0.135***	0.122***	0.116***	0.525
	(0.0185)	(0.0305)	(0.0322)	(0.457)
Obs	115533	50921	43130	30770
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Bank only
Controls	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

Panel B: ΔLn(Time Deposits)

Panel B.1: OLS	(1) ΔLn(Time Deposits)	(2) ΔLn(Time Deposits)	(3) ΔLn(Time Deposits)	(4) ΔLn(Time Deposits)
ΔLn(Reserves)	0.0122***	0.0133***	0.0130***	0.0160***
	(0.00125)	(0.00173)	(0.00188)	(0.00123)
Newey-West s.e.	(0.000997)	(0.00153)	(0.00162)	(0.00129)
N	116227	50579	42872	32037
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Reg Type	OLS	OLS	OLS	OLS
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3
Panel B.2: IV	(1) ΔLn(Time Deposits)	(2) ΔLn(Time Deposits)	(3) ΔLn(Time Deposits)	(4) ΔLn(Time Deposits)
ΔLn(Reserves)	-0.164***	-0.145***	-0.158***	0.954
	(0.0445)	(0.0441)	(0.0334)	(0.807)
Obs	114689	50555	42853	30551
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

Panel C: ΔLn(Uninsured Non-Time Deposits)

Panel C.1: OLS	(1)	(2)	(3)	(4)
		ΔLn(Uninsured Non-Time Deposits)		
ΔLn(Reserves)	0.0245***	0.0218***	0.0211***	0.0345***
	(0.00252)	(0.00406)	(0.00469)	(0.00254)
Obs	96586	38694	31061	31329
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Overall: 2001 Q1 - 2021 Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT: 2014Q4-2019Q3
Panel C.2: IV	(1)	(2)	(3)	(4)
		ΔLn(Uninsured Non-Time Deposits)		
ΔLn(Reserves)	0.0996***	0.105***	0.111***	-0.243
	(0.0213)	(0.0240)	(0.0268)	(0.430)
Obs	95114	38676	31051	29898
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Overall: 2001 Q1 - 2021 Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT: 2014Q4-2019Q3

Panel D: ΔLn(Uninsured Time Deposits)

Panel D.1: OLS	(1)	(2)	(3)	(4)
		ΔLn(Uninsured Time Deposits)		
ΔLn(Reserves)	0.0107***	0.00991***	0.00937***	0.0196***
	(0.00140)	(0.00192)	(0.00208)	(0.00236)
Obs	115198	49918	42292	31733
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Overall: 2001 Q1 - 2021 Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT: 2014Q4-2019Q3
Panel D.2: IV	(1)	(2)	(3)	(4)
		ΔLn(Uninsured Time Deposits)		
ΔLn(Reserves)	-0.179***	-0.181***	-0.190***	-0.0172
	(0.0512)	(0.0524)	(0.0363)	(0.569)
Obs	113664	49894	42273	30251
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Overall: 2001 Q1 - 2021 Q4	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 Credit Line Originations – 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 investment-grade and unrated firms in the U.S. as the dependent variable against change in bank's reserve holdings aggregated to the BHC level. 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). Change is the contemporary level minus the deposit level lagged by 4 quarters. Columns (1) represent the regressions on the overall sample ranging 2001 Q1 – 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 + QT period: 2014Q4 - 2019Q3. We report the second stage where Δ *Ln(Reserves)* is instrumented by *Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous 4 quarters* (z^R_{it}). 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. Newey West SEs correcting for autocorrelation up to four quarters are also reported in Panel A. * p<0.1, ** p<0.05, *** p<0.01

Panel A. OLS

	(1) Δ Ln(Credit Lines)	(2) Δ Ln(Credit Lines)	(3) Δ Ln(Credit Lines)	(4) Δ Ln(Credit Lines)
Δ Ln(Reserves)	-0.0492***	-0.0151	-0.0309*	-0.131
	(0.0151)	(0.0172)	(0.0177)	(0.0801)
Obs	2263	910	679	575
R-sq	0.191	0.273	0.210	0.121
Time-FE	Y	Y	Y	Y
Time Clustered SEs	Y	Y	Y	Y
Reg Type	OLS	OLS	OLS	OLS
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

Panel B. IV

	(1) Δ Ln(Credit Lines)	(2) Δ Ln(Credit Lines)	(3) Δ Ln(Credit Lines)	(4) Δ Ln(Credit Lines)
Δ Ln(Reserves)	0.0902***	0.0926**	0.0778*	0.429
	(0.0289)	(0.0409)	(0.0398)	(1.169)
Obs	2263	910	679	575
Time-FE	Y	Y	Y	Y
Time Clustered SEs	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

Table 5: Effect of Reserves and Deposits on CD Rate – Money Market Savings Rate Spread: Second Stage

The table shows the second stage of 2SLS IV regressions of *3, 12, 18 and 24-month CD – Money Market (MM) savings spread* against bank-level *Ln(Total Deposits)* and *Ln(Reserves)*. Panel A represents the overall sample. Panel B represents the sub-sample QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4. Panel C represents the sub-sample QE I-III: 2008Q4 - 2014Q3. Panel D shows results for the Post-QE III + QT2014Q4 - 2019Q3 CD and Money Market (MM) savings rates are sourced from *S&P Global's RateWatch* deposit data. 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). *Ln(Reserves)* are instrumented with *Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous 4 quarters* (z^{R}_{it}). *Ln(Total Deposits)* instrumented with the *Deposit Growth Instrument* (z^{D}_{it}) 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. The sample period is 2001 Q1 – 2021 Q4. * p<0.1, ** p<0.05, *** p<0.01

Panel A: Overall Period: 2001Q1 – 2021Q4

	(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
Ln(Reserves)	-0.134***	-0.0467	-0.209***	-0.108***
	(0.0327)	(0.0567)	(0.0341)	(0.0253)
Ln(Total Deposits)	0.141	0.306	0.882	0.352
	(0.525)	(0.481)	(0.550)	(0.509)
N	84006	89703	75179	88356
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Overall: 2001Q1-2021Q4			

Panel B: QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4-2021Q4

	(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
Ln(Reserves)	-0.173***	-0.0543*	-0.242*	-0.120**
	(0.0463)	(0.0299)	(0.120)	(0.0585)
Ln(Total Deposits)	0.143	0.466	0.314	0.421
	(0.537)	(0.425)	(0.743)	(0.473)
N	39347	42084	34972	41432
R-sq	-0.453	-0.0933	-1.133	-0.118
Time-FE	Y	Y	Y	Y
Two-way Clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	QE I-III+Pandemic QE: 20008Q4-2014Q3 + 2019Q4-2021Q4			

Panel C: QEI-III: 2008Q4 - 2014Q3

	(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
Ln(Reserves)	-0.175***	-0.0493	-0.244**	-0.122**
	(0.0392)	(0.0324)	(0.114)	(0.0536)
Ln(Total Deposits)	0.669	0.776*	0.854	0.791*
	(0.476)	(0.410)	(0.634)	(0.447)
N	34578	36818	30526	36200
Time-FE	Y	Y	Y	Y
Two-way clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	QE I-III: 20008Q4-2014Q3			

Panel D: Post-QEIII + QT: 2014Q4 - 2019Q3

	(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
Ln(Reserves)	0.486	0.0118	-0.257	0.230
	(0.358)	(0.650)	(0.515)	(0.605)
Ln(Total Deposits)	-0.984	-0.238	0.635	-0.993
	(1.720)	(2.358)	(1.770)	(2.225)
N	21426	23331	19429	23039
Time-FE	Y	Y	Y	Y
Two-way clustering	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Period	Post-QE III+QT: 2014Q4-2019Q3			

Table 6. Effect of Reserves and Credit Line Originations on AISD/AISU: Second Stage

The table shows the second-stage of 2SLS IV regressions of the price of credit lines measured as the *AISD/AISU*-ratio of credit lines originated to investment-grade and unrated firms in the U.S. as the dependent variable on a bank's reserve holdings and credit lines aggregated to the Bank Holding Company (BHC) level. Reserve data is sourced from FDIC's Call Report item RCON0090, credit line originations from the Refinitiv LoanConnector database. Reserves are cash and balances due from Federal Reserve Banks at the consolidated bank-level (RCFD0090) and are instrumented with the *Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous 4 quarters* (z^{R}_{it}). All specifications control for bank and time-FE. Column (1) represent the regressions on the overall sample ranging 2001 Q1 – 2021 Q4. Column (2) represent QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Column (3) represent the QEI-III period: 2008Q4 - 2014Q3. Column (4) show results for the Post-QE III + QT period: 2014Q4 - 2019Q3. We instrument *Ln(Credit Lines)* with *Ln(Credit Lines)*$_{it-1}$ *x ELP*$_{t-1}$ (z^{CL}_{it}). 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. * p<0.1, ** p<0.05, *** p<0.01

	(1) AISD/AISU	(2) AISD/AISU	(3) AISD/AISU	(4) AISD/AISU
Ln(Reserves)	-0.848**	-1.676***	-1.751***	-8.762
	(0.406)	(0.457)	(0.491)	(12.88)
Ln(Credit Lines)	-0.328	-2.531	-2.793	-4.046
	(0.920)	(1.671)	(2.072)	(6.071)
Obs	2200	767	714	586
Bank & Time-FE	Y	Y	Y	Y
Two-way Clusterings	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Controls	Y	Y	Y	Y
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

Table 7. Pennies in front of a Steamroller?

We estimate *Gains to Claims* as the relative benefit in switching from Time to Demandable deposits and issuing more credit lines when the Federal Reserve expanded its balance sheet during the time period 2010Q1 to 2014Q3. We use the formula: Gains to Claims = ¼(ΔReserves $_{QE\rightarrow QT}$ × IOR - ΔDemandable Deposits $_{QE\rightarrow QT}$ × Money Market Savings Rate - ΔTime Deposits $_{QE\rightarrow QT}$ × 12 month CD Rate + 1/(1-Drawdown Rate) × ΔUnused Credit Lines $_{QE\rightarrow QT}$ × (All in Spread Drawn × Drawdown Rate + All in Spread Undrawn × (1-Drawdown Rate)), where $\Delta Y = Y_{2014Q3} - Y_{2010Q1}$ for all variables. Data on Reserves, Demandable Deposits, Time Deposits and Unused Credit Lines is from Call Reports. Data on *12-month CD rate* and *Money Market Savings Rate* is from S&P Global's RateWatch database. *Drawdown Rate*, *All in Spread Drawn (AISD)* and *All in Spread Undrawn (AISU)* are from LPC DealScan database. The variable *Reserves* is item RCFD0090. *Demandable Deposits* is defined as RCON2210+RCON6810+RCON0352, *Time Deposits are* RCON6648 + RCONJ473 + RCONJ474 or RCON6648+RCON2604 and *Unused Credit Lines* is item RCFDJ457. Panel A takes the bank-specific *AISD* and *AISU* ratio into the calculation. For panel B we apply a *AISD* of 200bps and *AISU* of 30bps for all banks. We assume a uniform drawdown rate of 20%. Median net income is estimated as the median quarterly change in item RIAD4340 within a year in Call Reports during the period 2010Q1 – 2014Q3. As ITEM RIAD4340 is cumulative net income within a year, we estimate the change from the previous quarter. We only keep banks with a positive median net income.

	Panel A: BHC-level					**Panel B: Bank-level**				
	Mean	P10	P50	P90	N	Mean	P10	P50	P90	N
Gains to Claims/NI (%)	2.86	-1.77	2.81	6.92	23	12.7	-9.61	0.384	12	1328
Gains to Claims (1000$)	44097	-1223	7539	109613	23	650	-223	3.86	160	1328
Median Net Income (NI) (1000$)	765595	33209	219018	3114000	23	17578	321	1354	8287	1328
ΔTime Deposit (1000$)	-1.19×10^7	-2.72×10^7	-3333376	2874335	23	-277748	-237471	-42923	45346	1328
ΔDemandable Deposit (1000$)	7.9×10^7	2993870	2.24×10^7	3.32×10^8	23	1875346	21644	115986	897546	1328
ΔUnused Credit Lines (1000$)	2.65×10^7	858738	3908573	8.3×10^7	23	541820	-7438	5852	122020	1328
ΔReserves (1000$)	2.28×10^7	-3131823	23449	2.58×10^7	23	379095	-48669	141	46831	1328
Money Market Savings Rate (%)	0.09	0.03	0.088	0.189	23	0.194	0.05	0.15	0.382	1328
12-month CD Rate (%)	0.12	0.05	0.1	0.2	23	0.334	0.15	0.3	0.55	1328
AISD (%)	2.07	1.57	2.01	2.55	23					
AISU(%)	.29	.206	.273	.4	23					
IOR (%)	0.25	0.25	0.25	0.25	23	0.25	0.25	0.25	0.25	1328

Table 8. Demandable claims and fragility: The COVID shock

This table reports the results of OLS regressions of U.S. *banks' excess stock returns over the 1/1/2020 – 2/28/2020* period (column (1)), or over the *3/1/2020 – 3/23/2020 period* (columns (2)-(4)), and *Gross Drawdowns* relative to assets over the period Q1 2020 (columns (5)-(6)) on *Claims to Potential Liquidity* ratio as (Undrawn Credit Lines + Demand Deposits)/(Eligible Assets + Reserves) as of December 31, 2019, or on *Credit Lines to Potential Liquidity* ratio, defined using only banks' credit line exposures as the demandable claims [(Undrawn Credit Lines)/(Eligible Assets + Reserves), or *Demandable Deposits to Potential Liquidity* ratio, defined using only banks' demandable deposits as the demandable claims [(Demandable Deposits)/(Eligible Assets + Reserves). Stock returns over a period are measured as cumulative log excess returns $\log(1 + r - r_f)$, where r is the simple daily return (based on the daily closing price, adjusted for total return factor and daily adjustment factor), and r_f is the 1-month daily Treasury-bill rate. p-values based on robust standard errors are in parentheses. We do not report the coefficients on control variables for brevity. All variables are defined in the Online Appendix.

	(1) Excess Returns *1/1/2020 – 2/28/2020*	(2) Excess Returns *3/1/2020 – 3/23/2020*	(3) Excess Returns *3/1/2020 – 3/23/2020*	(4) Excess Returns *3/1/2020 – 3/23/2020*	(5) Gross Drawdowns Q1 2020	(6) Gross Drawdowns Q1 2020
Claims to Potential Liquidity	0.00132	-0.0159**				
	(0.210)	(0.024)				
Credit Lines to Potential Liquidity			-0.0960***		0.0049***	
			(0.000)		(0.002)	
Demandable Deposits to Potential Liquidity				-0.0165*		0.0003
				(0.053)		(0.403)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.307	0.443	0.463	0.435	0.426	0.375
Number obs.	143	143	138	143	138	143