Liquidity Provision and Co-insurance in Bank Syndicates

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Abstract

We study the capacity of the banking system to provide liquidity to the corporate sector in times of stress and how changes in this capacity affect corporate liquidity management. We show that the contractual arrangements among banks in loan syndicates co-insure liquidity risks of credit line drawdowns and generate a network of interbank exposures. We develop a simple model and simulate the liquidity and insurance capacity of the banking network. We find that the liquidity capacity of large banks has significantly increased following the introduction of liquidity regulation, and that the liquidity co-insurance function in loan syndicates is economically important. We also find that borrowers with higher reliance on credit lines in their liquidity management have become more likely to obtain credit lines from syndicates with higher liquidity. The assortative matching on liquidity characteristics has strengthened the role of banks as liquidity providers to the corporate sector.

JEL Classification: G21, G18, L14

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1 Introduction

Liquidity dried up in the early stages of the 2007-09 Global Financial Crisis (GFC), hampering banks' ability to meet credit line drawdowns by the corporate sector without explicit public liquidity support (Acharya and Mora, 2015). In part to minimize reliance on public liquidity backstops, post-crisis liquidity regulation requires large banks to accumulate high-quality liquid assets (HQLA) and align their liquidity positions with the credit commitments to the corporate sector (Yankov, 2020). However, the post-crisis liquidity regulation was largely designed as a micro-prudential tool, targeting individual bank balance sheets rather than the liquidity capacity of the banking system as a whole. Thus, while individual large U.S. banks now have strong liquidity positions well above the regulatory minima, the ability of the banking system as a whole to withstand large simultaneous drawdowns on credit lines has yet to be assessed.

In this paper, we take a step in this direction and study the capacity of the banking system to provide liquidity to the corporate sector in times of stress and how changes in this capacity affect corporate liquidity management. We begin by showing that to fully characterize banks' liquidity capacity, one needs to take into account the contractual obligations among banks that arise in the process of loan syndication. Around 67 percent of credit line commitments in our data are originated by bank syndicates, where multiple bank lenders pool the funding and liquidity risks associated with these commitments. These credit lines also frequently contain components, which are often referred to as sublimits, that allow the borrower or a third party to draw funds on a very short notice, and a designated bank in the syndicate has an obligation to advance (front) the funds on behalf of the whole syndicate. We document that the use of sublimits varies across sectors from around 5 percent to more than 30 percent of the committed credit line amount.

Credit line sublimits are beneficial for the borrower not only because of the same day availability of funds, but also because the fronting bank effectively insures the borrower against liquidity shortfalls at other member banks in the syndicate. However, sublimits expose the fronting bank to the risk that other syndicate members subsequently fail to purchase their pro-rata shares in the loan, leaving the fronting bank with a disproportionately larger share, which, in a stress scenario, could exacerbate the liquidity position of fronting banks. Because banks participate in many syndicated credit facilities, sometimes as fronting banks and at other times as members, this creates a complicated network of interbank exposures. We show that the network of fronting exposures has a well-defined core-periphery structure that remains relatively stable over our sample period. The core consists predominantly of large banks, which both provide and obtain fronting commitments, and the periphery is populated mainly by smaller banks, which rarely serve as fronting banks. On net, the fronting exposures are highly concentrated at a few banks in the core, and these banks therefore provide the bulk of the liquidity insurance associated with sublimits. To the best of our knowledge, these features of syndication and their implications for liquidity provision have not been addressed in the literature before.

We begin our analysis by constructing a simple model to measure the liquidity capacity of the banking system, explicitly accounting for the interbank network. The model incorporates stress scenarios in which a large fraction of firms draw on their credit lines, and banks simultaneously experience outflows of short-term wholesale funding (STWF). To find the feasible payments given the demand for liquidity from the corporate sector, the associated interbank obligations, and the available balance sheet liquidity, we employ an equilibrium clearing mechanism similar to Eisenberg and Noe (2001). This mechanism assumes that banks have limited liability and ration liquidity across their obligations—both to other banks and to the corporate sector. With the set of equilibrium feasible payments at hand, we calculate (1) the system-wide liquidity shortfall, (2) the amount of liquidity insurance provided by fronting banks to the corporate sector, and (3) the impact of the credit line drawdowns on banks' regulatory capital and liquidity ratios. We calibrate the model using detailed micro level data and compare banks' liquidity capacity for both the period leading to the GFC and the period following the GFC characterized by the introduction of liquidity regulation.

We establish four main stylized facts on banks' liquidity capacity. First, we find that the liquidity capacity of the banking system has expanded significantly following the GCF, in large part thanks to liquidity and capital regulation. Fewer banks, and especially large banks part of the core, are likely to experience liquidity distress under hypothetical scenarios of extreme drawdowns on credit lines by the corporate sector. The increase in the liquidity capacity is driven by both increases in balance sheet liquidity and declines in the reliance on STWF.

Second, we find that the fronting commitments provide an economically significant amount of liquidity insurance to the corporate sector. Specifically, based on data as of 2006, the maximum amount of liquidity insurance that the fronting commitments provide in a stress scenario is between 5 and 18 percent of the total liquidity provided to the corporate sector. Based on data as of 2019, liquidity insurance amounts to around 1 to 3 percent of committed amounts, depending on the drawdown scenario. However, in terms of the most liquid component of credit lines—the sublimits—the insurance provided by the fronting banks account for a much larger share of the sublimit draws: up to 41 percent in 2006 and 22 percent in 2019. Additionally, the reallocation of liquidity through fronting shifted from reallocation among banks in the core of the network to reallocation from the core to the periphery, as core banks increased their liquidity positions more than banks in the periphery.

Third, we show how the credit line drawdowns under the different stress scenarios affect banks' regulatory liquidity and capital requirements. The liquidity capacity of the banking sector has significantly improved in the post-GFC period thanks to the liquidity coverage ratio (LCR), which requires large banks to hold a sufficient amount of HQLAs to be able to sustain large but plausible outflows of liquidity over a one-month period. We document that the largest banks, which form the core of the fronting exposures network, have become significantly more liquid and well-capitalized relative to their credit line exposures. However, the ability of banks in the core to perform their liquidity insurance function crucially depends on their ability to dip into their liquidity buffers under LCR requirements. Should these banks be required to maintain a minimum LCR at all times, they would no longer perform a stabilizing function and would instead contribute to the liquidity shortfall in the network. In contrast, we find that regulatory capital constraints are not binding even in the most extreme drawdown scenario we consider.

Fourth, we show that the liquidity capacity of the banking system also depends on banks' ability to quickly liquidate the non-cash HQLAs. As the market turmoil in March 2020 made clear, even large and normally deep markets, such as the market for U.S. Treasury securities, can experience severe market illiquidity in periods of stress (Duffie, 2020). Because U.S. Treasuries and other debt securities account for around two-thirds of large banks' HQLAs, stress in this market, even if short lived, could significantly reduce the ability of these banks to honor large credit line draws, especially those on the most liquid components—the sublimits—requiring same-day liquidity. Specifically, we find that should banks be unable to convert the securities component of their HQLAs to cash, the system-wide liquidity shortfall increases by around 50 percent in the severe stress scenario and reaches $1.1 billion, or 50 percent of the drawdown amount, in the 2019 exercise. The number of banks experiencing liquidity distress increases by more than 60 percent, and the number of LCR banks in distress doubles. With one notable exception, only the very largest banks, the so-called global systemically important banks (G-SIBs), have sufficiently large holdings of cash and central bank reserves to honor their credit line and interbank obligations in full.

Theoretical results in Holmström and Tirole (1998) and Acharya et al. (2013) suggest that banks' liquidity capacity is jointly determined with the liquidity management choices of the corporate sector. We document how banks' liquidity influences borrowers' liquidity management choices, and we establish that firms with high reliance on credit lines and sublimits in their liquidity management obtain credit lines from syndicates with stronger liquidity positions. Furthermore, such assortative matching on liquidity characteristics has become more pronounced in the post-GFC period. The non-random association between bank liquidity capacities and firms' liquidity choices is further supported by the pricing of credit lines. On the demand side, firms with greater reliance on credit lines and sublimits are charged higher fees, controlling for risk characteristics. On the supply side, syndicates with higher liquidity capacities charge lower fees, controlling for firm and bank characteristics.

Our paper relates to a large literature that studies the role of banks as liquidity providers to the corporate sector. Kashyap et al. (2002), Gatev and Strahan (2006), and Gatev et al. (2009) show that there is synergy between the businesses of deposit-taking and lending under commitment, which gives banks a unique advantage among financial institutions to become liquidity providers to the corporate sector. However, Pennacchi (2006) emphasizes that government guarantees and deposit insurance are more important factors behind banks' ability to serve as liquidity providers in times of stress. Acharya and Mora (2015) provide evidence that, had it not been for government support, banks would not have been able to honor credit line drawdowns during the GFC by relying on deposit inflows alone. Furthermore, Ivashina and Scharfstein (2010) and Cornett et al. (2011) show that nonfinancial firms heavily drew on their credit lines during the GFC in a run-like fashion out of concern about banks' deteriorating liquidity positions, which further exacerbated liquidity at banks. Acharya et al. (2020) document that shocks to bank liquidity due to exposures to the asset-backed commercial paper (ABCP) market led to significant ex-post cuts and tightening of terms on credit lines for firms violating covenants. However, Santos and Viswanathan (2020) show that, in general, credit lines offer significant liquidity insurance to large borrowers during recessions even when credit rating downgrades and credit line cuts are anticipated.

Recent papers have examined the role of banks as liquidity providers during the COVID-19 pandemic. Chodorow-Reich et al. (2021), Kapan and Minoiu (2020), Li et al. (2020), Acharya and Steffen (2020), Acharya et al. (2021b), and Greenwald et al. (2020) emphasize that banks served as liquidity providers, absorbing significant credit line drawdowns from large corporations, but restricted lending to smaller borrowers. Relative to this literature, our paper is the first to propose a liquidity capacity measure that imposes individual and system-wide budget constraints on banks' balance sheet liquidity taking into account the interconnectedness that results from the process of loan syndication. Furthermore, we are the first paper to document the significant changes in banks' liquidity capacity that have occurred due to liquidity regulation implemented in the post-GFC period, which has not been discussed in the existing literature.

Our paper is also related to the literature studying the role of interbank networks in insuring against liquidity shocks as first highlighted by Allen and Gale (2000). The core-periphery structure of the fronting exposure network is a common feature of many financial networks—for example, Craig and von Peter (2014) for the German interbank market, Beltran et al. (2021) for the U.S. federal funds market, and Anderson et al. (2019) for the U.S. interbank market during the National Banking Era. Farboodi (2014) shows theoretically that the core-periphery structure emerges endogenously in the presence of heterogeneity in investment opportunity sets among banks and could expose banks to liquidity shortfalls and systemic defaults. We contribute to this literature by showing that the large banks in the core of the network of fronting exposures help insure the corporate sector against liquidity risks at the smaller, peripheral banks.

While this is not the first paper to study interconnectedness associated with loan syndication, the emphasis of the existing literature is very different from ours. Harris et al. (2020) find that a lender's centrality in the network of past syndicate relationships increases the lender's likelihood of serving as the lead arranger and offering more favorable loan terms to the borrowers. Karolyi (2015) shows that co-syndication relationships help address the moral hazard in monitoring problem. Gupta et al. (2017) show that loan rates in syndicates with overlapping industry exposures tend to be correlated above and beyond what is predicted by fundamentals. Cai et al. (2018) study the indirect interconnectedness of banks arising from syndicated loans and show that banks that are more connected tend to exhibit higher levels of common systemic risk measures during recessions. None of these papers, however, studies the question of insurance of liquidity risks in loan syndicates, nor the effects of syndicate liquidity on corporate liquidity management. Several papers document the persistence of lending relationships in the syndicated loan market and the effect of lead bank health on firm outcomes. For example, Chodorow-Reich (2014) document that bank health affects firm employment during the GFC. Schwert (2018) documents that more bank-dependent firms match with better-capitalized banks, and this assortative matching leads to less cyclical credit provision. To the best of our knowledge, the assortative matching on liquidity characteristics documented in this paper is novel to this literature.

Finally, we contribute to the literature studying the determinants of corporate liquidity management. Holmström and Tirole (1998) develop a theoretical framework to rationalize the need for corporate liquidity management, the role of public debt as a store of value, and the role of intermediaries in reallocating liquidity. Acharya et al. (2013) formally test the determinants of the choice between cash and credit lines as a function of firms' systemic risk and limited capacity of the financial sector to insure the liquidity needs of systemic firms. Acharya et al. (2021a) show that large and high credit quality firms are more likely to rely on bank credit lines for their liquidity management in stress periods. We contribute to this literature by showing that liquidity management choices of large firms depend on available liquidity of bank lenders and the liquidity capacity of the banking sector to absorb credit line drawdowns, taking into account the interconnectedness and liquidity co-insurance that arises from loan syndication.

The rest of the paper is organized as follows. In Section 2, we describe the mechanics of fronting exposures, and in Section 3 we describe our data and construction of variables. In Section 4, we present our model of liquidity capacity and the results of our stress testing exercise. In Section 5, we present our empirical analysis of the role of bank liquidity in firms' liquidity management, and in Section 6 we conclude. Details on data construction and supplementary results are collected in the Appendix.

2 Liquidity co-insurance in loan syndicates

A loan syndicate is a form of risk-sharing arrangement that involves several lenders who jointly provide credit to a large corporate borrower.[1] Usually, one lender, typically a bank, serves as a lead arranger and invites participation from other lenders. The lead bank often has an established long-term lending relationship with the borrower and performs the initial screening and subsequent monitoring (Ivashina, 2009). The main types of loans in syndicated credit facilities include revolving credit lines and term loans. A revolving credit line allows the borrower to borrow, repay, and borrow again up to a certain amount and under the conditions of the credit agreement. A term loan is a loan with a fixed maturity and amount and cannot be re-borrowed. Revolving credit lines are typically retained by banks, while term loans are often held by nonbank lenders (Gatev and Strahan, 2009).

Credit lines often remain undrawn or partially drawn for prolonged periods after origination. For many large corporations that have access to the corporate bond market or issue commercial paper, credit lines provide a liquidity backstop against credit markets disruptions. Furthermore, because credit lines are priced at fixed spread over a reference rate, they also provide insurance

[1] The discussion in this section is largely based on Bellucci and McCluskey (2017) who provide a comprehensive overview of the contractual characteristics of syndicated loans.

against spikes in the cost of external debt. Therefore, credit lines serve as insurance and a liquidity management tool for the corporate sector. However, simultaneous drawdowns on credit lines by a large fraction of firms could create liquidity pressures at syndicates, and liquidity provision could not always be guaranteed.

Many syndicated credit facilities contain credit line components such as swinglines and letters of credit. A swingline allows a borrower to obtain funds faster than would otherwise be allowed by the credit agreement. The amount of funds available under the swingline is often specified as a sublimit within a revolving credit facility, and the borrower is normally required to repay the swingline loans in a short period. Swinglines are, therefore, intended to help the borrower meet immediate liquidity needs and are not meant to replace the regular revolving line of credit. To facilitate the liquidity provision on a short notice, one of the revolving lenders of the syndicate assumes the role of a swingline lender and extends the swingline loan on behalf of the whole syndicate. Although the loan is expected to be repaid in a short period, the swingline lender has the right to ask the remaining syndicate members to purchase participations in the loan according to their pro-rate shares. This exposes the swingline lender to liquidity risk, because if a syndicate member fails to honor its obligation to purchase a participation in the swingline loan, the swingline lender is left with a disproportionately higher share of the loan on its books.

A letter of credit is an agreement that guarantees payment to third parties that the borrower has contractual relationships with. For example, trade or standby letters of credit are often used to guarantee payments to suppliers, whereas financial letters of credit or backup credit lines serve as a backstop for commercial paper issuance. The total amount of letters of credit the borrower can obtain is usually subject to a sublimit within the revolving credit facility. The issuer of the letter of credit, which is one of the revolving lenders, assumes the full responsibility for disbursing the funds to the third party upon presentation of the relevant documents. The remaining revolving lenders have an unconditional obligation to subsequently purchase participations in the letter of credit from the issuer. Thus, similar to a swingline, issuing a letter of credit exposes the issuing lender to the risk of a member bank default.

Swingline lenders and letter of credit issuers are called fronting lenders, because they front the payments to borrowers or third parties before requesting participation from the rest of the syndicate. The associated exposures are called fronting exposures. To illustrate how fronting exposures work, consider the simple example in Figure 3. In this example, a syndicate of three banks issues a credit line to a borrower, and the revolver contains a swingline sublimit of 100. Panel A shows the credit commitments and fronting exposures implied by the swingline. The fronting bank commits to advance the full 100 on demand by the borrower, and the member banks commit to purchase their participations worth 25 each. The fronting exposures of the fronting bank are thus 25 to each member bank. In panel B, we illustrate the situation where the borrower maxes out the swingline and both member banks purchase their participations in the swingline loan. The exposure of the fronting bank to the borrower is reduced to 50, the fronting bank's pro-rata share of the revolving facility, and the member banks now have a credit exposure of 25 each to the borrower. If any of the member banks fails to honor their obligation to the fronting banks, however, the fronting bank is left with a larger share of the swingline and effectively extends a loan to the defaulting member bank. This is shown in panel C, where we assume that only member bank 1 fully purchases its participation, while member bank 2 fails to do so. The fronting bank is thus left with a swingline loan of 75 to the borrower, rather than its pro-rata share of 50.

The existence of sublimits and fronting exposures creates value to both borrowers and banks. From the borrower's perspective, the ability to deal with only one syndicated lender and to access same-day funds on demand creates convenience that is similar to maintaining cash. From the perspective of non-fronting banks, the obligation of the fronting bank to initially disburse the full amount of the sublimit draw creates flexibility for non-fronting banks in managing their own liquidity. The fronting bank bears the full liquidity risk associated with the drawdown and effectively insures the borrower or a third party in the case of letters of credit against potential liquidity problems at member banks. Because banks can, and typically do, serve the role of a fronting bank in some syndicates while being member banks in other syndicates, they both benefit from and provide this form of insurance. But it also means that the fronting exposures create a potentially complicated interbank network. The ability of the banking system to honor drawdowns on sublimits and regular revolvers, therefore, depends not only on the amount of available liquidity at banks, but also on the structure of the interbank network.

3 Data

In this section we describe the data and variables used in the calibration of our model in Section 4 and the empirical analysis in Section 5. We use the Refinitiv and LoanConnector (DealScan) dataset as our primary source of information on syndicate structure, credit origination, price and non-price information of credit facilities. We supplement DealScan with information from the confidential supervisory bank reports FR Y-14Q Schedule H.1, or FR Y-14 for short. FR Y-14 data are collected by the Federal Reserve for the annual Dodd-Frank Act Stress Test (DFAST) and Comprehensive Capital Analysis and Review (CCAR) stress test exercise and contain detailed quarterly loan-level and borrower-level information for the corporate lending of the largest bank holding companies operating in the United States. To obtain borrower balance sheet and income information, we use S&P Compustat data along with S&P CapitalIQ available on the WRDS data platform. CapitalIQ contain detailed information on firms' capital and liability structure from the financial footnotes of SEC 10-K filings. Firms provide information on the drawn and undrawn portions of their credit lines in the sections devoted to liquidity and capital resources and in the footnotes dedicated to outstanding debt obligations. Historical stock price information used to construct market-based measures of assets, leverage, and Tobin's Q is obtained from CRSP on WRDS. We use Moodys Analytics and CreditEdge dataset to obtain information on borrowers credit ratings and empirical default frequencies (EDFs). Finally, we rely on consolidated FR Y-9C data to construct balance sheet and income information for bank lenders.

We perform several steps to construct the final data for analysis.[2] We first consolidate all lenders under the same bank holding company, taking into account mergers and acquisitions that occur over the sample period.[3] Second, information on sublimits is available in DealScan as part of the non-price terms of credit facilities, whereas information on interbank fronting exposures is only recorded in FR Y-14. Fronting exposures are reported as committed credit facilities between the fronting bank as a lender and syndicate member banks as borrowers. Unfortunately, FR Y-14 data do not contain syndicate identifiers that would allow us to reconstruct the syndicate and directly match FR Y-14 to DealScan. Furthermore, information on fronting exposures in FR Y-14 is only available at the end of 2016. Therefore, we use the relationships between sublimits and fronting exposures described in the previous section to reconstruct the implied interbank fronting commitments in DealScan.[4] We use the DealScan approximation for periods prior to 2017 and the combined information of DealScan and FR Y-14 for the overlapping sample starting in 2017.

Our main dataset is an unbalanced firm-bank panel containing 5451 borrowers and 754 bank

[2]See Appendix A.1 for a detailed discussion on the data construction. We follow common procedures to clean and merge the data with other datasets used in the existing literature.

[3]We use NIC data repository https://www.ffiec.gov/NPW, which contains historical information on the corporate structure of bank holding companies. It assigns a unique identification number (ID RSSD) to each institution affiliated with a bank holding company. We apply a matching procedure that allows us to track bank lenders over time and assign them to their respective bank holding company.

[4]In some cases, the underlying borrower is reported as the guarantor of the fronting loan. For those loans, we are able to match and verify information coming from DealScan with information in FR Y-14. Appendix A.2 provides a detailed analysis on the goodness-of-fit of this approximation and the robustness of our results.

holding companies that covers the period from 2004:Q1 until 2020:Q2. To study the effects of the COVID-19 pandemic, we also construct a firm-bank panel dataset based on FR Y-14 data. These data cover the period from 2013:Q1 until 2020:Q2 and are an unbalanced panel of 37 banks that report Y-14 data over the sample period and provide syndicated credit to 1324 corporate borrowers. There are important departures in our data construction as compared to the existing literature. First, unlike the existing literature, we do not limit our sample to nonfinancial firms. We include lending to nonbank financial firms and to utilities, because we study the overall liquidity exposures of banks to the corporate sector, and many utility companies and nonbank financial firms are large and systemic institutions that have high usage of credit lines and sublimits in their liquidity management. Second, we consolidate bank-level information to the top-holder bank holding company, which is important in our context for at least two reasons. First, the liquidity capacity of a particular bank is significantly influenced by the available liquidity in the bank holding company and the existence of an active internal market for funds. Second, capital and liquidity regulation is applied at the consolidated bank holding company.

Table 2 presents summary statistics of the combined dataset used for our analysis. Panels A.1 and A.2 document the distribution of contract characteristics for credit lines without sublimits (A.1) and for credit lines with sublimits (A.2). The average committed amount of credit lines in our sample is $826 million and the median is $300 million. The average credit line amount for credit facilities with sublimits is lower, at $734 million, but the median is the same as a credit line without a sublimit. The sublimit amount is, on average, about 25 percent of the total committed amount. Credit lines with sublimits have slightly higher fees and are significantly more likely to contain a financial covenant. On average, 23 percent of credit lines contain some form of financial covenant. In contrast, close to 90 percent of credit facilities with sublimits have at least one financial covenant.

In panel B, we show the average borrower characteristics. Because we include financial firms and utilities, our sample contains, on average, much larger and more levered borrowers than the average characteristics of publicly traded firms in related studies. The median borrower is a large corporation with total consolidated assets of about $2.4 billion, and the average borrower is a corporation with close to $18 billion in total assets. There is large heterogeneity in borrower asset sizes, with the inter quartile range varying between $712 million and $10 billion. The median borrower in our sample has a debt-to-asset ratio of about 61 percent, which is also higher than the average ratios reported in other studies that use DealScan.

We summarize the liquidity management of borrowers with three measures: the cash-to-asset ratio, the liquidity-to-asset ratio, and the revolver-to-liquidity ratio. We define corporate liquidity as the sum of the total committed amounts of credit lines and the total amount of cash and cash equivalents. The average cash-to-asset ratio is about 8 percent, with large heterogeneity across firms, and the median firm has a cash-to-asset ratio of about 5 percent. The inter quartile range varies from about 2 percent to about 11 percent of total assets. The liquidity-to-asset ratio is about 20 percent for the average firm, with some notable variation among firms. For most firms in our sample, a credit line is the predominant form of liquidity management. The median firm total credit lines comprise more than 70 percent of their available liquidity.

We summarize the asset size, capitalization, liquidity positions, deposit funding, and profitability of banks in panels C.1 for lead banks and C.2 for member banks based on data from FR Y-9C and the Call Reports. Most of the large banks in our sample are both lead and member banks in different syndicates and are part of the densely connected core. Smaller banks are mostly non-fronting and non-lead banks. As a measure of liquidity we use a measure of the HQLAs defined in the LCR requirement under Basel III. We define insured deposits as all deposits with balances within the relevant deposit insurance limit for the period. STWF is composed of all non-deposit short-term liabilities such as borrowing from the federal funds market and borrowed amounts under repurchase agreements as well as all uninsured deposits and debt with outstanding maturities of less than one year.

4 Liquidity capacity

In this section, we develop a simple model of the capacity of the banking sector to serve as a liquidity provider to the corporate sector in times of stress. We calibrate and use the model to study the evolution of liquidity capacity over the past two decades and the role fronting commitments plays in insuring the corporate sector against liquidity risks.

4.1 A model of liquidity capacity

We consider a banking system where N banks are endowed with stylized balance sheets shown in Figure 1. The banks are funded with equity (E), insured deposits (D), and uninsured debt (B). They invest in liquid assets L, which we also label as HQLAs to match the definition of the LCR requirement, as well as risky and illiquid loans and securities Z. The off-balance-sheet positions consist of undrawn lines of credit—both syndicated and direct—to nonbanks (U) and fronting exposures and participation commitments (F^{out}, F^{in}) arising from syndicated lines of credit. We take the balance sheets as given, and our goal is to assess the ability of banks to honor drawdowns on the revolving lines of credit (U).

Assets	Liabilities
HQLA (L)	Equity E
Illiquid loans (Z)	Deposits D
	Uninsured debt B
Undrawn revolvers U	
Fronting exposures F^{out}	Participation commitments F^{in}

Figure 1: Bank balance sheet.

We assume that there are K borrowers, indexed by k, and each borrower has one syndicated credit facility, so that k also indexes credit facilities or syndicates. A syndicate of banks providing the credit facility to the borrower is a subset of the banks in the system. The syndicate provides a revolving line of credit with a committed amount u_k, and the facility is composed of a regular revolving credit line, u_k^r, and a sublimit, u_k^s, i.e., $u_k = u_k^r + u_k^s$. Each bank i in the syndicate has a pro-rata share of the facility equal to $\gamma_{i,k} \in (0, 1)$.

The total undrawn credit line commitments of bank i are the sum of the undrawn credit lines in which the bank serves as the fronting bank and the undrawn credit lines in which the bank is a member bank. When the bank serves as the fronting bank in syndicate k, it commits to providing to the borrower its pro-rata share ($\gamma_{i,k}$) of the regular revolver (u_k^r) and the full sublimit (u_k^s). When the bank is only a member in the syndicate, it only commits to providing its pro-rata share of the regular revolver to the borrower, but it is obliged to purchase a participation in the submit loan from the fronting bank according to its pro-rata share. Thus, summing across all syndicates, the total undrawn credit line commitments of bank i are given by

$$U_i = \sum_{k \in K_f(i)} (\gamma_{i,k} u_k^r + u_k^s) + \sum_{k \in K_m(i)} \gamma_{i,k} u_k^r, \tag{1}$$

where $K_f(i)$ denotes the set of syndicates where bank i serves as the fronting banks and $K_m(i)$ is the set of syndicate where the bank is a member. Similarly, the total fronting exposures of bank i are given by the sum of the fronting exposures across syndicates in which i is a fronting bank, $F_i^{out} = \sum_{k \in K_f(i)} (1 - \gamma_{i,k}) u_k^s$. The total participation commitments are the sum of all participation commitments in syndicates where i is a member bank, $F_i^{in} = \sum_{k \in K_m(i)} \gamma_{i,k} u_k^s$. The interbank network of fronting exposures $F := \{f_{i,j}\}$ is given by $f_{i,j} = \sum_{k \in K_m(i)} \gamma_{j,k} u_k^s$. Thus, F_i^{out} is the sum of the i-the row and F_i^{in} is the sum of the i column of F. We will interchangeably refer to fronting exposures as "fronting-out" and participation commitments as "fronting-in."

To model drawdowns on the revolving lines of credit, we assume a drawdown rate of α_k^r on regular revolvers and α_k^s on sublimits. The demand for bank i's liquidity by firm k is given by

$$\bar{d}_{i,k}(\alpha_k) = \begin{cases} \alpha_k^r \gamma_{i,k} u_k^r + \alpha_k^s u_k^s, & \text{if } i \text{ fronting bank, } k \in K_l(i) \\ \alpha_k^r \gamma_{i,k} u_k^r, & \text{if } i \text{ is member bank, } k \in K_m(i)\ . \end{cases} \tag{2}$$

If bank i is the fronting bank in the syndicate lending to k, it assumes in full the drawdown amount on the sublimit. If the bank is a member bank, it is only directly responsible for its share in the drawdown of the regular revolver. Summing across all syndicates (borrowers) in which bank i is either a fronting bank or a member bank, the total request for funds that bank i faces is

$$\bar{d}_i(\alpha) = \sum_{b \in K_l(i)} (\alpha_b^r \gamma_{i,b} u_{i,b}^r + \alpha_b^s u_{i,b}^s) + \sum_{k \in K_m(i)} \alpha_k^r \gamma_{i,k} u_{i,k}^r, \text{ for } i = 1..N \tag{3}$$

However, the member banks also have an obligation to purchase participations in the sublimit loans from the fronting bank. Summing across syndicates, the total participation obligation arising from draws on sublimits that bank j has to bank i reads

$$\bar{f}_{i,j}(\alpha) = \sum_{k \in K_m(i)} \alpha_k \gamma_{j,k} u_k^s, \text{for } j = 1..N. \tag{4}$$

In addition to the drawdowns on revolving credit lines, we subject the bank to an additional liquidity shock: a shock to banks' STWF. We model the funding shock as an outflow of STWF equal to a fraction $\lambda_B \in [0, 1]$ of the outstanding stock of such short-term debt, B_i.[5] Figure 2 summarizes the state of the bank balance sheet in our model immediately after the liquidity shocks. The drawdowns on credit lines become on-balance-sheet loans leading to a transformation of liquid assets to illiquid loans. The drawdowns on sublimits create on-balance sheet interbank assets related to fronting exposures and liabilities related to the participation commitments. The funding shock further drains liquidity in proportion to the outstanding uninsured debt.

[5] Most of banks' secured and unsecured short-term debt is held by entities outside the banking system such as money market mutual funds. To simplify our analysis, we do not model interconnectedness among banks arising from such funding.

Assets	Liabilities
HQLA $(L_i - \lambda_B B_i - \bar{p}_i(\alpha))$	Equity E_i
Illiquid loans (Z_i)	Deposits D_i
Drawdowns $\bar{d}_i(\alpha)$	Uninsured debt $(1-\lambda_B)B_i$
$\sum_j \bar{f}_{i,j}(\alpha)$	$\sum_j \bar{f}_{j,i}(\alpha)$
Undrawn revolvers $U_i - d_i(\alpha)$	
Fronting exposures $\sum_j (f_{i,j} - \bar{f}_{i,j}(\alpha))$	Participation commitments $\sum_j (f_{j,i} - \bar{f}_{j,i}(\alpha))$

Figure 2: Bank balance sheet after liquidity shock.

We can summarize all post-shock liquidity flows in the model in a payment matrix:

$$\boldsymbol{P}(\alpha) = \begin{pmatrix} \bar{\boldsymbol{F}}(\alpha) & \bar{\boldsymbol{D}}(\alpha) \\ \mathbf{O} & \mathbf{O} \end{pmatrix}, \tag{5}$$

where $\bar{\boldsymbol{F}}(\alpha) = [\bar{f}_{i,j}(\alpha)]_{i,j}$ is a $(N \times N)$ matrix of interbank fronting obligations and $\bar{\boldsymbol{D}}(\alpha) = [\bar{d}_{i,k}(\alpha)]_{i,k}$ is the $(N \times K)$ matrix of credit line drawdowns. Because we assume that firms do not make payments to banks or one another during the stress scenario, the lower rows of the payment matrix are zero matrices. Banks face a total demand for funds equal to the sum of regular revolver drawdowns and fronting obligations:

$$\bar{p}_i(\alpha) = \sum_j \bar{f}_{j,i}(\alpha) + \sum_k \bar{d}_{k,i}(\alpha), \text{ for } i = 1, .., N. \tag{6}$$

We assume that banks prioritize the repayment of uninsured funding before other liabilities. Such priority of payments is justified by the fact that a failure to honor a credit line draw would not trigger insolvency, even if it may have reputation costs for the bank. The equilibrium payment that bank i makes must satisfy a resource constraint:

$$p_i(\alpha) \leq L_i - \lambda_B B_i + \sum_j \bar{f}_{i,j}(\alpha), \text{ for } \quad i = 1, .., N, \tag{7}$$

where L_i denotes the available liquidity and $\lambda_B B_i$ is the outflow of short-term funding. The withdrawals of short-term funding are repaid first, and the remaining liquidity, if any, is used for honoring draws by the corporate sector. Thus, banks with more stable funding in the form of equity and insured deposits are in a better liquidity position to honor credit line drawdowns than banks that rely more on uninsured funding.

To solve for the equilibrium payment vector, define the relative payment matrix A that contains the obligations of bank j to bank i as a fraction of the total obligations of i as $a_{i,j} = \frac{p_{i,j}(\alpha)}{\bar{p}_i(\alpha)}$. Following Eisenberg and Noe (2001), we can then define the equilibrium payment vector as the solution of the following system of equations:[6]

$$p_i(\alpha)^* = \bar{p}_i(\alpha) \wedge \Big(L_i - \lambda_B B_i + \sum_j a_{j,i} p_j(\alpha)^*\Big)_+, \text{for} \quad i = 1, .., N. \tag{8}$$

The equilibrium payment vector satisfies the following three assumptions. First, all else being equal, a bank with enough liquidity after meeting its uninsured debt withdrawals would honor all drawdowns on credit lines and fronting obligations. Second, a bank's total pay outs to the corporate sector cannot exceed a bank's available liquidity after debt payments. In other words, we assume that banks prefer to default on their credit line obligations rather than fire-sale their less liquid assets. Third, if a bank does not have sufficient resources to honor all credit line drawdowns and fronting obligations, it rations its available liquidity across all obligations in proportion to their relative shares captured by the matrix A.

We solve for $p(\alpha)^*$ using the fictitious default algorithm introduced by Eisenberg and Noe (2001).[7] Depending on the size of the liquidity shock and the distribution of liquidity among banks, some banks would run out of liquidity and default on their obligations to the corporate sector and to fronting banks. The resulting liquidity shortfalls are the difference between the demanded liquidity and the actual feasible payments made by the banks, $\sum_i \bar{p}_i(\alpha) - p_i^*(\alpha)$. This shortfall and different transformation of it serve as our measure of the liquidity capacity of the banking sector.

4.2 The network of interbank exposures

We begin the calibration of the model by characterizing the network of fronting exposures $F := \{f_{i,j}\}$. Panel A of Figure 4 plots the network as of the end of 2019. Four stylized facts about the network structure and the direction of exposures are worth highlighting. First, the network has a well-defined core-periphery structure. We define the core as the largest set of banks that have both fronting exposures and participation commitments to all other banks in the core–that is, the largest fully connected component. There are 12 banks in the core, shown at the center of the graph. The

[6]The operator $\wedge$ is the point-wise minimum of any two vectors $x \wedge y = (min(x_1, y_1), min(x_2, y_2), .., min(x_N, y_N))$ and $(x)^+$ operator is the point-wise non-negative components of a vector $(x)^+ = (max(0, x_1), max(0, x_2), .., max(0, x_N))$.

[7] It is easy to verify that the conditions for existence and uniqueness of the resulting payment vector derived in Eisenberg and Noe (2001) are also satisfied in this setting.

remaining banks form the periphery and are positioned on concentric circles around the core. The closer a periphery bank is to the core, the more fronting-based connections it has with banks in the core. Second, 98 percent of the total fronting exposures are concentrated in the core.[8] Thirty-four percent of the total fronting exposures are among banks in the core, and 64 percent of the total fronting exposures are between the core and the periphery banks. Third, fronting exposures are concentrated in four banks in the core, indicated in red, that have net positive fronting exposures to other banks–that is, their fronting exposures are larger than their participation commitments $F^{out} - F^{in} > 0$. All other banks have, on net, higher participation commitments than fronting exposures and are net recipients of fronting exposures. The four core banks, therefore, provide the bulk of the liquidity insurance across syndicated credit lines.

Finally, the core-periphery structure of the interbank network is relatively stable over our sample period, as can be seen in panels B and C. Panel B shows that the number of banks at the core and the number of net fronting banks are relatively stable over long periods. Furthermore, the shares of fronting exposures among core banks and from core banks to periphery banks also remain relatively stable over time (panel C). As a result of this stability, the main variation in the liquidity capacity of the network is determined by the distribution of liquidity across banks in the core and periphery.

4.3 Bank liquidity positions and funding

We next calibrate banks' liquidity positions (L_i) and funding structure (B_i and E_i). The primary driver of banks' liquidity positions in the post-GFC period was the introduction of the LCR requirement in 2014 and its full implementation in January 2017. The largest banks subject to the more stringent standard LCR requirement accumulated significant amounts of HQLAs.[9] As shown in Figure 5, the HQLA-to-assets ratios of those banks more than doubles relative to their 2006 levels. Similarly, banks subject to the less stringent modified LCR rules increased their liquidity but by less than the standard LCR group. In contrast, smaller banks, not subject to the LCR, after

[8] The aggregate fronting exposures in FR Y-14 averaged $288 billion over the period 2017 to 2019. The imputed fronting exposures based on sublimits in DealScan averaged $282 billion over the same period.

[9] At its introduction, the LCR requirement defined three categories of banks based on total assets. Standard LCR banks are bank holding companies with total consolidated assets exceeding $250 billion and those include the eight U.S. GSIBs. The less stringent modified LCR is applied to banks with total consolidated assets between $50 billion and $250 billion. Bank holding companies with assets below $50 billion are not subject to the LCR. On January 1, 2020, the standard LCR requirement was reduced to 0.85 for bank holding companies with total consolidated assets between $250 billion and $700 billion if those banks' STWF does not exceed $75 billion. Bank holding companies with consolidated assets below $250 billion were exempt from the LCR if their STWF was below $50 billion: otherwise, they were subject to a reduced LCR of 70 percent. All banks with total consolidated assets below $100 billion were exempt from the LCR.

initial accumulation of liquidity during and following the GFC, gradually reduced their liquidity to pre-2007 levels.

Apart from liquidity regulation, banks were also subjected to significantly tighter regulatory capital requirements in the post-GCF period, including stress testing and capital surcharges for the largest banks, referred to as G-SIBs, tied to their systemic footprint. As a result, the common equity Tier 1 (CET1) regulatory capital, which we use as a proxy for E_i, also increased substantially for the largest banks, shown in the top-right panel of Figure 5. Unlike HQLA positions, which significantly diverged across the bank size distribution, regulatory capital ratios converged to similar average levels in the post-GCF period.

Liquidity and capital regulation also impacted the liability structure of banks. In particular, banks reduced their reliance on unstable STWF (B_i). The use of STWF declined in half from about 40 percent of total assets for the largest banks to about 20 percent at the end of our sample. STWF was partially replaced with more stable sources of funding such as insured deposits and equity capital. Despite those reductions, the largest banks continued to be funded with significantly less stable sources of funding as compared to smaller banks.

4.4 Liquidity shocks

To calibrate the credit line drawdown rates (α), we use three scenarios with uniform drawdown rates of 10 percent, 15 percent, and 50 percent, respectively, and three data-driven scenarios that allow for industry-specific drawdown rates. These scenarios are summarized in Table 3. In the first data-driven scenario shown in column (2), we use the estimated realized drawdown rates observed during the GFC using data on utilization rates derived from CapitalIQ (see panel A of Figure 6 for a time-series of annual utilization rates based on CapitalIQ during our sample period). In aggregate, the drawdown rate was about 8.8 percent of the undrawn portion of the committed credit line amounts. There is some notable heterogeneity across industries in the drawdown rates. For example, firms in mining, oil, and gas drew more than 24 percent of their unused credit lines, whereas companies in the agriculture sector reduced, on balance, their utilization of credit lines.

Our second and third scenarios employ drawdown rates derived from quarterly FR Y-14 data. The drawdown rates in the second scenario (COVID-19) are reported in column (4) and computed based on the change in utilized amounts between 2019:Q4 and 2020:Q1 as a percent of the undrawn amount as of 2019:Q4. The aggregate drawdown rate was about 15.6 percent points (see panel B of Figure 6 for a time-series of quarterly net drawdown rates based on FR Y-14 during our sample period). Most large corporates repaid drawdowns in the second quarter of 2020 following massive monetary and fiscal stimulus that stabilized funding markets and reduced uncertainty. Similar to the drawdown rates during the GCF, there was significant heterogeneity in the use of credit lines that mostly reflects different exposures to the pandemic shock. Sectors particularly impacted by the pandemic such as the arts, entertainment, lodging, and food services experienced the highest drawdown rates.

The drawdown rates in the third scenario (EAD) are based on the expected exposures at default (EADs) reported in column (5). The EAD measures the expected utilization of a credit line in the event of distress of a borrower. The EADs are self-reported by banks in the FR Y-14 data and take into account contractual characteristics of credit lines such as covenants that would prohibit a borrower from fully utilizing their credit line in distress. Based on the EADs, the average expected drawdown rate in distress is about 54 percentage points of the undrawn committed amount. Although the EAD-based drawdown rate appears to be substantial by historical standards, we view this measure as an upper bound on contractually feasible drawdown rates of credit lines. In fact, the aggregate drawdown rate of credit lines in the arts, lodging, and food services in 2020:Q1 was about 48 percent of the undrawn committed amount, which is very close to the expected EAD drawdown rate of about 53 percent as of 2019:Q4.

Finally, we calibrate the STWF shock (λ) based on the outflows during the GFC. The outflows are illustrated in Figure 5. We set the STWF shock to a 10 percentage point drop in STWF as a share of total assets, which roughly corresponds to the drop observed during the GFC.

4.5 Evolution of liquidity capacity

We run our stress testing exercise with the six scenarios in two distinct time periods in our sample. The goal is to quantify the capacity of the banking system in recent years and to see how the capacity changed since the GFC. The pre-GFC period is captured by the fourth quarter of 2006, and the post-GFC period is captured by the fourth quarter of 2019, which is two years after the full phase-in of the LCR and less than a quarter before the COVID-19 pandemic shock. The results are summarized in Table 4.

The first three rows of Table 4 report the total drawdowns under the different scenarios in dollar terms as well as relative to aggregate HQLA or HQLA less the STWF shock. We see that despite a significant increase in the dollar drawdowns in 2019 across scenarios, the drawdowns relative to available liquidity decline, reflecting the significant increase in HQLA holdings and lower reliance on wholesale funding at large banks post-GFC. Specifically, under the high-drawdown scenarios of 50 percent and EAD, the available system-wide liquidity would be insufficient to cover the drawdowns in 2006, even without the funding shock. In contrast, in the 2019 exercise, aggregate liquidity exceeds the total drawdowns in these scenarios with and without the funding shock. Whether the banking system has the ability to actually honor these drawdowns in full depends on the allocation of liquidity across banks and on the interbank obligations, and this is what our stress testing model is designed to assess.

Panel A reports the liquidity shortfalls in the system after running the stress testing model without the short-term funding shock. Starting with the 2006 stress test, the overall shortfall ranges from $12 billion in the 10 percent scenario to $387 billion in the EAD scenario, or 6 percent and 40 percent of the initial drawdown, respectively. Relatively few banks experience a liquidity shortfall in the moderate 10 percent and 15 percent scenarios, but 40 banks experience a liquidity shortfall in the EAD scenario. Out of these banks, 8 are LCR banks, 13 are in the core of the fronting network, and 3 are net fronting banks. To gauge the insurance function of the fronting commitments, we calculate the amount of liquidity fronting banks provide above and beyond their pro-rata shares because of liquidity shortages at member banks. The fronting shortfall at $1 billion to $3 billion is relatively small for the moderate scenarios, but it reaches $38 billion, or 41 percent of the drawdown on sublimits in the EAD scenario.

Turning to the results for the 2019 stress test, we find similar overall shortfalls as in 2006 when expressed as a fraction of total drawdowns. However, the number of banks experiencing a liquidity shortfall is smaller in all scenarios, and only one core bank experiences liquidity distress in the 50 percent and EAD scenarios. The fronting shortfalls are also smaller both in dollar terms as well as relative to the total draws on sublimits, and no net fronting bank experiences liquidity distress even in the EAD scenario. The liquidity capacity of the banking system is therefore significantly higher in 2019.

In panel B, we introduce the 10 percent short-term funding shock, which reduces the amount of liquidity at banks available to honor their credit line commitments. The results show that the funding shock has a much bigger impact on the overall liquidity shortfalls and the number of distressed banks in the 2006 exercise. In the extreme 50 percent and EAD scenarios, the overall liquidity shortfall exceeds 70 percent of the drawdown amount and the number of banks with liquidity shortfalls exceeds 60. In contrast, in 2019, the increases in the overall (fronting) shortfalls are significantly smaller. The number of banks in distress increases, although no fronting bank experiences liquidity shortage, and only one LCR bank does. Clearly, less reliance on short-term funding post-GFC makes the banking system more resilient and expands banks' liquidity capacity.

To shed more light on the liquidity capacity in the cross-section of banks, we introduce the concept of drawdown feasibility, which we define as the maximum drawdown rate that a bank can sustain before running out of liquidity. We obtain this rate by increasing the drawdown rate α in our model until the bank runs out of liquidity. Thus, the drawdown feasibility at a bank takes into account the fact that all other banks are also experiencing the same rate of drawdowns on their credit lines and the same short-term funding shock. Figure 7 summarizes the cross-section of drawdown feasibility over time. Consistent with our findings above, the figure shows a significant increase in the liquidity capacity of the core banks and net fronting banks since the end of the GFC. While at the peak of the GFC these banks could barely withstand a 10 percent system-wide drawdown rate, in 2019 the net fronting banks are able to accommodate an impressive 85 percent drawdown rate and the core banks can sustain a 75 percent drawdown rate, on average. The liquidity capacity of most other banks improves as well but to a much lesser extent. The inter quartile range of drawdown feasibility increases in the post-GCF period and lies between 15 percent and 45 percent, but more than a quarter of banks in our sample would not be able to sustain drawdown rates of 20 percent or more.

Result 1 (R2): *The liquidity capacity of core banks has expanded significantly following the GCF due to both increased balance sheet liquidity and reduced reliance on short-term funding. Fewer banks experience liquidity distress and the core of the fronting network is more resilient.*

4.6 Co-insurance through fronting

We next take a closer look at the insurance function of the fronting commitments and how it is co-determined by the structure of the fronting network. Specifically, we first examine how much liquidity can be potentially reallocated among banks through fronting in different drawdown scenarios and compare the magnitude of liquidity reallocation across our two reference periods. Recall that the amount of liquidity reallocation through fronting equals the total amount of liquidity provided by fronting banks above and beyond their pro-rata share. This extra liquidity covers liquidity shortfalls at member banks and effectively insures the corporate sector against liquidity distress at these banks. Because our focus in this section is on the maximum possible liquidity reallocation through fronting, we will modify our stress test scenarios and assume that the corporate sector fully draws on their sublimits and, additionally, draws an increasing fraction of their remaining available revolvers, where we vary the fraction drawn between zero and one. Similar to the previous analysis, we examine scenarios with and without outflows STWF.

Panel A of Figure 8 shows the magnitude of the liquidity reallocation via fronting in the different scenarios and the two reference periods, expressed as a percent of the total liquidity obtained by the corporate sector. Comparing the two periods, we first note that fronting supports a significantly larger fraction of drawdowns in 2006 as compared to 2019. For drawdown rates on regular revolvers below 20 percent, the reallocation of liquidity among banks through fronting supports between around 5 and 7 percent of overall drawdowns in 2006. In other words, in a counterfactual without the fronting commitments by the fronting banks, the corporate sector would be able to access 7 percent less liquidity. In contrast, the liquidity reallocation through fronting plays a significantly smaller role in 2019 and peaks at about 2.5 percent of total drawdowns. Second, the scenarios that include an STWF shock lead to significantly higher liquidity reallocation in 2006 as compared with 2019, which is consistent with the significantly higher reliance on such funding in 2006. In particular, the share of the total drawdown rate supported by fronting declines monotonely from about 18 percent of the total amount drawn for low drawdown rates on regular revolvers to about 8 percent when all credit lines are fully drawn.

Panel B decomposes the amount of liquidity reallocation into that occurring among banks in the core and that occurring between banks in the core and banks in the periphery. In 2006, most liquidity reallocation occurs among banks in the core. In contrast, in 2019, most liquidity reallocation flows from fronting banks in the core to member banks in the periphery. The reason behind the differences between the two periods can be explained by examining panel C, which plots the number of core banks with liquidity shortages. In 2006, banks in the core were much more fragile than in 2019, and 3 out of the 14 banks in the core at the time were not able to honor the full drawdowns on sublimits even without outflows of STWF or drawdowns on regular revolvers. Ten out of the 14 banks in the core experience liquidity shortages under STWF outflow scenario, and all core banks become illiquid for drawdowns on regular revolvers above 20 percent. In contrast, in 2019, none of the 12 banks in the core at that time runs out of liquidity when all sublimits are drawn, and all banks in the core remain liquid for drawdown rates of up to 16 percent of regular revolvers. As a result, liquidity is primarily reallocated through fronting from the liquid core to the less liquid periphery banks.

The structure of the network post-GFC helps explain the humped shape of the liquidity reallocation profile in the 2019 exercise (Figure 8, top-right panel). As the drawdown rate increases, the net fronting banks, which are in the core, are able to fully offset the shortages at the member banks, and the amount of liquidity reallocation increases. Eventually, however, even the fronting banks become overwhelmed by the liquidity demand and have to start rationing liquidity. As a result, the amount of liquidity reallocation starts declining.

Result 2 (R2): *The reallocation of liquidity through fronting shifted from reallocation among banks in the core to reallocation from the core to the periphery. The maximum amount of liquidity insurance that fronting commitments provide declined from a maximum between 7 and 20 percent in 2006 to a maximum between 2 and 3 percent of total credit line drawdowns in 2019.*

4.7 Effect on liquidity and capital requirements

In this section, we examine how the drawdowns on credit lines and the associated outflows of liquidity and new loans affect banks regulatory liquidity and capital ratios. The LCR requirement is designed to ensure that banking organizations have enough liquidity in the form of unencumbered HQLA to withstand a 30-day period of liquidity stress.[10] The LCR requirement is formulated as a ratio of HQLA to net cash outflows during the 30-day stress scenario. We can express the requirement using our stylized bank balance sheet as follows

$$LCR_i \equiv \frac{L_i}{\underbrace{\phi_D D_i + \phi_B B_i + \phi_U U_i}_{\text{Outflow}} - \min\{\text{Inflow}, 0.75 \times \text{Outflow}\}} \geq 1. \tag{9}$$

In the numerator of the LCR ratio is the amount of HQLAs (L_i). In the denominator of the LCR ratio is the net outflow of liquidity defined as a linear combination of balance sheet and off-balance-sheet positions and their respective outflow rates. The LCR assumes particular outflow rates for insured deposits ϕ_D, uninsured debt ϕ_B, and the unused credit line commitments ϕ_U. The outflows are netted out with potential inflows of liquidity, which is capped at 75 percent of the outflow.

The outflow assumptions are summarized in panel A of Table 5. The LCR distinguishes between two types of credit lines. The first, called *credit facilities*, form the bulk of credit lines. The second, called *liquidity facilities*, are credit lines that serve the purpose of backing the issuance of commercial paper or other corporate debt that are part of sublimits. Because such credit lines are more likely to

[10]Basel III introduced two frameworks of liquidity regulation—the LCR and the net stable funding ratio (NSFR) requirement. The NSFR targets longer-term sustainability of a bank's funding sources. It aims to ensure that banking organizations have enough stable funding sources to meet liquidity and funding demands over a 12-month horizon. Although the conceptual framework of the NSFR was finalized in 2010 with the Basel III proposal and in 2016 in the U.S. with the issuance of a proposed rule making, as of the end of 2018, the NSFR has not been implemented. Therefore, we focus our analysis entirely on the LCR.

be drawn in periods when credit markets are in turmoil, they are assigned a higher outflow rate.[11] Undrawn credit facilities to nonfinancial firms receive a 10 percent outflow assumption, whereas undrawn liquidity facilities receive a 30 percent outflow rate. The LCR treats differentially credit lines provided to nonfinancial firms and those provided to nonbank financial firms. In particular, credit lines to nonbank financial institutions receive outflow rate assumptions that about three times higher than credit lines to nonfinancial firms. In particular, credit facilities receive a 40 percent outflow assumption, and liquidity facilities receive a 100 percent outflow assumption. This means that for every dollar of undrawn credit lines classified as a liquidity facility to a nonbank financial, banks need to keep a dollar in HQLA.

The results are summarized in panel A of Table 6. We report the pre- and post-stress LCR ratios for all LCR banks and separately for the eight U.S. G-SIBs. We run the exercise using the 2019 data. All banks start with sizable liquidity buffers relative to their net outflow exposures as shown in the first column of panel A (zero drawdown). The average bank has an LCR ratio of 1.23 and the largest banks–the U.S. GSIBs–have an average ratio of 1.20. LCR positions of banks vary substantially from the lowest ratio of 1.06 to the maximum of 1.75. In columns (2) through (6) we increase the drawdown rate and calculate the post-stress LCR. In column (2), we show a scenario of a uniform 10 percent drawdown rate, which is close to the average drawdown rate during the GFC (Table 3, column (2)). Six LCR banks breach their regulatory minima and the average LCR ratio drops below 1; none of the large U.S. G-SIBs violates its regulatory minima at this level of drawdowns. However, as we increase the magnitude of drawdowns, liquidity is quickly depleted even at the largest and most liquid banks. At the 25 percent drawdown rate, four of the eight G-SIBs breach their LCR requirements, and their average LCR equals 0.99. The average LCR drops to 0.79 for all LCR banks. At the drawdown rate of 50%, which roughly corresponds to the average rate in the EAD scenario (Table 3, column (5)), all but one G-SIB breach their LCR minimum, and the average LCR equals 0.77. For the average LCR bank, the LCR equals 0.55. At this drawdown rate, many LCR banks breach their LCR requirements, and some LCR banks run out of liquidity completely. At the full drawdown rate, all LCR banks, including the G-SIBs, breach their LCR requirements.

The results of this analysis show that the LCR would be a binding constraint even at modest drawdown rates and would significantly restrict banks' capacity to provide liquidity to the corporate

[11] Our data do not allow us to precisely classify credit lines with respect to their treatment under the LCR. However, in our simulations, we use approximations based on credit facility purpose reported in FR Y-14.

sector in stress periods. Although current regulation does not have an explicitly established countercyclical policy for relaxation of the LCR similar to the countercyclical capital buffer, it does leave some discretion to the supervisors in choosing the penalties for violating the LCR. This discretion of the regulator to relax liquidity requirements was used during the COVID-19 pandemic, when banks were encouraged to use their available liquidity to support lending.

We next examine how the credit line drawdowns affect risk-based regulatory capital. The risk-based capital requirement of bank i is defined as the ratio of regulatory capital (CET1) to the total amount of risk-weighted assets

$$\rho_i(\alpha) \equiv \frac{E_i}{\kappa_Z Z_i + \kappa_U U_i + (\kappa_Z - \kappa_U) d_i(\alpha)}. \tag{10}$$

Risk-weighted assets are the linear combination of risky on-balance sheet loans, which normally receive a $\kappa_Z = 100$ percent risk-weight, and undrawn lines of credit, which normally receive a $\kappa_U = 50$ percent risk-weights. Therefore, a drawdown on a credit line increases risk-weighted assets by one half of the amount drawn. The bulk of the credit lines in our data are not cancellable and have maturities that exceed one year, which, according to Table (5), receive 50 percent outflow on-balance sheet conversion factor.

Panel B of Table 6 reports the effect of credit line drawdowns on capital ratios. We find that under all scenarios, all banks meet their minimum capital requirements, and some banks still remain with significant capital buffers. The analysis of the regulatory requirements can be summarized in the following result.

Result 3 (R3): *In the post-GFC period, regulatory capital is not a binding constraint for honoring credit line drawdowns, even in the most extreme drawdown scenarios. However, despite the significant increases in balance sheet liquidity at banks subject to liquidity requirements, the LCR would be a binding constraint for many LCR banks, even at moderate drawdown rates.*

There are important caveats and assumptions behind R3. First, because our focus is on liquidity risks, we do not consider changes in credit risk following drawdowns on credit lines and their implications for regulatory capital. In particular, we do not examine worsening of credit conditions of borrowers that would also increase banks' loan loss provisioning and realized loan losses that reduce bank capital. Second, we ignore general equilibrium effects related to the fact that following a credit line drawdown, banks credit firms' deposit accounts, which are often with the same bank, and so such drawdowns do not immediately reduce the banks' liquid assets but could increase bank leverage through increased firm deposits. Finally, we ignore additional inflows of deposits stemming from flight-to-safety dynamics or fiscal and monetary stimulus that the existing literature has emphasized as the main determinant of banks' liquidity capacity in times of stress (Pennacchi, 2006).

4.8 Liquidity capacity and HQLA composition

The analysis in the previous sections assumes that banks can use all of their HQLAs to meet the demand for liquidity from the corporate sector. In this section, we examine how the liquidity capacity of the banking system changes when banks cannot utilize some of the assets that comprise the HQLAs, because, for example, they cannot easily and quickly convert these assets into cash in times of stress. The stress in March 2020 shows that even normally highly liquid assets such as Treasury securities can experience short periods of severe market illiquidity, precisely at a time when the demand for liquidity from the corporate sector is elevated (Duffie, 2020). It is thus important to understand how much the liquidity capacity of the banking system declines should banks be unable to deploy all of their HQLAs.

The LCR defines two categories of assets that are eligible as HQLAs. Level 1 assets include cash and reserves with the Federal Reserve, Treasuries, and Government National Mortgage Association mortgage-backed securities (MBS). Level 1 assets are considered to be the safest and most liquid and do not require haircuts. Level 2 assets contain agency debt, agency MBS, and commercial mortgage-backed securities (CMBS) securities.[12] Table 7 shows the composition of liquidity at the largest eight banks in our sample—designated as G-SIBs and subject to the most stringent capital and liquidity regulation—and the remaining banks in our sample (non-G-SIBs), at the end of 2019.[13] U.S. G-SIBs concentrate roughly three-quarters of the liquidity in the banking system. These large banks also have a significantly higher share of the more liquid Level 1 components of HQLA. Seventy percent of G-SIBs' HQLA is held in Level 1 assets, whereas 51 percent of non-G-SIB banks' liquidity is in Level 1 assets.

The heterogeneity in liquidity positions is particularly important because most of the largest banks subject to the standard LCR are part of the core of the interbank network of fronting exposures and some are also net fronting banks, whereas the smaller and less liquid banks reside in the periphery. Such concentrations of liquidity in the core has implications for how shocks

[12] Level 2 assets are subject to a 15 percent haircut and are capped at 40 percent of the total HQLA amount.

[13] GSIBs include JP Morgan, Bank of America, Wells Fargo, Citigroup, Morgan Stanley, Goldman Sachs, Bank of New York Mellon, and State Street.

propagate in the network and the value of liquidity co-insurance provided by fronting exposures in times of stress. To assess the role of the composition of balance sheet liquidity and its distribution across banks, we repeat our 2019 stress test but now assume that banks can only use a subset of HQLAs to meet credit line drawdowns.

The results are reported in Table 8. Panel A reports liquidity shortfalls in a scenario where banks can only use cash and cash equivalents, which are predominantly in the form of reserves with the Federal Reserve. For all drawdown rates reported in the panel, banks experience liquidity shortfalls ranging from around 21 to 25 percent of the drawdown in the 10 percent and GFC scenarios to nearly 50 percent in the EAD scenario. These shortfalls are almost double the shortfalls observed when banks can use all of their HQLAs (panel C). The bulk of the shortfalls occur at smaller banks outside the group of the U.S. G-SIBs, banks subject to the LCR, or banks that appear in the core of the fronting exposures network. However, for the 50 percent and EAD drawdown scenarios, 4 out of 10 banks in the core also experience liquidity shortfalls. Most of the remaining banks in the core have enough cash to withstand the liquidity shocks in all of the scenarios, and only one G-SIB runs out of cash in the EAD scenario. Thus, the largest banks and the core of the interbank network remain resilient even if their available liquidity is restricted to cash and reserves only.

Panels B expands the definition of liquidity to include all Level 1 assets. As expected, the liquidity capacity of the banking system to honor credit lines notably increases. The system liquidity shortfalls fall by 20 to 50 percent compared with the scenario of cash and reserves only (panel A), but they are still around 20 to 30 percent higher than with all HQLAs (panel C). All U.S. GSIBs remain liquid even in the extreme 50 percent and EAD scenarios, and only three core banks experience liquidity distress in this case. However, there are shortfalls of liquidity at a number of smaller banks and a few LCR banks. In all, being able to convert the Level 1 and Level 2 assets into cash and use this cash to honor credit line drawdowns significantly improves the resilience of the system as a whole, mainly due to an improvement at smaller banks and LCR banks.

5 Liquidity capacity and corporate liquidity management

So far, we have focused on the capacity of the banking system to provide liquidity to the corporate sector, taking the demand for liquidity as given. However, theory suggests that banks' liquidity capacity is jointly determined with the liquidity management choices of the corporate sector. Holmström and Tirole (1998) show that in the presence of limited pledgeability of firm assets or income to outside investors, firms need to secure funding in advance to insure against liquidity risks. The two main tools of liquidity management are accumulating cash or securing a credit line. The choice between the two liquidity management tools depends on the trade-off between the opportunity cost of accumulating and holding cash, and the cost of maintaining a credit line. Acharya et al. (2013) show theoretically and empirically that firms with higher aggregate risk exposures are more likely to simultaneously draw credit lines in crisis periods and such large drawdowns could lead to depletion of liquidity at banks and require banks to maintain larger stocks of liquid assets. The opportunity cost of holding liquid assets leads banks to charge a premium for originating credit lines to firms with aggregate risk exposures. The higher cost of credit lines tilts those firms' liquidity management choices towards cash and away from credit lines. The models of Holmström and Tirole (1998) and Acharya et al. (2013) imply that, all else being equal, corporations that rely more on credit lines in their liquidity management would prefer to obtain their credit lines from syndicates with higher liquidity capacity. We test two hypotheses that explore the relationship between liquidity capacity of banks and the liquidity management choices of firms motivated by these observations.

Hypothesis 1 (H1): *Firms with higher reliance on credit lines for their liquidity management would borrow from syndicates with higher liquidity capacity.*

H1 explores the idea that because banks are heterogeneous in their liquidity capacities and firms are heterogeneous in their liquidity demands, in equilibrium, there must be assortative matching on liquidity characteristics. Second, if H1 is supported by the data and matching on liquidity characteristics is non-random, then the pricing of credit lines should also reflect the liquidity characteristics of firms and banks. Firms with higher reliance on credit lines should pay higher fees than firms that maintain higher cash-to-asset ratios. Analogously, banks with higher liquidity capacities should offer cheaper credit lines. We summarize the relationship between liquidity characteristics and pricing of credit lines in the following hypothesis.

Hypothesis 2 (H2): *Firms with higher reliance on credit lines for their liquidity management would be charged higher fees. Bank syndicates with higher liquidity capacities would charge lower fees on credit lines, controlling for firm characteristics.*

5.1 Corporate liquidity management

We study three main characteristics of liquidity management—the cash-to-asset ratio, the revolver-to-assets ratio, and the revolver-to-total liquidity ratio. Panel B of Table 2 and Table 9 reveal that individual borrowers and industries differ substantially in their liquidity management characteristics. The heterogeneity in liquidity management coexists with heterogeneity in bank liquidity capacities documented in Figure 7.

We test for the presence of assortative matching between firms' corporate liquidity management choices and the capacity of bank syndicates to absorb credit line drawdowns. Our empirical strategy is based on a decomposition of the liquidity management characteristics $LiqMan_{k,t}$ of firm k at time t into borrower-specific and bank-specific factors. Because most borrowers in the syndicated loan market have a persistent long-term relationship with a lead bank, our empirical framework also examines the effects of bank liquidity on firms' liquidity management choices throughout the span of the firm-bank relationship. In particular, we examine a firm-bank syndicate panel regression:

$$\begin{aligned} LiqMan_{k,t} = \beta_L' Liquidity_{i,t-1} + \beta_E' Capital_{i,t-1} + \beta_D' Deposits_{i,t-1} + \\ \alpha_k + \beta_i + \tau_t + \gamma' X_{k,t-1} + \epsilon_{k,i,t}. \end{aligned} \tag{10}$$

Our primary coefficient of interest is the association of firm liquidity management characteristics and banks' liquidity positions, β_L. We use two measures of syndicate liquidity. The first is the HQLA-to-asset ratio of the lead bank and the average of the HQLA-to-asset ratios of other syndicate member banks. The second is an indicator for whether the lead bank is a net fronting bank. Therefore, combined the two measures take into account both the individual liquidity positions of lead banks and their network exposures to liquidity risks of other banks. We also control for other observable bank characteristics such as regulatory capital as measured by CET1 and the share of stable funding in the form of insured deposits.

In terms of observable firm characteristics $X_{k,t-1}$, we use variables that proxy for corporate liquidity demand such as firms' investment opportunity set as measured by Tobin's Q, leverage, and profitability. We include a measure of firms' systemic risk based on the 12-month rolling window correlation of the firm's stock return with a bank stock return index constructed for the banks in our sample. Finally, we control for credit risk with the firm's credit rating and the five-year EDF. To control for unobservable firm and bank characteristics, we include a set of firm α_k and a set of lead-bank fixed effects β_i. To absorb aggregate and industry-level trends, we also include a set of industry-time fixed effects τ_t.[14]

The results of the estimation are summarized in Table 10. The first three columns, which

[14]We estimate the regression model as a high-dimensional panel fixed-effects regression using the method of alternating projections implemented by Gaure (2013).

examine only firm characteristics, replicate findings by Acharya et al. (2013). More systemic firms as measured by higher bank industry beta rely more on cash and less on credit lines in their liquidity management. The effects are sizable and statistically significant. An increase in a firm's bank industry beta by one unit increases the cash-to-asset ratio by about 1 percentage point, reduces the revolver-to-asset ratio by about 60 basis points, and increases the revolver-to-liquidity ratio by about 4 percentage points. Other firm characteristics, such as investment opportunities measured by Tobin's Q, increase both the use of cash and revolvers, but overall higher Tobin's Q shifts liquidity management towards cash. Conditioning on leverage and profitability, firms with higher credit risk as measured by credit rating or EDF have lower shares of credit lines.

Columns (3) through (6) examine the effects of lead and syndicate member bank characteristics conditioning on observable and unobservable firm characteristics. A lead bank with a 10 percentage point higher share of liquid assets is lending to firms that, on average, have 1 percentage point lower cash-to-assets ratios, 90 basis points higher revolver-to-asset ratios, and 4 percentage points higher share of credit lines in their overall liquidity management. Firms borrowing from syndicates with a lead bank that is a net fronting bank have 2 percentage points lower cash-to-asset ratios and 9 percentage points higher share of credit lines in their liquidity management. The results are both statistically and economically significant given the historical distribution of liquidity management characteristics.

The relationship between firm liquidity management and syndicate liquidity is not static over our sample period. To capture the time variation in this relationship, we re-estimate our baseline regression, adding an interaction term between banks' HQLA-to-asset ratios and yearly dummy variables. Figure 9 plots the estimates of the time-varying sensitivity of firms' revolver-to-asset ratios to the HQLA-to-asset ratios of lead banks (panel A) and of member banks (panel B). The coefficient estimates for the lead bank's liquidity are not statistically significant at the 5 percent level in the first half of our sample; in fact, the relationship is negative in 2007. However, the estimates become statistically significant beginning in 2013 and remain so for most of the remaining sample period, averaging about 0.22. This estimate implies that for every 10 percentage point increase in the lead banks' HQLA-to-asset ratio, the borrower has, on average, 2.2 percentage points higher revolver-to-asset ratio. In contrast, the coefficient estimates for member banks remain close to zero and are statistically insignificant throughout the sample period.

These results are consistent with the stylized fact that member banks are smaller and less liquid because they are either exempt from liquidity regulation or subject to the less stringent LCR requirement. Furthermore, member banks are more likely to be recipients of fronting exposures from the lead bank, and their liquidity positions are less important for borrowers' ability to draw on credit lines. Even though we do not formally test whether the LCR regulation impacts the assortative matching on liquidity characteristics between borrowers and lead banks, the increase in the coefficient estimate in panel A coincides with the implementation of the LCR. In summary, the results of Table 10 and Figure 9 are in line with the predictions of our hypothesis H1.

5.2 Pricing of liquidity management

We next test H2 and examine whether and how liquidity management choices of firms and the liquidity characteristics of banks are priced in newly originated credit lines. The first part of hypothesis H2 is a statement about liquidity demand under stress. Firms with lower cash-to-asset ratios and higher reliance on credit lines and sublimits in their liquidity management mix are more likely to heavily rely on their credit lines in times of stress. Therefore, banks would price this liquidity risk by charging higher fees. The second part of the hypothesis reflects the degree to which liquidity capacity determines how scarce liquidity is for syndicate banks. All else being equal, higher liquidity capacity increases supply of liquidity and should reduce the cost of credit lines. We use the following empirical specification to test this hypothesis:

$$\begin{aligned} Spread_{k,i,t} = \alpha_k + \beta_i + \tau_t + \lambda' LiqMan_{k,t-1} + \gamma' X_{k,t-1} + \\ \beta'_L Liquidity_{i,t-1} + \beta'_E Capital_{i,t-1} + \beta'_D Deposits_{i,t-1} + \xi_{k,i,t}. \end{aligned} \tag{10}$$

We examine two components of pricing. The first component is the all-in-spread drawn (AISD), which contains all the fees and interest rate spreads that the firm is charged at origination and for drawn portions of revolvers. The second component is the all-in-spread undrawn (AISU), which contains all the fees that are charged for the undrawn portion of credit lines. We examine the effect of the lagged liquidity management characteristics of the firm, controlling for other observable and unobservable firm characteristics. The second line examines the role of the same bank characteristics as those in the liquidity management regression. The panel regression includes a set of firm, bank, and industry-time fixed effects to absorb unobserved firm and bank characteristics and industry trends.

The results of the regression are presented in Table 11. The first three columns examine the AISD spreads and the last three columns examine the AISU spreads. The first and fourth columns include only firm variables. The second and third columns, and the fifth and sixth columns add lead bank characteristics and average syndicate member bank characteristics, respectively. First, as predicted by H2, firms with liquidity management that relies more on bank credit lines are charged higher AISD and AISU fees. The use of sublimits entails, on average, around 17 to 19 basis points higher AISD fees and around 6 basis points higher AISU fees. This is consistent with the higher liquidity risks associated with the same-day delivery of funds under sublimit drawdowns. A firm with a higher revolver-to-asset ratio is also charged higher fees. A firm with a 10 percentage point higher share of revolvers-to-asset ratio is, on average, charged around 5 basis points higher AISD and close to 1 basis point higher AISU. In contrast, firms with higher liquidity as measured by the stock of their cash-to-asset ratios or their cashflows measured by the returns on assets pay, on average, lower fees for obtaining a new credit line. Finally, as expected, riskier firms with high leverage, high bank industry betas, and high expected default frequencies are charged higher fees.

Bank liquidity positions also matter for the pricing of credit lines. Lead banks with higher HQLA-to-asset ratios and banks with positive net fronting positions offer cheaper credit lines. For example, the estimates imply that a bank with a 10 percentage point higher HQLA-to-assets ratio demands, on average, 8 basis points lower AISD fees and 2 basis points lower AISU fees. The effect, however, becomes insignificant when member bank characteristics are included. Syndicates with more liquid member banks offer lower fees on credit lines. Syndicate member banks with 10 percentage points higher HQLA-to-asset ratios offer, on average, 20 basis points lower AISD and 6 basis points lower AISU credit spreads. Finally, syndicates with lead banks with net positive fronting exposures charge significantly lower fees on credit lines. Depending on the specification, the AISD spreads are between 37 and 44 basis points lower, and the AISU spreads are between 4 and 5 basis points lower. The lower cost of credit lines provided by net-fronting banks is consistent with the fact that these banks pool the idiosyncratic liquidity risks of a larger set of borrowers.

To conclude, the results of this section provide further evidence for the assortative matching hypothesis by showing that the matching on liquidity characteristics of the firms and the bank syndicates are in fact priced in a way consistent with variation of liquidity demand and supply factors.

6 Conclusion

We contribute to the theoretical and empirical literature that examines the role of banks as liquidity providers to the corporate sector. We document a little known feature of syndicated credit facilities—fronting exposures—that allow banks to share liquidity risks related to credit line drawdowns. We characterize the resulting network of interbank exposures and show that it has a well-defined core-periphery structure with a densely connected core of large banks. We construct a measure of banks' liquidity capacity that imposes individual and aggregate resource constraints on banks' available liquidity, taking into account the interconnectedness of banks' balance sheets arising from the process of syndication.

The introduction of liquidity requirements on the largest banks increased balance sheet liquidity and reduced reliance on unstable STWF in the post-GFC period. These reforms significantly improved the capacity of large banks in the core of the network to co-insure liquidity risks and provide liquidity to the corporate sector in times of stress. Banks' role as providers of corporate liquidity became even more important in the post-GFC period because of the increasing assortative matching between the liquidity management choices of the corporate sector and the liquidity positions of syndicate lead banks. Firms with higher reliance on credit lines in their liquidity management have become more likely to obtain credit lines from syndicates that have higher liquidity capacity. We also document that the expansion of liquidity capacity has significantly lowered the cost of providing credit lines to the corporate sector.

Our analysis and results suggest several avenues for future research. First, extending the model to incorporate the constraints on banks resulting from liquidity and capital regulation is an important next step. This extension would allow us to evaluate the endogenous response of banks' liquidity positions to regulation and exposures to the corporate sector. It would also allow us to do welfare analysis of the design of liquidity and capital regulation. Second, incorporating liquidation costs for the different components of HQLAs could allow us to evaluate the potential welfare losses stemming from fire-sale externalities from selling less liquid components of banks' securities portfolios. Third, we have provided evidence for assortative matching on liquidity characteristics of borrowers and banks that has emerged in the post-GCF period. To understand the welfare implications of such matching would require modeling firms' endogenous choices of liquidity management and exposures to liquidity risks as a function of banks' liquidity capacities. Such modeling would allow for structural estimation of the supply and demand factors behind the equilibrium choices. Finally, our framework could be used in tailoring the size of future government interventions designed to stabilize credit and funding markets.

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A Data sources and construction

A.1 DealScan

Our primary source of information on the structure of bank syndicates and the provision of credit lines and sublimits is Refinitiv LoanConnector (DealScan). We use and expand the DealScan-Compustat link constructed by Chava and Roberts (2008) to assign company identifiers (gvkeys) to match DealScan with Compustat, CRSP, and Moodys' KMV datasets. We next expand the RSSD-DealScan linking table provided by Keil (2018) with the relationship tables from the National Information Center (NIC) to assign bank identifiers (RSSD IDs) and consolidate lenders at their parent bank holding company. We account for mergers and acquisitions by tracking the historical parent holding company using the NIC top holder tables. This allows us to merge consolidated bank holding company balance sheet and income statement data from FR Y-9C reports. To identify the lead credit arranger in the syndicate, we employ the procedure used by Bharath et al. (2011). Finally, to construct interbank exposures and the resulting network, we first allocate the committed credit and fronting exposure based on banks' pro-rata shares in all active syndicates. For syndicates with missing information on pro-rata shares we use a procedure commonly used in the literature to assign pro-rata shares based on information from similar syndicates (e.g., Schwert (2018)).

While a combined version of the DealScan and FR Y-14 would be ideal, fundamental differences between the two datasets make such a merge impossible. First, DealScan data record a credit facility and the structure of the syndicate at origination. In contrast, FR Y-14 are a panel of credit facilities measured at a quarterly frequency since their origination. Second, FR Y-14 record whether a credit facility is syndicated or not but do not have a unique syndicate identifier that allows us to reconstruct the structure of the syndicate and its participating banks. Third, DealScan has a much more exhaustive universe of lenders involved in syndicated dealers, whereas FR Y-14 are collected only for the largest bank holding companies subject to the Federal Reserve's annual stress test exercises DFAST and CCAR.

A.2 Fronting exposures in FR Y-14

The FR Y-14 wholesale corporate schedule contains comprehensive loan-level and borrower-level information of banks' lending to the corporate sector the purposes of the Federal Reserve's DFAST and CCAR.[15] FR Y-14 are the only source of information on the interbank fronting exposures that we are aware of. The FR Y-14 instructions define fronting exposures as follows.

> ”Fronting exposures are those that represent a BHCs or IHCs exposure to fund certain obligations (e.g., swingline or letters of credit) on behalf of other participant lenders. For such exposures, BHCs and IHCs should indicate Option 18 in Field 20 “Credit Facility Type” and report their pro-rata portion of the stated commitment amount as

[15] Detailed information on the FR Y-14 reporting form can be found on https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDZGWnsSjRJKDwRxOb5Kb1hL

one facility to the borrower and the fronting obligations as separate credit facilities to each of the lending group participants. For example, consider a facility with $400 million committed balance where the BHC or IHC is the agent bank and the BHCs or IHCs pro-rata share of the commitment is 10% or $40 million. Assume further that the credit facility contains a $50 million sublimit. that the BHC or IHC, as agent, has an obligation to advance on behalf of lending group participants which may include swinglines, letters of credit and other fronting obligations. In this example, the agent BHC or IHC would report a $40 million pro-rata commitment as one credit facility to the borrower and would report 90% of the $50 million sublimit (or $45 million) as separate pro-rata credit facilities to the lending group participants."

Although banks were required to report fronting exposures in the third quarter of 2016, most banks began reporting fronting exposures in the first quarter of 2017. Fronting exposures are recorded as committed credit facilities between a fronting bank as a lender and a syndicate member bank as a borrower. We validate the institutional details described in the FR Y-14 instructions with a few specific loan contracts that public firms publish in their 10-K/Q filings. These agreements outline the amounts of sublimits and define the fronting bank.

To incorporate fronting exposures reported in the FR Y-14 data in our analysis, we consolidate the exposures to the bank holding company following the same consolidation procedure as in DealScan. Out of the $400 billion in fronting exposures reported in Y-14 as of 2019:Q4, around $100 billion involve entities that banks report as "masked" or "confidential." We drop those observations from our analysis data. The median fronting exposure in FR Y-14 is around $10 million and is significantly smaller than the sublimit loan amounts reported in Table 2 because it reflects the pro-rata shares of participating banks. Most fronting exposures are not utilized at quarter-ends when the Y-14 data are reported. This is consistent with the short-term nature of the underlying sublimit loans as well as with the fact that most banks have enough liquidity to pay their shares in normal times. However, banks self-report that the expected utilization rates at default could be substantial. For example, the median EAD is around 50 percent of the committed amount and banks anticipate almost full drawdowns for some fronting exposures.

Because DealScan contains a larger set of banks and is more exhaustive in its reporting of syndicated loans, it has a larger imputed fronting exposures than FR Y-14 over the common sample period. There also appear to be differences in the trends between the two datasets. The imputed fronting exposures decline from around $450 billion at the end of 2016 to less than $300 billion at the end of our sample. In contrast, there is an upward trend in FR Y-14, which partly reflects the entry of new reporting banks and renegotiation of sublimit amounts post-origination. For example, many firms obtain sublimits following the origination of the main credit facility, and those are captured in FR Y-14 and not in DealScan. We conduct a number of robustness checks that compare our results using the DealScan approximation of fronting exposures with the actual interbank exposures measured in Y-14. Table 1 shows the liquidity shortfalls resulting from a scenario of a 100 percent drawdown rate calibrated using fronting exposures based on Y14 and the imputed values using DealScan.

Table 1: Comparison between analysis based on FR Y-14 and DealScan. All scenarios involve full drawdowns of credit lines and no STWF shock.

	2017		2018		2019	
	Y14	DS	Y14	DS	Y14	DS
Banks with shortfalls	80	81	71	70	73	73
Overall shortfall ($ bn)	2408	2405	2536	2484	2522	2502
Overall shortfall (pct)	0.46	0.46	0.48	0.47	0.47	0.47
Fronting shortfall ($ bn)	86	147	110	131	89	112
Fronting shortfall (pct)	0.39	0.48	0.43	0.48	0.36	0.48

B Definition of variables

The table below summarize the definitions of variables used in the analysis and the data source from which they are obtained.

Variable	Construction	Source
	A. Borrower characteristics	
Total assets	Total consolidated assets	Compustat (WRDS)
Total liabilities	The sum of long-term debt and short-term debt	Compustat (WRDS)
Net worth	Total assets minus total liabilities	Compustat (WRDS)
Leverage	The ratio of total liabilities to total assets	Compustat (WRDS)
Tobin's Q	The sum of market value of equity and book value of debt divided by book value of assets	Compustat (WRDS)
Market-to-book ratio	Market value of equity divided by book value of equity	Compustat and CRSP (WRDS)
ROA	The ratio of operating income before taxes to total assets	Compustat (WRDS)
Market beta	12-month rolling window OLS coefficient estimate of borrower stock returns on the stock market return	CRSP (WRDS)
Bank beta	12-month rolling window OLS estimate of borrower returns on the bank stock index returns	CRSP (WRDS)
Cash and cash equivalents		Compustat (WRDS)
Total revolver	The sum of the drawn and undrawn revolver	CapitalIQ (WRDS)
Utilization on revolvers	Ratio of the drawn portion of the revolver to the total revolver	CapitalIQ (WRDS)
	B. Bank characteristics	
Total assets	Total consolidated assets of the bank holding company	FR Y-9C
Insured deposits	The share of deposits with balances below the deposit insurance limit. Constructed at the bank subsidiary level and consolidated to the bank holding company.	Call Reports
CET1 capital	Common equity Tier 1 capital	FR Y-9C
HQLA	Combination of banks' holdings of cash and reserves, Treasuries, and eligible MBS securities with applicable Level 2 asset caps defined under the LCR. Holdings of assets that are eligible to be HQLA have been estimated by Ihrig et al. (2001). We incorporate the same caps on Level 2 assets that are required under the LCR regulation.	Call Reports and FR Y-9C
STWF	Short-term wholesale funding includes all uninsured deposits and liabilities with outstanding maturities less than one year.	Call Reports and FR Y-9C
Insured deposits	All deposits with balances below the deposit insurance limit	Call Reports
	C. Loan characteristics characteristics	
AISD	All-in-spread drawn	Refinitiv and Loan-Connector (Dealscan)
AISU	All-in-undrawn spread	Refinitiv and Loan-Connector (Dealscan)
Facility amount	The amount of credit facility which could be a credit line or a term loan	Refinitiv and Loan-Connector (Dealscan)
Facility maturity	Maturity of the facility in months	Refinitiv and Loan-Connector (Dealscan)
Sublimit	The amount of the sublimit credit line facility	Refinitiv and Loan-Connector (Dealscan)
Fronting exposure	The interbank credit line between the agent bank and member banks that is in proportion to the pro-rata share of the member bank	FR Y-14
Imputed fronting exposure	The implied fronting exposures based on the sublimit amount and the pro-rate share of a member bank	Refinitiv and Loan-Connector (Dealscan)

Table 2: **Descriptive statistics:** The data are quarterly and span the period from 2004:Q1 to 2020:Q2. Variables with significant outliers are truncated symmetrically at 1 percent of their historical distributions. The data contain an unbalanced panel of 5451 borrowers and 754 bank holding companies, of which 165 are lead banks. Source: Refinitiv DealScan and LoanConnector, Moody's KMV, S&P Compustat (WRDS), CRSP (WRDS), FR Y-9C, and authors' calculations.

Statistic	Mean	St. Dev.	Min	25th	Median	75th	Max
	A.1 Contract characteristics: Credit lines without sublimits						
Credit line amount ($mn)	826.5	1,415	5	95	300	900	11,094
All-in-drawn spread (bps)	166.4	114.5	15.50	70.00	150.0	250.0	537.5
All-in-undrawn spread (bps)	26.73	18.85	4.12	11.25	22.50	37.50	108.8
Maturity (months)	50.92	26.62	0.00	35.83	58.25	59.92	892.8
Financial covenant (0,1)	0.23	0.42	0	0	0	0	1
	A.2 Contract characteristics: Credit lines with sublimits						
Credit line amount ($mn)	734.9	1,096	10	105	300	850	7,655
Sublimit amount ($mn)	157.5	278.3	1	20	60	155	2,285
Sublimit (% of credit line)	25.03	18.46	1.68	11.11	20.00	33.33	98.33
All-in-drawn spread (bps)	171.3	86.60	23.00	105.0	156.3	225.0	444.0
All-in-undrawn spread (bps)	31.26	15.69	6.25	18.50	28.75	43.75	99.00
Maturity (months)	52.69	13.36	0.00	46.07	58.67	59.93	119.4
Financial covenant (0,1)	0.87	0.33	0	1	1	1	1
	B. Borrower characteristics						
Borrower assets ($bn)	17.97	63.77	0.010	0.712	2.462	9.952	1,781
Leverage (Debt/Assets)	59.95	18.05	12.98	47.76	60.75	72.84	97.05
Cash-to-assets	7.94	9.23	0	1.61	4.60	10.70	53.88
Liquidity-to-assets	22.99	15.19	0.84	11.64	19.54	30.98	80.41
Revolver-to-liquidity	66.72	27.39	0	46.19	73.15	91.44	100.0
Return on assets	2.97	9.07	−53.11	0.34	3.38	7.12	33.64
Tobin's Q	1.59	0.73	0.69	1.09	1.37	1.84	5.28
Market β	1.12	0.47	−0.01	0.81	1.09	1.41	2.51
Bank stock index beta	1.23	0.59	−0.10	0.82	1.18	1.62	2.97
Moody's EDF (5-year)	1.55	2.08	0.07	0.29	0.77	1.83	13.94
Moody's credit rating	Ba2	-	C	B2	Ba2	Baa2	Aaa

Continues on next page.

Statistic	Mean	St. Dev.	Min	25th	Median	75th	Max
			C.1 Lead bank characteristics				
Total assets ($bn)	1,145	884.6	0.16	254.2	1,032	2,032	2,765
CET1 ratio	10.37	2.96	0.23	8.35	10.23	11.92	107.8
Securities-to-assets	16.01	6.41	0.00	11.53	15.45	19.87	86.29
HQLA-to-assets	12.72	6.61	0.06	7.17	11.14	17.79	86.29
Insured-deposits-assets	27.55	14.25	0.06	14.86	29.45	36.72	90.46
STWF-to-total assets	29.33	16.22	0.06	17.35	26.09	41.58	92.59
Return on assets	0.80	1.08	−38.77	0.53	0.96	1.30	25.60
			C.2 Member bank characteristics				
Total assets ($bn)	608.4	460.5	0.15	266.3	530.1	819.8	2,765
CET1 ratio	10.84	3.09	0.23	8.63	10.72	12.40	107.8
Securities-to-assets	17.03	5.01	0.00	13.85	16.91	19.79	86.29
HQLA-to-assets	12.44	5.28	0.06	8.39	11.99	15.76	86.29
STWF-to-assets	25.92	11.67	0.06	17.73	24.79	32.46	92.59
Insured deposits-to-assets	32.02	12.17	0.02	24.86	32.05	38.79	90.46
Return on assets	0.78	0.95	−21.04	0.56	0.90	1.21	25.60

Table 3: **Drawdown rates of credit lines under stress by industry**. The first column shows the average utilization rates of credit lines in 2007. The second column shows drawdown rates of the undrawn portions of credit lines during the GFC computed using CapitalIQ. The last three columns show utilization rates on total committed amounts and drawdown rates on the unutilized portions of syndicated credit lines observed in FR Y-14 data. Expected drawdown rates at default (EAD) are derived from the reported expected EAD minus the current utilized amount as a fraction of the undrawn amount. SOURCE: CapitalIQ, FR Y-14, and authors' calculations.

Industry 2-digit NAICS code	Utilization 2007 (1)	Drawdown GFC 2007-2009 (2)	Utilization 2019:Q4 (3)	Drawdown COVID 2020:Q1 (4)	Drawdown EAD 2019:Q4 (5)
11 Agriculture	42.4	-4.5	34.2	-3.3	51.1
21 Mining, Oil, and Gas	44.0	24.7	29.5	7.8	54.5
22 Utilities	19.2	20.4	14.3	8.7	55.1
23 Construction	34.2	2.8	22.7	15.7	50.6
31-33 Manufacturing	21.9	8.3	19.6	15.2	53.8
42 Wholesale Trade	35.8	9.3	36.7	11.0	49.1
44-45 Retail Trade	22.6	6.2	28.7	19.7	51.5
48-49 Transportation and Warehousing	33.0	21.9	25.6	18.8	54.1
51 Information	23.3	7.9	23.2	13.0	49.8
52 Non-bank Financial Companies	33.3	7.9	37.4	12.1	53.3
53 Real Estate and Rental and Leasing	35.7	9.4	29.3	20.6	61.3
54 Professional and Technical Services	27.2	8.0	24.4	19.4	48.0
56 Admin. and Support Services	30.2	6.2	31.1	19.7	49.2
61 Educational Services	14.1	7.9	17.0	11.9	55.5
62 Health Care	24.4	12.7	23.8	20.9	59.8
71-72 Arts, Lodging, and Food Services	31.1	22.4	32.5	47.5	52.6
81-92 Other services	31.0	13.1	25.1	14.1	60.3
Aggregate	29.6	8.8	27.1	15.6	53.6

Table 4: **Liquidity shortfalls.** The aggregate amount of HQLA assets in the banking system was $833 billion in 2006 and $ 3727 billion in 2019. The aggregate amount of STWF was $4650 billion in 2006 and $4197 billion in 2019. The core of fronting banks includes 14 banks in 2006 and 12 banks in 2019. The GFC, COVID, and EAD scenarios are based on the reported drawdown rates by industry in Table 3.

	2006Q4						2019Q4					
Drawdown rate (α)	10 %	15 %	50 %	GFC	COVID	EAD	10 %	15 %	50 %	GFC	COVID	EAD
Drawdown amount ($)	182	273	909	214	281	971	435	653	2177	528	645	2321
— Sublimits ($)	17	26	85	21	26	91	25	37	124	31	36	134
Drawdown/HQLA	0.24	0.36	1.2	0.28	0.37	1.29	0.13	0.19	0.65	0.16	0.19	0.69
Drawdown/(HQLA-0.1 x STWF)	0.58	0.86	2.88	0.68	0.89	3.08	0.15	0.22	0.73	0.18	0.22	0.78
A. No outflows of short-term wholesale funding ($\lambda_B = 0$)												
Liquidity shortfall	12	24	336	17	24	387	41	92	729	64	86	797
Liquidity shortfall/Drawdown	0.06	0.09	0.37	0.08	0.09	0.4	0.09	0.14	0.33	0.12	0.13	0.34
Net fronting ($)	1	2	33	2	3	38	0	2	26	1	2	29
Net fronting/Drawdown	0.07	0.09	0.39	0.08	0.1	0.41	0.02	0.05	0.21	0.03	0.05	0.22
Banks with shortfall	11	14	42	12	15	44	6	13	39	9	13	40
LCR banks	1	1	8	1	1	8	1	2	4	2	2	4
Core banks	1	2	13	1	3	13	0	0	1	0	0	1
Net fronting banks	0	0	3	0	0	3	0	0	0	0	0	0
B. Outflows of short-term wholesale funding ($\lambda_B = 10\%$)												
Liquidity shortfall	44	90	667	58	94	728	61	121	786	90	115	856
Liquidity shortfall/Drawdown	0.24	0.33	0.73	0.27	0.33	0.75	0.14	0.19	0.36	0.17	0.18	0.37
Net fronting($)	4	8	59	6	8	65	1	3	29	2	3	32
Net fronting/Drawdown	0.24	0.32	0.7	0.27	0.32	0.71	0.04	0.07	0.23	0.06	0.07	0.24
Banks with shortfall	33	39	62	35	41	63	12	19	51	16	20	51
LCR banks	4	6	10	4	6	10	2	2	4	2	2	4
Core banks	6	8	14	6	8	14	0	0	1	0	0	1
Net fronting banks	1	3	4	1	3	4	0	0	0	0	0	0

Table 5: **Regulatory liquidity and capital charges for undrawn credit lines.** Panel A shows the outflow assumptions applied to undrawn lines of credit when calculating the denominator of the liquidity coverage ratio (net outflow). Panel B reports the capital charges applied to undrawn lines of credit when calculating the denominator of the capital ratio (risk-weighted assets).

	Nonfinancial firms	Nonbank financial firms
	A. LCR outflow assumptions	
Credit facilities	10%	40%
Liquidity facilities	30%	100%
	B. On-balance sheet conversion factor	
Unconditionally cancellable	0%	0%
Not cancellable, ≤ 1 year	20%	20%
Not cancellable, > 1 year	50%	50%

Table 6: **Impact of credit line drawdowns on banks' capital and liquidity ratios.** The results are reported for all LCR banks and for U.S. G-SIBs alone, and under different assumptions on the sublimit and revolver draws. We report the average, minimum, and maximum ratios in the cross section of banks, and the number of banks that breach their regulatory minima. Regulatory capital is based on the CET1 risk-based capital ratio. The minimum capital ratio is set to 7 percent for non-GSIBs and to 7 percent plus G-SIB surcharge for G-SIBs. The minimum LCR ratio is set to 1 for G-SIBs and banks with total assets greater than $700 billion, 0.85 for banks with total assets between $250 billion and $700 billion, 0.7 for banks with total assets between $100 billion and $250 billion, and zero for all other banks. The analysis uses balance sheet data as of 2019Q4.

		Fraction drawn (%)					
		0	10%	25%	50%	75%	100%
		A. Liquidity ratios					
All LCR banks	Average	1.23	0.98	0.79	0.55	0.39	0.25
	Min	1.06	0.55	0.21	0	0	0
	Max	1.75	1.27	1.11	1.04	1.01	0.97
	# breaches	0	6	10	14	14	15
U.S. GSIBs	Average	1.20	1.12	0.99	0.77	0.53	0.30
	Min	1.10	1.05	0.88	0.58	0.25	0
	Max	1.34	1.25	1.11	1.04	1.01	0.97
	# breaches	0	0	4	7	7	8
		B. Capital ratios (%)					
All LCR banks	Average	12.30	12.12	12.00	11.89	11.81	11.77
	Min	7.44	7.43	7.42	7.37	7.36	7.36
	Max	26.19	24.39	23.85	23.02	22.57	22.56
	# breaches	0	0	0	0	0	0
U.S. GSIBs	Average	12.43	12.24	11.97	11.55	11.16	10.79
	Min	11.14	10.96	10.70	10.30	9.92	9.56
	Max	16.43	16.14	15.72	15.07	14.47	13.91
	# breaches	0	0	0	0	0	0

Table 7: **HQLAs and its components**. The Level 1 and Level 2 assets are obtained from FR-Y9C. HQLA are calculated by summing Level 1 and Level 2 assets, subject to a 15 percent haircut and 40 percent cap on Level 2 assets. U.S. GSIBs includes the eight largest bank holding companies by assets that are designated as systemically important. Those banks are subject to the Standard LCR requirement throughout our sample period and following the relaxation of those requirements in 2020Q1. SOURCE: FR Y-9C and authors' calculations.

	U.S. GSIBs		non-GSIBs	
	billion	% of total	billion	% of total
Level 1	2,279.29	70.9	592.73	51.2
–Cash and reserves	1,164.67	51.1	289.12	48.8
–Treasuries	838.42	36.8	186.26	31.4
–GNMA MBS	276.19	12.1	117.35	19.8
Level 2	937.10	29.1	565.57	48.8
–Agency debt	21.86	2.3	21.71	3.8
–Agency MBS	850.40	90.7	442.40	78.2
–Agency CMBS	64.84	6.9	101.46	17.9
Level 1 + Level 2	3,216.39	-	1,158.30	-
HQLA	3,075.82	-	882.64	-

Table 8: **Liquidity shortfalls and composition of liquidity.** The table reports the drawdown amounts and liquidity shortfalls under a set of hypothetical drawdown rates. The GFC, COVID, and"EAD" scenarios are based on the reported industry-specific drawdown rates in Table 3. In all scenarios, we assume equal drawdown rates on regular revolvers and sublimits. The table uses data as of 2019Q4 and assumes no outflows of STWF ($\lambda_B = 0$).

	Fraction drawn (%)					
	10 %	15 %	50%	GFC	COVID	EAD
Drawdown amount ($)	435	653	2177	528	645	2321
—Sublimits ($)	25	37	124	31	36	134
	A. Cash and reserves					
Liquidity shortfall ($)	92	189	1065	132	183	1157
Liquidity shortfall (pct)	0.21	0.29	0.49	0.25	0.28	0.5
Net fronting ($)	3	7	49	5	7	55
Net fronting (pct)	0.12	0.18	0.4	0.14	0.18	0.41
Banks with shortfall	18	28	66	24	29	67
Core banks	0	2	4	1	2	4
LCR banks	2	5	8	4	5	8
U.S. GSIBs	0	0	1	0	0	1
	B. Level 1 assets					
Liquidity shortfall ($)	53	115	853	82	109	932
Liquidity shortfall (pct)	0.12	0.18	0.39	0.15	0.17	0.4
Net fronting ($)	1	3	35	2	3	39
Net fronting (pct)	0.04	0.08	0.28	0.06	0.08	0.29
Banks with shortfall	12	20	57	15	21	60
Core banks	0	0	3	0	0	3
LCR banks	1	2	6	2	2	6
U.S. GSIBs	0	0	0	0	0	0
	C. HQLA					
Liquidity shortfall ($)	41	92	729	64	86	797
Liquidity shortfall (pct)	0.09	0.14	0.33	0.12	0.13	0.34
Net fronting ($)	0	2	26	1	2	29
Net fronting (pct)	0.02	0.05	0.21	0.03	0.05	0.22
Banks with shortfall	6	13	39	9	13	40
Core banks	0	0	1	0	0	1
LCR banks	1	2	4	2	2	4
U.S. GSIBs	0	0	0	0	0	0

Table 9: **Average liquidity management characteristics by industry.** The cash-to-asset ratio is computed as the ratio of reported cash and cash equivalents to total assets using Compustat data. Liquidity is defined as the sum of cash and cash equivalents and committed amounts of credit lines. The total outstanding sublimit amounts are computed from DealScan. SOURCE: DealScan, CapitalIQ, and S&P Compustat.

Industry	Cash -to- asset (1)	Revolvers -to- assets (2)	Revolvers -to- liquidity (3)	Sublimits -to- revolvers (4)
11 Agriculture	1.1	24.2	94.0	4.5
21 Mining, oil, and gas	3.4	16.7	84.7	17.2
22 Utilities	0.6	5.8	89.3	32.6
23 Construction	6.9	16.7	67.9	32.7
31-33 Manufacturing	6.6	14.0	66.6	13.8
42 Wholesale Trade	2.0	22.6	90.3	13.3
44-45 Retail Trade	3.9	19.6	79.7	19.5
48-49 Transportation	3.0	8.4	71.4	20.6
51 Information	9.6	8.5	52.8	13.3
52 Non-bank financials	5.8	4.1	30.4	18.7
53 Real Estate	1.4	14.5	90.5	13.5
54 Professional and Technical Services	5.0	18.0	76.1	10.5
56 Administrative and Support Services	4.3	18.3	82.4	13.5
61 Educational Services	17.7	11.5	37.3	30
62 Health Care	2.6	8.6	72.5	17.0
71-72 Arts, lodging, and food services	5.0	12.9	68.3	20
81-92 Other services	1.6	30.3	89.1	12.5

Table 10: **Determinants of corporate liquidity management** We examine three liquidity management characteristics of firms (1) C/A cash-to-assets, (2) R/A revolvers-to-assets, and (3) R/(C+R) credit lines to total corporate liquidity. All regressions include firm, industry-time, and lead bank fixed effects. Standard errors are adjusted for auto-correlation and heteroscedasticity with clustering at the firm and bank levels. The sample is an unbalanced panel of covers 2004Q1-2019Q4. Significant at *p<0.1; **p<0.05; ***p<0.01.

	C/A (1)	R/A (2)	R/(C+R) (3)	C/A (4)	R/A (5)	R/(C+R) (6)
log(Assets),t-1	1.413***	−3.894***	−8.976***	1.161***	−3.757***	−8.351***
	(0.194)	(0.183)	(0.507)	(0.189)	(0.184)	(0.535)
Tobin's Q,t-1	4.401***	1.410***	−7.003***	4.279***	1.435***	−6.696***
	(0.329)	(0.279)	(0.693)	(0.322)	(0.284)	(0.697)
ROA,t-1	0.029***	0.014	−0.077***	0.030***	0.016*	−0.076***
	(0.010)	(0.010)	(0.021)	(0.009)	(0.009)	(0.021)
Leverage, t-1	−0.163***	0.022	0.320***	−0.162***	0.025*	0.318***
	(0.015)	(0.014)	(0.038)	(0.015)	(0.014)	(0.038)
S&P Rating, t-1	−0.648***	−0.213***	1.305***	−0.644***	−0.144**	1.348***
	(0.073)	(0.071)	(0.213)	(0.073)	(0.070)	(0.208)
EDF5, t-1	0.202*	−0.394***	−1.341***	0.167*	−0.362***	−1.246***
	(0.104)	(0.141)	(0.368)	(0.101)	(0.138)	(0.361)
Bank industry β,t-1	0.959***	−0.586**	−3.986***	1.160***	−0.174	−4.216***
	(0.276)	(0.297)	(0.800)	(0.290)	(0.303)	(0.838)
log(Lead assets),t-1				0.990*	1.777***	−2.144
				(0.512)	(0.600)	(1.493)
Lead CET1, t-1				0.279***	0.020	−0.602**
				(0.095)	(0.096)	(0.258)
Lead insur. dep.,t-1				0.038	−0.101***	−0.105
				(0.024)	(0.029)	(0.066)
Lead HQLA, t-1				−0.111***	0.088***	0.379***
				(0.028)	(0.033)	(0.084)
Lead net front.> 0, t-1				−2.118***	−0.855	9.341***
				(0.731)	(1.299)	(2.682)
log(Members assets),t-1				0.096	0.583**	0.944
				(0.224)	(0.262)	(0.680)
Members CET1, t-1				0.188**	−0.108	−0.461**
				(0.086)	(0.083)	(0.213)
Members insur. dep.,t-1				−0.079***	0.113***	0.241***
				(0.022)	(0.020)	(0.056)
Members HQLA, t-1				0.089**	−0.060	−0.436***
				(0.038)	(0.041)	(0.117)
Observations	47,082	47,082	47,082	47,026	47,026	47,026
Adjusted R^2	0.215	0.301	0.195	0.230	0.313	0.213

Table 11: **Pricing of corporate liquidity.** All regressions include lead firm, industry-time, time, and bank fixed effects. Auto-correlation and heteroscedasticity consistent standard errors are clustered at the bank and firm level.

	All-in-spread: drawn			All-in-spread: undrawn		
	(1)	(2)	(3)	(4)	(5)	(6)
Use of sublimit,t-1	17.27***	19.69***	18.07***	6.115***	6.247***	5.661***
	(6.254)	(4.425)	(4.500)	(1.455)	(1.224)	(1.182)
Cash-to-assets,t-1	0.381**	−0.116	0.007	−0.021	−0.057	−0.026
	(0.186)	(0.183)	(0.184)	(0.025)	(0.035)	(0.035)
Revolver-to-assets,t-1	0.521***	0.412***	0.298***	0.082**	0.076**	0.042
	(0.123)	(0.086)	(0.090)	(0.037)	(0.035)	(0.035)
Bank industry β,t-1	5.124*	20.63***	19.20***	4.136***	5.530***	5.119***
	(2.754)	(4.153)	(3.843)	(0.682)	(1.016)	(0.954)
Firm ROA,t-1	−1.664***	−1.201***	−1.176***	−0.274***	−0.253***	−0.248***
	(0.395)	(0.358)	(0.328)	(0.071)	(0.084)	(0.083)
EDF5, t-1	17.17***	15.98***	15.06***	3.555***	3.385***	3.038***
	(2.462)	(2.250)	(2.188)	(0.876)	(0.889)	(0.854)
Firm leverage,t-1	0.256***	0.234**	0.312***	0.052**	0.052**	0.079**
	(0.092)	(0.093)	(0.093)	(0.025)	(0.025)	(0.029)
log(Lead assets),t-1		41.36***	38.79***		5.988***	4.772**
		(8.113)	(9.282)		(1.681)	(2.087)
Lead CET1,t-1		14.79***	12.82***		1.519***	1.003**
		(1.435)	(1.546)		(0.434)	(0.422)
Lead insur. dep.,t-1		−0.305	−0.784		−0.084	−0.219**
		(0.607)	(0.586)		(0.096)	(0.091)
Lead HQLA-assets,t-1		−0.847***	−0.222		−0.253***	−0.055
		(0.201)	(0.214)		(0.055)	(0.057)
Lead net front.> 0,t-1		−44.19***	−37.61***		−5.469**	−4.023**
		(6.998)	(5.215)		(1.978)	(1.674)
log(Members assets),t-1			−6.196***			−0.450
			(2.214)			(0.548)
Members CET1, t-1			5.621***			1.270***
			(1.106)			(0.208)
Members insur. dep.,t-1			0.714***			0.235***
			(0.174)			(0.045)
Members HQLA, t-1			−2.098***			−0.587***
			(0.391)			(0.102)
Observations	4,146	3,932	3,884	3,537	3,366	3,325
Adjusted R^2	0.269	0.384	0.416	0.188	0.205	0.237

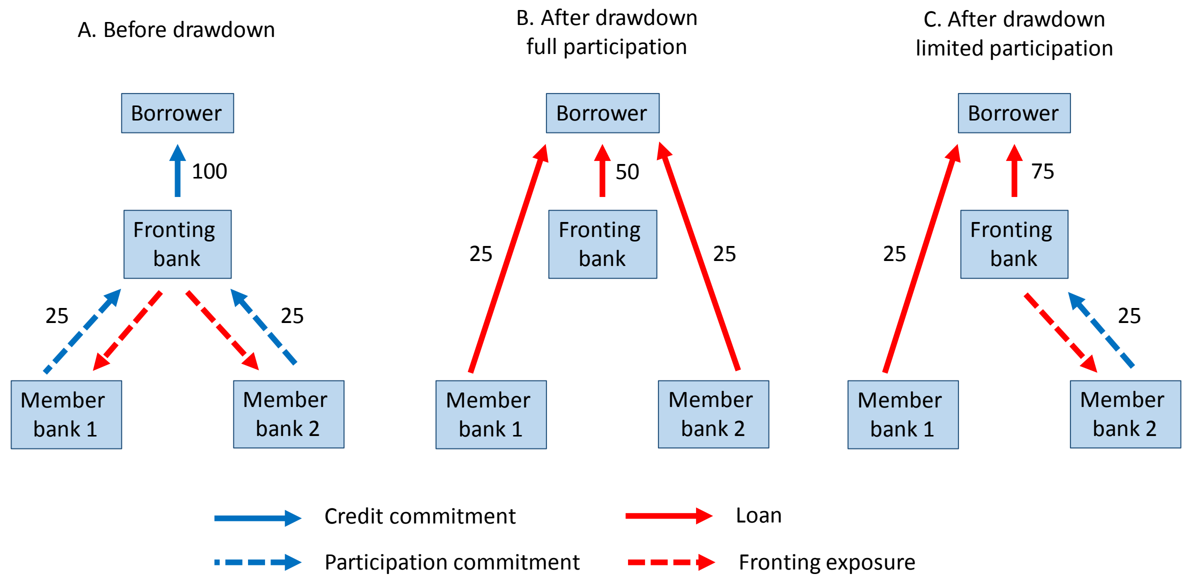
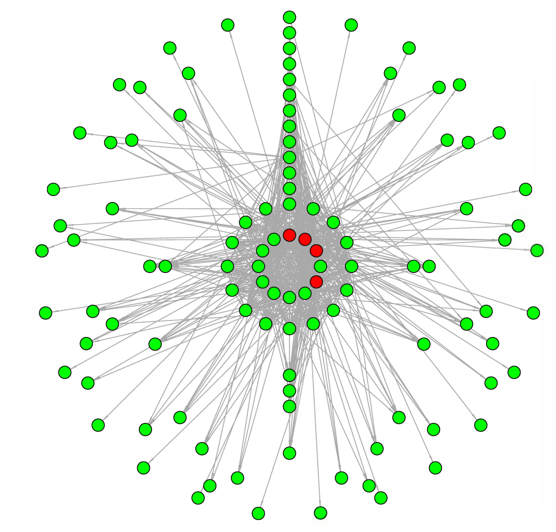
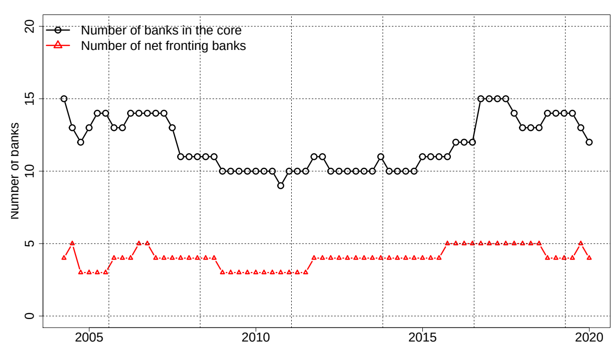


Figure 3: **Example of fronting exposures arising from swinglines.** A syndicate of three banks originates a revolving line of credit to a borrower. The revolver has a swingline of 100 and the pro-rata shares of the fronting bank and the two member banks are 0.5, 0.25, and 0.25, respectively. Panel A shows the credit commitments and fronting exposures implied by the swingline. Panel B shows a situation where the swingline is fully drawn and both member banks fully purchase their participations in the swingline loan. Panel C shows a case where member bank 2 fails to honor its commitment to the fronting bank and does not fund its participation in the swingline loan.

A. The core-periphery structure of the network of fronting exposures



B. Number of core and net fronting banks



C. Share of core-to-core and core-to-periphery fronting exposures

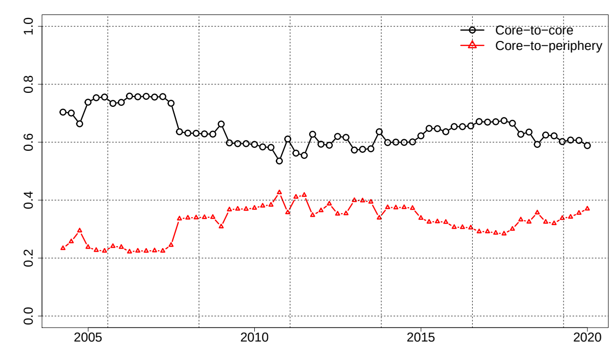


Figure 4: **The network of fronting exposures**. Panel A shows that the network of fronting exposures has a well-defined core-periphery structure. The core is defined as the largest set of banks in which any bank has both fronting-in and fronting-out exposures to all the other members of the core. We use the Eppstein et al. (2010) algorithm to identify the largest fully connected set of banks (maximal "clique"). We identify 12 banks to be in the core as of 2019Q4 shown here as the inner most circle. The concentric circles of periphery banks surrounding the core are arranged based on fronting-in connectedness to the core. The red nodes are banks that are net providers of fronting exposures, whereas the green nodes are banks that are net recipients of fronting exposures. Panel B shows the number of core banks and the number of net fronting banks over the sample period. Panel C shows the share of fronting exposures among banks in the core and from banks in the core to banks in the periphery. SOURCE: DealScan and authors' calculations.

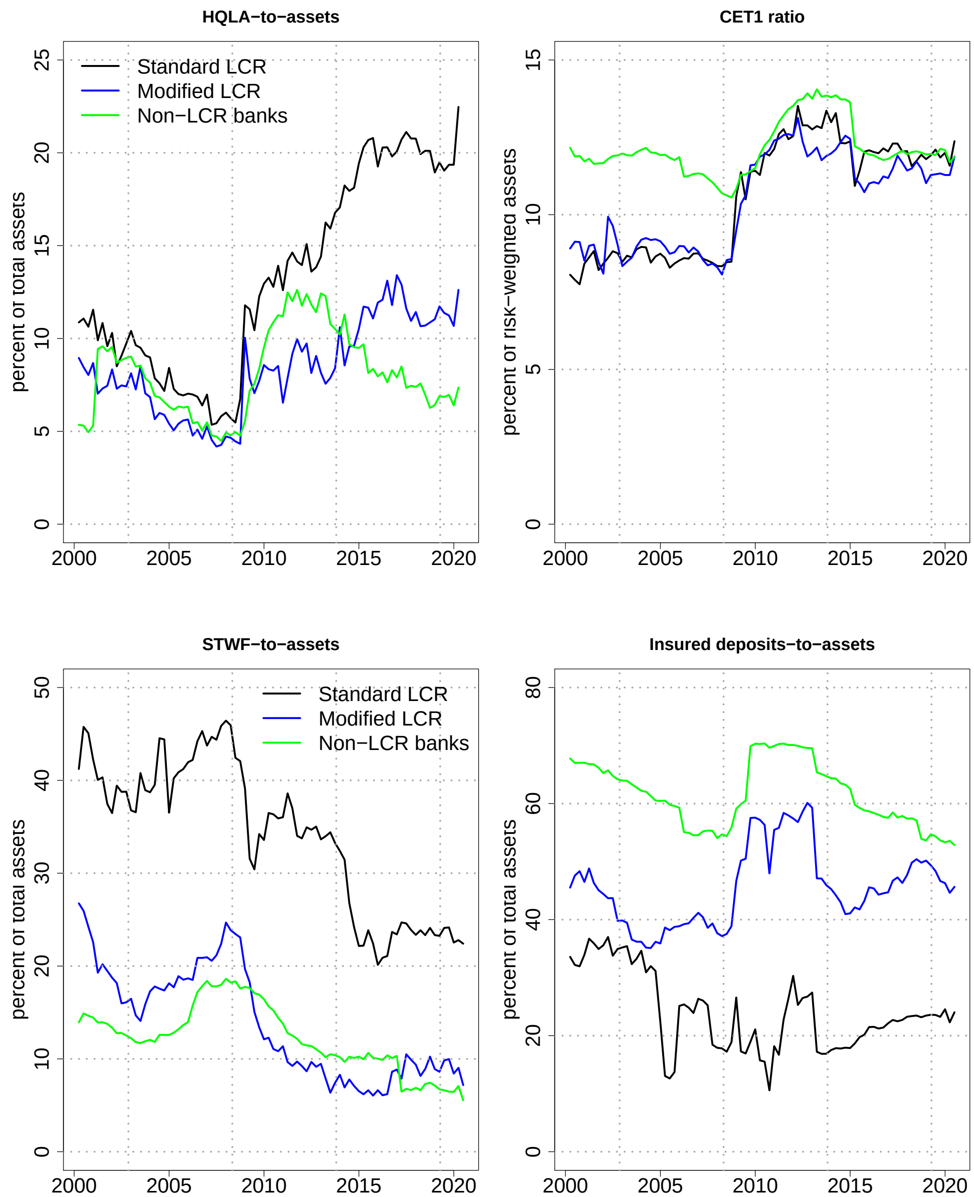


Figure 5: **Liquidity, capital, and funding sources at banks by LCR treatment.** Standard LCR banks are all banks with assets above $250 billion. Modified LCR banks are those with total assets between $50 billion and $250 billion, and non-LCR banks are banks with less than $50 billion in total assets. CET1 ratio is the ratio of CET1 capital to the total risk-weighted assets. STWF is all uninsured deposits and liabilities with outstanding maturities less than one year. Insured deposits includes all deposits below the relevant deposit insurance limit.

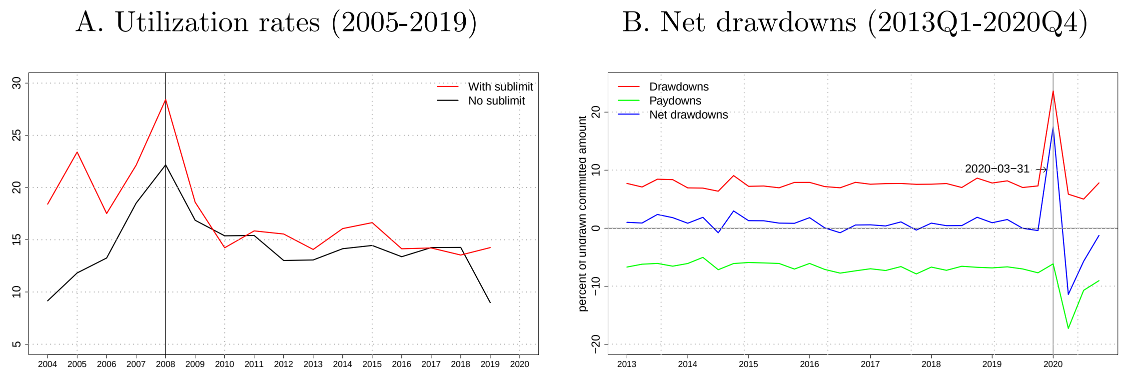


Figure 6: **Measures of aggregate drawdown rates.** Panel A uses annual data from S&P CapitalIQ (WRDS) to construct utilization rates of credit lines over the period 2005 to 2019. Utilization rate is the amount drawn as a fraction of the committed amount. Panel B uses quarterly FR Y-14 data to construct drawdowns, paydowns, and net drawdowns of credit lines as a fraction of the undrawn committed amount over the period 2013:Q1 to 2020:Q4.

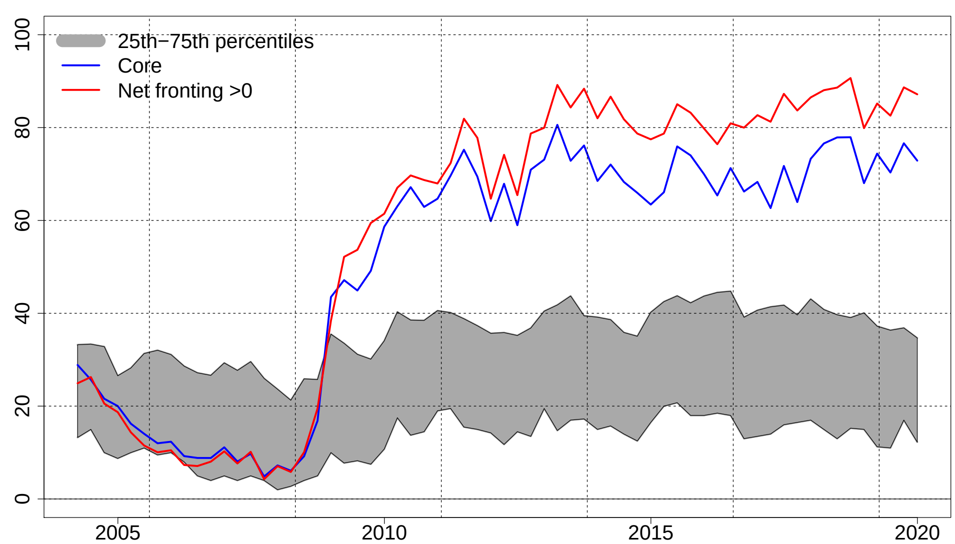


Figure 7: **Liquidity capacity as drawdown feasibility.** Drawdown feasibility is the maximum drawdown rate on both regular and credit lines with sublimits that would not deplete a bank's available liquidity. The shaded area is the inter-quartile range of drawdown feasibility across all banks in our sample. The blue and red lines are the weighted-average drawdown feasibility of banks in the core and banks with net fronting exposures, respectively. We also assume a simultaneous outflow of STWF $\lambda_B = 10$ %.

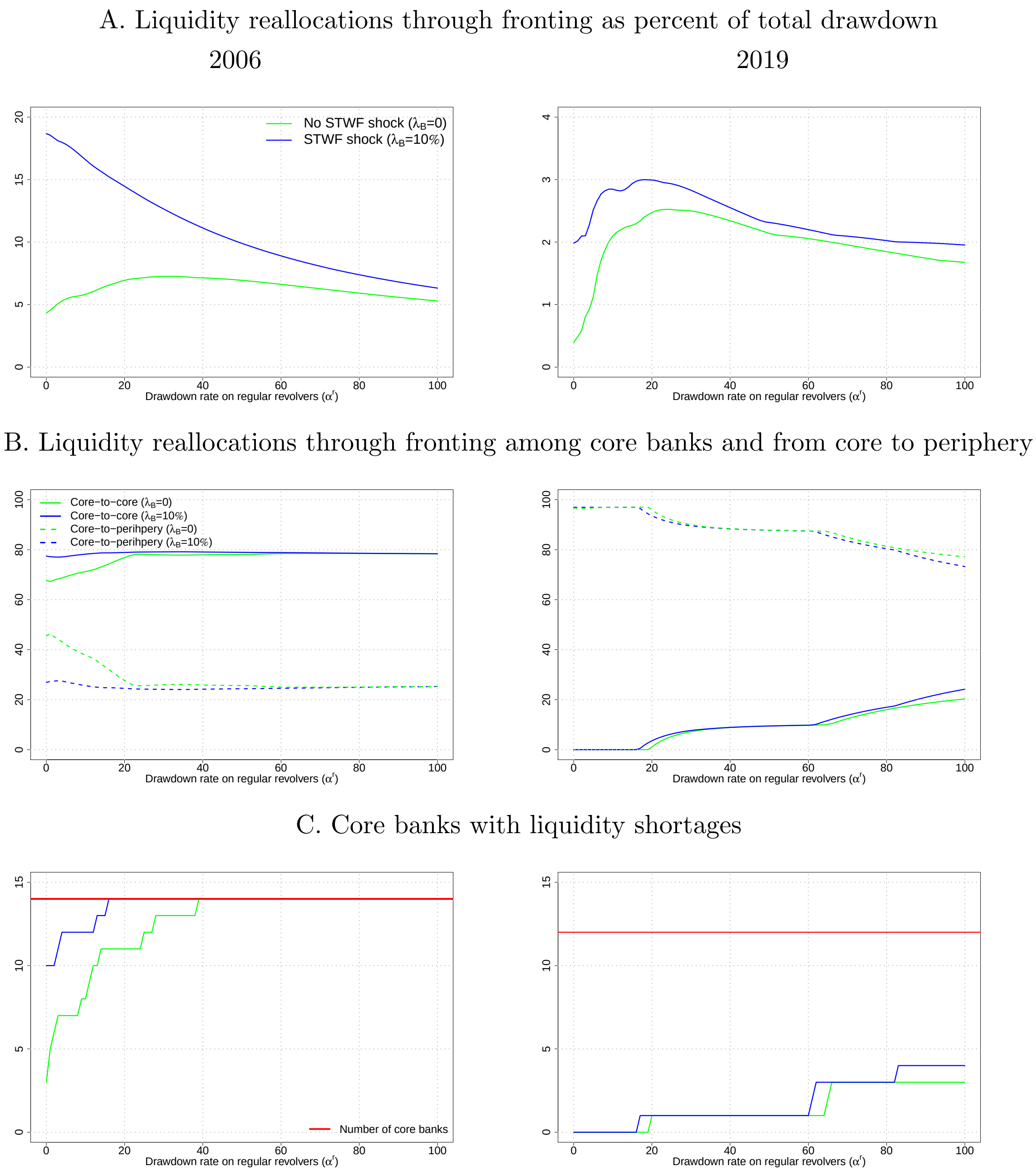


Figure 8: **Liquidity shortages and liquidity reallocations among banks.** The figure examines the degree to which liquidity reallocations among banks through fronting exposures support credit line drawdowns for two periods: 2006 prior to the GFC, and 2019 following implementation of the LCR and prior to the COVID-19 pandemic. In all exercises, we assume that firms with sublimits draw those components first and in full ($\alpha^s = 100$).

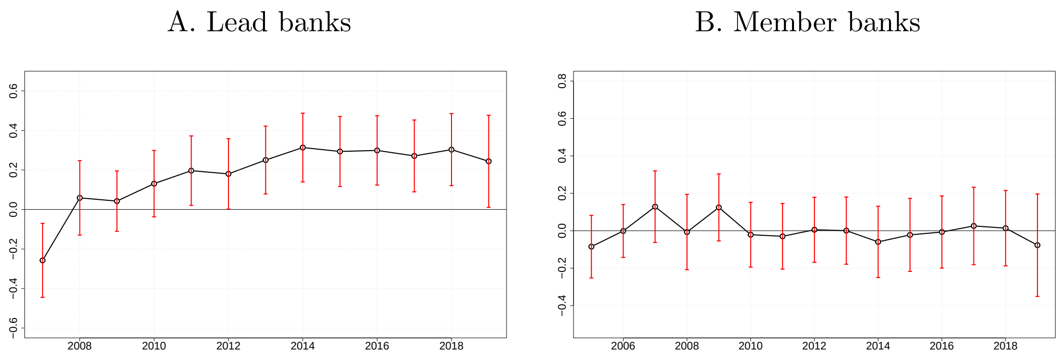


Figure 9: **Syndicate liquidity and firms' revolver-to-asset ratio.** The figure plots the coefficient estimates of the HQLA-to-asset ratio of the lead bank in panel A and the average HQLA-to-asset ratio of syndicate member banks excluding the lead bank in panel B estimated for each year based on interaction with yearly dummies. The red bars indicate the 95% confidence intervals of the coefficient estimates.