Liquidity Dependence: Why Shrinking Central Bank Balance Sheets is an Uphill Task

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1. Introduction

As central banks start reducing the size of their balance sheets, it is important to ask if this will be an entirely benign process. At one level, it seems relatively innocuous. The central bank will either let bonds on its balance sheet mature or sell them, thus extinguishing reserves, its liabilities. While there are concerns about whether bond prices will have to adjust to draw in sufficient replacement demand and whether the swap of bonds for reserves with the private sector will enhance the term spread, these possible price adjustments seem natural consequences to the rebalancing of portfolios between the central bank and the private sector. Yet, when the Federal Reserve (Fed) embarked the last time around on quantitative tightening–that is, a shrinkage of reserves– financial markets in the U.S. experienced two episodes of significant liquidity stress: in September 2019 and again in March 2020 (by when the Fed had already restarted injecting liquidity). 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. The latter is attributed to the panic surrounding the COVID-19 outbreak. Notwithstanding the relevance of these proximate causes, it is reasonable to 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, and as a result, dependent on further liquidity interventions by the Fed.

We start with the theoretical framework of Acharya and Rajan (2022). They argue that when the central bank expands its balance sheet, the commercial banking sector, which has to (typically) hold the reserves the central bank issues to finance its asset purchases, tends to finance them with demandable deposits.[1] 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), which typically coincides with low interest rates. Indeed, commercial banks also issue other claims on liquidity such as lines of credit–the reserve holdings become a backstop for commercial banks to issue claims on liquidity that may not all materialize at the same time in the normal course, allowing commercial banks to generate higher fees (see Kashyap, Rajan, and Stein (2002)).[2] Net of these claims, therefore, there is far less spare liquidity in the system for stressed times than might be suggested by the increase in commercial bank holdings of reserves.

Given this backdrop, we seek to answer the following important questions: How does the Fed balance sheet expansion affect the size and demandable deposit base of the banking sector? Do other demandable liabilities issued by banks, such as credit lines to corporations, also grow with reserves? If banking sector liabilities grow, do they reverse seamlessly when the Fed shrinks its balance sheet? Relatedly, is the system better placed today to sustain a shrinkage of the Fed's balance sheet? Note that our focus on claims on liquidity is different from the standard analysis of the effects of QE, which has focused on how changes in bank assets leads to changes in real activity. This ignores, however, the liability side of the banking sector and changes there, which is where the key concerns lie from a financial stability standpoint.

We start our empirical investigation by first documenting that during the initial period of Fed balance sheet expansion–QE I from

November 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 increased, while time deposits decreased. Importantly, the shorter maturity, i.e., more demandable, claims written 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, as we show, 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.

There is a commensurate effect on the aggregate pricing of liquidity. As Lopez-Salido and Vissing-Jorgensen (2022) argue, the effective fed funds rate less the interest on excess reserves is a measure of the price of claims on reserves or liquidity. When this is regressed on aggregate reserves and aggregate commercial bank deposits, there is a statistically significant influence of *both* reserves and deposits on the price of liquidity, with more reserves reducing it and more deposits increasing it. Put differently, we cannot account for the pricing of aggregate liquidity fully without adjusting for the claims on liquidity that commercial banks issue as their reserve holdings expand. We build on the work of Lopez-Salido and Vissing-Jorgensen (2022) by showing that the lines of credit commercial banks issue are another effective proxy for the claims on liquidity that are issued, and they play a similar role to deposits when introduced in the pricing regression. Of course, the model has the best fit when both are in the pricing regression, along with reserves. We show that these results also hold in differences, alleviating concerns about co-integration. The bottom line is that aggregate claims on liquidity need to be accounted for before we can judge how much spare liquidity the system has.

We then turn to the cross section of banks over time to establish whether the macro patterns are replicated at the micro level. This would provide stronger causal inference on the impact of reserves on the banking sector's demandable liabilities and help rule out confounding factors such as gross domestic product (GDP) growth and the level of interest rates. We find that during the periods of QE, banks that obtain more reserves (instrumented to examine the exogenous component) 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; if anything, they continue increasing them. So there seems to be some momentum in bank behavior as reserves expand, which continues as reserves shrink.

What about bank-level pricing of liquidity? One 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; 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. We find that during periods of QE, banks with exogenously (i.e., instrumented) greater reserves tend to reduce the term spread and banks with exogenously (i.e., also instrumented) greater deposits tend to increase their term spread, consistent with the spread reflecting their need for liquidity. Interestingly again, we find that these patterns do not persist in the period between when the first sequence of QE ends in October 2014 and the central bank starts expanding its balance sheet again in September 2019. Put differently, banks that lose reserves do not raise term spreads and banks that lose deposits 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.

Liquidity dependence, i.e., the asymmetric response of commercial banks to QE (expand claims on liquidity) and QT (not shrink claims on liquidity) may explain why the financial system became more prone to liquidity accidents in 2019. No doubt, the accumulation of reserves in the Treasury account and the uneven distribution of remaining reserves across banks (see Copeland, Duffie and Yang (2021) or D'Avernas and Vandeweyer (2021), for instance) were the proximate causes of the repo rate spike in September 2019. But Fed studies earlier in the 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 that 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 tightening of reserves relative to potential claims on liquidity. Indeed, the substantial drawdown in lines of credit in March 2020 may have been an important additional precipitating factor, explaining the persistent stock market underperformance of banks relative to other financial firms even after the implementation of fiscal and monetary policy backstops of an unprecedented scale (Acharya, Engle and Steffen (2021)).

If, as we suggest, liquidity stress partly arises from the asymmetric relationship between the stock of aggregate claims on liquidity and the stock of reserves, the policy implications can be different from the traditional ones. If claims on liquidity are considered as 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 withdrawn too many reserves relative to needs in 2019, and recommend a higher sustained level. This is indeed a reasonable suggestion in the short run, but it does not address our concern that a higher level of reserves would in turn lead to a commensurate increase in claims on liquidity. In other words, the supply of reserves creates its own demand for reserves over time, ratcheting up the required size of the Fed's balance sheet. If there are no costs to forever expanding the Fed's balance sheet, this too is not a concern. However, we will highlight some costs.

Consider next whether the financial system is better positioned to handle QT today. Clearly, the starting point for QT today is different. The Fed does over $2 trillion in reverse repo transactions with the non-banks (typically money market funds); the amount has been rising steadily but exponentially 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. However, this will reduce the aggregate availability of reserves relative to claims on liquidity. More problematic will be when the aggregate reserve shrinkage starts reducing the reserve holdings of individual banks. If banks do not reduce the claims they have written on liquidity commensurately, as observed in the past QT period, the system could become more prone to liquidity stress.

Another difference today is that the Fed introduced the Standing Repo Facility (SRF) in 2021, partly in response to previous episodes of liquidity stress. This allows primary dealers, among others, to borrow more reserves from the Fed against high-quality collateral. While the SRF will help alleviate individual liquidity stress at primary dealers, it is not universally available. As Acharya and Rajan (2022) argue, the real problem could emanate if some banks/dealers with access to liquidity hoard liquidity in times of stress. The Fed will then have no option but to intervene once again and lend widely, as it did in September 2019 and March 2020. Such repeated intervention may not just go against the Fed's monetary policy stance, but may also engender less liquidity-prudent behavior in the private sector.[3]

Before we conclude this introduction, it is useful to consider the implications of our analysis both for monetary policy and 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 with reserves, the Fed 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, they have been shortening the maturity of their liabilities, even within deposits, over the period of QE (both in the aggregate time series and the panel of banks), making it harder for banks to finance long-term loans without incurring costly asset/liability maturity mismatches. This behavior dampens the effectiveness of at least this channel through which QE might work.

From a financial stability perspective, understanding why commercial banks behave asymmetrically and, more precisely, why they do not reduce demandable claims as the aggregate quantity of reserves shrinks is key to understanding the appropriate policy interventions (if any) as QT gets under way. One possibility is within-bank agency–the departments that raise deposits or write lines of credit have a momentum of their own and do not shrink their activities as aggregate reserves fall. Another possibility is moral hazard–banks know that they have a problem only when aggregate liquidity seizes up, and the Fed has shown a repeated willingness to intervene at such times. Such moral hazard would induce excessive writing of liquidity claims, liability-shortening, and in turn the excessive dependence of the banking system on the Fed for liquidity (see endnote 3). Yet another possibility is the effect of regulation which may have made it hard for banks to not hold reserves but made it cheaper to finance reserves with demandable claims on liquidity. Perhaps regardless of the rationale, close monitoring of the aggregate claims that are written on liquidity relative to available aggregate reserves is warranted. Any mismatch might need to be managed with counter-cyclical supervisory actions.

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 data on deposit and credit line amounts, and deposit rates and credit line fees, respectively. Section 6 summarizes some additional results; Section 7 discusses implications for monetary policy, liquidity stress and managing and monitoring such stress; and Section 8 concludes.

2. Data

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

2.1. Time Series

We obtain a variety of data from the Federal Reserve Economic Data (FRED) online database. Specifically, we collect data on central bank, i.e., Fed, reserves with the banking system (H6 release) and bank deposits (H6 and H8 release), as well as the FDIC-collected time-series of outstanding off-balance-sheet credit lines to corporations.[4] We also obtain the effective federal funds rate (EFFR), interest on excess reserves (IOR), and GDP from FRED.[5] Wherever possible, we use monthly data (data other than credit lines); if, however, data are not available at a monthly frequency, we turn to quarterly data (credit lines). The time-series data span the 2009 to 2021 period.

2.2. Panel with Cross Section of Banks

2.2.1 Bank-Level Deposits

We also use FDIC's Summary of Deposits - Branch Office Deposits data to obtain branch-level deposit values. We use bank-balance sheet data from the Call Reports of the FDIC for the time period 2001Q1-2021Q4, including bank-level deposits and their components, and 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.

2.2.2 Bank-Level Deposit Rates

We obtain deposit rate data from Standard and Poor's (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.

2.2.3 Bank-Level Credit Lines Issuance and Fees

We obtain data on the origination of credit lines by U.S. non-financial firms from *Refinitiv Loan Connector*.[6] These data include the name of the company issuing the loan 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. Loan Connector also includes the company credit rating at loan origination. To obtain lender information, we use the Schwert (2020) link-file to map lenders in Loan Connector 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 Time Series: Fed's Balance Sheet, Bank Deposits and Credit Lines

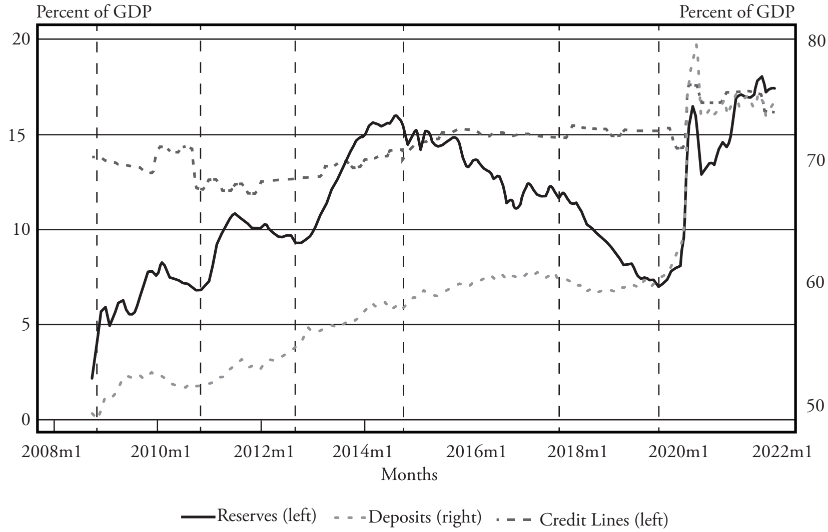
3.1. Descriptive Evidence

In Chart 1, we plot credit lines, deposits and reserves 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 Fed QE/QT programs: (1) November 2008 (QE I), (2) November 2010 (QE II), (3) November 2012 (QE III), (4) October 2014 (QE halted without actively reducing balance sheet size), (5) October 2017 (QT or active balance sheet reduction), and (6) September 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).

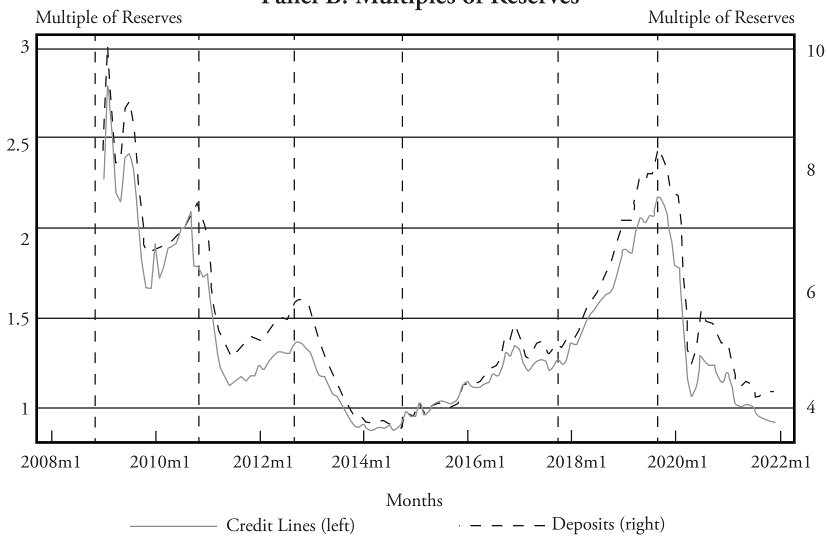
Central bank reserves expanded from the start of QE I in November 2008 to the end of QE III in September 2014 from less than 5 percent of GDP to more than 15 percent of GDP. There is some stabilization, even decline, in reserves when each phase of QE ended and before the next phase began. At the same time, bank deposits grew from about 50 to 60 percent of GDP, again with some stabilization when each phase of QE ended and before the next one began. While the increase in outstanding credit lines was less pronounced at first, they too increased from November 2010 (the start of the QE II) from about 12 percent to over 15 percent of GDP by September 2014.[7] Importantly, while reserves dropped by more than half after

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

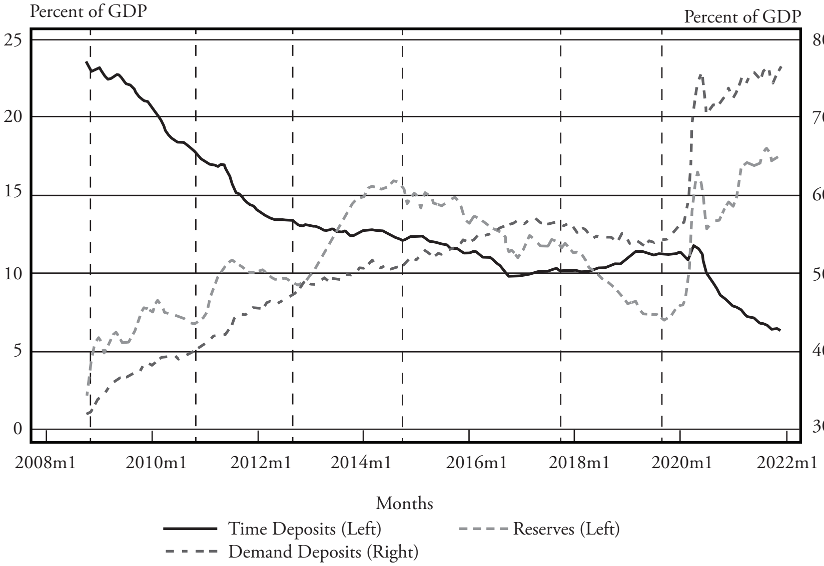
Panel A. As percentage of GDP



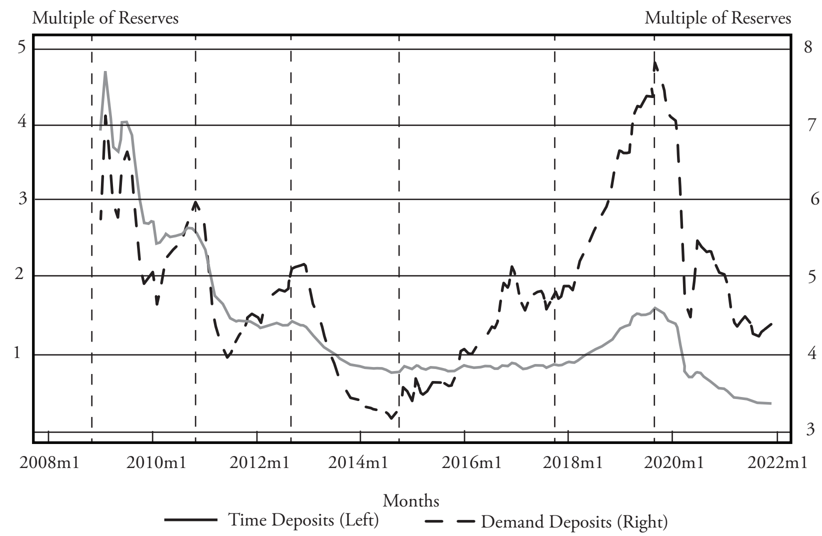
Panel B. Multiples of Reserves



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



Panel D. Demand and Time Deposits as Multiples of Reserves



This chart 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. All data are obtained from the Federal Reserve Economic Data (FRED) online database. The vertical lines correspond to the beginning of the different Federal Reserve QE / QT phases: (1) November 2008 (QE I), (2) November 2010 (QE II), (3) November 2012 (QE III), (4) October 2014 (Post-QE III), (5) QT period, (6) September 2019 (Pandemic QE).

QE was halted in October 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 percent to more than 17 percent of GDP during the pandemic QE period, bank deposits jumped again from 60 percent to almost 80 percent of GDP and credit lines also increased to about 17 percent 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. Panel B shows this in a different way. 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. Hence, 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 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 ceases, including sharply through QT when the Fed shrinks reserves, suggests this cannot just be lagged bank reactions.

Even more interestingly, 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 reaching their pre-QE levels. Therefore, far more reserves were needed in September 2019, and then again in March 2020, to back the liquidity claims that had been written during and post QE.

We then split deposits into demand deposits and time deposits. 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 release. In Panel C, we plot demand deposits, time deposits and reserves all as percentages of GDP. The figure indicates the positive correlation between demand deposits and reserves as well as the 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 have almost quadrupled over the 2009 to 2021 period, time deposits have all but lost their importance, declining from about 25 percent of GDP to just about 5 percent of GDP. Demand deposits, on the other hand, have increased from 30 percent to about 80 percent 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 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 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, on the other hand, exhibit a secular decline over the QE periods, flattening after it ends and rising only in the QT period.

Finally, it is important to know whether these patterns are driven by insured or uninsured deposits. In Online Appendix, we document that the patterns in Figures 1A-D for deposits are either mirrored in both insured and uninsured demand deposits, or driven primarily by uninsured demand deposits (especially the correlated growth of reserves and deposits during the QE periods). For instance, while there is a surge in insured deposits with the onset of the pandemic due to fiscal transfers, as pandemic QE expanded the stock of reserves after

March 2020, it is eventually only the stock of uninsured demand deposits that rose in tandem.

The plan in the rest of the analysis is as follows. First, in Section 3 we turn to time-series regressions, both on aggregate quantities and prices, and confirm the patterns we have identified econometrically. Then we turn in Section 4 to panel data on individual banks (or bank holding companies) and verify the effect of reserves on quantities of deposits and credit lines across individual banks over different time periods. Finally, in Section 5, we examine the pricing of deposits and credit lines across banks for different time periods.

3.2. Time Series Regressions

3.2.1. Bank Deposits, Credit Lines, and Reserves

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

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

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. Standard errors reported in parentheses are adjusted for autocorrelation in the residuals up to 12 months. Descriptive statistics for all variables are relegated to the Online Appendix.

In Table 1, 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 *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 percent over the last 12 months is associated with an increase in *Deposits* by about 1.4 percent, *Demand Deposits* of 1.8 percent, and *Credit Lines* of 0.8

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

	(1) Change in Ln(Deposits)	(2) Change in Ln(Demand Deposits)	(3) Change in Ln(Time Deposits)	(4) Change in Ln(Credit Lines)	(5) Change in Deposits	(6) Change in Demand Deposits	(7) Change in Time Deposits	(8) Change in Credit Lines
Change in 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)				
Change in 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
Reg-Type	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
S.E.(# Lags)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)

This table reports the results from time-series regression of changes in deposits or credit lines on changes in reserves. 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. 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). 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 Reservest-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

percent, but with a reduction in *Time Deposits* of 2.4 percent, consistent with demand and time deposits moving in opposite directions with reserves as we saw in Panel C of Chart 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* 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 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.

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 inter-bank market for reserves.

3.2.2. Price of Liquidity

The effective fed funds rate (EFFR) is how much suppliers of liquidity can get in the fed funds market. The interest on excess reserves (IOR) is a benchmark for 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). We estimate OLS versions of the following general specification using quarterly data:

$$EFFR\text{-}10R_t = \alpha\, Ln(Reserves)_t + \beta\, Ln\ (Deposits)_t + \gamma\, Ln(Credit\ Line)_t + \varepsilon_t \quad (2)$$

We also include a constant term. Standard errors reported in parentheses are adjusted for autocorrelation in the residuals up to four quarters. The results are reported in Table 2 Panel A.

In column (1), we only include *Ln(Reserves)* and find that there is no economically and statistically significant correlation between EFFR-IOR and reserves over time. Column (2) shows the results of the estimate in LS-VJ (2022). As they report, this specification suggests a negative correlation of reserves with the price of liquidity, and a positive correlation of deposits, with the coefficient on deposits almost 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 deposits are positively correlated with 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

Table 2
Aggregate Price of Liquidity (Time-Series)

Panel A

	(1) EFFR-IOR	(2) EFFR-IOR	(3) EFFR-IOR	(4) EFFR-IOR	(5) EFFR-IOR	(6) EFFR-IOR
Ln (Reserves)	-0.0122 (0.0266)	-0.188*** (0.0125)	-0.188*** (0.0148)	-0.150*** (0.0107)	-0.145*** (0.0103)	-0.191*** (0.0158)
Ln (Deposits)		0.365*** (0.0159)				
Ln (Demand Deposits)			0.315*** (0.0147)			0.251*** (0.0433)
Ln (Time Deposits)			0.105** (0.0350)			*0.0701 (0.0445)
Ln (Credit Lines)				0.333*** (0.0215)	0.294*** (0.0199)	0.0893* (0.0481)
Ln (Usage)					0.0200** (0.00781)	-0.00754 (0.00628)
Constant	0.00446 (0.198)	-2.048*** (0.113)	-2.355*** (0.408)	-1.570*** (0.164)	-1.709*** (0.180)	-2.028*** (0.478)
Obs	155	155	155	155	155	155
R-sq	0.00702	0.894	0.895	0.843	0.851	0.902
Reg-Type	OLS	OLS	OLS	OLS	OLS	OLS
S.E. (# Lags)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)	Newey-West (12)

Table 2 continued

Panel B

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔEFFR-IOR	ΔEFFR-IOR	ΔEFFR-IOR	ΔEFFR-IOR	ΔEFFR-IOR	ΔEFFR-IOR
ΔLn	-0.155***	-0.188***	-0.186***	-0.161***	-0.173***	-0.220***
(Reserves)	(0.0319)	(0.0368)	(0.0308)	(0.0290)	(0.0313)	(0.0213)
ΔLn		0.474**				
(Total Deposits)		(0.211)				
ΔLn			0.344***			0.376***
(Demand Deposits)			(0.125)			(0.0961)
ΔLn			-0.00215			0.0460
(Time Deposits)			(0.0612)			(0.0610)
ΔLn				0.140**	0.183***	0.170***
(Credit Lines)				(0.0523)	(0.0496)	(0.0482)
ΔLn					-0.0157***	-0.0123*
(Usage)					(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

Table 2 continued

Panel C

	(1)	(2)	(3)	(4)
	EFFR-IOR	EFFR-IOR	EFFR-IOR	EFFR-IOR
Ln (Reserves)	-0.0106			
	(0.0273)			
U.S. Banks Ln(Reserves)		0.0114		-0.115***
		(0.0240)		(0.0151)
Non-U.S. Banks Ln(Reserves)			-0.0432*	-0.0873***
			(0.0256)	(0.0170)
U.S. Banks Ln(Deposits)				0.353***
				(0.0157)
Non-U.S. Banks Ln (Deposits)				0.0105**
				(0.00438)
Constant	-0.00796	-0.167	0.207	-2.010***
	(0.203)	(0.163)	(0.175)	(0.135)
Obs	52	52	52	51
Reg-Type	OLS	OLS	OLS	OLS
Data Frequency	Quarterly	Quarterly	Quarterly	Quarterly
Standard-Error	Newey-West	Newey-West	Newey-West	Newey-West
# Lags	4	4	4	4

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 EFFR-IOR on levels of reserves, deposits (and its constituents), and credit lines. Panel B reports the specification in changes. Columns (1)-(3) use monthly data whereas columns (4)-(8) use quarterly frequency as credit lines data is available quarterly on FRED. Panel C, Columns (2) and (3) represent regressions of EFFR-IOR on U.S. Banks' Ln(Reserves), calculated as the aggregate sum of cash and balances due from Federal Reserve banks (RCFD0090) and Non-U.S. 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 U.S. Banks' Ln(Deposits) ,estimated as the aggregate sum of domestic deposits (RCON2200), and Non-U.S. Banks' Ln(Deposits) calculated as the difference between Total Deposits of H.6 and H.8 release and aggregate sum of RCON2200. Standard errors (Newey-West) account for auto-correlation up to 12 months. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

document that most of the effect from deposits in column (2) is driven by demand rather than time deposits. The coefficient on demand deposits is larger than the magnitude of coefficient on reserves; the opposite is true for time deposits, 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 use outstanding credit lines measured as *Ln(Credit Lines)* from FRED in column (4). The coefficient on *Ln(Credit Lines)* is of similar magnitude to that on *Ln(Deposits)* in column (1). Once again, this suggests the demandability of credit lines leads their outstanding amount to be positively associated with the price of liquidity.

Next, we obtain quarterly data on credit lines usage of U.S. firms from Capital IQ. In column (5), we add the natural logarithm of drawn credit lines *Ln(Usage*). EFFR-IOR loads positively on both *Ln(Credit Lines)* and *Ln(Usage)*, though the latter coefficient is small and turns negative albeit insignificant in column (6), where we add *Ln(Demand Deposits)* and *Ln(Time Deposits)*. Importantly, while the coefficients on time deposits becomes small and that of credit line usage rates even insignificant, the coefficients of *Ln(Demand Deposits)* and the coefficient on *Ln(Credit Lines)* remain significant and economically meaningful. Since both *Ln(Demand Deposits)* and *Ln(Credit Lines)* are driven by the availability of liquidity, it is not surprising that the standard errors are higher in this estimation, suggesting a degree of multi-collinearity. The R^2 of 0.902 from column (6) in Table 2 is somewhat higher than the R^2 of column (3) or (5), but not by much, suggesting that either deposits or lines of credit alone capture significant aspects of the claims on liquidity. Importantly, the coefficient on *Ln(Reserves)* in both specifications is negative, large in magnitude, and statistically significant, unlike the case with *Ln(Reserves)* alone when it is statistically insignificant.

Following LS-VJ (2022), we can rewrite equation (2) above as follows:

$$EFFR - IOR_t = \alpha\left[Ln\left(Reserves\right)_t + \frac{\beta}{\alpha}Ln\left(Deposits\right)_t + \frac{\gamma}{\alpha}Ln\left(Credit\ Line\right)_t\right] + \varepsilon_t \quad (2a)$$

Where $Ln\left(Reserves\right)_t + \frac{\beta}{\alpha} Ln\left(Deposits\right)_t + \frac{\gamma}{\alpha} Ln\left(Credit\ \ Line\right)_t$ represent the deposits- and credit-lines-adjusted reserves. Chart 2 shows a scatter plot of EFFR-IOR on *Ln(Reserves)* in Panel A. Panel B reflects adjustment due to deposits alone, mirroring that in LS-VJ (2022). We augment their analysis in Panel C to adjustment due to credit lines alone, and Panel D due to demand deposits, time deposits, and credit lines.[8]

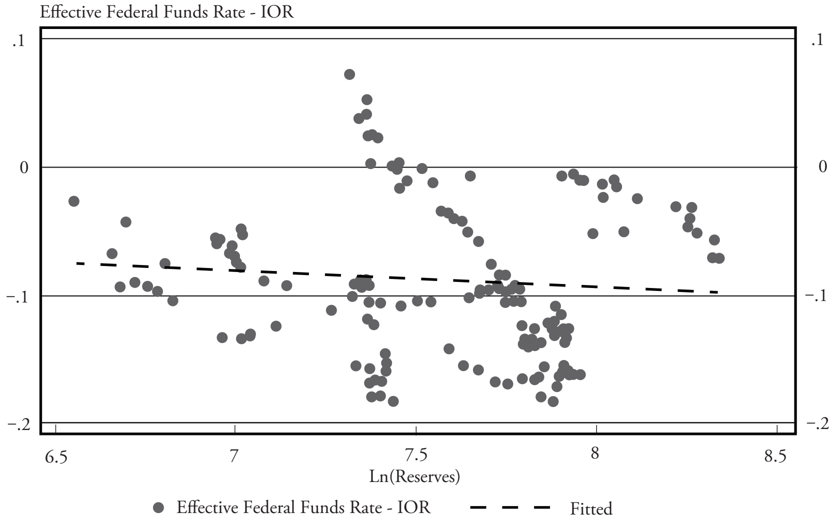
As is clear, without adjusting for deposits and credit lines, the scatterplot in Panel A is dispersed and there is no visible relationship between the price of liquidity and the amount of reserves outstanding. However, once we adjust reserves by bank deposits, or credit lines, or both (Panels B-D), a strong negative relationship between the amount of reserves and the price of liquidity emerges.

We examine two further issues. In Panel B, we look at the regressions in changes to mitigate issues of co-integration and non-stationarity. In columns (1)-(3), we use only reserves and deposits data, so we have monthly data. In column (4) onward, we include data on outstanding credit lines, which are available only at a quarterly frequency. Throughout, both magnitude and sign of the correlations of reserves, deposits, and credit lines with the price of liquidity are preserved (or even improve) in the specification with changes. Within deposits, the correlation is driven by demandable rather than time deposits.

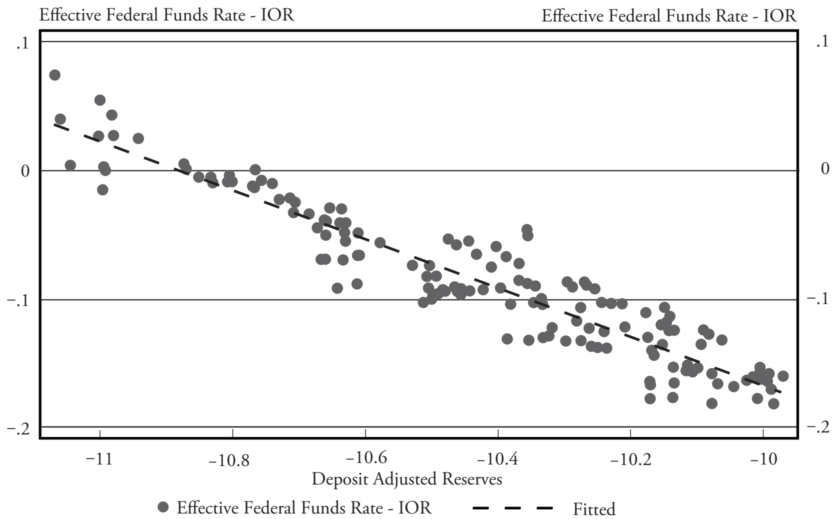
In Panel C, we separate the data on deposits and reserves into those for the overall banking system, for U.S. banks, and for foreign banks (overall minus U.S. banks), and estimate the specification of Panel A with reserves only and with reserves and deposits. In Columns (1)-(3), we find that as in Panel A, when deposits are not included as an explanatory variable, overall reserves and U.S.-bank reserves do not explain EFFR-IOR well. In contrast, reserves of foreign banks have a negative and significant coefficient estimate (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). However, once we control for deposits in column (4), not only are the coefficient estimates on reserves of both U.S. and foreign banks negative and significant, the magnitude of the coefficient estimate on U.S. bank

Chart 2
Aggregate Price of Liquidity (EFFR-IOR)

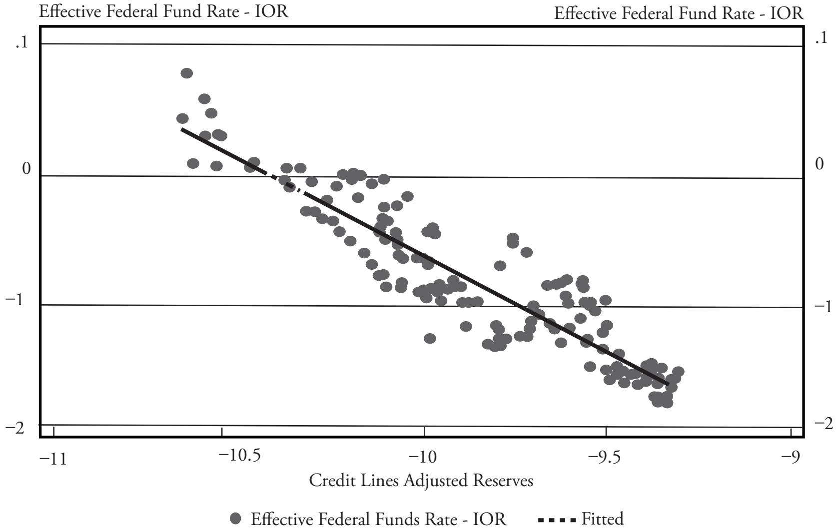
Panel A. EFFR-IOR on Ln(Reserves)



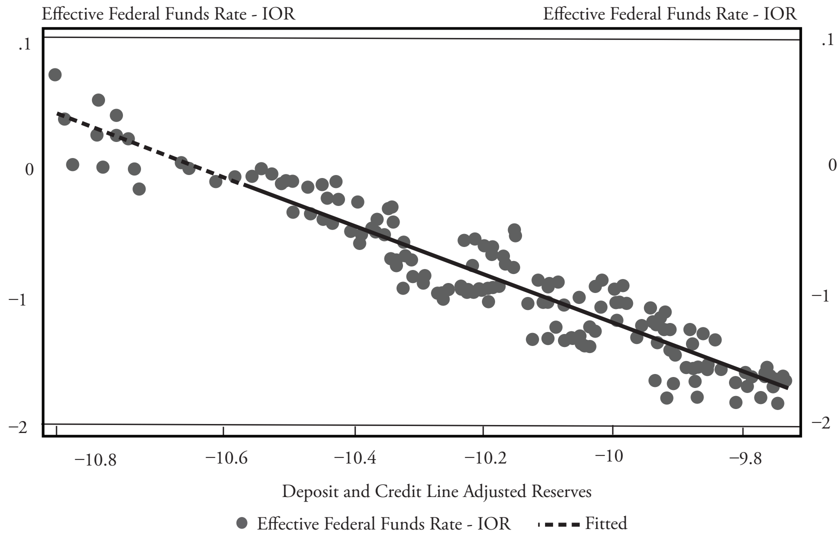
Panel B. EFFR-IOR on Deposit Adjusted Reserves



Panel C. EFFR-IOR on Credit Line Adjusted Reserves



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



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

reserves is larger than that on foreign bank reserves, which in turn is double its estimated magnitude in column (3). Similarly, the coefficient estimate on deposits of both U.S. and foreign banks is positive and significant, with the coefficient estimate on U.S. bank deposits an order of magnitude larger. A one-standard-deviation increase in the log deposits of U.S. (foreign) banks is associated with an increase in EFFR-IOR of 0.1 percent or 10 basis points (1 bp). Similarly, a one-standard-deviation increase in the log reserves of U.S. (foreign) banks is associated with a decrease in EFFR-IOR of 5 bps (3 bps). This is suggestive that both deposits and reserves of U.S. banks have greater effects on liquidity than the deposits of the foreign banks.

Together, time-series results in Tables 1 and 2, combined with Figures 1 and 2, illustrate the importance of understanding how demandable claims issued by the banks (i.e., deposits and credit lines) are associated with changes in reserves, and the importance of recognizing this association in assessing the determinants of the price of liquidity. However, aggregate time-series analysis is not conducive to a causal analysis of the impact of reserves on these variables, especially for different phases of central bank activity, since the small number of observations within each phase runs immediately into issues of statistical power. Time-series analysis also cannot adequately rule out confounding effects from factors such as the level of economic activity and interest rates, which directly affect deposit creation and deposit demand in the economy. This necessitates understanding individual bank behavior at a disaggregated level. 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)

Let us now turn to effects of reserves across individual banks. One challenge is that reserves in the aggregate are determined by the central bank (the Fed), so we need an instrument defined at the bank level to tease out the effect of changes in reserves on deposits and credit lines. Before describing this instrumental variable analysis, we confirm that bank-level Call Reports data paint the same picture in the aggregate as we saw based on the flow-of-funds (FRED) data.

To this end, we plot in Chart 3 the value-weighted aggregate share of time, money-market (MM) savings, non-MM savings, and other demand deposit accounts (excluding MM and non-MM savings) in total domestic deposits over time, using Call Reports data.[9] We aggregate up from the disaggregated depository level. As before, the vertical lines correspond to the beginning of the different QE I-III, QT and pandemic-QE phases.

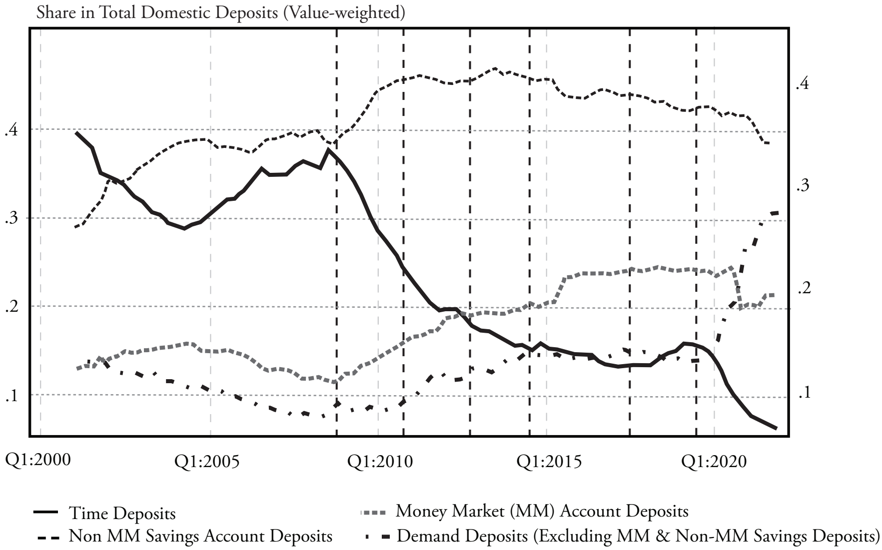
Consistent with the aggregate data in Figure 1C-D, the share of time deposits in the bank-level Call Reports data has been falling since the beginning of QE I and did not reverse after the end of QE III or the beginning of QT periods; the reversal is observed only after late 2017. In contrast, the shares of savings and other demand deposits have been rising, with some rotation away from MM savings to non-MM savings during QT and away from both types of savings towards other demand deposits during the pandemic QE period starting in 2019 Q4.

4.1. Methodology

In general, reserves are issued by the Fed based on its monetary stance.[10] In that sense, aggregate reserve growth can be reasonably considered as largely exogenous to the circumstances or needs of individual banks. Arguably, though, the bank-level stock of reserves could be *endogenous* to the bank's deposit funding. For instance, a bank (or a region) could witness deposit inflows away from another bank (or regions) increasing its reserves, i.e., 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. Of course, without any aggregate change in reserves, such variation driving reserves would be purely redistributive across banks. To allay such endogeneity concerns, we employ a two-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.

An increase in central bank reserves is unlikely to be distributed evenly across banks. In Kashyap, Rajan, and Stein (2002), banks can

Chart 3
Decomposition of Deposits



This chart plots the share of total time deposits (of all sizes), money market deposit accounts (MMDA), non-MMDA savings accounts and total demand deposit accounts in total domestic deposits from Call Reports data schedule RC-E. The deposit shares are value-weighted at the quarterly level. The vertical lines correspond to the beginning of the different Federal Reserve QE / QT phases: (1) November 2008 (QE I), (2) November 2010 (QE II), (3) November 2012 (QE III), (4) October 2014 (Post-QE III), (5) QT period, (6) September 2019 (Pandemic QE).

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. 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 location-centricity could, however, shift at low frequency over time. Centricity could also be determined by relationships. During QE, non-banks may tender assets, placing the associated reserves with their relationship bank with some banks having 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.

With this in mind, our bank-level *Reserve Instrument* is the most recent change in aggregate reserves times the bank's recent share of reserves:

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

Bank i's share of aggregate reserves in quarter *t* is calculated by dividing the bank-level *Reserves* by aggregate central bank reserves. Effectively, we assume that a bank's lagged share in reserves is exogenous to the central bank's decision to change aggregate reserves and instead reflects some characteristic such as some banks being money center banks or primary dealers or having strong non-bank relationships. This would cause them to hold relatively higher reserve shares but will not affect their liability structure directly. We average a bank's share over four 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 such adjustment is uncorrelated or weakly correlated from one quarter to the next). Results on alternative instrument choices are in the Online Appendix.[11,12]

4.2. Impact of Reserves on Quantities of Deposits

We estimate a two-stage least square specification by (i) instrumenting in the first-stage the bank-level change in reserves, measured as $\Delta Ln(Reserves)$, by the reserve instrument, and then (*ii*) regressing in the second-stage the change in deposits, measured as $\Delta\ Ln(Deposits)$, against the instrumented $\Delta\ Ln(Reserves)$. In particular, the first-stage is estimated as

$$\Delta Ln(Reserves)_{it} = \gamma_1 Reserves\ Instrument_{it} + \gamma_2 Ln(Reserves_{it-5}) + \delta_t + \mu_{it} \quad (4)$$

where $\Delta(Y)_{it} = Y_{it} - Y_{it-4}$, and δ_t represents (quarter) time-fixed effects which soak up any aggregate change in reserves 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 five-quarter lag. For the first stage estimates in Table 3, 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 August-October 2010 (between QE I and QE II) and September 2011-August 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 Δ *Ln(Reserves)* has a positive and strong correlation with the *Reserves Instrument* as seen in Column (1) of Table 3 for the overall period and for the QE periods. Interestingly, Δ *Ln(Reserves)*. has a negative and significant correlation with the instrument in the post QE III and QT period. The first stage F-statistics are reported in Table 3.[13]

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

$$\Delta Ln(Deposits)_{it} = \beta_1 Instr\ \Delta Ln(Reserves)_{\mathrm{it}} + \beta_2 Ln(Reserves)_{it-5} + \tau_t + \varepsilon_{it} \qquad (5)$$

Quarter time-fixed effects absorb any aggregate trends in deposit growth such as due to fluctuations in economic activity. In Table 4 Panel A.1, we present OLS estimates, in panel A.2, instrumental variable (IV) estimates. The coefficients on the change in log reserves and on lagged reserves are positive and significant in the OLS estimates for the overall period and all sub-periods. In the IV estimates, the change in log deposits is indeed positively and significantly correlated with the instrumented change in log reserves in the overall sample (column (1)), the QE periods (column (2)), and QE I-III periods (column (3)), but is negative and significant for the post QE III/QT period (column (4)). There is a positive and significant correlation with lagged log reserves also (except again for the post QE III/QT period). The negative and significant coefficient on the change in reserves in the post QE III/QT period is noteworthy. Since reserves shrink during these periods, the coefficient implies a continued ratcheting up in deposits.

In terms of magnitudes, an exogenous 10 percent year-on-year increase in a bank's reserves leads to a 0.28 percent rise in its deposits in the overall sample, and 0.27 percent rise in the QE periods. Note that–consistent with there being some bank-level endogeneity that causes reserves to rise when deposits are shrinking–these IV magnitudes are about one and a half to two times greater than those observed in the OLS estimation (Table 4 Panel A.1); conversely, consistent with there being some macroeconomic variation inducing reserves to rise when deposits are rising, the panel estimate is about a fifth to a sixth of the simple time-series estimate (Table 1, Column 1). Finally, Δ *Ln(Deposits) increases* by 1.24 percent when Δ *Ln(Reserves) contracts* by 10 percent during the Post QE III/QT periods.

We also split deposits into its two constituents, viz., demand and savings deposits, and time deposits, to test whether short-term demandable or long-term costly-to-break deposits drive the response of total deposits to an exogenous increase in reserves observed in Panel A. Once again, in Panel B.1 of Table 4, we present OLS estimates of regressions with Δ *Ln*(*Demand + Savings Deposits*) and Δ *Ln*(*Time Deposits*) as dependent variables respectively, while in Panel B.2, we present the second-stage IV results.

Turning first to the IV estimates, Panel B.2.1 column (1) suggests that *Demand and Savings Deposits* move in the same direction with reserves as total deposits. An exogenous 10 percent year-on-year increase in a bank's reserves leads to a 1.28 percent increase in the bank's demandable deposits in the overall sample period. The coefficient estimates are similar during the QE periods (columns (2) and (3)). However, demandable deposits increase by 1.34 percent when a bank's reserves decline by 10 percent year-on-year in the Post QE III/QT periods. As in our time-series results of Table 1, demandable deposits seem particularly prone to growing with the injection of reserves, but continue growing even when QE ends or QT gets under way and bank reserves begin to shrink.

Panel B.2.2 presents results on time deposits. An exogenous 10 percent year-on-year increase in a bank's reserves leads to a 1 percent *decrease* in the bank's time deposits in the overall sample period, with approximately an 0.8 percent decrease during the QE periods (columns (2) and (3)). However, during the post QE III/QT period, the effect of reserves on time deposits becomes positive but statistically insignificant.

Overall, Panel B.2 suggests that there is a maturity-shortening of deposits at the bank level during QE periods, as demand and savings deposits increase with an influx of reserves, while longer-maturity

Table 3
Effect of Reserves on Deposit Quantities – First Stage (Bank-level)

First Stage: Change in Reserves by Period	(1) ΔLn(Reserves)	(2) ΔLn(Reserves)	(3) ΔLn(Reserves)	(4) ΔLn(Reserves)
z_{it}^{R} (=Ln($Reserves_t$/$Reserves_{t-1}$) × Lagged Share in Agg. Reserves over 4Q)	17.55***	18.46***	18.25***	-63.22*
	(1.493)	(3.599)	(1.795)	(34.41)
$Ln(Reserves)_{t-5}$	–0.101***	–0.124***	–0.127***	–0.0674***
	(0.00597)	(0.00609)	(0.00967)	(0.00576)
Constant	1.098***	1.611***	1.559***	0.734***
	(0.0518)	(0.0584)	(0.0858)	(0.0564)
N	115839	51062	43236	30830
R-sq	0.111	0.137	0.139	0.0192
F-stat	152.6	211.5	96.05	68.40
Time-FE	Y	Y	Y	Y
Bank & Time Clustered FE	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

This table shows the first stage results of the instrumental variable two-stage least-squares regressions in Table 4. Bank balance sheet data is sourced from Consolidated Reports of Condition and Income for a Bank with Domestic and Foreign Offices (Call Reports) of the FDIC. Reserves are cash and balances due from Federal Reserve Banks at the consolidated bank-level (RCFD0090). The instrument for reserves, z_{it}^{R} is defined as *Growth in Aggregate Reserves* × *Lagged Share in Reserves*, *averaged over past four quarters. Aggregate Reserves* are sourced from FRED. We use *ΔLn(Reserves) = $Ln(Reserves)_t$ - $Ln(Reserves)_{t-4}$* as the dependent variable. Column (1) represents the regressions on the overall sample ranging 2001 Q1 – 2021 Q4. Column (2) represents QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Column (3) represents the QEI-III period: 2008Q4 - 2014Q3. Column (4) shows results for the Post-QE III + QT period 2014Q4 - 2019Q3. All specifications contain time-fixed effects. Standard errors are two-way clustered at the bank and time level. * p<0.1, ** p<0.05, *** p<0.01

Table 4
Effect of Reserves on Deposit Quantities – Second Stage
Panel A: Quantity Regressions with ΔLn(Total Deposits) as the Dependent Variable

Panel A.1: OLS	(1) ΔLn(Total Deposits)	(2) ΔLn(Total Deposits)	(3) ΔLn(Total Deposits)	(4) ΔLn(Total Deposits)
ΔLn(Reserves)	0.0157*** (0.000951)	0.0157*** (0.00145)	0.0146*** (0.00150)	0.0188*** (0.00109)
Newey-West s.e.	(0.000748)	(0.00110)	(0.00117)	(0.000916)
$Ln(Reserves)_{t-5}$	0.00171*** (0.000506)	0.00103 (0.000704)	0.000996 (0.000726)	0.00228** (0.000898)
Newey-West s.e.	(0.000417)	(0.000547)	(0.000599)	(0.000612)
Constant	0.0520*** (0.00434)	0.0470*** (0.00642)	0.0326*** (0.00641)	0.0463*** (0.00809)
Obs	117225	51009	43196	32279
Time-FE	Y	Y	Y	Y
Bank & Time Clustered SE	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

Table 4 continued

Panel A.2: IV	(1) ΔLn(Total Deposits)	(2) ΔLn(Total Deposits)	(3) ΔLn(Total Deposits)	(4) ΔLn(Total Deposits)
ΔLn(Reserves)	0.0252** (0.0112)	0.0248** (0.0101)	0.0248** (0.0100)	-0.130** (0.0617)
$Ln(Reserves)_{t-5}$	0.00264** (0.00121)	0.00215 (0.00139)	0.00227 (0.00141)	-0.00771* (0.00401)
Obs	115680	50982	43177	30789
Time-FE	Y	Y	Y	Y
Bank & Time Clustered SE	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 4
Panel B.1
OLS Quantity Regressions with ΔLn(Demand + Savings Deposits) and ΔLn(Time Deposits) as the Dependent Variables

Panel B.1.1	(1)	(2)	(3)	(4)
	ΔLn(Demand + Savings Deposits)	ΔLn(Demand + Savings Deposits)	ΔLn(Demand + Savings Deposits)	ΔLn(Demand + Savings Deposits)
ΔLn(Reserves)	0.0128***	0.0151***	0.0152***	0.0171***
	(0.00186)	(0.00292)	(0.00323)	(0.00125)
Newey-West s.e.	(0.00142)	(0.00233)	(0.00256)	(0.00105)
$Ln(Reserves)_{t-5}$	0.00204***	0.00223**	0.00197*	0.000952
	(0.000693)	(0.000953)	(0.00104)	(0.00125)
Newey-West s.e.	(0.000556)	(0.000715)	(0.000791)	(0.00105)
Constant	0.0804***	0.0885***	0.0767***	0.0783***
	(0.00607)	(0.00844)	(0.00890)	(0.0114)
N	117076	50948	43149	32258
Time-FE	Y	Y	Y	Y
Bank & Time Clustered SE	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

Table 4 continued

Panel B.1.2	(1) ΔLn(Time Deposits)	(2) ΔLn(Time Deposits)	(3) ΔLn(Time Deposits)	(4) ΔLn(Time Deposits
ΔLn(Reserves)	0.0134*** (0.00129)	0.0133*** (0.00184)	0.0139*** (0.00198)	0.0185*** (0.00138)
Newey-West s.e.	(0.00104)	(0.00163)	(0.00176)	(0.00134)
Ln(Reserves)$_{t-5}$	-0.00219** (0.00109)	-0.00781*** (0.00147)	-0.00566*** (0.00103)	0.00436** (0.00187)
Newey-West s.e.	(0.000743)	(0.00102)	(0.000973)	(0.00145)
Constant	0.0275*** (0.00944)	0.0205 (0.0132)	0.00879 (0.00879)	-0.0162 (0.0173)
N	116227	50579	42872	32037
Time-FE	Y	Y	Y	Y
Bank & Time Clustered SE	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

Table 4
Panel B.2
2nd Stage IV Quantity Regressions with ΔLn(Demand + Savings Deposits) and ΔLn(Time Deposits) as the Dependent Variables

Panel B.2.1	(1) ΔLn(Demand + Savings Deposits)	(2) ΔLn(Demand + Savings Deposits)	(3) ΔLn(Demand + Savings Deposits)	(4) ΔLn(Demand + Savings Deposits)
ΔLn(Reserves)	0.128***	0.121***	0.124***	-0.134**
	(0.0168)	(0.0172)	(0.0147)	(0.0677)
$Ln(Reserves)_{t-5}$	0.0136***	0.0152***	0.0156***	-0.00929**
	(0.00185)	(0.00246)	(0.00228)	(0.00436)
Obs	115533	50921	43130	30770
Time-FE	Y	Y	Y	Y
Bank & Time Clustered SEs	Y	Y	Y	Bank only
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 4 continued

Panel B.2.2	(1) ΔLn(Time Deposits)	(2) ΔLn(Time Deposits)	(3) ΔLn(Time Deposits)	(4) ΔLn(Time Deposits)
ΔLn(Reserves)	-0.102*** (0.0323)	-0.0831** (0.0309)	-0.0789*** (0.0233)	0.125 (0.175)
$\text{Ln(Reserves)}_{t-5}$	-0.0138*** (0.00388)	-0.0198*** (0.00486)	-0.0175*** (0.00325)	0.0116* (0.0116)
Obs	114689	50555	42853	30551
Time-FE	Y	Y	Y	Y
Bank & 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

The table shows OLS and the second-stage of 2SLS IV regressions of ΔLn(Total Deposits) as the dependent variable against *ΔLn(Reserves)*. Deposit and reserve data are sourced from *FDIC's Call Reports*. Panel A uses *Total Deposits* defined as the total deposits held in domestic and foreign offices (RCON2200+RCFN2200). Panel B uses the Ln(*Demand and Savings deposits*) (RCON2210+RCON6810+RCON0352) and Ln(*Time Deposits*) (RCON6648 + RCONJ473 + RCONJ474) or (RCON6648+RCON2604) as the dependent variables. *Reserves* are cash and balances due from Federal Reserve Banks at the consolidated bank-level (RCFD0090). $\Delta Y = Y_t - Y_{t-4.}$ All specifications control for time-FE. 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. Panel A.1 shows the OLS result and panel A.2 shows the second stage for ΔLn(*Total Deposits*), respectively. Panel B shows the corresponding results for ΔLn(Demand & Savings Deposits) and ΔLn(*Time Deposits*) as the dependent variable. In all second-stage regressions, *ΔLn(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

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; demand and savings deposits continue increasing, while the impact on time deposits is statistically insignificant. The differential effect for demand and time deposits suggests that it is not just that deposit financing grows with reserves; there seems to be an active move by banks to substitute term financing with demandable financing.

Importantly, there is some difference between the OLS estimates (Panel B.1) and the IV estimates (Panel B.2). Specifically, the OLS estimates do not reverse sign for either time or demand deposits during the post QE III/QT periods, and the coefficient estimate on the change in log reserves for time deposits is positive for the OLS, not negative as in the IV. Therefore, instrumenting does make a difference in estimation and inference.

One value of our panel tests is that 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 toward demandable deposits/away from time deposits for reserve-intensive individual 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. The continuing growth of demandable deposits relative to time deposits through QE, and following the end of QE, suggests that the implementation of Liquidity Coverage Ratio (LCR) for banks in 2015 was not the primary causal factor. Time deposits require significantly lower High Quality Liquid Assets (HQLA) to be maintained under the LCR Guidelines than demand deposits. If LCR was a binding constraint, we would see a rotation that is opposite of what we find in data. We will shortly corroborate these findings on deposit liabilities with tests on their pricing.

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. Our time-series results in Table 1 already suggest that an increase in reserves positively correlates with an increase in outstanding credit line amounts. In this section, we provide corroborating evidence in the panel with a cross section of banks using information on credit-line originations to corporations, sourced from Refinitiv's Loan Connector.

4.3.1 Credit Line Originations: Descriptive Evidence

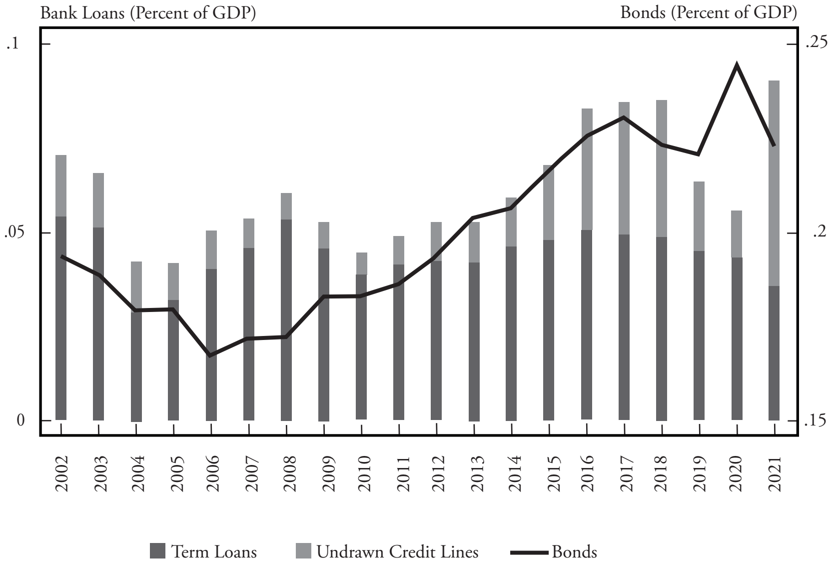
Before we turn to data on credit line originations, we use data from Capital IQ's debt capital structure database, which provides an annual overview of the debt structure (bank debt and bond financing in particular) of U.S. publicly traded firms. Bank debt includes both term loans as well as undrawn credit lines.[14] We plot a time-series of *Term Loans, Undrawn Credit Lines*, and *Bonds*, all as percentage of *GDP* in Panel A of Chart 4.

Since the Global Financial Crisis (2008), we observe a significant increase in bond financing as a percentage of GDP, while term loan funding has, on net, been declining. At the same time, we observe a stark increase in credit lines as a percentage of GDP consistent with the flow of funds data in Chart 1 earlier. Interestingly however, and similar to Chart 1, we observe that the stock of outstanding credit lines relative to GDP remains flat in the QT period, in particular it doesn't reverse. 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)). In spite of this unprecedented usage, the amount of outstanding credit lines increased even beyond the pre-pandemic levels by the end of 2021.

In Panels B to D, we show the same data for firms that are investment-grade rated (Panel B), non-investment-grade rated (Panel C), and unrated (Panel D). Overall, it appears that credit line issuances are particularly important for investment-grade rated as well as unrated firms consistent with the evidence in Colla et al. (2013). Moreover, 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

Chart 4
Debt Structure of the U.S Non-Financial Firms

Panel A. All firms



Panel B. Investment-grade rated firms

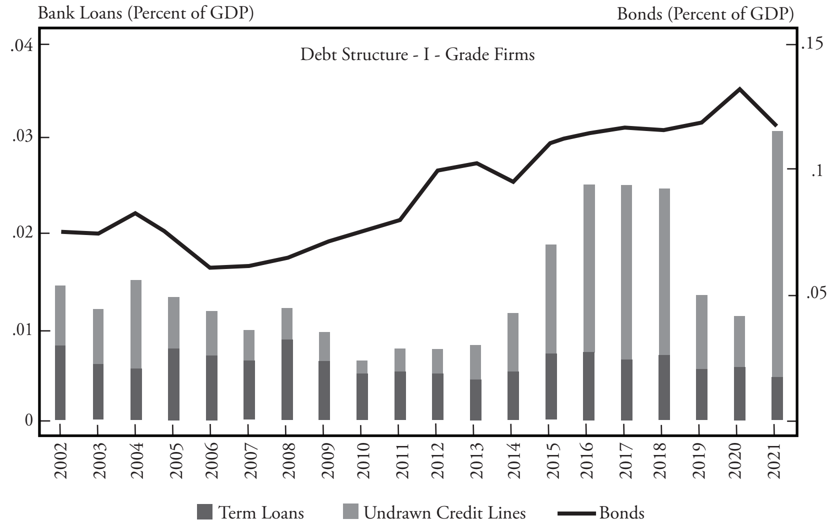
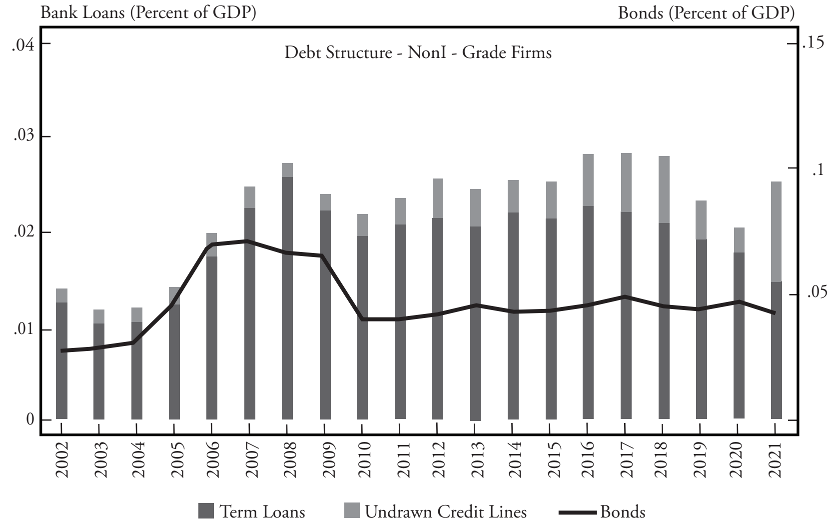
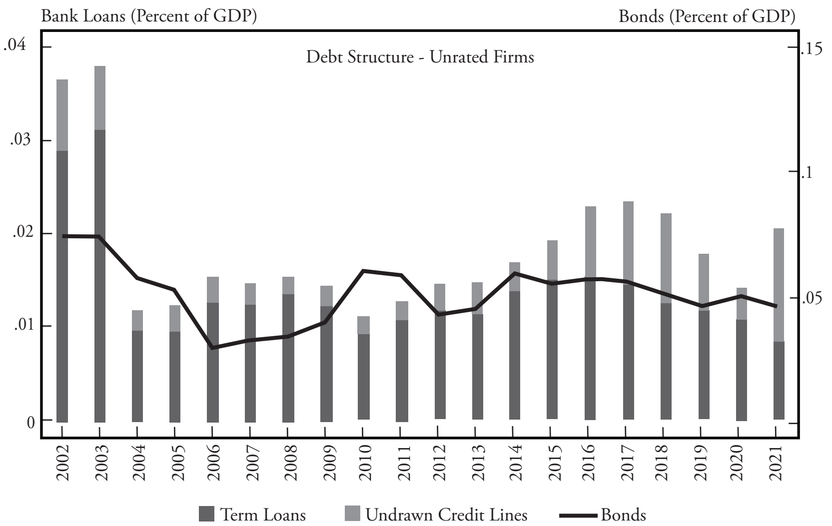


Chart 4 continued

Panel C. Non-investment-grade rated firms



Panel D. Unrated firms



This chart plots the debt structure of publicly listed firms in the U.S. over the 2002 to 2021 period excluding financials (SIC 6000-6999) as well as utilities (SIC4900-4949). Term loans (including drawn credit lines), undrawn credit lines as well as bonds are shown, all as a percentage of GDP in the respective year. The data are sourced annually from Capital IQ' debt structure summary. Panel A shows the full sample including all firms. Panel B includes only investment-grade rated firms. Panel C includes only non-investment grade rated firms. Panel D includes only unrated firms.

credit lines in combination with term loans and for transaction purposes (e.g., mergers and acquisitions, leveraged buyouts, or dividend recapitalizations). Finally, banks appear to be unique in their function of providing credit lines (Kashyap, Rajan and Stein (2002)) and hence their balance-sheets are likely the primary supply-side drivers of amounts and terms of credit lines.[15]). Given these considerations, we focus our analysis on credit line originations by banks to investment-grade and unrated firms.

4.3.2 Credit Line Originations

To investigate the effect of an exogenous change in reserves on the origination of credit lines across banks, we now construct the instrument for reserves (that we have already used in our analysis on deposit volumes) at the bank holding company (BHC) level since data on bank participation in the syndicates that offer credit lines are at the BHC level. Much of our other data, however, are defined at the bank level. Using a link-table of parent-offspring relationships provided by the Fed, we link each commercial bank in each quarter to its respective BHC. We then aggregate data from the commercial bank level to the BHC. We estimate the following regressions at the BHC (i) -quarter (t) level:

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

where 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 bank and quarter level. Before investigating this relationship with OLS and IV regressions, we inspect the first stage of the IV regressions as well as the quality of the BHC-level instruments. To do that, we use the same specifications reported in Table 3 above but using BHC-level analysis instead of the bank-level analysis.

We report the first-stage results in Table 5 for all credit line specifications, which show a positive and statistically significant relationship between Δ*Ln(Reserves)* and the instrument for reserves in the Overall and QE periods. This is, however, not so for the QT period at BHC

Table 5
Effect of Reserves on Credit Line Originations – First Stage (BHC-level)

	(1) Δ Ln(Reserves)	(2) Δ Ln(Reserves)	(3) Δ Ln(Reserves)	(4) Δ Ln(Reserves)
z_{it}^{R}	7.270***	7.431***	5.246***	6.460
	(0.928)	(1.167)	(0.752)	(19.79)
$Ln(Reserves)_{t-5}$	-0.0853***	-0.104***	-0.447***	-0.0392*
	(0.0203)	(0.0333)	(0.0545)	(0.0212)
Constant	1.374***	2.076***	6.766***	0.556*
	(0.265)	(0.463)	(0.758)	(0.315)
Obs	2268	911	678	578
R-sq	0.235	0.298	0.415	0.0808
Time-FE	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y
F	35.09	20.16	400.9	4.758
Period	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

This table shows the first stage results of the instrumental variable two-stage least-squares regressions in Table 6. *Reserves* is aggregated to the bank holding company (BHC) level from Call Reports, in particular, cash and balances due from Federal Reserve Banks at the consolidated bank level (RCFD0090). The instrument for reserves, z_{it}^{R} is defined as *Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over past four quarters*. Aggregate Reserves are sourced from FRED. Column (1) represents the regressions on the overall sample ranging 2001 Q1 – 2021 Q4. Column (2) represents QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Column (3) represents the QEI-III period: 2008Q4 - 2014Q3. Column (4) shows results for the Post-QE III + QT period: 2014Q4 - 2019Q3. All specifications contain time fixed effects. Standard errors are two-way clustered at the bank and time level. * p<0.1, ** p<0.05, *** p<0.01

level.[16] Next, we estimate the regressions outlined in equation (6) and report the results in Table 6. Panel A is the OLS estimate. We find that an increase in reserves leads to a decrease in the amount of credit lines that are originated. A possible concern with this OLS estimate is 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. To address this concern, we use the same instrument for reserves as in our deposit tests above and estimate the effect of an

Table 6
Effect of Reserves on Credit Line Originations – Second Stage

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)	-0.0503*** (0.0149)	-0.0216 (0.0175)	-0.0318* (0.0184)	-0.122 (0.0798)
Newey-West s.e.	(0.0153)	(0.0224)	(0.0227)	(0.0567)
$Ln(Reserves)_{t-5}$	-0.0157 (0.00954)	-0.0105 (0.0146)	-0.0116 (0.0145)	-0.0158 (0.0196)
Newey-West s.e.	(0.00850)	(0.0124)	(0.0138)	(0.0114)
Constant	0.299** (0.129)	0.273 (0.208)	0.279 (0.202)	0.295 (0.291)
Obs	2263	910	679	575
R-sq	0.187	0.270	0.210	0.117
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

Table 6 continued

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)	0.0584** (0.0248)	0.0678** (0.0268)	0.0614** (0.0231)	0.440 (3.847)
$Ln(Reserves)_{t-5}$	-0.00684 (0.00870)	-0.00207 (0.0126)	-0.00255 (0.0121)	0.00755 (0.174)
Obs	2263	910	679	575
Time-FE	Y	Y	Y	Y
Bank and 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

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. All specifications control for time–FE. 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_{it}^{R}). Standard errors are two–way clustered at the bank and time or at the time level (second stage). 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

exogenous increase in reserves on the amount of credit lines that are originated by banks.

The IV estimate is reported in Panel B. As before, column (1) shows the results for the full sample, column (2) for the QE I-III and pandemic QE period, 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 QE periods, an exogenous 10 percent increase in reserves of a bank leads to an increase in the origination of lines of credit to investment-grade and unrated firms by about 0.6 percent. Such a positive statistically significant relationship between reserves and credit line amounts is, however, missing in the QT period, with the coefficient turning insignificant and standard errors 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. We reiterate that the coefficient estimate on the change in log reserves in the OLS estimate (Panel A) is typically negative for the overall and QE periods. So once again, the instrumenting of reserves changes the sign of the effect.

5. Central Bank Reserves and Bank Pricing of Deposits and Credit Lines

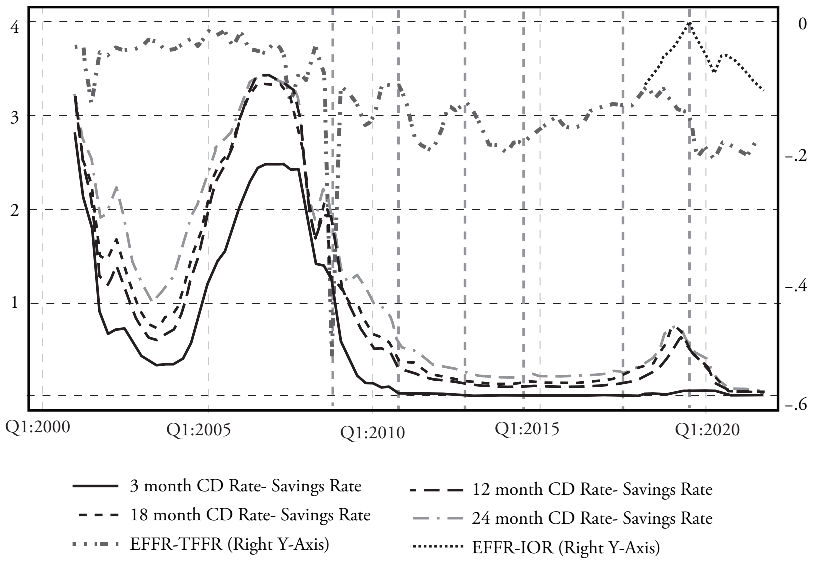
One way to get further insights into the issuance of claims on liquidity by commercial banks is to examine their pricing across banks. As econometricians operating outside the Fed, we do not have inter-bank data in order to determine a variant of EFFR-IOR at the bank or BHC level; hence, we must examine alternative measures of the price of liquidity. In particular, we identify measures of the price of liquidity using bank-level deposit rates and BHC-level fees charged for credit lines.

We start by examining bank deposit rates. Since checking accounts typically have close-to-zero rates given the transactional convenience they offer, we focus in our cross-sectional deposit rate tests on the spread between time-deposit rates (in particular, rates on Certificates of Deposits (CD) where the depositor is locked in for the term by high withdrawal penalties) and non-MM savings rates.[17] 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–the bank is not willing to pay more for term protection and indeed reduces the issuance of term deposits. Importantly, this would suggest a bank response on the liability side that does not sit easily with theories of QE that emphasize a portfolio rebalancing channel of transmission on the asset side.

5.1. Descriptive Analysis of Deposit Rates

In Chart 5, we plot the aggregate spread of CD rates of 3, 12, 18 and 24 months over the savings rate (i.e., CD rate minus the savings

Chart 5
CD Rate – Savings Rate Spread by Maturity



This chart plots the aggregate spread of CD rates of 3, 12, 18 and 24-month maturities w.r.t. savings rate at the bank level weighted by bank-quarter level deposits. All CD rates and savings rates are sourced from S&P Global's RateWatch deposits dataset. The Effective Federal Funds Rate (EFFR), Target Federal Funds Rate (TFFR) and Interest on Reserves (IOR) are sourced from FRED. The vertical lines correspond to the beginning of the different Federal Reserve QE / QT phases: (1) November 2008 (QE I), (2) November 2010 (QE II), (3) November 2012 (QE III), (4) October 2014 (Post-QE III), (5) QT period, (6) September 2019 (Pandemic QE).

rate) at the bank-level weighted by bank-level deposits. We also plot 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) to compare the trends in inter-bank price of liquidity against the CD to savings rate spread.

The trend across all maturities seems to suggest that the CD to savings rate spreads came down significantly after the first QE and haven't returned to their 2006 peak since. We do see some reversal in the second half of the QT period, but the spreads start falling again in the pandemic QE period. Importantly, the CD to savings rate spread seems to spike during the Global Financial Crisis as well as in the run up to the repo-market spike in EFFR-IOR of September 2019, suggesting that the spread likely moves in tandem with the bank-level price of liquidity in the market for reserves. Equally importantly, we find in descriptive statistics that even though the average level of CD to savings rate spreads is low, there is considerable cross-bank variation which we relate next to the bank-level (exogenous) reserves.

5.2 Impact of Bank-Level Reserves and Deposits on Deposit Rates

In keeping with the time-series regression of Lopez-Salido and Vissing-Jorgensen (2022) that links the aggregate stock of reserves and deposits to the EFFR-IOR spread, we investigate how an exogenous increase in bank-level reserves and deposits affects the CD to savings rate spread across banks. We control for bank- and time-fixed effects, among other reasons to address stationarity issues relating to the explanatory variables being 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.

Our instrument for deposits focuses on the counties the bank is present in and the growth in deposits there. Specifically,

$$z_{it}^{D} = \ln\left(\sum_{c \in Ci,t} w_{ict} \cdot \frac{Dep_{c,t}}{Dep_{C,t-1}}\right) \text{where } w_{ict} = \frac{Dep_{c,t-1}}{\sum_{c' \in C_{i,t}} Dep_{c',t-1}} \cdot w_{ict}$$

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 instrument is the overall deposit growth rates of the counties the bank has a presence in, weighted by their relative aggregate deposit size last period among all the counties the bank has a presence in.

Implicitly, we assume the deposit growth rates in the larger (in terms of aggregate deposits) counties that bank has a presence in will drive the growth rate in its own deposits, or 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 spreads, other than through the size and growth of its own deposits. We test the robustness of our results with alternative instruments for deposits that are based on different assumptions of exogeneity.[18]

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

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

$$Ln(Deposits)_{it} = \gamma_{21} Deposit\ Instrument_{it} + \gamma_{22}\ Reserves\ Instrument_{it} + \rho_i + \delta_t + \mu_{it} \quad (8)$$

where *i* represents bank, *t* represents quarterly data, ρ_i represents bank-fixed effects, and δ_t represents (quarter) time-fixed effects. The first stage results can be seen in Table 7. *Ln(Deposits*) has a positive and significant correlation with the *Deposit Instrument*. Similarly, *Ln(Reserves)* has a positive and significant correlation with the *Reserves Instrument*.[19]

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

$$Deposit\ Rate\ Spread_{it} = \beta_1 Ln(Deposits)_{it} + \beta_2 Ln(Reserves)_{it} + \pi_i + \tau_t + \varepsilon_{it} \quad (9)$$

where *i* represents bank *i, t* represents the quarterly date, π_i represents bank-fixed effects and τ_t represents (quarter) time-fixed effects. *Deposit Rate Spread* refers to the 3-, 12-, 18- and 24-month CD Rate Certificate of Deposit (CD) Rate – 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 spreads. Conversely, banks with more deposits, a claim on liquidity, will want to increase spreads so as to increase the maturity of their deposits, so we would expect β_1 to be positive.

Table 7
Effect of Reserves and Deposits on CD Rate – Savings Rate Spread: First Stage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Ln(Total Deposits)				Ln(Reserves)		
z^R_{it}	1.038*** (0.352)	0.329** (0.151)	0.0204 (0.131)	6.829 (5.595)	11.96*** (1.467)	9.537*** (0.843)	8.583*** (0.707)	38.13* (21.70)
z^D_{it}	0.0449*** (0.00690)	0.0291*** (0.0101)	0.0439*** (0.00992)	0.0320*** (0.00773)	0.0296 (0.0241)	–0.00300 (0.0397)	0.0298 (0.0345)	0.0701** (0.0294)
Constant	13.48*** (0.000607)	13.47*** (0.000779)	13.29*** (0.000678)	13.66*** (0.000674)	8.968*** (0.00208)	9.643*** (0.00307)	9.309*** (0.00209)	9.802*** (0.00247)
N	133964	57975	49607	34682	121851	53372	45439	31354
R-sq	0.939	0.960	0.967	0.988	0.726	0.763	0.755	0.843
F-stat	26.79	6.886	10.69	10.72	34.59	64.84	73.78	4.650
Bank & Time-FE	Y	Y	Y	Y	Y	Y	Y	Y
Bank & Time Clustered FE	Y	Y	Y	Y	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	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

This table shows the first stage results of the instrumental variable two-stage least-squares regressions in Tables 8 and 9. Bank Balance Sheet Data is sourced from Consolidated Reports of Condition and Income for a Bank with Domestic and Foreign Offices (Call Reports) of the FDIC. Reserves are cash and balances from Federal Reserve Banks at the consolidated bank-level (RCFD0090). Total Deposits are the sum total of deposits held in domestic and foreign offices (RCON2200 + RCFN2200). The instrument for deposits, z^D_{it} (henceforth, Deposit Growth Instrument) is the deposit growth rates of the counties the bank has a presence in, weighted by their relative deposit size last period. Data for branch-level deposits are from FDIC's Summary of Deposits. The instrument for reserves z^R_{it} is defined as *Growth in Aggregate Reserves* × Lagged Share in Reserves, averaged over past four quarters. Aggregate Reserves are sourced from FRED. Columns (1) & (5) represent the regressions on the overall sample ranging 2001 Q1 – 2021 Q4. Columns (2) & (6) represent QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Columns (3) & (7) represent the QEI-III period: 2008Q4 - 2014Q3. Columns (4) & (8) show results for the Post-QE III + QT period 2014Q4 - 2019Q3. We control for 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

Table 8
Effect of Reserves and Deposits on CD Rate – Savings Rate Spread: Second Stage

Panel A: OLS

	(1) 3 month CD Rate - Savings Rate	(2) 12 month CD Rate - Savings Rate	(3) 18 month CD Rate - Savings Rate	(4) 24 month CD Rate - Savings Rate
Ln(Total Deposits)	-0.0112	0.00565	0.000805	-0.00624
	(0.0168)	(0.0180)	(0.0196)	(0.0182)
Ln(Reserves)	-0.00434**	-0.00114	-0.000928	-0.000381
	(0.00201)	(0.00196)	(0.00221)	(0.00205)
Constant	0.730***	0.925***	1.092***	1.333***
	(0.224)	(0.239)	(0.261)	(0.241)
Obs	94752	101306	84738	99680
R-sq	0.854	0.910	0.904	0.907
Bank & Time-FE	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y
Reg Type	OLS	OLS	OLS	OLS
Period	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4

Table 8 continued

Panel B: IV	(1) 3 month CD Rate - Savings Rate	(2) 12 month CD Rate - Savings Rate	(3) 18 month CD Rate - Savings Rate	(4) 24 month CD Rate - Savings Rate
Ln(Total Deposits)	0.179	0.330*	0.496*	0.400**
	(0.178)	(0.177)	(0.253)	(0.169)
Ln(Reserves)	-0.109***	-0.0502	-0.220***	-0.111***
	(0.0304)	(0.0528)	(0.0558)	(0.0282)
Obs	85319	91212	76421	89830
Bank & Time-FE	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4	Overall: 2001Q1 - 2021Q4

The table shows OLS and second stage of 2SLS IV regressions of *3, 12, 18 and 24-month CD – savings spread* against bank-level *Ln(Total Deposits)* and *Ln(Reserves)*. CD and 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). *Deposits* are the sum total of deposits held in domestic and foreign offices (RCON2200 + RCFN2200). Panel A shows the OLS regression. Panel B shows the IV regression with *Ln(Total Deposits)* instrumented with the *Deposit Growth Instrument* ($z^{D}it$) and *Ln(Reserves)* instrumented with *Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous 4 quarters.* ($z^{R}it$). All specifications control for 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, ***"

Table 8 Panel A presents the OLS and Panel B the second stage of the 2-SLS regression results for the overall sample period. We see in Panel B that except for the 12-month CD spread, the coefficients on *Ln(Reserves)* are negative and statistically significant as expected (and always negative), while the coefficient on *Ln(Total Deposits)* is positive, and statistically significant except for the 3-month CD spread. In terms of economic magnitude, a one-standard-deviation–2.18–increase in the instrumented log reserves (demeaned for bank- and time-fixed effects) translates into a 48 basis points (2.18 * the coefficient of -0.22 percent) narrower 18-month CD to savings rate spread, which is about 1.5 times the standard deviation of the demeaned spread in data.

We find similar results for the QE periods in Table 9 (Panel A) and the QE I-III periods (Panel B), with the economic magnitude of the effect being higher than in the overall sample. Interestingly, pricing in the Post QE III/QT period (panel C) becomes much noisier, with the coefficients on *Ln(Total Deposits)* turning negative and the coefficient on *Ln(Reserves)* turning positive, 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 (Table 7, column (8)). 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 does not simply reverse with the shrinkage in reserves; instead, it turns noisy.

5.3. 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, viz., (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 of this ratio conveys a bank preference to supply immediacy by selling claims on reserves. In

Table 9
Effect of Reserves and Deposits on CD Rate – Savings Rate Spread: Sub-samples

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

	(1) 3 month CD Rate - Savings Rate	(2) 12 month CD Rate - Savings Rate	(3) 18 month CD Rate - Savings Rate	(4) 24 month CD Rate - Savings Rate
Ln (Total Deposits)	0.211 (0.219)	0.567** (0.255)	0.282 (0.375)	0.538** (0.263)
Ln (Reserves)	-0.0989*** (0.0319)	-0.0216 (0.0460)	-0.172** (0.0756)	-0.0830*** (0.0290)
Obs	39947	42777	35550	42095
Bank & Time-FE	Y	Y	Y	Y
Bank & Time Clustered SEs	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4			

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

	(1) 12 month CD Rate - Savings Rate	(2) 12 month CD Rate - Savings Rate	(3) 18 month CD Rate - Savings Rate	(4) 24 month CD Rate - Savings Rate
Ln (Total Deposits)	0.279* (0.152)	0.462** (0.168)	0.388 (0.257)	0.459** (0.175)
Ln (Reserves)	-0.102** (0.0396)	0.00334 (0.0604)	-0.174** (0.0814)	-0.0696** -0.0305)
Obs	35129	37429	31021	36794
Bank & Time-FE	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	QE I-III: 2008Q4 - 2014Q3			

Table 9 continued

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

	(1) 3 month CD Rate - Savings Rate	(2) 12 month CD Rate - Savings Rate	(3) 18 month CD Rate - Savings Rate	(4) 24 month CD Rate - Savings Rate
Ln(Total Deposits)	-0.940 (1.305)	-1.684 (1.882)	-0.893 (1.503)	-1.935 (2.056)
Ln(Reserves)	0.525 (0.376)	0.695 (0.592)	0.382 (0.552)	0.780 (0.629)
Obs	21949	23938	19934	23631
Bank &Time-FE	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y
Reg Type	IV	IV	IV	IV
Period	Post-QE III + QT2014Q4 - 2019Q3			

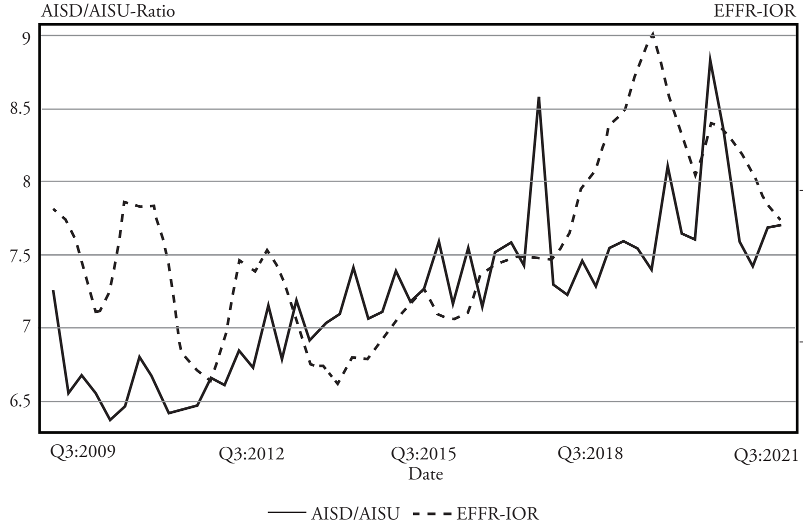
The table shows the second stage of 2SLS IV r*egressions*[30] *of 3, 12, 18 and 24-month CD – savings spreads* against bank-level *Ln(Total Deposits) and* Ln(Reserves) during various sub-sample periods. Panel A represents the sub-sample QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4. Panel B represents the sub-sample QE I-III: 2008Q4 - 2014Q3. Panel C show results for the Post-QE III + QT2014Q4 - 2019Q3. CD and 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 from Federal Reserve Banks at the consolidated bank level (RCFD0090). Deposits are the sum total of deposits held in domestic and foreign offices (RCON2200 + RCFN2200). Ln(Total Deposits) are instrumented with the Deposit Growth Instrument (zDit) and Ln(Reserves) are instrumented with Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous four quarters (zRit). All specifications control for 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

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 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.[20] Berg et al. (2016) also show that this relationship holds particularly for investment-grade and unrated firms, and in the sample of large syndicated loan borrowers, these groups of firms are similar to each other in terms of credit quality and demand for liquidity.

In addition, 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 pandemic. In contrast, below investment-grade firms might

Chart 6
Pricing of Credit Lines and EFFR-IOR

Panel A. All loans



Panel B. Only investment-grade rated and unrated loans

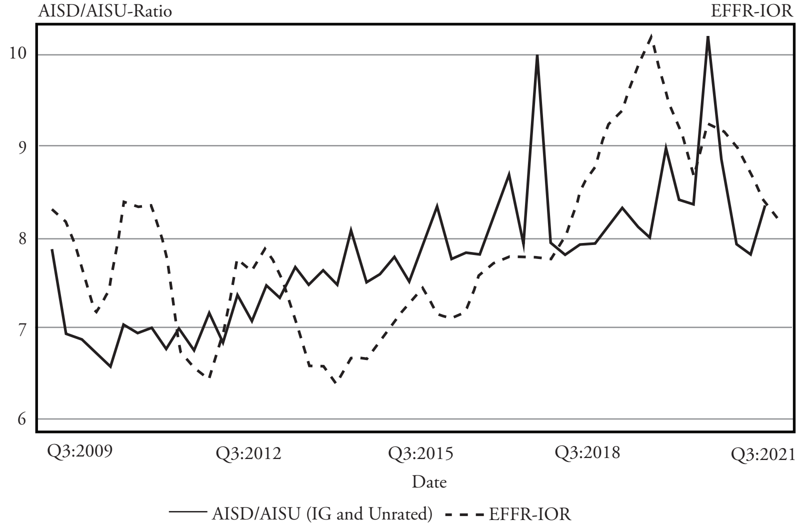
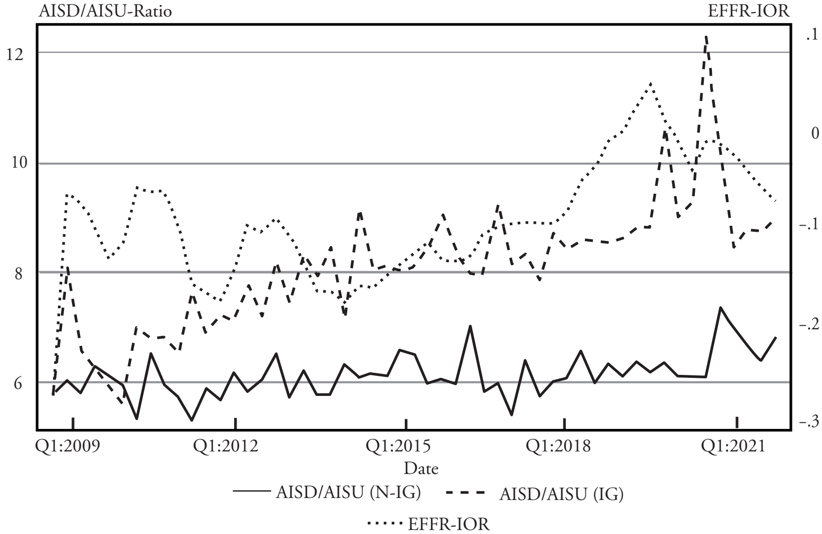


Chart 6 continued

Panel C. Investment-grade rated non-investment-grade rated loans



This chart plots the time-series of the AISD/AISU-ratio and the EFFR-IOR over the 2008 to 2021 period using data from the Refinitiv LoanConnector and the Federal Reserves' Flow of Funds. Panel A plots both time-series using all credit lines originated by U.S. borrowers; Panel B plots only credit lines issued to investment grade-rated and unrated firms. The Effective Federal Funds Rate (EFFR) and Interest on Reserves (IOR) are sourced from FRED.

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.

To confirm these intuitions, we investigate 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 about ρ=0.51 with EFFR-IOR, both AISD and AISU are insignificant individually–if anything–negatively correlated with the EFFR-IOR ratio (respectively, ρ=.0.1 and ρ=0.17). We thus employ the AISD/AISU-ratio as price measure for credit lines in our empirical tests.

We then investigate the correlation between EFFR-IOR and the AISD/AISU-ratio for investment-grade, non-investment-grade, and unrated firms using the S&P long-term issuer credit ratings at loan origination provided from Loan Connector. We plot the time-series of the EFFR-IOR (right y axis) and the AISD/AISU-ratio over the 2009 to 2021 period in Chart 6, for all credit lines originated to U.S. firms in Panel A (correlation between the two time-series is 0.49) and for credit lines originated by investment-grade rated and unrated firms in Panel B (correlation between the two time-series is 0.45). We plot the AISD/AISU-ratio for credit lines originated by non-investment-grade rated firms versus investment-grade rated and unrated firms in Panel C (the correlation between the two time-series is 0.3 which drops to 0.18 after 2013 as the AISD/AISU-ratio for non-investment-grade rated firms hardly varies over time).

Overall, the graphs mirror our earlier correlation results, i.e., the AISD/AISU-ratio is highly correlated with the EFFR-IOR for investment-grated and unrated firms. We thus focus in our subsequent analysis on the subsample of investment-grade rated and unrated borrowers, as we did also for the analysis of credit-line originations.[21]

5.4. Cross-Sectional Tests: Pricing of Credit Lines

We ask how an *exogenous* shock to credit lines and reserves affects the pricing of credit lines by banks. Intuitively, more liquidity should not only enable banks to expand the origination of credit lines as suggested earlier, but should, *ceteris paribus*, also decrease the price for providing liquidity via credit lines. To test this, we use the AISD/AISU-ratio as the price of credit line liquidity and estimate variants of the following model specification:

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

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 (π_i) and quarter-time (τ_t) fixed effects; standard errors are clustered at the bank and quarter level.

We estimate a 2-SLS specification, instrumenting in the first stage BHC-level credit 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 7). As Credit Line Instrument, we use the lagged credit line originations times the lagged aggregate Excess Loan Premium (ELP) from Saunders et al. (2022) to capture demand for credit lines). (Ln(Credit Lines)$_{it-1}$ x ELP$_{t-1}$). Note that we are interested in how a bank might alter the pricing of credit lines in response to exogenous changes in credit lines, either stemming from *exogenous* changes in demand or supply of lines. Aggregate ELP is regarded as an indicator of the tightness of financial conditions in the economy.[22] The credit line instrument is obtained by multiplying lagged ELP by an individual bank's lagged credit line originations. A high predicted 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 is a proxy for easier supply, which should lead to a reduction in the price of liquidity. In contrast, higher un-instrumented credit lines may reflect either easier supply (suggesting a lower price of liquidity) or higher demand (suggesting a higher price).

Table 10
Effect of Reserves and Credit Line Originations on Credit Line Fees (AISD/AISU) - First Stage

	(1) Ln(Credit Lines)	(2) Ln(Credit Lines)	(3) Ln(Credit Lines)	(4) Ln(Credit Lines)	(5) Ln(Reserves)	(6) Ln(Reserves)	(7) Ln(Reserves)	(8) Ln(Reserves)
z_{it}^{R}	0.401	2.432***	0.458***	-259.9**	11.37***	12.66***	3.846***	-536.7***
	(1.159)	(0.523)	(0.151)	(99.35)	(1.504)	(2.251)	(0.422)	(147.7)
z_{it}^{CL}	0.398***	0.318***	0.0407***	1.204***	0.286***	0.251***	-0.0542***	1.226***
	(0.0473)	(0.0428)	(0.0130)	(0.211)	(0.0571)	(0.0610)	(0.0148)	(0.210)
Constant	5.280***	3.638***	8.472***	5.555***	10.39***	9.989***	15.51***	10.44***
	(0.509)	(0.764)	(0.250)	(0.706)	(0.590)	(1.099)	(0.285)	(0.708)
Obs	2325	807	744	646	2213	774	720	588
R-sq	0.465	0.606	0.920	0.458	0.494	0.301	0.838	0.399
Bank & Time-FE	Y	Y	Y	Y	Y	Y	Y	Y
Bank and Time Clustered SEs	Y	Y	Y	Y	Y	Y	Y	Y

Table 10 continued

F-stat	38.95	109.8	9.037	43.25	172.1	54.48	50.32	45.66
Period	Overall: 2001Q1 -2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3	Overall: 2001Q1 - 2021Q4	QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4	QE I-III: 2008Q4 - 2014Q3	Post-QE III + QT2014Q4 - 2019Q3

This table shows the first stage results of the instrumental variable two-stage least-squares regressions in Table 11. Bank Balance Sheet Data is sourced from Consolidated Reports of Condition and Income for a Bank with Domestic and Foreign Offices (Call Reports) of the FDIC. Reserves are cash and balances from Federal Reserve Banks at the consolidated bank-level (RCFD0090). Credit lines are credit line originations from the Refinitiv LoanConnector database. The instrument for credit lines, z_{it}^{CL} (henceforth, *Credit Line Instrument*) is the $Ln(Credit\ Lines)_{it-1} \times ELP_{t-1}$. The instrument for reserves z_{it}^{R} is defined as Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over past four quarters. Aggregate Reserves are sourced from FRED. Columns (1) & (5) represent the regressions on the overall sample ranging 2001 Q1 – 2021 Q4. Columns (2) & (6) represent QE I-III + Pandemic QE of 2008Q4 - 2014Q3 & 2019Q4-2021Q4. Columns (3) & (7) Standard errors are two-way clustered at the bank and time level. * p<0.1, ** p<0.05, *** p<0.01"

Table 11
Effect of Reserves and Credit Line Originations on AISD/AISU - Second Stage

Panel A. Univariate

	(1) AISD/AISU	(2) AISD/AISU	(3) AISD/AISU	(4) AISD/AISU
Ln(Reserves)	-0.480* (0.263)	-1.023*** (0.268)	-1.202*** (0.265)	-1.154 (3.092)
Obs	2423	968	728	593
Bank & Time-FE	Y	Y	Y	Y
Bank and 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

Panel B. Credit line originations (un-instrumented credit line amount)

	(1) AISD/AISU	(2) AISD/AISU	(3) AISD/AISU	(4) AISD/AISU
Ln(Reserves)	-0.493* (0.254)	-1.007*** (0.262)	-1.118*** (0.247)	-0.785 (4.079)
Ln(Credit Lines)	-0.000143 (0.000297)	0.000498 (0.000602)	0.00149** (0.000584)	0.000291 (0.00113)
Obs	2423	968	728	593
Bank & Time-FE	Y	Y	Y	Y

Table 11 continued

Bank and 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

Panel C. Credit line originations (instrumented with credit line instrument)

	(1) AISD/AISU	(2) AISD/AISU	(3) AISD/AISU	(4) AISD/AISU
Ln(Reserves)	-0.840***	-1.545***	-1.581***	-3.380
	(0.301)	(0.360)	(0.379)	(4.279)
Ln(Credit Lines)	-0.335	-2.208*	-2.460	-5.722
	(0.572)	(1.141)	(1.483)	(6.405)
Obs	2202	768	715	586
R-sq	-0.160	-1.355	-1.539	-0.696
Bank & Time-FE	Y	Y	Y	Y

Table 11 continued

Bank and 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 + QT 014Q4 - 2019Q3

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 (Panel A) and credit lines (Panels B and C) 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) and are instrumented with the Growth in Aggregate Reserves × Lagged Share in Reserves, averaged over previous four quarters (zRit). 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. Panel B includes the natural logarithm of credit lines originated by bank-quarter. In Panel C, we instrument Ln(Credit Lines) with Ln(Credit Lines)it-1 x $ELP_{t-1}(z_{it}^{CL})$. Standard errors are two-way clustered at the bank and time level. * p<0.1, ** p<0.05, *** p<0.01

We estimate the 2-SLS as:

$$Ln(Credit\ Lines)_{it} = \gamma_{11} Credit\ Line\ Instrument_{it} + \gamma_{12}\ Reserves\ Instrument_{it} + \rho_i + \delta_t + \mu_{it} \quad (11)$$

$$Ln(Reserves)_{it} = \gamma_{21} Credit\ Line\ Instrument_{it} + \gamma_{22} Reserves\ Instrument_{it} + \rho_i + \delta_t + \mu_{it} \quad (12)$$

where i represents bank, t represents quarterly data, ρ_i represents bank-fixed effects and δ_t represents (quarter) time-fixed effects.

Table 10 shows the first stage results. *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*.[23]

We report the second-stage regression results in Table 11. Panel A of Table 11 presents the regression of AISD/AISU-ratio against only the instrumented log of reserve holdings. In panel B, we also include the un-instrumented log of credit lines, and in Panel C, we include instead the instrumented credit lines. 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 standard errors blow up, similarly to the case with credit line quantities in Table 6, Panel B). Finally, while the coefficient estimate on the instrumented log of credit lines is always negative (Panel C), it is statistically significant only for the QE periods, suggesting a greater volume of exogenous credit line originations by banks tends to decrease the price of liquidity provided by credit lines. Note that the un-instrumented log of credit lines (Panel B) has overall an unstable sign, but it is positive–as hypothesized above–when estimated separately for QE and post-QE/QT periods.[24]

The robust bottom line is that the price of credit-line-provided liquidity tends to fall when the Fed expands its balance sheet but the effect becomes noisy when it stops expansion or shrinks. The overall symmetry of 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 when the central bank shrinks its balance sheet.

6. Additional Results and Discussion

There are several additional results that are worthy of brief mention by way of robustness as well as because they help understand drivers of phenomena we have documented.

6.1 Additional Results

First, while we combined QE I, QE II and QE III (along with short interim non-QE periods) into a single overall QE I-III period, our cross-sectional results of Sections 4 and 5 are overall robust to separating out the individual periods as well as to excluding the interim periods, though there is some loss of statistical power in so doing. The same is the case with separating out post QE III and QT periods. In other words, the broad patterns we have uncovered on the impact of central bank balance-sheet on bank liabilities are not driven by specific sub-periods.

Second, we provide preliminary evidence in the Online Appendix that these results–including the asymmetry between QE and non-QE/QT periods–are driven by banks with (i) above-90th percentile size of assets (they especially keep growing deposits and credit lines post QE when their reserves shrink), and (ii) below-median equity-to-assets ratio (they especially increase demandable deposits and shrink time deposits when their reserves rise, consistent with a preference among less well-capitalized banks to increase liquidity risk). This has important implications for financial stability–the liquidity dependence of the banking system following the end of QE may be the most acute for larger and relatively less well-capitalized banks.

Third, we use data from Call Reports on deposit quantities by size relative to the FDIC guarantee thresholds to identify insured and uninsured portions of demandable and time deposits. Analyzing these categories separately in our cross-sectional tests reveals that uninsured time deposits shrink with bank reserves during the QE periods, whereas uninsured demandable deposits rise; these relationships with reserves are reversed during the post-QE III + QT sub-sample but are statistically insignificant for uninsured time deposits. These patterns are all relatively muted for insured deposits, demandable or time, confirming that liquidity dependence we identify as emerging from the QE periods poses material concern for future liquidity stress as it manifests itself primarily in uninsured bank deposits.

Finally, in order to better understand the relationship of OLS and IV analysis in our panel tests, we examine which bank characteristics drive the OLS results and how our reserves instrument is related to these characteristics. For instance, bank reserves are positively related to time deposits in OLS, but negatively so in IV. We find that a part of the OLS variation is driven by shocks to bank risk as proxied for by the current-quarter volatility of a (publicly listed) bank's stock returns; a risky bank raises both reserves and time deposits. This endogenous relationship is, however, reversed to a negative sign once we instrument bank-level reserves for an exogenous change–aggregate change in reserves multiplied by the past four quarters of the bank's share of aggregate reserves. Consistent with the validity of this instrument, its correlation with the bank risk measure is close to zero (and stays that way after we take out bank- and time-fixed effects, which we control for in our estimations). Indeed, the instrument is also uncorrelated with bank size and capitalization, two other relevant bank heterogeneity measures discussed above.

6.2 Discussion

There are alternative perspectives in the literature on liquidity stress. One strand emphasizes the present-day regulation of liquidity risk of banks. Since 2015, the U.S. banks have been subject to liquidity coverage ratio (LCR) requirements, with the largest banks having to meet them on a daily basis. Clearly, such requirements can reduce the mobility of reserves within the banking system and from banks to non-banks (D'Avernas and Vandeweyer (2021)). There are, however, reasons to believe that this is not the entire picture. 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 shrunk, banks should have had incentives to increase their time deposits since deposits with maturity greater than one month attract zero run-off rates in LCR calculation, and shrink their demandable deposits which carry positive run-off rates. We do not observe this in data, and in fact in Chart 1, Panel C, time deposits keep shrinking and demand deposit rising at least until 2017. Paradoxically, if the LCR were indeed binding, such strange bank behavior would require the Fed to keep injecting reserves even when it has decided to stop doing so, given monetary policy considerations.

A somewhat different but related perspective is that demandable claims on the banking system are no longer the source of financial stability risks given regulations such as the LCR. Instead, the culprit is some other balance-sheet constraint, or high liquidity charges for inter-bank contracts in LCR that have reduced the mobility of U.S. bank reserves (such as during the repo-rate spike of September 2019, see Anderson et al. (2021), Copeland et al. (2021), among others). Such frictions would make our findings more worrisome, especially if LCR calculations are not robust in all situations. If reserves are indeed not too mobile within the banking system, then a stress scenario in which run-off rates at specific banks exceed the assumptions of the LCR calculations would be more likely to trigger liquidity stress in the system, requiring Fed injection of more reserves. More importantly, liquidity and solvency risks can interact when shocks emanate from the real economy, such as during 2007-08 and March 2020 (unlike in September 2019). At such times, the non-shrinking stock of demandable claims on the banking system can require en masse support of the financial system.

In summary, the data we have presented–and the phenomenon of liquidity dependence of a banking system coming out of quantitative easing that we have documented–do not necessarily contradict some of these alternative perspectives. They should be regarded as complementary, suggesting at a minimum that the financial system was made–and going forward can become–more vulnerable to unexpected shocks given the private response of the banking sector's demandable liabilities to the Fed balance sheet expansion.

7. Policy Implications.

We have documented an important phenomenon of liquidity dependence that has implications for monetary policy and financial stability. As the Fed increased its balance sheet through successive waves of QE, commercial banks issued claims on liquidity such as demand deposits and lines of credit. This certainly meant that liquidity was never as plentiful as suggested by the simple increase in reserves. Indeed, claims on liquidity may not only render the banking sector vulnerable to liquidity stress, as analyzed by Acharya and Rajan (2022), but bank actions may also have limited the working of monetary policy as we explain below.

7.1. Monetary Policy Implications

For instance, by buying long-term bonds from the market with reserves, the Fed expects to compress the yield on long-term financing, thereby facilitating the financing of long-term projects. This is one way that QE could be transmitted into real activity (Krishnamurthy and Vissing-Jorgensen, 2011). However, banks do not seem to be taking advantage of the compression in term spreads. Instead, they have been shortening the maturity of their liabilities over the period of QE, even within deposits, making it harder for them to finance long-term loans. Indeed, in the cross-section, banks with more reserves have been reducing the term spread they pay, suggesting the aggregate level reduction in term deposits during QE has its counterpart at the bank level; banks with more reserves offer rates that would shorten the maturity of their deposits.

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; in the extreme, banks may in fact even shorten the maturity of non-reserve assets. This may explain in part why it has been somewhat challenging to identify the real effects of QE (Greenlaw et al., 2018, and Fabo et al., 2021).[25]

More generally, this suggests that commercial bank behavior is crucial in understanding the impulses transmitted by central bank balance sheet expansion. For instance, plausible theoretical arguments (see, e.g., 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 however works best if reserves are held by non-banks. If they are held by banks, we have seen that commercial banks, in aggregate and individually, shorten the maturity of their deposits in response to an expansion in reserves. The theoretical argument thus works less well when commercial banks hold the reserves on their balance sheet; after accounting for commercial bank behavior, the empirical finding is thus that a larger central bank balance sheet is correlated with more demandable claims, not less.

7.2. Liquidity Stress

Conversely, however, when central banks stop expanding reserves or actively shrink them (QT), we have seen that commercial banks do not extinguish demandable claims rapidly. This then can tighten liquidity conditions considerably, making the system prone to liquidity stress of the kind seen in September 2019. A variety of observers have attributed such phenomena to short-term disruptions in the availability of liquidity–for instance, a large inflow of reserves into the Treasury account depleted the availability of reserves elsewhere in the system (see Copeland, Duffie, and Yang (2022) and the references within). While these explanations are undoubtedly relevant, it is important to ask why the system was so stretched and prone to disruption. As we show in Chart 1 (Panels B and D), the claims on liquidity as a multiple of reserves had grown significantly by September 2019, because the claims did not shrink, even as QT shrank outstanding reserves. Could it be that the Treasury account straw broke the financial system's liquidity back because the financial system was already overloaded with potential liquidity claims relative to available liquidity?

From a monetary policy perspective, the fear of such episodes of liquidity stress when past central bank balance sheet expansion is being reversed may further limit real investment and the transmission of balance sheet expansion. The greater concern is for financial stability. Since some banks may be overly stretched at such times, and even the available liquidity may not be appropriately circulated to choke points because other banks want to hoard liquidity, the system may seize up without further central bank intervention. However, this may set the grounds for yet more central bank intervention. It may thus be hard to wean the system of dependence on central bank liquidity.

7.3. Why Do Commercial Banks Not Shrink Liquidity Dependence?

Before we turn to other policy implications, we have to ask why we see the observed patterns. In particular, why do commercial banks not shrink their issuance of claims on liquidity when the central bank withdraws reserves from the system?

One possible explanation is drift or some sort of momentum–plans are set in place to write lines of credit contracts or accept deposits, and it is hard to reverse them quickly. Yet as Chart 1 Panel C suggests, deposits continued growing after the end of QE III in late 2014 right until nearly the end of 2018. It is hard to imagine that such growth over years would happen without active connivance by the banks.

A second possibility is institutional hysteresis/agency costs. 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 liquidity. Until the shortage of aggregate liquidity makes itself felt, such as through the events of September 2019, 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.[26]

A third possibility that sometimes drives bank behavior is regulation. There has been substantial liquidity and capital regulation put in place since the Global Financial Crisis. Binding maximum leverage ratios would make it costly for banks to hold liquid reserves on their balance sheets, since these add to capital requirements. Yet banks have to hold all the reserves (with the possible exception of some portion of the central bank balance sheet financed by non-banks through reverse repo transactions). So one way for banks to offset the cost is to write claims on liquidity (see Kashyap, Rajan, and Stein (2002)) and thus obtain cheap financing (for example through demand deposits) or fee income (through commitment fees on lines of credit). 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 also reduce the claims written on liquidity. That they do shrink reserves (at least on average) but not claims on liquidity is hard to attribute to regulation alone.

7.4. Monitoring and Managing Liquidity Stress

Clearly, without more detailed investigation of bank behavior, it is hard to specify micro interventions. Yet our evidence suggests a number of areas of concern for policy makers, which may lead to altered policies:

1) Central banks have to be alert for growing liquidity mismatches during the process of QT and respond quickly if they see them, either forcing a reduction in liquidity claims through supervisory action or slowing the process of reserve withdrawal to ensure the reduction in reserves and demandable bank claims is commensurate. Exercising the latter option naturally creates a conflict between financial stability and monetary objectives of central bank.

2) If aggregate liquidity shortages precipitate systemic liquidity stress, central banks have to be aware that additional liquidity provision will resolve the problem temporarily, but may strengthen the underlying behavior that led to the shortages in the first place. Also, Bagehot's dictum–lend freely but at a penalty rate–may not dissuade banks if the penalty is small. Once again, direct supervisory action may be necessary to de-risk the system after stress episodes and central bank liquidity intervention. One policy that might prove unhelpful is if supervisors ratchet up liquidity requirements, demanding greater reserve holdings (see Nelson (2019, 2022)). Certainly, the phenomenon of reserve hoarding by banks, in part because of fear of such

supervisory action, requires greater consideration (Bank of England (2022), Copeland, Duffie, and Yang (2021)).

An interesting alternative that could be considered to deal with supervisor-induced hoarding is one employed by emerging market central banks such as the Reserve Bank of India: Regulators can allow some state-contingent tolerance (e.g., +/- 5 percent, 10 percent, …) 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 any supervision-related stigma attached to arbitraging inter-bank rates in times of stress and, in turn, induce surplus banks to pass around liquidity.

3) Another possibility raised by Acharya and Rajan (2022) is the incentive of banks to hoard liquidity for non-supervisory reasons. Specifically, in a crisis liquidity may not move to banks that need it because other banks hoard it–because they fear drawdowns themselves or want to take care of arbitrage opportunities that may emerge. Therefore, as liquidity claims narrow the gap with reserves, central bankers should worry. Of course, they can always bridge any gap ex post by intervening in times of stress, but this put distorts banker incentives.

Better still might be to alter individual bank liquidity conditions if the aggregate liquidity surplus tightens considerably. For instance, individual banks could be required/incentivized to maintain a longer duration of deposits, especially during quantitative easing when we observe substantial duration-shortening.[27] Similarly, capital and liquidity stress tests could factor in higher drawdowns on bank lines of credit (dash for cash) in aggregate risk scenarios, as illustrated for the case of capital requirements in Acharya, Engle and Steffen (2021). In effect, solvency requirements that incentivize bank liabilities to be more long term may need to be jointly designed with liquidity requirements and modulated to be at higher levels before embarking upon QT.

4) Liquidity dependence resulting from QE and the poor reallocation of liquidity within the system in times of stress can also have implications for market-making by banks in systemically important

markets such as the Treasuries. This can affect the orderly functioning of shadow banks, as seen at the time of the COVID outbreak. Given the crucial role non-banks play in markets and the broader economy, a standing repo facility for non-banks (beyond just for primary dealers) against high-quality collateral, with appropriate eligibility criteria and ongoing supervisory overview, such as the one introduced recently by the Bank of England, is one option.[28] Another, not mutually exclusive, option is to improve the redistribution of liquidity in the financial system by removing the capital requirement on banks against reserves (as recommended by Liang and Parkinson (2020)) and induce a willingness in banks to lend reserves to non-banks against high quality collateral.

5) Overall, since (i) QE may not have as powerful an effect on economic activity as suggested by theories that ignore the buildup of claims on liquidity written by the banking sector, and (ii) central bank balance sheet expansion may be harder to reverse than earlier thought and a part of it may be irreversible due to hysteresis and financial stability considerations, our work suggests careful reconsideration of the merits of QE. If monetary authorities have few other tools to encourage economic activity, it may be appropriate to appeal to others (such as the fiscal authorities) to support activity since pushing on the string of QE when economic transmission is muted may primarily increase eventual financial fragility and the likelihood of liquidity stress.

8. Conclusion

The focus of academic, industry and policy research in teasing out the effects of QE and QT has been on the asset side of financial intermediaries, and their effects on intermediary capital and attendant asset-price implications. How central bank balance-sheet expansion affects the liquidity claims on the banking system has largely been ignored. Working from the theoretical results in Acharya and Rajan (2022), we address this important issue. We document that banking deposits increase, and become more demandable when QE expands reserves. Importantly, the maturity-shortening of banking sector liabilities when the stock of reserves rises is evidenced not just at the aggregate level in time-series data but also at an individual bank level in the cross-section. Banks also originate more corporate lines of credit. We observe little reversal of all this during QT.

We argue that this asymmetric behavior makes the banking system dependent on the central bank for ever larger liquidity infusions during stress and can explain tightening liquidity conditions and occasional stress episodes when QT is under way, despite the central bank balance sheet being large relative to historical standards. QT may therefore not be as benign or painless for the financial sector and the economy as QE. This also implies reserve expansion may have muted, even adverse, effects on available liquidity and thence financial stability, with greatest vulnerability when reserves are shrunk.

A fruitful area for further inquiry is to understand the precise determinants of these behaviors, for it would help inform central bank policy responses. Equally importantly, the increase in bank short-term deposit funding and bank issuance of credit lines when reserves expand is likely to be associated with a reluctance by banks to make long-term loans and hold long-term assets, countering some of the proposed mechanisms through which QE is meant to impact the real economy. Teasing out the relation between the expansion of banking sector's demandable claims and the transmission of unconventional monetary policy to the real economy appears to be another fertile area for future analysis.

Finally, while our evidence has theoretical underpinnings that seem general, it is based entirely around the balance-sheet decisions of the Fed. Several other systemically large central banks such as the Bank of England, European Central Bank, and the Bank of Japan, also undertook many rounds and incarnations of QE and QT. It would be extremely valuable to know if the response of the U.S. banking sector's liquidity claims to the Fed's balance-sheet expansion carry over to these other settings. For instance, it is interesting to note that both the European Central Bank and the Bank of Japan, in implicit acceptance of the weak real effects of the first rounds of QE, ultimately resorted to directly purchasing securities (bonds and/or equity) of corporations and effectively financing them. Clearly, there is scope for much more empirical work to assess if the tenor of our empirical findings is replicated in other settings.

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Endnotes

[1]As explained in Acharya and Rajan (2022), some of this is mechanical to start with. If non-banks sell their assets to the central bank, which is empirically the case, then their commercial bank receives reserves in exchange from the central bank and non-banks create wholesale demandable bank deposits in the process (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 banking sector balance-sheet with reserves when central banks swaps assets with non-banks. The question thereafter is whether banks alter their capital structure and move away from these wholesale deposits towards longer-term liabilities such as time deposits and capital.

[2]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 by Acharya and Mora (2015) for the global financial crisis). Another possibility is that even if net withdrawals on the stressed bank are not large enough to induce direct liquidity stress, gross drawdowns can put stress on solvency (as shown by Acharya, Engle and Steffen (2021) for the COVID-19 outbreak in March 2020), and in turn, on liquidity of the bank, as capital requirements tend to be greater against drawn-down credit lines than undrawn ones.

[3]See Acharya, Shin and Yorulmazer (2011), Diamond and Rajan (2012) or Farhi and Tirole (2012) on the theoretical modeling of such collective moral hazard.

[4]Note that the central bank reserves can exceed the reserves with the banking system due to reserves being (i) redeposited by banks with the central bank as reverse repo, (ii) held by non-banks (such as under the Reverse Repo Facility of the Fed), and (iii) circulated as currency in the economy. For instance, in August 2022, the Fed balance-sheet size of around $9 trillion corresponded to roughly $4 trillion with the banking system, $1 trillion in reverse repos of banks, $2 trillion in reverse repos of non-banks, and $2 trillion currency-in-circulation. We often refer to reserves with the banking system as aggregate reserves given our focus on the banking system.

[5]We use the IOR terminology adopted in Lopez-Salido and Vissing-Jorgensen (2022) instead of IOER (interest on excess reserves) or IORB (interest on reserve balances).

[6]We rely on syndicated credit line data to get directly at their originations. While the Call Reports data provide outstanding credit lines (to both corporations and individuals) for a bank, time-series variation in this variable confounds originations of credit lines with maturity of existing credit lines. Furthermore, since we also analyze fees on credit lines at the time of origination, focusing on syndicated credit lines maintains consistency of datasets across different parts of our analysis.

[7]Outstanding bank credit lines to corporations declined from $2.37 trillion in Q4 2007 to $1.89 trillion in Q4 2011, largely due to drawdowns by corporations during and following the global financial crisis, corresponding to a drawdown rate of about 22% in the aggregate (see Acharya, Engle and Steffen (2021)). Since there is also maturing of credit lines along the way, aggregate data do not allow for a clear separation between credit line originations and drawdowns plus expiration.

[8]For Panel D, we break up deposits into demand deposits and time deposits in Model (2a). The full model specification is shown in column (6) of Table 2.

[9]This decomposition within demand deposits 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.

[10]Possible exceptions include the short period after September 2019 when reserves were issued to confront financial fragility during the repo rate spike of September 2019, and possibly also at the very early stage of QE I in November 2008 to deal with aftermath of the Lehman Brothers collapse.

[11] An alternative instrument is to multiply the log growth in aggregate reserves over the year (instead of the quarter) by the lagged reserve share. It has similar effects (see Online Appendix). The previous quarter's change in reserves, i.e., aggregate quarterly reserve growth times lagged share, is likely to be more exogenous than the aggregate reserve growth over the previous year, in that banks are less likely to have fully optimized individual balance sheets in response to the change within a quarter.

[12]Yet another instrument that can be considered is the log growth in aggregate reserves multiplied by the bank's lagged share of eligible securities, where eligible refers to collateral such as Treasuries or Agency mortgage-backed securities (MBS) that can be tendered to the Fed in exchange for reserves, averaged over previous four quarters. We estimate the eligible securities by taking the sum of bank's treasury securities and guaranteed MBS assets in Schedule RC-B of Call Reports. While this instrument leads to similar results for deposit quantities, in line with the theory of Acharya and Rajan (2021) it does not lead to lower term deposit spreads (see Online Appendix): more eligible securities can lead to a greater acquisition of reserves, but it also implies a higher stock of longer-term fixed-income securities which the bank will seek to maturity-match with longer-term deposits, confounding the maturity-shortening effect of reserves.

[13] All first-stage regressions have a F-statistic above the Staiger and Stock (1997) cutoff of 10. Since we drop the i.i.d. assumption on error terms by employing two-way clustering at the bank and quarter-level, we confirm that the Kleibergen and Paap (2006) Wald F-statistics lie above the Stock and Yogo (2005) critical value for 10% maximal IV bias.

[14]Given that Capital IQ and Refinitiv source the raw data from public SEC filings, their coverage of firms is likely similar with respect to credit line issuances, but Capital IQ allows us to track different type of debt components on firm balance-sheets.

[15]In contrast, term loans are usually held by institutional investors (mainly Collateralized Loan Obligations, or CLOs) and thus origination amounts and terms likely reflect supply-side requirements of institutional non-bank rather than traditional bank lenders (see e.g. Ivashina and Sun (2011) and Nadauld and Weisbach (2012).

[16]All first-stage regressions have a F-statistic above the Staiger and Stock (1997) cutoff of 10 except Column (4) in the Post-QE III + QT: 2014Q4 – 2019Q3 period.

[17]The results are similar for money-market savings rates as shown in the Online Appendix which also shows that the time-series of the spread between CD and various demandable deposit rates are highly co-moving.

[18]In the Online Appendix, we report results when deposits are instrumented based on (i) senior-share at the county- level inspired by Becker (2007), and (ii) zip-level disaster assistance from Small Business Administration based on the disaster instrument from Diamond, Jiang and Ma (2021). The first-stage and second-stage results are robust to these alternate instruments.

[19]All first-stage regressions have a F-statistic above the Staiger and Stock (1997) cutoff of 10 for all but Column (2) with Ln(Deposits) as the endogenous regressor in QE I-III + Pandemic QE: 2008Q4 - 2014Q3 & 2019Q4 - 2021Q4 period and Column (8) with Ln(Reserves) as the endogenous regressor in the Post-QE III + QT2014Q4 - that the Kleibergen and Paap (2006) Wald F-statistics lie above the Stock and Yogo (2005) critical value for 10% maximal IV bias.

[20]Also see, for example, Thakor and Udell (1987) and Shockley and Thakor (1997), for a theoretical discussion of credit lines along these lines.

[21]Comparative results for the subsample of non-investment-grade rated firms are in the Online Appendix.

[22]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.

[23]All first-stage regressions have a F-statistic above Staiger and Stock (1997) cutoff of 10 except Column (3) with Ln(Credit lines) as the endogenous regressor in the QE I-III: 2008Q4 - 2014Q3 period.

[24]Using the Excess Bond Premium (EBP) from Gilchrist and Zakrajsek (2012) instead of the Excess Loan Premium (ELP) of Saunders et al. (2022) in the construction of our instrument, we obtain qualitatively similar results (see Online Appendix). The economic and statistical significance, however, is somewhat muted as firms with excess to public bond markets are less financially constrained and therefore less saliently reflect the tightness of financial conditions in the rest of the economy.

[25] Indeed, we show in the Online Appendix 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.

[26] This is not to say illiquidity is costless. Banks did face a costly aggregate liquidity crisis during 2007-08 as shown by Acharya and Mora (2015), despite substantial Fed intervention.

[27]Of course, this has to be balanced against the need to finance an expanded central bank balance sheet. It may well be that in the interests of financial stability, that expansion has to be more muted.

[28]See, in particular, https://www.bankofengland.co.uk/markets/market-notices/2022/august/short-term-repo-facility-provisional-market-notice-4-august-2022.

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