Bank Funding Risk, Reference Rates, and Credit Supply

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Abstract

Pre-committed revolving credit lines tend to be drawn heavily when bank funding markets are stressed, presenting an important funding risk to banks. Until recently, banks have mitigated this funding risk by linking the interest paid on lines to risk-sensitive reference rates such as the London Interbank Offered Rate (LIBOR). We show that incentives to provide credit lines are dampened by the debt-overhang cost to bank shareholders associated with funding stressed-market drawdowns. However, the associated adverse effect on credit supply is attenuated if: (1) drawdowns are expected be left on deposit at the same bank, which occurred at the largest banks during the COVID shock of March 2020, and (2) revolvers are linked to credit-sensitive reference rates that reduce borrower incentives to draw more heavily on their lines during stressed markets. We estimate how the replacement of LIBOR with risk-free alternative reference rates will affect the supply of revolving credit.

JEL: G00, G01, G02, G20, G21, E4, E43

Keywords: bank funding risk, credit supply, reference rates, credit lines, London Interbank Offered Rate (LIBOR), Secured Overnight Financing Rate (SOFR)

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1 Introduction

Until 2022, most new US corporate loans were indexed to the London Interbank Offered Rate (LIBOR).[1] Credit-sensitive reference rates like LIBOR, and EURIBOR in Europe, reduce the incentives of borrowers to draw on pre-committed credit lines when the costs to banks of funding of these drawdowns rise sharply, such as during the Global Financial Crisis (GFC) and the COVID recession. In most of the world, however, banking has made a transition from credit-sensitive interest-rate benchmarks to new "risk-free" benchmark reference rates such as the Secured Overnight Financing Rate (SOFR). As opposed to credit-sensitive reference rates, risk-free loan reference rates typically fall when markets are stressed, which could incite corporate borrowers to draw more heavily on credit lines linked to risk-free reference rates. Because of this, a collection of large US banks argued that reference-rate transition may exacerbate the impact of bank funding shocks and reduce ex-ante incentives for bank credit provision.[2]

In this paper, we explore the nature of bank funding risk, how this risk affects credit supply, and the degree to which this impact depends on the form of loan contracts and the type of loan reference rate. First, we provide a simple equilibrium model of credit provision in which revolving credit lines give borrowers the option to draw funds at a pre-agreed fixed spread over a floating reference rate. If borrowers are anticipated to draw credit lines during episodes in which bank funding costs are high, bank shareholders bear a debt-overhang cost of providing revolving credit. This debt-overhang cost dampens the incentives of banks to provide credit in this form, ex-ante, to an extent that is increasing in the covariance between future bank funding costs and drawdowns. However, this adverse impact of debt overhang on credit-line provision is attenuated if: (1) draws on lines offered by a given bank are expected to be left on deposit at the same bank; and (2) the interest rate on credit lines is linked to credit-sensitive reference rates that reduce borrower incentives to draw heavily on their lines under stress-market conditions.

In order to explore this problem, we first provide an empirical analysis of the sources of bank funding risk. We use several data sources, including confidential bank-level data from the Federal Reserve, such as FR 2052a, FR Y-14Q, and FR 2420, which cover the largest US bank holding companies (BHCs). The high granularity of the balance-sheet data collected in the FR2052a dataset—collected to

[1]We find that at the end of 2019 in the U.S., around 70% of all bank-firm lending referenced LIBOR as the underlying floating interest rate.

[2]See the letter from Credit Sensitivity Group banks of September 23, 2019 to Randall Quarles, Vice-Chair of Supervision of the Board of Governors of the Federal Reserve System, Joseph Otting, Comptroller of the Currency, and Jelena McWilliams, Chair Federal Deposit Insurance Corporation.

monitor the liquidity profile of large US BHCs—allows us to pin down bank funding risk for large US BHCs in much more detail than was possible in prior work. We find that there is limited funding risk for large US BHCs arising from the need to roll over existing debt. These banks are primarily financed by deposits that are empirically insensitive to bank risk, as measured by the spread between three-month LIBOR and the three-month overnight index swap rate (OIS). Further, wholesale bank funding is mostly long term and at fixed rates, and is thus significantly insulated from rollover risk.[3]

Our theory suggests that substantial bank funding risk can, however, arise from the provision of pre-committed lines of credit. As of the end of 2019, for our main sample consisting of the 20 largest US BHCs, non-financial corporates borrow more from large BHCs by utilizing credit lines ($544 billion) than with conventional term loans and other forms of commercial and industrial (C&I) lending ($444 billion), and about as much from credit lines as from commercial real estate (CRE) lending ($591 billion). Moreover, at the end of 2019, the largest 20 banks alone had around $1.3 trillion of undrawn credit line commitments, fully 80% of the magnitude of total utilized C&I and CRE lending. Contractually, these lines can be drawn at any time, including during stress periods associated with sharp increases in LIBOR. Unless a bank can pass on its costs for funding credit-line draws to its borrowers, or unless the borrowers leave the proceeds of their line drawing on deposit at the same banks, each bank may need to obtain significant new funding to meet these draws just as its funding costs spike. Banks were indeed subject to substantial drawdowns on credit lines during recent episodes when bank funding costs soared, such as the GFC and the COVID recession. However, we find that the nature of drawdowns was much different across the two episodes.

During the GFC, we find that most of the proceeds of drawdowns were not left on deposit. Instead a large fraction of the funds drawn during the GFC left the banking sector (Ivashina and Scharfstein, 2010; Acharya and Mora, 2015), causing banks to fund the drawdowns with other new borrowing, potentially at elevated bank credit spreads. Some corporate borrowers may have drawn on their lines, taking drawn funds out of their deposit accounts, as a precaution against a potential deterioration of the solvency of their banks. In contrast, during the COVID recession, drawdowns were generally of a "precautionary" nature. That is, largely, firms kept the drawn funds as cash in their corporate deposit accounts. Given the uncertainty over their own future credit quality over the course of the pandemic period, firms plausibly chose to draw the cash on their lines before their banks might have invoked covenants that

[3]Banks make relatively little use of short-term funding at credit spreads that are closely related to the LIBOR-OIS spread. Indeed, this is the reason that LIBOR is no longer viewed as an acceptable reference rate: there are too few wholesale short-term unsecured bank funding transactions to support a robust estimate of LIBOR.

could have blocked them from doing so. We estimate that for every dollar drawn, 89 cents were placed into low-interest-rate corporate deposit accounts at the same set of banks. This eliminated the majority of the cost to banks of funding the draws for the *average* bank. Banks raised the remaining funds via secured advances from Federal Home Loan Bank (FHLBs) that tended to be cheaper than unsecured wholesale funding.

Although we find that most banks were largely able to avoid significant expensive new unsecured wholesale funding during the COVID recession, we also find that some banks, especially some large regional banks, were required to fund a substantially larger part of their drawdowns by using FHLB advances. Thus, even during the COVID recession, funding risk associated with pre-committed credit lines partially did materialize for this subset of banks.

Were it not for the debt overhang costs to bank shareholders of funding line draws, the choice of reference rate would merely affect how funding-cost risks are shared between banks and their corporate borrowers. With risk-free reference rates, banks bear the majority of this risk, whereas with credit-sensitive reference rates, corporate borrowers absorb the bulk of this risk. However, our paper brings to light a funding-cost wedge that is not related to risk sharing: the ex-ante expected debt overhang cost to bank shareholders associated with offering committed credit to corporate borrowers at a pre-agreed spread to a reference rate. This ex-ante cost to bank shareholders is roughly proportional to the covariance between bank funding credit spreads and the quantity of drawn credit that must be funded. This covariance is higher under new risk-free reference rates than under legacy credit-sensitive reference rates, heightening this wedge to the provision of credit lines. For the alternative of term lending, reference rate transition does not affect this wedge because of the absence of a covariance between the funding already provided on a term loan and changes in bank funding spreads. Term lending does not give an option to the borrower of how much credit to draw. We show that reference rate transition has a negligible impact on the incentives of banks to supply term loans.

In the final part of our analysis we combine our theoretical and empirical insights by calibrating our equilibrium model to estimate the impact of the ongoing transition from LIBOR to SOFR on credit supply. We show that the transition away from credit-sensitive reference rates will likely increase expected borrowing rates on revolving credit lines. For the calibrated model, the transition from LIBOR to SOFR causes the equilibrium expected debt-overhang cost to bank shareholders associated with funding credit line draws to rise by approximately 30% per dollar of expected line usage. For the most extreme cases, when we assume that drawdowns attain levels reached during the COVID recession and are financed by banks at wholesale market rates, similar to those observed during the GFC, we find that LIBOR-to-SOFR transition leads in equilibrium to credit lines that are about 10 basis points more costly in normal times (at our sample-average LIBOR-OIS spread of 32 basis points), but about 90 basis points cheaper when LIBOR-OIS reached about 140 basis during the COVID shock of March 2020. (These estimates are extremely preliminary and subject to updates as we refine our calibration approach.) Moreover, as revolving credit becomes more expensive, the overall quantity of line commitments decreases. Although risk-free reference rates cause credit line draws to be cheaper for corporate borrowers in times of distress, the increased cost to bank shareholders of offering these lines is passed through to corporate borrowers and leads them to choose smaller committed lines. This effect of reference-rate transition is reduced, however, roughly in proportion to the fraction of stressed-market line draws that is expected to be deposited at the same bank. For example, for our calibrated model, for credit lines referencing LIBOR, holding fixed line drawing behavior, the expected debt overhang cost to bank shareholders for funding line draws rises by about 10% per dollar of expected line usage when banks assume that borrowers will reduce the drawn funds left on deposit in stressed-market scenarios by about two thirds.

Our findings regarding the effects of credit lines were anticipated by a group of banks that the wrote to bank regulators in September 2019, stating:

"Specifically, borrowers may find the availability of low cost credit in the form of SOFR-linked credit lines committed prior to the market stress very attractive and borrowers may draw-down those lines to 'hoard' liquidity. The natural consequence of these forces will either be a reduction in the willingness of lenders to provide credit in a SOFR-only environment, particularly during periods of economic stress, and/or an increase in credit pricing through the cycle. In a SOFR-only environment, lenders may reduce lending even in a stable economic environment, because of the inherent uncertainty regarding how to appropriately price lines of credit committed in stable times that might be drawn during times of economic stress."

Banking regulators responded by convening the Credit Sensitivity Group,[4] a group of these banks that was invited to a series of meetings at the New York Fed to discuss this issue and eventually to consider a "credit sensitive rate/spread that could be added to SOFR."

Since January 2022, supervisory guidance provided in interagency statements has suggested that US banks should not reference LIBOR in their loan contracts.[5]Banks have generally followed the guidance of

[4]See Transition from LIBOR: Credit Sensitivity Group Workshops, Federal Reserve Bank of New York, February 04, 2021.

[5]See, for instance, SR 20-27 which states: "Given consumer protection, litigation, and reputation risks, the agencies believe entering into new contracts that use USD LIBOR as a reference rate after December 31, 2021, would create safety and soundness risks and will examine bank practices accordingly"

the Alternative Reference Rate Committee (ARRC) and now use SOFR, primarily, as their loan reference rate. For example, ARRC reported that over 95% of US syndicated loans issued in April 2022 referenced SOFR.[6] This does not rule out the possibility that some banks may eventually choose to link some of their corporate lending to credit-sensitive reference rates other than LIBOR.[7] Our work is the first to probe the implications of this transition for credit-provision incentives and to provide the quantitative implications based on detailed bank asset-and-liability data.

The rest of the paper unfolds as follows. Section 2 relates our work to the most relevant prior research. Section 3 provides a simple equilibrium model of credit line provision. Section 4 describes our data. Our main empirical analysis consists of mapping bank funding risk for large US BHCs and quantifying the importance of reference rates in mitigating funding shocks, in Section 5. In Section 6, we calibrate our theoretical model to key empirical moments in order to quantify the effects of the LIBOR-SOFR transition on credit-line supply. Section 7 concludes.

2 Related Literature

Our paper relates to four strands of the literature. First, we contribute to the literature on bank liquidity provision through revolving credit lines. Credit lines allow firms to access funds on demand and can thus provide insurance against idiosyncratic liquidity shocks (Holmström and Tirole, 1998). Banks that are financed by deposits are naturally well positioned to provide this type of liquidity insurance (Kashyap et al., 2002; Gatev and Strahan, 2006).[8] Existing work on the pricing of credit lines typically emphasizes the option value of revolving credit, with drawdowns becoming more likely when a borrower's financial condition deteriorates (Thakor et al., 1981). Adverse selection with respect to borrower credit quality creates incentives for banks to screen borrowers and to price credit lines with a combination of spreads and fees (Thakor and Udell, 1987; Berg et al., 2016).[9] Our paper focuses on another, previously unstudied, aspect of credit line pricing. We show that debt-overhang costs to bank shareholders are higher for credit lines than for term loans, to an extent that is roughly proportional to the covariance between bank funding credit spreads and quantities of draws on lines. Further, we

[6]See Alternative Reference Rates Committee May 18 Meeting Readout, May 18, 2022.

[7]Alternative US dollar credit sensitive reference rates currently include Ameribor, BSBY, and AXI. One of authors, Duffie, is also a co-author of the proposal for AXI (Berndt et al., 2020), but has no related compensation or other affiliation with its commercialization.

[8]Empirical evidence from Brown et al. (2021) and Santos and Viswanathan (2020) suggests that credit lines indeed insure firms against liquidity shocks, although Chodorow-Reich et al. (2021) find that this insurance is only available to large firms but not to small firms. Other important work on credit lines is by Sufi (2009), Acharya et al. (2014), and Acharya et al. (2020)

[9]For example, accepting a higher spread and lower commitment fee would signal a lower probability of drawing.

model: (1) how credit-sensitive reference rates can mitigate the adverse impact of funding shocks; and (2) how re-depositing of drawdowns also impacts ex ante credit provision.

Our paper thus connects to prior work that studies the role of drawdowns during times of distress. During the GFC, many non-financial firms drew on their pre-committed credit lines (see, for example, Ivashina and Scharfstein, 2010; Campello et al., 2011; Acharya and Mora, 2015) starting in August 2007 and especially after the Lehman failure in September 2008.[10] Importantly, drawdowns during the GFC were also, in part, a form of run on some banks as borrowers became concerned about their banks' abilities to provide credit in the future (Ivashina and Scharfstein, 2010; Ippolito et al., 2016). By contrast, after the 1998 Russian default, banks experienced both credit line drawdowns and transaction deposit inflows (Gatev et al., 2007). More recently during the COVID recession, firms drew on existing credit lines to an even larger extent than during the GFC, with \$300 billion to \$500 billion drawn in March 2020 alone (Li et al., 2020; Acharya and Steffen, 2020b). But these draws were accompanied by a large increase in deposits (Li et al., 2020; Levine et al., 2021).

Using the novel FR 2052a data, we provide more detailed information on drawdowns and deposit flows. In contrast to the GFC, we show that drawdowns during the COVID shock were almost entirely precautionary, in the sense that borrowers left their drawn funds on deposit. To the extent that banks needed to raise non-deposit funding at all, they did so with relatively cheap FHLB advances. There was limited-to-no reliance on unsecured wholesale funding. We also show that a significant portion of deposit growth in March 2020 was driven by corporate drawdowns. Retail and small business deposits increased more gradually, in line with precautionary savings motives and in reaction to government stimulus payments, contributing to the increases in deposits in April and May (Cox et al., 2020). Our evidence bearing on the dynamics of bank balance sheets during the COVID recession also emphasizes that banks were not constrained by their ability to raise funding. Nonetheless, banks may have been constrained in their term lending via the impact of regulatory capital requirements and the expansion of their balance sheets caused by drawdowns, increased deposits, and other effects (Acharya et al., 2021; Greenwald et al., 2020; Kapan and Minoiu, 2021).

Second, we contribute to the literature studying the sensitivity of bank income and expenses to changes in macroeconomic conditions and their effect on credit supply. Most existing research focuses on the impact of changes in risk-free rates and term premia on monetary policy transmission (e.g., Drechsler et al., 2017; Gomez et al., 2021) or bank equity value (e.g., Begenau and Stafford, 2021; Drechsler et al.,

[10]See also Berrospide et al. (2012), Acharya et al. (2020), and Chodorow-Reich and Falato (2017).

2021; Paul, 2021) or the pass-through of bank deposit rates on loan provision (Duquerroy et al., 2021). By contrast, our work focuses on the impact of increases in measures of bank riskiness, such as the LIBOR-OIS spread, on bank credit supply. We provide the insight that, for recent data covering the COVID recession, deposit funding is not sensitive to bank risk, including uninsured deposits by financial institutions and non-financial corporates.

Third, our paper contributes to recent papers that study the impact of the transition from LIBOR to risk-free reference rates for the cost to banks of funding loans. There has been limited academic work exploring this transition. Most existing work examines LIBOR as a measure of bank funding costs, and documents historical divergences between LIBOR and risk-free rates, such as SOFR or SOFR-proxies.[11] We add to these analyses by considering bank asset exposure to the LIBOR transition. We build on work by Jermann (2019) by focusing specifically on the implications for credit lines that reference SOFR.[12] We find that line sizes will decrease and loan spreads will increase under SOFR relative to LIBOR as banks adjust loan terms to reduce debt overhang costs to shareholders under stress. By contrast, our theory implies only a minimal impact on term loans, which aligns with recent evidence by Klingler and Syrstad (2022) finding a small effect in floating-rate bond markets. The effect for credit lines is higher than term loans due to the option value borrowers have to draw at SOFR under stressed market conditions. When bank stress rises, borrowers draw more on a line linked to a risk-free rate than a line linked to a credit-sensitive rate, exacerbating bank debt overhang costs. Our conclusion that risk-sensitive rates provide benefits in credit line markets aligns with Kirti (2022), which finds that welfare benefits increase through hedging uncertainty in bank funding costs. However, our mechanism emphasizes debt overhang costs to shareholders as the channel through which risk-sensitive rates provide benefits.

Fourth, we contribute to the theoretical literature on reference rates. Santomero (1983), Chang et al. (1995), and Kirti (2020) provide a rationale for floating rate loans based on the assumption that banks are risk averse. Relatedly, Jermann (2019) studies the impact of LIBOR-SOFR transition on a bank's ability to hedge changes in its funding costs. Ho and Saunders (1983) analyze hedging in the context of fixed rate unfunded loan commitments. Their model also highlights the importance of the covariance

[11] For example, Schrimpf and Sushko (2019) and Abate (2020) document that the LIBOR-SOFR gap spikes for extended periods of time during past financial market stress and recessions. Kuo et al. (2018) find that during the GFC, LIBOR broadly tracks alternative measures of short-term bank funding costs but also document large dispersion in bank borrowing costs not captured by LIBOR. However, Bowman et al. (2020) question if LIBOR is even a good measure of marginal funding costs of banks, noting that (1) wholesale unsecured funding is a tiny fraction of GSIB and non-GSIB liabilities and (2) depending on time period and type of term SOFR (in arrears vs in advance), SOFR can be more correlated with average funding costs than LIBOR.

[12] We also extend work by Jermann (2020) by calibrating an equilibrium model of credit line provision and estimating the impact to both prices and quantities of switching from LIBOR to SOFR.

between borrower draws and loan costs for pricing at origination. Risk aversion plays no role in our analysis. In our model, banks are risk neutral but bank shareholders suffer an expected cost when banks offer committed lines of credit that are likely to be heavily drawn when bank credit spreads rise. The incentives in our model are driven by debt overhang rather than risk aversion. If one treats banks and borrowers as risk averse in the sense of these prior studies, then the choice between risk-free and credit-sensitive reference rates is largely an issue of whether borrowers will insure banks by using credit-sensitive rates such as LIBOR, or banks will insure borrowers by using risk-free reference rates such as SOFR. This choice is not among the main concerns of our paper.

3 A Model of Credit Line Provision

The following simple equilibrium model of credit lines allows us to show the degree to which the incentives of banks to provide credit lines is affected by the choice of the floating reference rate. In Section 6, we calibrate this model to the empirical experience with LIBOR credit lines originated by large US banks in order to illustrate the potential impact of reference rate transition and the key economic channels at work.

Credit lines are contracted at time 0, giving the option to a borrower to draw on the line at time 1 at an interest rate equal to a fixed contractual spread over the reference rate. We analyze cases in which the reference rate R is either a credit-sensitive rate like LIBOR or the risk-free rate r. These interest rates apply to loans contracted at time 1 and maturing at time 2. We ignore risk aversion throughout.

At time 0, as depicted in Figure 1, the bank offers the borrower a menu $\{(L, s(L)) : L \geq 0\}$ of credit-line terms distinguished by the size L of the line and the associated fixed spread $s(L)$ over the variable loan benchmark rate R. The borrower selects its preferred choice $(L, s(L))$ from this menu. At time 1, information reveals the rates R, r, and the credit spread S of the bank for unsecured wholesale funding maturing at time 2. By "wholesale," we mean that bank creditors break even in market value by providing marginal quantities of new funding to the bank at the interest rate $r + S$.

At time 1, after observing S, r, and R, the borrower chooses the quantity $q \leq L$ of cash to draw, and leaves $d \leq q$ of the drawn funds on deposit at the same bank. In this basic version of the model, the deposited fraction $\varphi = d/q$ can be contingent on the state of the market at time 1, but is exogenously chosen. In Section A in the Appendix, we extend the model so as to endogenize φ, state by state, based on the borrower's fear that the condition of the borrower or the bank may deteriorate so as to block

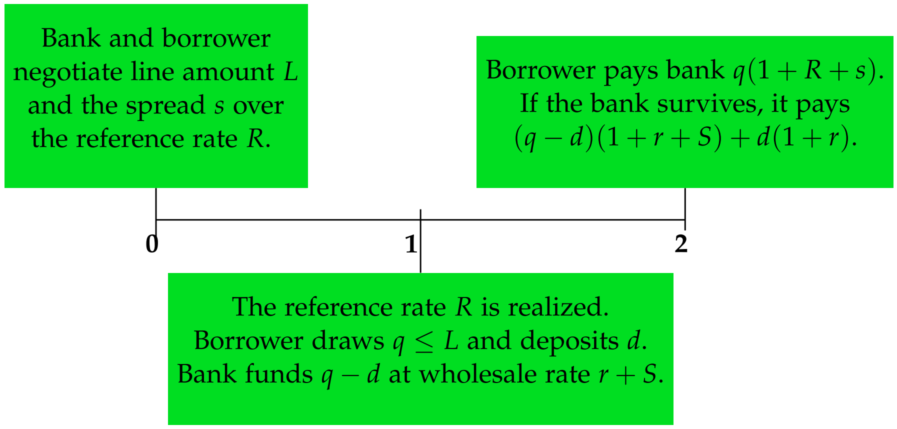


Figure 1: Model timeline. Under LIBOR, the reference rate R is $r+S$. Under SOFR, $R=r$.

later drawing on the line. The undeposited quantity $q-d$ of drawn cash is funded by the bank at its unsecured wholesale rate $r+S$. The interest rate offered to the borrower on the deposited amount d is assumed to be the risk-free rate r. (Empirically, we will later show that the interest rate paid on corporate transaction deposits is near the risk free rate.) At time 2, the total assets and total liabilities of the bank are revealed and the bank is either solvent or not. For simplicity, the bank will not default before time 2 because the bank has no liabilities maturing before time 2. If solvent at time 2, the bank pays back $(q-d)(1+r+S)+d(1+r)$ on the funding that it obtained at time 1. The corporate borrower repays $q(1+R+s(L))$ on the line, and receives $d(1+r)$ in interest, whether or not the bank is solvent at time 2. For simplicity, our basic model assumes that the borrower will not default on the credit line. We examine the impact of borrower default risk in a later footnote.

For a given reference rate R, it remains to specify the preferences of the bank's shareholders and the borrower, and then solve for the equilibrium line size L, contractual spread $s(L)$, and amount q drawn.

At time 1, the benefit to the borrower of receiving x in cash is $b(x,\psi)$, where ψ is a liquidity-preference variable that is revealed at time 1 and b is a function in two non-negative variables such that (i) for any y, $b(x,y)$ is increasing, differentiable, and strictly concave with respect to x, and (ii), for any x, the marginal benefit $b_x(x,y)$ of cash is at least 1 and is increasing in the outcome y of ψ. At time 1, given the committed size L of the credit line, the borrower chooses the amount $Q(L)$ to draw that maximizes the benefit of receiving the cash, net of the present value of the loan repayment less deposit proceeds. That is, state by state, $Q(L)$ solves

$$\sup_{q \le L} \ b(q,\psi) - q\delta(1 + R + s(L)) + q\varphi, \tag{1}$$

where $\delta = 1/(1+r)$. In the event that $b_x(0,\psi) \le \delta(1+R+s(L)) - \varphi$, the optimal cash draw $Q(L)$ is zero. In the event that $b_x(L,\psi) \ge \delta(1+R+s(L)) - \varphi$, the optimal cash draw $Q(L)$ is L. Otherwise, from the first-order condition for optimality,

$$Q(L) = B\left(\delta(1+R+s(L)) - \varphi, \psi\right), \tag{2}$$

where $B(\,\cdot\,, y)$ is the inverse of $b_x(\,\cdot\,, y)$, meaning that $b_x(B(z,y),y) = z$. At time 0, the borrower chooses the size L^* of the credit line that achieves the maximal expected net benefit

$$U_F = \sup_{L} E\left[b(Q(L),\psi) - Q(L)(\delta(1+R+s(L)) - \varphi)\right] - fL, \tag{3}$$

where fL is the line-size fee, for some constant $f \ge 0$. We assume that this line-size fee fL compensates bank shareholders for any capital requirements associated with the committed line size L. There is also an equity capital requirement Cq for the drawn amount q, for some constant capital ratio C[13].

From Theorem 1 of Andersen, Duffie, and Song (2019), the marginal increase[14] at time 1 in the equity value of the bank associated with given contractual credit line terms $(L, s(L))$ is

$$G(L) = p_1\pi_L - \kappa p_1 \delta Q(L) S, \tag{4}$$

[13]The impacts of capital requirements on credit provision are widely discussed in the literature. For example, Favara, Infante, , and Rezende (2022) state that, "Our central finding is that drawdowns reduce bank participation in Treasury markets because they lower SLRs. We show that a higher SLR buffers attenuate the negative relation between drawdowns and Treasury market participation. Our estimates suggest that, in March 2020, the decline in dollar amounts of Treasuries in response to each dollar of credit line drawn for a bank in the bottom quartile of the SLR distribution was about twice as large and the decline for a bank in the top quartile."

[14]Specifically $E[G(L)]$ is equal to the right derivative $\partial_+ V(0)$ of the market value $V(c)$ of the bank's equity with respect to the incremental quantity c of customers contracting credit lines with the bank, evaluated at $c = 0$. The second-order approximation of the gain, $\partial_+ V(0)c + \partial_+^2 V(0)c^2/2$, is computed explicitly in Andersen, Duffie, and Song (2019).

where $\kappa = (1-\varphi)(1+C)$, p_1 is the conditional probability[15] at time 1 of bank solvency at time 2, and

$$\pi_L = \delta Q(L)(1+R+s(L)) - Q(L)$$

is the bank's profit on the drawn line, which is the discounted loan payoff net of the loan proceeds. The first term of (4) is the expectation at time 1 of credit-line profit going to bank shareholders, noting that equity owners get paid at time 2 if and only if the bank is solvent. The second term of (4) is the debt-overhang cost to bank shareholders caused by funding the line draw at wholesale unsecured rates, after adjusting for the fraction φ of the drawn amount that does not require wholesale funding and for the equity capital requirement Cq.

Collecting terms, we have the shareholder marginal benefit for a line of size L given by

$$G(L) = p_1 \delta Q(L)(1+R+s(L) - \kappa S - (1+r)). \tag{5}$$

We assume that the bank maximizes the initial market value of its equity and Bertrand-competes against other banks of the same credit quality for providing the customer's credit line. The bank therefore offers the borrower a spread $s(L)$ at which the bank's shareholders break even on marginal new credit lines, meaning that $E[G(L)] = 0$. This pins down the contractual spread

$$s(L) = \frac{E[p_1 Q(L)(1 - \delta(1+R-\kappa S))]}{E[\delta p_1 Q(L)]} \tag{6}$$

over the reference rate benchmark R that is offered to the borrower for a given line amount L. The borrower then solves (3) for the optimal line amount L^*. An alternative would be to model imperfect competition between banks, which would be more realistic with respect to the magnitudes of profit markups, but would not alter the thrust of our characterization of the effect of reference rate choice on incentives for loan provision.

For the following illustrative cases, we assume that the bank is of LIBOR credit quality. For the case in which the loan reference rate R is LIBOR, this implies that $R = r + S$. For the special case of $\kappa = 1$, we can solve (15) to see that the contractual spread $s_{r+S}(L)$ over LIBOR is actually zero. In other words,

[15]Given the fractional loss ℓ at default to the bank's unsecured creditors, we can solve for the credit spread $S = (1-p_1)\ell$, and substitute $p_1 = 1 - S/\ell$ into (4). As shown by Andersen et al. (2019), for a borrower with default risk that is positively correlated with the default risk of the bank, there is also a risk-shifting benefit to bank shareholders of $\delta \operatorname{cov}_1(1_H, Y_L)$, where 1_H is the indicator of the event H of bank solvency and cov_1 denotes covariance conditional on information available at time 1. This term is zero in our setting because the borrower is default free.

even though the borrower is free of default risk, bank shareholders are willing in this case to offer the credit line if and only if the borrower compensates the bank for the funding value adjustment (debt overhang cost to shareholders) by paying interest on the drawn line at the LIBOR spread S over the risk-free rate. More generally, the spread over the credit-sensitive reference rate $r+S$ is

$$s_{r+S}(L) = \frac{E[p_1 Q(L)(1-\delta(1+r+(1-\kappa)S))]}{E[\delta p_1 Q(L)]}. \tag{7}$$

For the alternative case of the risk-free reference rate $R = r$, (15) implies the contractual spread

$$s_r(L_r) = \frac{E[\delta p_1 Q(L_r)\kappa S]}{E[\delta p_1 Q(L_r)]}, \tag{8}$$

where L_r is the associated equilibrium line size, implying that

$$s_r(L_r) = E(\kappa S) + \theta \operatorname{cov}(\delta Q(L_r), \kappa S) - \theta \operatorname{cov}(\delta Q(L_r)(1-p_1), \kappa S), \tag{9}$$

where $\theta = 1/E[\delta p_1 Q(L_r)]$.

We naturally assume that ψ and S are affiliated random variables, based on the idea that the borrower is likely to be under greater liquidity stress when the bank is under greater credit stress. The affiliation of ψ and S and the concavity of the liquidity benefit function $b(\,\cdot\,,\psi)$ implies that $B\,(\delta(1+r+s_r(L_r)),\psi)$ and S are also affiliated, so $\operatorname{cov}(Q(L_r), S) \geq 0$. This is strongly consistent with our empirical evidence that total C&I and CRE lending and line drawing are not significantly correlated with LIBOR when LIBOR-OIS spreads are low, but are significantly positively correlated with LIBOR-OIS during stress periods in which LIBOR-OIS is high. The third term of (9) is typically small, relative to the first and second terms, because the probability distribution of $1 - p_1$ is typically concentrated near 0.

Regardless of the choice of reference rates, the bank's shareholders and new creditors break even on new credit line contracts, at the margin, and are indifferent to the choice of reference rate. Legacy bank creditors improve the market value of their debt claims through the debt overhang channel more with the risk-free reference rate r than with the LIBOR reference rate $r + S$. In summary, in our setting, the switch from credit-sensitive reference rates like LIBOR to risk-free reference rates typically reduces the provision of credit lines and, for each credit line contracted, benefits legacy bank creditors at the expense of corporate borrowers.

The welfare effect associated with the choice of reference rate is captured in our model by the impact on the borrower's expected net benefit $E(b(Q(L), \psi) - Q(L))$ of drawing. This follows from the fact that at time 1, the bank transfers $Q(L)$ to the borrower, and at time 2, the corporate borrower transfers $Q(L)(1 + R + s)$ to the bank. The deposit transfer effects and line-size fee fL are offsetting. These pecuniary transfers don't contribute to welfare, but the borrower receives a total benefit $b(Q(L), \psi))$ that includes the pecuniary transfer $Q(L)$ plus a liquidity benefit of $b(Q(L), \psi) - Q(L)$. We are assuming a competitive frictionless market for bank funding, without welfare effects, and we are ignoring any incremental distress costs for the bank. In pratice, there is some financial stability benefit associated with LIBOR reference rates, because of the mitigation of funding stress on banks that we have modeled. Our modeled net welfare gain $b(Q(L), \psi) - Q(L)$ is increasing in $Q(L)$, state by each state, because $b_x(x, y) \geq 1$.

In Section 6, we calibrate this model to empirical data in order to illustrate the implications for equilibrium credit line provision of reference rate transition, depending on the degree to which corporate borrowers are anticipated to leave their drawn funds on deposit when the bank funding costs reach stressed levels.

4 Data

Our empirical analysis builds mainly on two confidential data sets available at the Federal Reserve: the FR 2052a and the FR Y-14Q. We use several additional sources such as the FR Y-9C, FR 2420, FRED, RateWatch, Bloomberg, S&P Compustat, and Capital IQ. In the following we briefly describe these data. A more detailed documentation of the data can be found in Appendix Section B.

Our first main data source is the FR 2052a data collection, which is used to monitor the liquidity profile of large US Bank Holding Companies (BHCs). The respondent panel consists of BHCs designated as Global Systemically Important Banks (G-SIBs) and foreign banking organizations (FBOs) with US broker-dealer assets greater than \$100 billion. The data collection was started in December 2015 and expanded to a larger panel of banks in July 2017. This data source provides two crucial advantages over publicly available regulatory bank filings such as the FR Y-9C. First, the FR 2052a data are more granular and report assets and liabilities by product type, maturity, collateral status, and counterparty. This additional granularity allows us to establish several previously unknown facts about US banks' funding structures and their exposures to variations in bank funding spreads. For instance, Appendix Figure B.1 illustrates how the FR2052a data allow us to break down deposits and wholesale funding by more detailed categories than would be possible from the publicly available data in FR Y-9C. Second, the data are collected at a higher frequency. Firms with $700 billion or more in total consolidated assets or $10 trillion or more in assets under custody must submit a report on each business day. Firms with more than $50 billion but less than $700 billion in consolidated assets report at the end of each month. This higher frequency allows us to document how bank balance sheets evolved during the COVID recession more precisely than previous work.

Our second main data source is the FR Y-14Q data collection, which is a supervisory data set maintained by the Federal Reserve to assess capital adequacy and to support stress testing. The reporting institutions comprise US BHCs, intermediate holding companies (IHCs) of foreign banking organizations, and savings and loan holding companies with more than $100 billion in total consolidated assets. We use the corporate loan schedule (H.1) and the commercial real estate schedule (H.2). Both schedules contain loan-level information on loans involving a commitment of at least $1 million. These data allow us to study how reference rates are used in C&I and CRE lending, given that banks report a large set of characteristics, including the spread, reference rate (LIBOR, PRIME, other, mixed, fixed), committed amount, utilized amount, loan type (revolving credit line, term loan, etc.), issue date, and maturity date. Data from the corporate loan schedule (H.1) also include borrower reference information, such as Employer Identification Numbers (EINs), stock tickers, and CUSIPs. We use these reference data to merge firm financials from S&P Compustat and Capital IQ to analyze firm-level drawdowns and cash management during the COVID shock.

Combining the above data sets, along with publicly available information from the FR Y-9C and bank call reports, our primary sample of banks consists of 24 of the largest US banks. We exclude the US operations of foreign banks from our analysis that relies on the FR 2052a, as we do not observe the full liability profile for these institutions. For our analysis, we distinguish between different bank types: universal banks, regional banks, credit card firms, trusts, and investment banks. For some analyses, namely when using the FR Y-14Q to identify details on bank loan terms, we restrict further to a subset of 20 banks that reported the Y-14Q as of December 31, 2019. A list of all banks in our sample, their type, and the panel in which they report, can be found in Appendix Table B.1.

We also construct measures of bank funding rates using various sources. First, we use the FR 2420 to construct measures for corporate deposit, interbank, and other deposit and wholesale funding rates. The FR 2420 is a transaction-based report that collects daily liability data on federal funds purchased, certificates of deposits (CDs), and selected deposits by counterparty type, allowing us to distinguish rates paid by financial and non-financial counterparties. The reporting panel comprises US commercial banks and thrifts that have $18 billion or more in total assets. Bank savings and checking deposit rates are taken from RateWatch. Additional information on bank funding costs is sourced from FRED and Bloomberg, including term LIBOR, SOFR, and BSBY rates. We additionally source data on fixed rate advances provided by Federal Home Loan Banks (FHLBs) from Des Moines, Pittsburgh and Dallas.

5 Bank Funding Risk for Large U.S. BHCs

In this section, we ask: To what extent are contemporary large US BHCs exposed to variations in measures of bank funding cost? First, we provide a set of key facts about the composition of bank funding and document the historical sensitivity of various bank funding rates to measures of bank funding spreads such as the LIBOR-OIS spread. We measure LIBOR-OIS as the difference between 3-month LIBOR and 3-month overnight index swap rates (OIS), for which the underlying rate is the effective fed funds rate. Second, we investigate to which extent revolving credit could pose bank funding risk by studying outstanding revolving credit for BHCs and the funding of drawdowns during both the COVID recession and the GFC.

5.1 The Composition of Bank Deposit and Wholesale Funding

Table 1 provides evidence on composition of bank funding as reported in the FR 2052a, allowing us to establish several novel facts about composition of bank funding. In Panel A of Table 1 we report deposits by counterparty, maturity, and type. Note that the level of granularity that the FR 2052a offer has historically been unavailable for US banks.

As of December 2019, deposits account for 59% of total bank assets, and the largest providers of bank deposits are retail customers, who provide around 50% of all deposit funding. The second most important source of deposit funding is non-financial corporate deposits (23%) followed by deposits from financial institutions (15%) and small businesses (7%). Most financial deposits are held by non-bank financial institutions (NBFIs), around 11%.[16]

Our data allow us to document additional details about the nature of deposits held by different counterparties. Across all counterparty types, more than 91% of all deposits are without maturity and

[16] There is also heterogeneity across banks, see for instance Table E.1 in the Appendix that shows cross-bank distributions. While most banks predominantly rely on retail deposits, the reliance on these deposits vary, as the interquartile range varies from 43% to 83%. See also Table E.2 in the Appendix that restricts the sample to "Regional" banks. Regional banks are slightly more reliant on retail and small business deposits than the rest of the industry.

are available on demand—these are referred to as "open". Time deposits are uncommon. The share of deposits with a fixed term is largest among retail depositors, at less than 14%. Retail and small business deposits are mostly FDIC-insured, in contrast to deposits from all other counterparties which are almost entirely uninsured. Further, most deposits – around 62% – are considered stable, labeled as "relationship" accounts in Table 1, and are thus unlikely to see funding cost increases in stress.[17] Finally, only a small portion of deposits (<5%) are less stable and more rate-sensitive brokered deposits.

We turn next to the composition of wholesale funding in Panel (B) of Table 1. Around 16% of outstanding bank assets are financed by wholesale funding. Reflecting regulatory reforms after the GFC, the majority of wholesale funding of large US BHCs is longer-term.[18] As of December 2019, less than one-third of outstanding wholesale funding was expected to mature within 12 months and only 13% within one month. Most wholesale funding is provided through unstructured or structured long-term debt issues, which together account for 71% of total wholesale funding[19] and are mostly fixed rate.[20]

The second most important type of wholesale funding are advances from Federal Home Loan Banks (FHLBs). Banks that join the FHLB system can obtain secured loans from FHLBs, which in turn raise funds from money market funds (Gissler and Narajabad, 2017). FHLB advances are typically secured by real estate mortgages and a "super lien" on other bank assets. The maturity of FHLB advances can range from very short-term (overnight) to very long-term (30 years). Overall, FHLB funding is an important source of bank funding and accounts for 8% of wholesale funding.[21]

[17]We use categories of funding as defined in the Liquidity Coverage Ratio (LCR) rule to identify these types of deposits. For retail and small business deposits, relationships accounts consist of transaction accounts (e.g., demand deposits) or non-transaction accounts (e.g., savings accounts). For corporates and other counterpary types, relationship accounts are operational deposits – defined as those used for cash management, clearing, or custody services.

[18]Anderson et al. (2021) find that post-GFC the majority of short-term wholesale funding is used to fund bank arbitrage capital positions, such as IOER and CIP arbitrage.

[19]Structured debt refers to debt instruments with original maturity greater than one year whose principal or interest payments are linked to an underlying asset (e.g., commodity linked notes). Unstructured debt refers to vanilla products with original maturity greater than one year, for instance floating rate notes linked to indexes like LIBOR or effective fed funds or with standard embedded options (i.e., call/put).

[20]According to data obtained from Bloomberg, we find that most of bank long-term debt is fixed rate. Only 29% of claims are floating rate, and of those only 11% reference LIBOR, see Table E.4. Note that we are only to "confidently" match data long-term debt with public balance sheets data for a subset of the banks in our sample which consists mostly of banks classified as "regional" banks. See Figure E.2 for details on our match quality.

[21]There is also cross-sectional variation in the types of wholesale funding used. For instance, regional banks rely more on FHLB advances, which make up around 30% of their wholesale funding, see Panel (B) of Table E.2 in the Appendix. These regional banks tend to have a larger share of C&I lending of overall lending. They also rely relatively more on deposit funding than the average bank, as 76% of all assets are financed by deposits and only around 11% by wholesale funding. The U.S. Operations of Foreign Banks (FBOs) also have a substantially different funding profile than the domestic U.S. banks, see Table E.3. Nearly all deposits are uninsured, and their U.S. operations primarily on corporate deposits and internal funding from overseas branches (via deposits or wholesale funding). We exclude FBOs from our primary analyses because we do not observe the full consolidated asset and liability profile of the institution – only that of their U.S. operations.

Table 1: **Deposit and Wholesale Funding Breakdown as of December 31, 2019.**

Panel A: Deposit Funding by Counterparty

Counterparty	% Open	% 1 Day-1 Year	% 1 Year+	% Uninsured	% Relation-ship	% Brokered	% Total Deposits	% Total Assets
Retail	86.6	9.2	4.2	28.6	67.8	7.2	50.0	29.5
Non-Financial Corporate	96.5	3.3	0.1	96.1	45.2	1.0	23.3	13.7
NBFI	94.7	3.7	1.6	94.6	60.2	1.6	11.2	6.6
Small Business	98.0	1.9	0.1	45.8	80.5	6.0	6.6	3.9
Bank	96.7	2.8	0.5	97.3	65.4	0.1	4.2	2.5
Other Counterparty	90.1	8.9	1.0	95.6	59.1	0.1	2.5	1.5
Public Sector Entity	96.0	3.7	0.2	97.3	50.6	0.3	2.4	1.4
All Counterparties	91.3	6.3	2.4	59.0	61.8	4.4		

Panel B: Wholesale Funding by Type

Product	% Open-30 Days	% 1-6 Months	% 6 Months-1-Year	% Long-Term	% Collateral-ized	% Prime Brokerage	% Wholesale Funding	% Total Assets
Unstructured LTD	1.1	4.5	5.3	89.1	0.0	0.0	59.1	9.1
Structured LTD	3.1	8.4	9.3	79.2	0.0	0.0	12.4	1.9
FHLB	22.5	31.9	13.0	32.6	100.0	0.0	8.1	1.3
Conduit and SPV	13.9	23.3	8.3	54.5	99.4	0.0	6.5	1.0
Free Credits	100.0	0.0	0.0	0.0	0.0	50.7	6.3	1.0
Other Wholesale Funding	55.7	30.8	10.5	3.1	0.0	0.0	4.0	0.6
Wholesale CDs	15.9	54.9	25.3	3.8	0.0	0.1	2.4	0.4
CP	27.8	64.9	7.3	0.0	0.0	0.0	1.2	0.2
All Products	13.0	11.2	7.0	68.9	14.6	3.2		

Notes: Data Sources: FR2052a, FR Y-9C. Panel represents the distribution of deposit characteristics by counterparty type across 24 banks in monthly FR 2052a panel. Other Counterparty includes Central Banks, Debt Issuing SPEs, GSEs, Multilateral Development Banks, Sovereigns, Other Supranationals, counterparties categorized as "Other" and deposits with missing counterparty type information. Maturity information reflects remaining maturity as of Dec. 31, 2019, and not maturity at origination. Relationship deposits reflect retail and small business deposits classified as transactional accounts (e.g. demand deposits) or non-transactional relationship accounts (e.g. savings accounts), and operational deposits at all other counterparties. Panel B represents the distribution of wholesale funding characteristics by product type in monthly FR 2052a panel across all banks. Conduit and SPV financing includes asset-backed commercial paper, other asset-backed securities, collateralized CP, covered bonds, and tender option bonds. Other Wholesale Funding includes banks' draws on committed lines, government supported debt, onshore and offshore borrowing (for example, fed funds), structured notes, and unsecured notes.

There is relatively little reliance on other forms of wholesale funding, especially those types of funding that are most sensitive to financial distress. For instance, there is very little reliance by large US banks on unsecured funding sources such as wholesale certificates of deposits (2.4%) and commercial paper (1.2%).[22] Instead, banks tend to make more use of secured funding provided by conduits (e.g. asset-backed commercial paper) which constitutes around 6% of wholesale funding. Free credits (i.e. deposits placed at broker-dealers) account for around 6% of wholesale funding, half of which come from prime brokerage clients.

5.2 Sensitivity of Bank Funding Rates to the LIBOR-OIS Spread

Next, we study the sensitivity of various bank funding rates to changes in funding conditions. As shown in the previous section, banks are largely funded by short-term deposits that must be rolled over at prevailing market rates. However, given variation in market power, riskiness, sophistication or opportunity costs across different counterparties and product types, the extent to which the various types of short-term debt *actually* vary with LIBOR is an important empirical question.

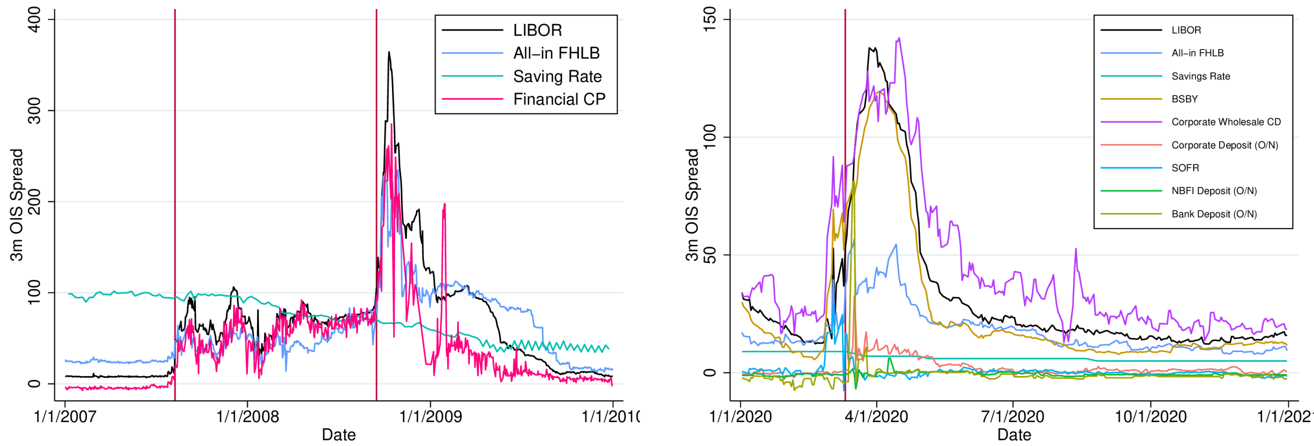
We thus study the historical sensitivity of bank funding rates that correspond to the different funding sources listed in Table 1 to the LIBOR-OIS spread during periods of financial distress. Figure 2 shows data for some key funding rates during the GFC in Panel (a) and during the COVID recession in Panel (b). During the GFC, LIBOR-OIS started to increase around August 2007, at the collapse of the asset-backed commercial paper (ABCP) market (see, e.g., Covitz et al., 2013). Between the summer of 2007 and September 2008, LIBOR-OIS remained elevated and just below 100bp. Reported LIBOR rates, however, were downward biased by manipulative reporting (Duffie and Stein, 2015). LIBOR-OIS only returned toward normal levels near the end of the crisis, and after significant government intervention.

During this period, rates for retail deposits (proxied by savings and checking account rates from RateWatch) are not sensitive to movements in LIBOR-OIS spreads. This is unsurprising since most retail deposits are insured and banks exhibit substantial market power over depositors, implying a low sensitivity to changes in economic conditions (Drechsler et al., 2017). Rates on financial CP increase, in contrast, as LIBOR-OIS increases. As documented in Ashcraft et al. (2010), "safer" borrowing—such as collateralized advances from FHLBs—was significantly cheaper than LIBOR in the early stages of the crisis, but these somewhat safer rates also increased during the peak of the GFC.

[22] By contrast, U.S. Operations of FBOs rely more heavily on Wholesale CDs, which account for 25% of third-party assets, see Table E.3.

Figure 2: **Bank Funding Rates During Financial Distress**.

(a) Global Financial Crisis (b) COVID-19 Recession



Notes: Figures represent wholesale and deposit funding rates during the Great Financial Crisis and COVID pandemic. Data Sources: FR2420, FRED, Bloomberg, FDIC, RateWatch, FHLB Des Moines Historical Rate File.

"All-in" FHLB spreads are calculated similarly to Ashcraft et al. (2010), with additional parameters to capture equity cost for FHLB stock. Appendix Section B provides details. In the COVID figure, Corporate Wholesale CD and Bank, Corporate, and NBFI O/N deposit rates are calculated from bank-level transactions in the FR 2420 report. 3M CD rates reflect trades with maturity between 89 and 92 days. O/N rates reflect trades with 1-day maturity. We aggregate trades by date, calculating the median daily interest rate weighted by transaction amount. We exclude dates with fewer than 10 transactions, and carry forward the prior date's rate. We then calculate a rolling average rate which averages the interest rates paid on the five most recent trading dates, to smooth our series.

A similar pattern holds for the COVID recession, as shown in Panel (b) of Figure 2. LIBOR-OIS increased throughout March, especially once the World Health Organization announced on March 11 that COVID-19 had become a global pandemic. However, LIBOR-OIS reached a much lower peak than it had during the GFC. For the COVID episode, we have more precise measures for bank funding costs. For instance, we can obtain the rates for overnight corporate deposits and rates on deposits held by other banks or non-bank financial institutions (NBFI). These rates are unlike retail deposit rates sensitive to the effective fed funds rate. However, spreads of deposit rates over the Effective Federal Funds Rate are surprisingly insensitive to the LIBOR-OIS spread during the COVID episode.[23] We find that an increase in LIBOR-OIS of 100 basis points is associated with a mere 10-basis-point increase in overnight corporate deposit spreads, a 5-basis-point increase in bank deposit spreads, and a 1-basis-point increase in NBFI deposit spreads, as illustrated in Appendix Figure E.1.

As expected, bank funding spreads such as spreads of corporate wholesale CDs over OIS closely track LIBOR-OIS during the COVID recession.[24] Moreover, the new Bloomberg credit-sensitive 3-month

[23]We construct these spread by averaging across overnight deposits held by either non-financial corporates, banks or NBFIs as reported in the FR 2420 and subtract the effective fed funds rate.

[24]Figure E.3 provides additional evidence on the cross-sectional variation in CD rates for both non-financial corporates and non-bank financial institutions (NBFIs). We can see that even across the trade distribution, spreads widened for term CDs

bank funding rate index, BSBY, also closely tracks LIBOR. In line with patterns observed during the GFC, the "All-in" FHLB spreads also rose, but peaked at less than 40% of LIBOR-OIS.

Our analysis of funding rate sensitivity together with evidence in Section 5.1 suggests that funding risk for large US BHCs associated with rolling over existing liabilities is limited. Bank deposits—while being the most important source of bank funding—are mostly insensitive to variation in LIBOR. While this is less surprising for retail deposits (Drechsler et al., 2017), it also holds for corporate deposits and for open deposits from financial institutions, which are sensitive to risk-free rates but not to LIBOR-OIS. Wholesale funding is mostly long-term and fixed rate, and thus largely insulates banks from roll-over risk. The banks in our sample have low reliance on credit-sensitive forms of funding such as unsecured wholesale funding. Instead, they tend to make greater use of secured and funding from FHLBs. Importantly, secured funding from FHLBs is more sensitive than deposit rates to LIBOR-OIS but is less sensitive to LIBOR-OIS than unsecured wholesale funding.

5.3 Undrawn Commitments

Going beyond risks associated with funding outstanding assets, banks are also exposed to the risk of being required to fund draws on pre-committed credit lines, especially during stressed market periods when bank funding costs are high. Table 2 shows outstanding utilized credit and commitments for the banks in our main sample. As of 2019, these banks had a total of around $1.58 trillion of funded C&I and CRE loans. The most important types are revolving credit lines and CRE loans, with each representing more than $0.5 trillion of utilized credit. Notably, overall commitments sum to more than $3.5 trillion and are thus twice as high as funded credit. These unfunded commitments represents a substantial risk to bank liquidity. If borrowers draw on their lines in periods of distress, banks may need to pay expensive funding costs in order to obtain the cash demanded by their borrowers. Unless a bank can pass on those costs to borrowers – or unless the borrowers deposit the proceeds of their line drawing at the same bank – these draws can lead to large losses for banks. More importantly for our purposes, the shareholders of the bank can shoulder a disproportionate share of the funding costs, because their banks may be forced to issue substantial amounts of new debt whose credit spreads reduce shareholder profits, whereas the additional assets shore up the position of legacy creditors. This is a form of debt overhang costs to bank shareholders, known as funding value adjustments (FVAs), explained by Andersen, Duffie, and Song (2019), who show that the associated marginal cost to shareholders of funding new assets is

while spreads remained relatively flat for overnight deposits.

approximately equal to the quantity of needed funding multiplied by the blended average credit spread of the associated funding sources. If the funding source turns out to be deposits created by the line draws, the relevant funding credit spread is near zero and the cost to bank shareholders is minimal, which is largely what happened to the average bank during the COVID recession. If, however, banks are forced to obtain funding at more risk-sensitive rates, then shareholders can bear a substantial cost.

Table 2: **Bank Credit by Loan Type for Large U.S BHCs as of December 31, 2019**

Loan Type	Util ($B)	Comm ($B)	% Utilized	No. Banks
All Loans	1579.16	3551.52	44.46	21
Credit Line	543.76	1876.39	28.98	20
Term Loan	310.37	375.26	82.71	20
Other C&I	133.88	540.05	24.79	21
Commercial Real Estate	591.16	759.82	77.80	20

This table displays the distribution of utilized and committed credit across loan products. We source exposures from the FR Y-14Q Schedule H1 B (corporate loans) and Schedule H2 (commercial real estate). Data as of 2019q4. We include only domestic C&I and CRE lending. US subsidiaries of foreign banks are excluded from our analysis. "Other" C&I loans include non-revolving credit lines, capitalized lease obligations, standby letters of credit, other assets, fronting exposures, commitments to commit, and exposures classified as "other".

Not all unfunded commitments are available on demand. For instance, the proceeds of CRE and term loans are typically funded at origination or are otherwise anticipated.[25] However, for revolving credit lines, borrowers can draw and repay funds at their discretion, at least "on paper." As of December 2019, overall credit-line commitments were almost four times the total of drawn amounts. Hence, the banks in our sample alone could theoretically have faced a need to finance $1.3 trillion in a short amount of time, during potentially adverse conditions. In practice, not all commitments can be drawn, because of covenants (Sufi, 2009) or other loan terms that may dis-incentivize draws (Chodorow-Reich et al., 2021). Nonetheless, unlike the case of funding outstanding assets, the extent to which credit line drawdowns need to be funded is largely out of the control of a bank and is a major source of funding risk for large US BHCs.

5.4 Dynamics of Assets and Liabilities During Times of Distress

Given the large outstanding unfunded credit commitments, we next ask: How do bank balance sheets evolve during times of distress when bank funding costs rise? What is the historical extent of credit lines drawdowns?

As descriptive evidence bearing on the evolution of bank balance sheets, Figure 3 shows cumulative

[25] For instance, CRE construction loans are typically not fully funded at origination but disbursements are only released in accordance with verified construction progress.

industry-level changes, in trillions of dollars, of various balance sheet items in the periods surrounding the COVID recession and for GFC.

For the GFC, we rely on publicly available data from the Federal Reserve H8 series, sourced via FRED. These data allow us to distinguish between broad loan types (e.g. C&I, home equity lines) on the asset side and, on the liability side: deposits, interbank funding, and other borrowing (which pools wholesale funding, FHLB funding, and borrowing from the Federal Reserve). For the COVID recession, we use the FR 2052a data, which are more detailed. For instance, the FR 2052 gives us the ability to distinguish within both loans and deposits between counterparty types, allowing us to separate C&I loan growth to large corporates versus small businesses. Figure 3 shows the dynamics of bank balance sheets, split into assets and liabilities. Panels (a) and (b) show the dynamics for large US BHCs reporting monthly in the FR2052a around the COVID recession. Panels (c) and (d) show the dynamics for large domestically chartered banks around the Lehman failure.

Following both shocks, we notice that there is a substantial growth in C&I lending, partly or entirely driven by credit line drawdowns, as shown in Panels (a) and (c) of Figure 3. During the COVID recession, we observe that drawdowns on corporate credit lines increase by close to $300 billion by April, which is an almost 20% increase in total C&I lending (Li et al., 2020; Acharya and Steffen, 2020a). Most of these drawdown were in LIBOR-linked facilities[26] and were driven by the largest firms (Chodorow-Reich et al., 2021). Following Lehman's failure, there was a $50 billion (6%) increase in C&I lending overall, as large corporations drew on their lines in fear of future bank failures (Ivashina and Scharfstein, 2010).[27]

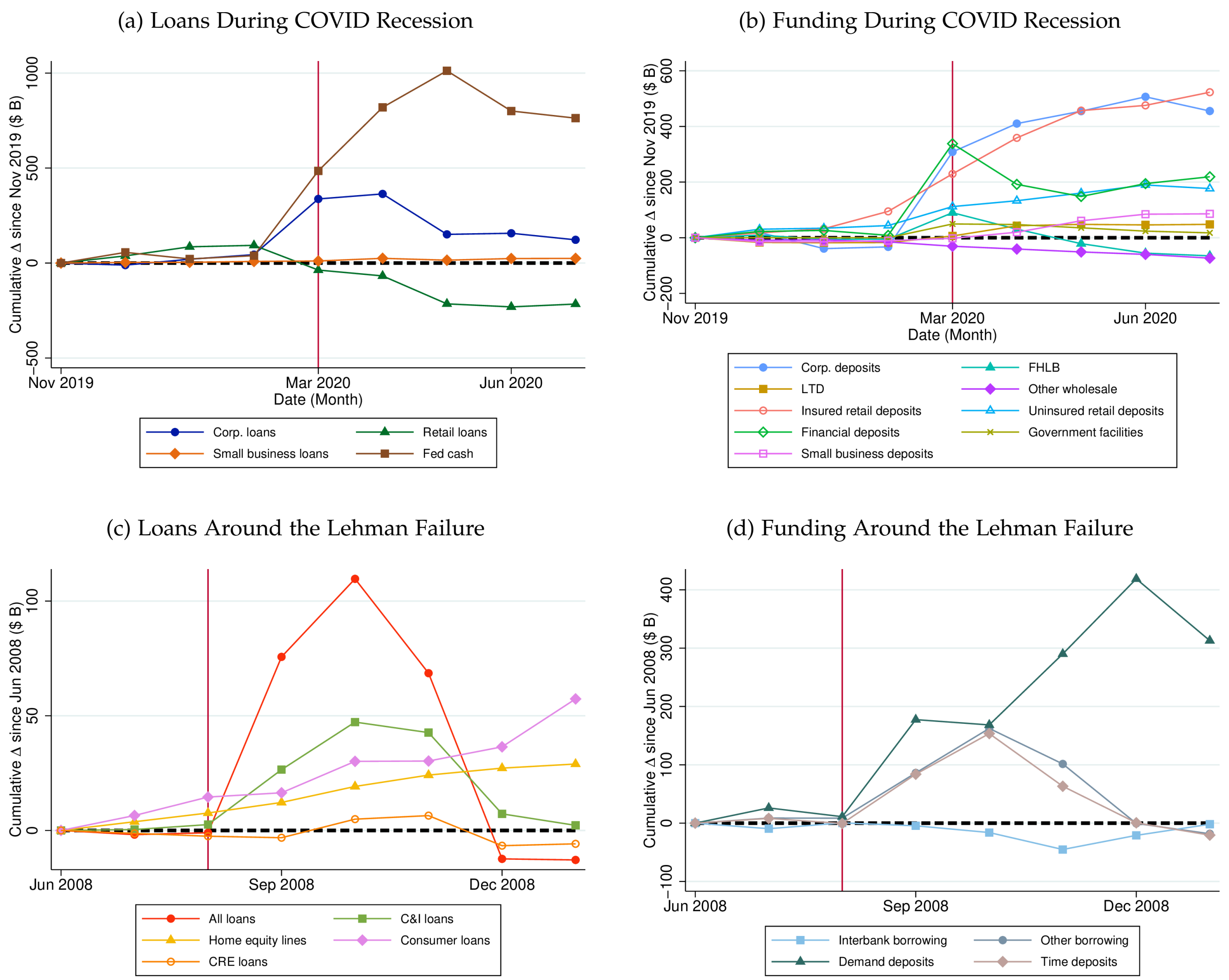
There was limited growth in other loans after the COVID shock. Following the March 2020 pandemic declaration, there was a decrease in aggregate retail lending. Small business only increased in April with the launch of the Paycheck Protection Program (PPP) (see, e.g., Granja et al., 2020). After Lehman's collapse, there were continued draws on home equity lines and consumer loans (and, possibly, credit cards), although both increases generally followed pre-Lehman growth trends.

We next turn to the evolution of bank liabilities, in Panels (b) and (d) of Figure 3. In contrast to corporate lending, which increased in both periods of distress, the evolution of bank liabilities varied more between the COVID pandemic and the Lehman failure. Starting with the COVID pandemic, we notice that the increase in bank liabilities was driven by liabilities that exhibited limited sensitivity bank credit risk (as measured by LIBOR-OIS). Both corporate and financial deposits increased by around $340

[26] See Panel (a) of Figure E.4 in the Appendix.

[27] There was also a sustained increase in C&I lending after the ABCP run in 2007, partly due to draws on corporate credit lines (Berrospide et al., 2012).

Figure 3: **Industry Assets & Liabilities in Periods of Distress.**



This figure shows aggregate asset and liability evolution during the GFC (following Lehman's collapse) and during the COVID pandemic (following the declaration of the global pandemic in March 2020). Values represent cumulative growth/decreases compared to the starting month in billions of dollars. Data from the GFC are sourced from FRED series for large domestically chartered banks, adjusted for large M&A based on public notes to H8 series. Data from COVID are sourced from the FR 2052a monthly balanced panel of 24 banks. Due to balance reclassifications between business segments in the FR 2052a, we exclude one bank from our aggregate series for: small business loans, small business deposits. We include a similar version of these figures, based on log-change vs. the pre-shock values, in Appendix Figure E.5. We also include a version of the COVID graphs for U.S. Branches of FBOs in Appendix Figure E.6.

billion (20%) in March 2020, almost entirely in open maturity deposits (see Appendix Figure E.4). This deposit growth was not costly for banks, as rates on these deposits largely tracked the Federal Funds rate during the COVID recession (recall Figure E.1). We also notice a striking increase in FHLB advances – nearly $100 billion, or 40% – in March 2020. The reliance on FHLB advances in distress aligns with evidence from the GFC (e.g., Ashcraft et al., 2010; Acharya and Mora, 2015), as FHLBs provide cheaper funding than unsecured wholesale markets. Retail deposits also rose significantly in March, by $200 billion, with steady increases in subsequent months. The increase in retail deposits can be explained in part by government stimulus checks and precautionary savings (Cox et al., 2020). Small business deposits also increased starting in April-May, likely related to the disbursement of PPP funds. We also see a *decrease* in more expensive sources of short-term wholesale funding, such as commercial paper (CP), certificates of deposits (CD), and funding from off-balance sheet conduits. The sole increase in expensive funding was in the form of long-term debt issuance, starting in April-May 2020, which may have been a response to reduced yields that came on the back of the Fed's announcement on March 23 that it would purchase corporate bonds.[28]

Following Lehman's failure, we see an increase of around $160 billion (approximately 15%) in "other borrowing"—a broad category of liabilities that includes short-term unsecured wholesale funding, as well as advances from FHLBs. Deposits grew by over $300 billion (about 9%), of which a significant portion (by October 2008, nearly 50%) was in more expensive large time deposits. A crucial difference between the GFC and the COVID recession is that the GFC saw a collapse of interbank borrowing following Lehman's failure (Afonso et al., 2011), requiring some banks to raise additional funds to make up for the lost interbank funding.

While both of these episodes saw significant credit line drawdowns, the composition of aggregate bank funding appears to tilt toward more expensive sources during the GFC than during the COVID recession. During the COVID recession, cheap deposit funding increased and relatively expensive wholesale funding decreased. In contrast, the evidence suggests that the increase of deposit funding during the GFC was in the form of relatively more expensive time deposits, especially at weaker banks (Acharya and Mora, 2015). Further, corporate drawdowns during the GFC were akin to a run on some banks (Ivashina and Scharfstein, 2010), forcing some banks to turn to relatively expensive wholesale funding.

[28]See Federal Reserve announces extensive new measures to support the economy, Board of Governors of the Federal Reserve System, March 23, 2021 as well as Boyarchenko et al. (2020). Further, note that most of these aggregate trends for the COVID pandemic also hold true in the cross-section of banks.

5.5 How Are Credit Line Drawdowns Funded?

We next address how banks finance drawdowns. At the bank level, we can exploit the granularity of FR 2052a data and use cross-sectional variation to tighten our empirical understanding of how drawdowns are funded during the COVID recession. At the borrower level, we use data from FR Y-14Q, Compustat, and Capital IQ to study the relationships between drawdowns and cash holdings during both the COVID recession and the GFC.

Bank-level Evidence We first study the raw data and correlate changes in outstanding utilized C&I exposure from the end of February 2020 through end of April 2020 with changes in corporate deposits, FHLB advances, and unsecured wholesale funding. Figure 4 shows linear fits. Here, for confidentiality reasons, we group BHCs into bins, with several BHCs per bin.

We see a strong correlation between an increase in C&I loans on the one hand and corporate deposits and FHLB advances on the other, with the slope being much higher for the former. Thus, our findings suggest that drawdowns in March and April 2020 were by and large for precautionary purposes, with corporates drawing their credit lines but leaving the drawn amounts in their deposit accounts. Further, to the extent this drawing was not precautionary and the funds drawn were transferred to other banks, banks raised funds from relatively cheaper FHLB advances rather than tapping expensive unsecured wholesale funding.

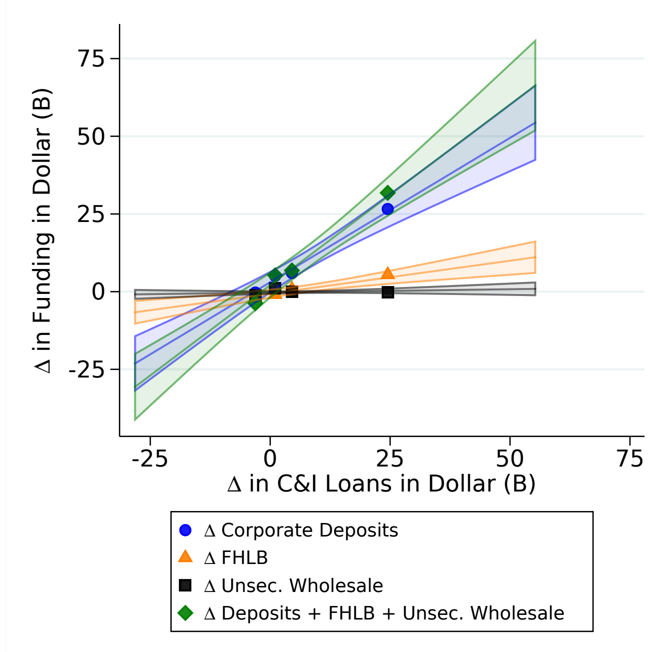
We confirm this in the cross-section by estimating a model of the form:

$$\Delta y_{bt} = \tau_t + \gamma_b + \Delta \text{Drawdowns}_{bt} + \Delta \text{Drawdowns}_{bt} \times \text{COVID} + \epsilon_{bt}, \tag{10}$$

where $\Delta y_{bt} = y_{bt} - y_{bt-1}$ and y_{bt} is the dollar amount of corporate deposits of bank b, FHLB advances, or unsecured wholesale funding in month t. Here, $\Delta\text{Drawdowns}_{bt}$ is the month-to-month dollar change in C&I loans. COVID is a dummy that takes the value one during March and April 2020. Finally, τ_t is a set of time fixed effects and γ_b a set of bank fixed effects.

Results are reported in Table 3. We find that each dollar of corporate drawdowns during the COVID recession is associated with an 89 cent increase in corporate deposits, supporting the notion that drawdowns are precautionary and deposited at the *same* bank, see Panel (a). However, this was mostly driven by the largest U.S. banks. At the large regional banks in Panel (b), only around 40% of

Figure 4: **Drawdowns and Corporate Deposits.**



Binned scatterplot. 4 bins for 24 banks implies a bin size of 6. Cross-Section of Drawdowns, Deposit Inflows, FHLB Funding during March and April 2020. Data Source: FR2052a.

drawdowns were re-deposited. The regional banks instead relied on advances from FHLBs,[29] which funded around 40% of additional draws.[30] Importantly, banks did not require additional unsecured wholesale funding to fund corporate draws irrespective of their business model. In fact, the largest banks saw deposit growth significantly in excess of their drawdowns, see column (5) of Panel (a).[31] This was driven by a growth in deposits by NBFIs, possibly due to Federal Reserve asset purchases and concentration of reserves at larger banks.

Our bank-level analysis may be associated with endogeneity concerns: namely, there can be factors that cause both corporate deposits to increase and lines to be drawn. For instance, a less balance-sheet constrained bank may be more willing to both provide credit and at the same time would attract deposits. Hence, the findings on deposit-line drawing relationships could be confounded, leaving the possibility

[29] The entirety of these advances were sourced from pre-pledged collateral at FHLBs, as we show in Table E.6.

[30] A potential explanation for the fact that regional banks had to raise relatively more funding from FHLBs is that drawdowns on syndicated facilities may not be deposited at the lending bank but rather at the main relationship bank of the borrower. While we do not observe each borrower's relationship bank, there is a significant correlation between bank size and being agent on a syndicated facility (which is possibly correlated with being the main relationship bank). Our results also echo findings by Glancy et al. (2020) that smaller banks saw a smaller portion of drawdowns re-deposited than larger banks; however, we show that even among the largest US banks (>$ 100 billion in assets), there were differences in the level of re-depositing that occurred.

[31] This increase in both total deposits and drawdowns during COVID is also consistent with "flight to safety" during previous stress events (Gatev and Strahan, 2006), excluding the GFC when banks were at the center of the crises (Acharya and Mora, 2015). The simultaneous increase in deposits and drawdowns is also consistent with the theoretical synergies of banks as liquidity providers through both deposits and pre-committed credit lines (Kashyap et al., 2002).

Table 3: **Drawdowns and Deposits in the Cross-Section: Monthly Data**. Data Source: FR2052a.

Dependent variable	Δ Corp. Deposits	Δ FHLB	Δ Unsec. WSF	Δ Total Cols. (1-3)	Δ Total Deposits
Panel A: All Banks					
	(1)	(2)	(3)	(4)	(5)
Δ Drawdowns	0.01	-0.01	-0.00	0.00	-0.03
	(0.01)	(0.03)	(0.01)	(0.03)	(0.03)
Δ Drawdowns × COVID	0.89***	0.16	0.02	1.07***	1.79**
	(0.27)	(0.10)	(0.05)	(0.37)	(0.78)
N	1107	1107	1107	1107	1107
No. Banks	25	25	25	25	25
R^2	0.397	0.177	0.100	0.394	0.424
Panel B: Regional Banks Only					
	(1)	(2)	(3)	(4)	(5)
Δ Drawdowns	0.01*	-0.01	-0.00	-0.01	0.02
	(0.00)	(0.03)	(0.01)	(0.03)	(0.02)
Δ Drawdowns × COVID	0.42**	0.40***	-0.05	0.77***	0.37
	(0.20)	(0.14)	(0.06)	(0.23)	(0.46)
N	522	522	522	522	522
No. Banks	12	12	12	12	12
R^2	0.387	0.320	0.143	0.381	0.454

This table reports results from estimating a bank-month-level panel regression of the following form:

$$\Delta y_{bt} = \alpha + \Delta \text{Drawdowns}_{bt} + \Delta \text{Drawdowns}_{bt} \times \text{COVID} + \gamma_b + \eta_t + \epsilon_{bt}.$$

Robust standard errors in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. We exlcude from our analysis the bank-month in which BB&T merged with SunTrust. We include bank and time fixed effects in all specifications. The dependent variable in column (3), unsecured wholesale funding (WSF), captures short-term wholesale funding categories: CP, CD, non-prime brokerage free credits, and other unsecured wholesale funding. The dependent variable in column (4) is the change in the sum of corporate deposits, FHLB advances, and unsecured wholesale funding.

that increase in corporate deposit is not directly linked to credit line draws. To tighten the empirical relationship of drawdowns and their fundings, we thus also estimate a dynamic difference-in-differences model in Appendix Section C, where we use details regarding each bank's loan portfolio in the Y-14 data to construct a bank-level measure that captures the extent to which a bank has committed lines to firms that are adversely affected by the COVID shock and able to draw their lines (Chodorow-Reich et al., 2021). We find that our results connecting drawdowns and deposit/FHLB funding hold, even after controlling for bank-level exposure to the COVID shock.

Borrower-level Evidence Our evidence thus far indicates a substantial portion of drawdowns were re-deposited with banks during the COVID shock. However, our bank-level data do not include deposit-level information, so we cannot establish a direct link between drawdowns and precautionary deposit increases at the borrower level. To address this concern, we turn to granular borrower-level information from the FR Y-14Q, Compustat, and Capital IQ to examine the extent to which draws were associated with an increase in borrower cash—a proxy for corporate deposit holdings. We conduct this analysis for both COVID and the GFC to see how drawdown motives differed across the two stress events.

We estimate cross-sectional regressions of the following form:

$$\Delta \text{Cash}_i = \alpha + \beta_1 \Delta \text{Drawdowns}_i + X_i + \epsilon_i, \tag{11}$$

where ΔCash_i[32] is the change in the dollar-amount of deposit holdings of borrower i and $\Delta\text{Drawdowns}_i$ is change in the dollar-amount of drawdowns over the same time period.

Results can be found in Table 4. For the COVID recession, we use drawdowns as reported in the FR Y-14Q and cash holdings as either reported in the FR Y-14Q (columns 1-2) or reported in Compustat (columns 3-4). We find that for this period, a one dollar increase in drawdowns is associated with an increase in cash holdings of 86 to 97 cents, roughly in line with our bank-level evidence reported earlier.

In contrast, for the GFC, we find *no* statistically significant relationship between drawdowns and deposits (columns 5-7).[33] This indicates that drawdowns were not re-deposited in the banking system,

[32]For our analyses using Compustat, we use CHQ to measure cash. Importantly, cash does not include money market fund holdings or reverse repo transactions. For our analyses solely using the FR Y-14Q in columns 1 and 2 of Table 4, as the FR Y-14Q does not separate cash from cash equivalents, these analyses pool both cash and cash-like instruments.

[33]This is consistent with evidence from Ivashina and Scharfstein (2010), that drawdowns following Lehman's failure were a bank run on institutions with greater Lehman exposure. It also echos results from Berrospide and Meisenzahl (2021) that drawdowns during the GFC were not precautionary in nature and instead funded capital expenditures.

but instead were consumed elsewhere – either via other investments or for firm expenses, such as investment or compensation. Importantly, since these drawdowns were not precautionary,[34] banks would have been required to fund them via other methods – which may have included costly unsecured wholesale funding.[35]

Table 4: Precautionary Draws: COVID vs. GFC

	COVID				GFC		
	Y-14		Y-14 / Compustat				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ Util.	0.97***	0.97***	0.92***	0.86***	-0.01	0.04	-0.01
	(0.07)	(0.07)	(0.11)	(0.09)	(0.07)	(0.07)	(0.07)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year	No	Yes	No	Yes	No	Yes	Yes
Match Quality			No	No	No	No	Yes
Data	Y-14		Y-14 / Compustat		Compustat/CIQ		
R^2	.275	.275	.314	.303	.0791	.0859	.148
N	7130	7130	1635	1468	1317	1217	811

This table provides cross-sectional evidence on drawdowns and re-depositing during the COVID pandemic (before and after March 11, 2020) and the GFC (before and after Lehman's failure in September 2008). It estimates cross-sectional regressions of the form $\Delta\text{Cash}_i = \alpha + \beta_1 \Delta\text{Drawdowns}._i + X_i + \epsilon_i$ where the dependent variable is change in cash for firm i before and after the shock, $\Delta\text{Drawdowns}_i$ is the change in credit line utilization for firm i, and X_i are firm controls. Firm controls include industry fixed effects (NAICS 2-digit codes) and cash flow controls. For COVID analysis using the Y-14, cash flow controls include EBITDA and Δ Total Debt less drawdowns. For COVID and GFC analyses using Compustat & Capital IQ (CIQ), cash flow controls include cash dividends paid (DVY), operating cash flow (OANCFY), and long-term debt issuance (DLTISY). Columns 1-2 conduct firm level analyses on quarterly data using the FR Y-14Q (aggregated by borrower TIN) using borrowers who reported financials in either 2019q3 or 2019q4 AND also in March 2020. Columns 3-4 conduct firm level analyses on quarterly data during COVID using drawdowns from the Y-14 matched to financials as reported in Compustat. Columns 5-7 conduct firm level analyses on annual data during the GFC using drawdowns from Capital IQ (Δ IQ_RC) and financials from Compustat. In Columns 2, 4, 6, and 7, we restrict to borrowers whose financial statement "as-of" dates correspond to calendar year quarters (i.e. March, not February). In Column 7, we restrict to a sub-sample of firms where we match long-term debt between Compustat (DLTTQ) and CIQ (IQ_TOTAL_DEBT - IQ_ST_DEBT) within 10% on average. We conduct annual analysis during the GFC as credit line drawdowns appear most predominantly reported on an annual basis at this time. The dependent variable in columns 1-2 is the change in cash *and cash equivalents*, as the Y-14 does not segregate cash from equivalents. By contrast, the dependent variable in columns 3-7 are the change in cash *excluding cash equivalents*. In all cases, we trim both Δ cash and Δ draws at 1% and 99% to attenuate the impact of outliers. Robust standard errors in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. For robustness, we also include a version of this table in which we source drawdowns on revolving credit lines from CIQ during the recent COVID recession. See Appendix Table E.7. We also include versions where we examine drawdowns during the GFC in a one-quarter and two-quarter window surrounding Lehman's failure. See Appendix Table E.8.

[34] For drawdowns to be precautionary, it is necessary for deposit holdings to increase in response to credit line drawdowns. As we do not observe an increase in deposit holdings following drawdowns, we can conclude that drawdowns following Lehman's failure were not precautionary. This does not preclude reshuffling of corporate deposits among banks; however, that poses a different funding risk beyond the scope of this paper.

[35] Indeed, using borrower-level data, Ippolito et al. (2016) found that Italian corporates drew *more* from banks subject to higher interbank stress in 2007, subjecting these banks to a "double bank run."

5.6 Credit-sensitive Reference Rates and Bank Funding Risk

Credit sensitive reference rates tie bank loan revenues to bank funding costs, thus potentially mitigating the adverse impact of funding shocks. Using the FR Y-14Q data on C&I and CRE lending commitments, which measure 21% and 5% of banking assets in our sample, respectively, we can measure banks' exposure to LIBOR and other credit sensitive rates.

Table 5 shows that, as of December 31, 2019, around 83% of all C&I and CRE lending was referenced to floating rate indices, with 68% of total credit using LIBOR as the reference rate. Thus, over two-thirds of bank lending to corporates directly links interest income on loans to bank funding costs. Other floating rate facilities either use PRIME or Base (5%) or other types of reference rates (9%). Around 17% of all lending is fixed rate. LIBOR-based floating rate loans thus represent a material portion of the banking sector — over 7% of banking assets and 130% of short-term wholesale funding. LIBOR exposure is material across banks in our sample with an inter-quartile range from 62 to 80% of loans.

Table 5: **Floating Rate Loans at Large US BHCs (as of December 31, 2019)**

(in %)	Industry	Bank Holding Company			No. of
		25th	Median	75th	Banks
% LIBOR	68.49	62.21	75.37	80.75	21
% Prime	5.08	0.61	2.49	4.90	21
% Fixed	17.18	8.18	12.71	15.69	21
% Other	9.25	4.21	7.85	10.49	21
LIBOR Util. / Assets	7.39	1.99	10.81	20.38	21
LIBOR Util. / STWF	129.73	34.13	171.79	287.65	21

This table displays the distribution of floating-rate loan terms across banks that file the FR Y-14Q Schedule H1 B (corporate loans) and FR Y-14Q Schedule H2 (commercial real estate). This includes all domestic C&I loans and domestic loans secured by real estate. We exclude all holding companies that are owned by foreign (non-U.S.) banks. Data are as of December 31, 2019 and reflect utilized loans (and not unfunded commitments). We define short-term wholesale funding (STWF) similarly to Bowman et al. (2020), as the sum of commercial paper, fed funds purchased, and large time deposits with remaining maturities of less than one year, as reported in the FR Y-9C. We add to their definition other borrowed money maturing in one year or less. We break out the reference rate distributions by loan type (e.g. credit lines, term loans, and CRE) in Table E.9.

The use of credit sensitive reference rates can have material benefits for banks in periods of stress. A simple "accouting" counterfactul on bank loan revenues during both the GFC and COVID recessions indicates a potential loan revenue loss of 9% had underlying transactions referenced a risk-free rate, like SOFR, instead of LIBOR, as shown in Appendix Section D. But this calculation only captures the profit transfers from banks to corporate borrowers. In the next section, we show that allowing for the endogenous response of borrower drawdown behavior to a change in reference rates from LIBOR to SOFR, a bank will price into its credit lines an extra wedge of debt overhang costs to its shareholders, which in turn leads to an inefficient reduction in credit provision. This efficiency loss is reduced to the extent that the credit line drawdowns are expected, ex ante, to result in precautionary increases in the borrower's deposits at the same bank.

6 Calibrating the Impact of LIBOR Transition on Credit Supply

Based on an empirical calibration of the simple theoretical model presented in Section 3, we now provide illustrative numerical examples of the impact of LIBOR-SOFR transition on the equilibrium provision of credit lines, as well as some comparative static effects. The comparative statics include the effect of variation in the degree to which banks assume that line draws are left in deposits, depending on the level of market stress as represented by the spread between LIBOR and OIS. A detailed guide to our calibration is found in the appendix. Here, we offer only a brief summary. We allow for heterogenous banks and borrowers.

We let W denote the spread between LIBOR and OIS, and do not require that the external funding spread S of the specific bank is equal to W. For a specific parameterization, we let $S = \theta W$, for some positive θ. For example, with $\theta = 2$, the bank has double the credit spread represented by LIBOR-quality banks. The probability distribution of W is calibrated as log-normal, with the underlying normal mean and variance fitted to empirical distribution of the logarithm of quarterly LIBOR-OIS, as sampled daily for the period January 2005 to April, 2021.

Time is measured in years. We take the risk-free rate r to be zero. The deposited fraction φ of drawn funds is modeled as $\Phi(W)$, where $\Phi(\,\cdot\,)$ is the logistic function

$$\Phi(x) = \frac{D}{1 + e^{-m(x-w_0)}}, \tag{12}$$

with $D = 1$, $m = 0.223$, and $w_0 = 130$ basis points, so that in low-stress states, when LIBOR is closer to the risk-free rate, the borrower deploys most of the drawn funds into its business operations, but in high-stress states, the borrower deposits a higher fraction of the drawn funds, given its precautionary motives. This is intended to capture the COVID experience, when the maximal deposited fraction $\Phi(W)$ reached 90% as LIBOR-OIS reached its local maximum of 140 basis points.

The corporate borrower's cash draw liquidity benefit is modeled by taking $\psi = K(W) + \epsilon$, where ϵ is a non-negative random variable independent of W, and

$$b(q, \psi) = \psi \log(q - \underline{q}) + (1 - \Phi(W))q, \tag{13}$$

where $\underline{q}$ is a subsistence level of funding and $K(\cdot)$ is a function fitted to empirical aggregate line draw behavior for our sample of 20 banks.

Under LIBOR reference rates, governing the history to which we calibrate, the equilibrium amount drawn is

$$Q(L) = \min\left(\underline{q} + \frac{K(W) + \epsilon}{\delta(W + s(L))}, L\right).$$

The bank shareholder marginal benefit for a line of size L given by

$$G(L) = p_1 \delta Q(L)(1 + r + \theta W + s_L - \kappa \theta W - (1 + r)), \tag{14}$$

where $\kappa = (1 - \Phi(W))(1 + C)$. We take the loss given default on the bank's funding to be 50% for simplicity, so that $p_1 = 2\theta W$.

We assume that the bank maximizes the initial market value of its equity and Bertrand-competes against other banks of the same credit quality for providing the customer's credit line. The bank therefore offers the borrower a spread $s(L)$ at which the bank's shareholders break even on marginal new credit lines, meaning that $E[G(L)] = 0$. This pins down the contractual spread over LIBOR given by

$$s(L) = \frac{E[p_1 Q(L)(1 - \delta(1 + r + W - \kappa\theta W))]}{E[\delta p_1 Q(L)]} \tag{15}$$

The borrower picks the optimal optimal choice of L from the breakeven menu $\{(L, s(L)) : L \leq 0\}$.

Assuming a continuum of bank-borrower pairs of the same type, with independence of ϵ across borrowers, the exact law of large numbers implies that the total amount of drawn credit at a given outcome w of LIBOR-OIS is

$$q(w) = E[Q(L)|W = w] = E\left[\min\left(\underline{q} + \frac{K(w) + \epsilon}{\delta(w + s(L))},\right)\right].$$

In order to calibrate the function $K(\cdot)$, we conduct a least-squares fit of observed aggregate monthly drawing behavior for our sample of 20 large banks over the period from July 2017 to April 2021, to

$$\hat{q}(w) = \lambda e^{\eta w}, \tag{16}$$

by choice of the positive constants λ and η. From this, for states in which the drawn amount q^* is below the line size L, we can solve for

$$K(w) = \delta(W + s)(\hat{q}(w) - \underline{q}) = \delta(w + s(L))(\lambda e^{\eta w} - \underline{q}). \quad (17)$$

This functional form for $K(\cdot)$ is assumed to apply at any level w of LIBOR-OIS.

With the resulting calibration to historical aggregate experience for LIBOR-linked credit lines, we can calculate the fitted equilibrium line size L, drawn quantities, and fixed spread $s(L)$ over the reference rate for various illustrative cases, varying both the reference rate and other model inputs parametrically. These results are extremely preliminary and subject to significant updates as we refine our calibration approach.

For our base case, we take $\epsilon = 0$ and $\theta = 1$. With a transition from LIBOR to SOFR reference rates, Figure 5 shows a substantial reduction in the line size L chosen by the borrower from the menu $\{(L, s(L) : L \geq 0\}$ of terms offered by the bank, because the bank charges a spread $s(L)$ for SOFR lines that increases sharply with line size, discouraging the borrower from choosing a large line size. The dependence of $s(L)$ on L is the bank's response to the desire of the borrower to maximally draw when S is high, exploiting the relatively low drawn interest rate, SOFR $+ s(L)$. There is also a low drawn amount q at low outcomes of S, relative to the case of LIBOR-linked credit lines, because the equilibrium SOFR spread $s(L)$ must be high enough for the bank's shareholders to break even, on average across all states, including states in which the borrower draws aggressively and the bank's funding costs are high. For the legacy case of LIBOR reference rates, however, when LIBOR-OIS is extremely low, the drawn interest rate on the credit line is also extremely low, so the borrower takes advantage of the relatively inexpensive credit by drawing somewhat heavily on its line.

Figure 6 illustrates the quantitative importance for credit line provision of the fraction of the drawn credit that is left on deposit, as a function of the degree of market stress represented by LIBOR-OIS. As shown, for the case of LIBOR reference rates, if the bank perceives that the borrower will leave a lower fraction of drawn funds on deposit when the bank's funding spread S is high, the bank will offer more expensive line terms, which both reduces the equilibrium line size L chosen by the borrower and also increases the borrower's spread $s(L)$ over LIBOR.

Figure 7 illustrates how the debt-overhang costs to bank shareholders are determined in each state. The left-hand vertical scale shows the cost $S(1 + C)(1 - \Phi(W))$ to bank shareholders for funding each dollar of drawn credit, for each of two cases, high and low depositing of drawn funds. The right-hand

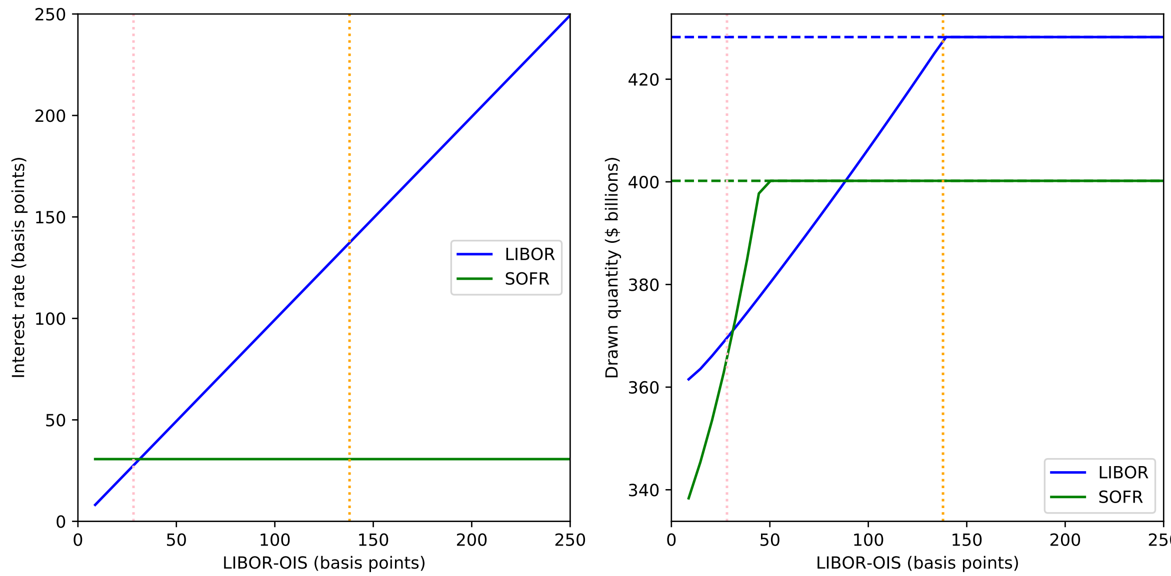


Figure 5: **The effect of the LIBOR-SOFR transition on credit line prices and quantities.** Parameterization: $C = 0.06$; $\psi = S$, $b(q, \psi)$ is as specified by (13) with $\underline{q} = 330$ billion dollars; $r = 0$; $f = 2.5$ basis points; Φ is as specified by (12) with $D = 1$, $m = 0.223$, and $\overline{w}_0 = 130$ basis points; $K(w)$ is as specified by (17), where q^* is measured in millions of dollars and S is measured in basis points, with $\lambda = 355,000$ and $\eta = 0.00134$; and $\log S$ is Gaussian with mean -6.416 and standard deviation 0.892. Vertical gray dotted lines are shown at the sample average of LIBOR-OIS (28 basis points) and at the 140 bps level of LIBOR-OIS reached in the COVID shock of March, 2020.

vertical scale shows the shareholder funding cost after scaling by the quantity of drawn credit and by likelihood of each outcome of LIBOR-OIS. The assumed quantity of drawn credit, at each level of LIBOR-OIS, is the historically fitted quantity $\hat{q}(w)$ of (16). The total shareholder funding cost is the area under this curve. When shifting from the high-deposit case to the low-deposit case, holding the amount of drawn credit fixed, state by state, can see from the figure that most of the incremental shareholder cost associated with the need to obtain external (non-deposit) funding occurs when LIBOR-OIS is between about 125 and 250 basis points.

7 Discussion

Draws on unfunded credit line commitments represent an important funding risk to banks. The largest draws occur in periods of severe market stress such as the COVID recession or the GFC, just when the cost to banks for unsecured wholesale funding rise sharply. Historically, banks have used risk-sensitive reference rates, such as LIBOR, to reduce the cost to bank shareholders associated these line draws. Crucially, even if banks' wholesale funding transactions are breakeven deals between the banks and

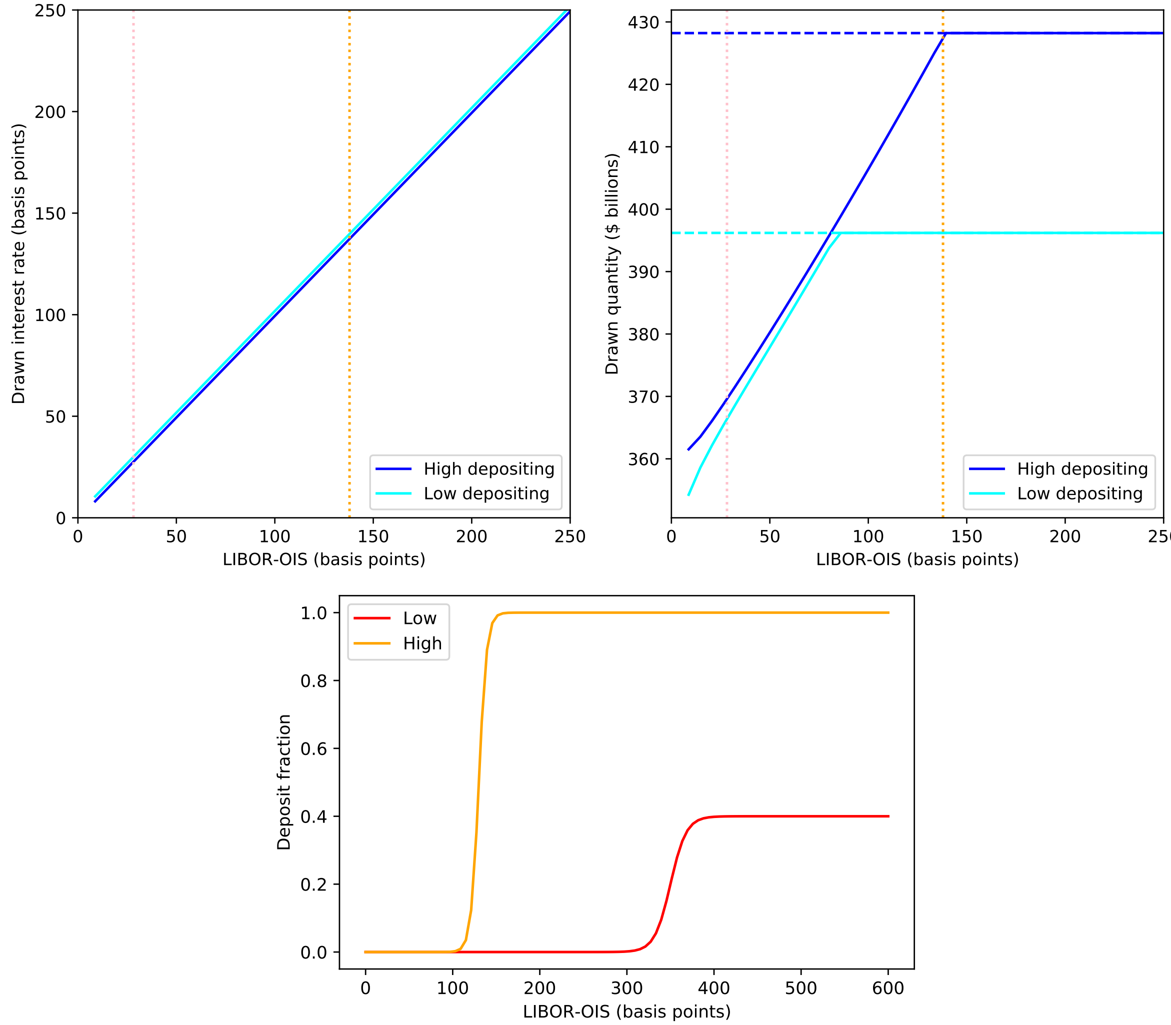


Figure 6: **The effect of shifting the fraction of drawn funds left on deposit.** For the high-deposit case, all parameters are as specified in the caption of Figure 5. For the low-deposit case: $D = 0.4$, $m = 0.11$, and $S_0 = 350$ basis points.

their creditors, bank shareholders do not break even when their funding is invested in corporate loans, unless they extract a rent from their corporate borrowers that compensates bank shareholders for the credit spread paid on the bank's wholesale funding. In market practice, this compensation is called a "funding value adjustment" (Andersen et al., 2019). Our analysis suggests that the transition to risk-free reference rates such as SOFR will increase these costs to bank shareholders by inciting borrowers to draw on their lines even more heavily during periods of market stress, because the cost of drawing on a line referencing a risk-free rate is extremely cheap under stress relative to the cost of drawing on LIBOR-linked lines. When a SOFR-linked line is originally contracted, the higher expected future funding cost to bank shareholders is a frictional wedge that will be priced into the terms of credit facilities, leading to an equilibrium reduction in revolving credit.

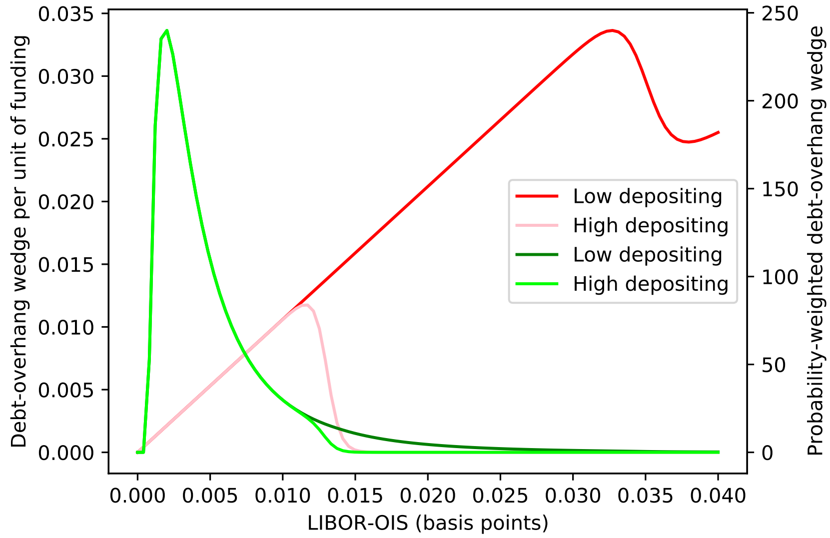


Figure 7: **The debt-overhang cost to bank shareholders for funding drawn credit.** The left-hand vertical axis corresponds to the bank shareholder debt-overhang component $S(1+C)(1-\Phi(W))$ of the funding cost. The right-hand vertical scale corresponds to $S(1+C)(1-\Phi(W))$ scaled by the empirically fitted quantity $\hat{q}(w)$ of drawn credit and also by the likelihood of each outcome of S associated with the fitted normal density. For the high-deposit case, all parameters are as specified in the caption of Figure 5. For the low-deposit case, only the parameters determining $\Phi(W)$ are changed, to $D = 0.4$, $m = 0.11$, and $w_0 = 350$ basis points.

As opposed to prior work giving a rationale to credit-sensitive reference rates, our finding that credit sensitive reference rates improve credit provision is not driven by hedging or risk aversion, and does not apply to term loans, which do not give borrowers the option to increase the loan size when market stress increases. In an upcoming revision, we will show that the reduction in credit provision associated with the transition away from LIBOR is mitigated by the incentive for borrowers to substitute some of their credit lines with term loans, given the increased cost of credit lines and the negligible impact of transition on the pricing of term loans.

Our findings apply to lines offered to both low-risk and high-risk corporate borrowers, although the magnitudes of the impacts on loan pricing could be slightly different. The incremental frictional wedge cost to bank shareholders is the cost of funding the line draws, and so depends on the magnitudes of funding needed by banks and not on the riskiness of the loans funded.

Our paper identifies a new channel of synergy between deposit-taking and credit line provision. Kashyap et al. (2002) emphasize the synergy associated with a bank's ability to draw on a common pool of liquid assets whenever liquidity is needed, whether to meet line draws or for other funding needs. Gatev and Strahan (2006) empirically demonstrate that deposits increase in historical distress episodes.

We show that there is also a synergy between these two business lines, revolvers and deposit taking, via a complementary channel, namely the associated reduction in debt overhang costs to bank shareholders. This synergy is stronger for risk-free reference rates than for credit-sensitive reference rates because, when markets are stressed and bank funding costs rise, borrowers are expected to draw more heavily on lines linked to risk-free reference rates. However, this effect is not uniform across the banking sector. During the COVID pandemic, for example, there was significant bank heterogeneity in the degree to which the proceeds of line draws were left on deposit. Large regional banks saw significantly less of the proceeds of drawn lines left on deposit than did the largest US banks. Based on our results, one may expect LIBOR transition to cause a relative shift in credit line provision toward the largest banks, given their relatively lower stressed-market credit spreads and their relatively higher fraction of drawn line proceeds that are left on deposit.

Finally, our findings should not be interpreted as suggesting that a transition away from LIBOR has negative overall benefits. It is well documented that LIBOR is not a trustworthy benchmark, given the extent of its past manipulation and the paucity of underlying transaction data needed to determine LIBOR, especially under stressed market conditions.[36]

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[36]See Bloomberg (2017); Bailey (2017); Duffie and Stein (2015); Kuo et al. (2018).

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APPENDIX [FOR ONLINE PUBLICATION ONLY]

- Appendix A: Endogenous re-depositing
- Appendix B: Data
- Appendix C: Drawdowns and Deposit Inflows
- Appendix D: Counterfactual Assumptions & Additional Results
- Appendix E: Supplementary Figures Tables

A Incitements to draw early or to run

The following extension addresses the incentives of a borrower to draw on its credit lines even before they are needed, and when drawing to deposit the resulting funds at the same bank. These incentives are influenced by the combined effects of potential future deteriorations in the credit qualities of the bank or the borrower. Ideally, we want to capture the following incentives:

1. There is a relationship benefit or convenience to keeping drawn funds on deposit in the same bank.
2. If the bank's credit quality is at risk of worsening significantly, the borrower has an incentive to maintain liquidity by drawing early and placing the funds in another cash instrument, such as deposits in a different bank. This could be part of a run on the bank.
3. If the borrower's or the bank's credit quality is at risk of worsening significantly, the borrower has an incentive to draw on the line early, before the bank blocks the borrower from doing so by claiming that the borrower has not met the necessary covenants. If the bank's credit quality were to deteriorate significantly, then the bank has an incentive to block the drawing on lines to preserve its liquidity, even if the borrower's quality has not deteriorated, in which case there is an associated relationship cost to the bank.

First, however, we ignore for simplicity the borrower's credit risk, which makes the problem complicated.

Lines are contracted at time 0, giving the option to the borrower to draw on the line at time 1 or at time a at an interest rate equal to a fixed contractual spread s over the reference rate. We analyze cases in which the reference rate is either a credit-sensitive rate like LIBOR or a risk-free rate r like SOFR. Purely for notational simplicity, given the increased model complexity, we assume that the risk-free rate r is always zero. The reference rate is R_1 for loans taken at time 1 and maturing at time a, and R_a for loans taken at time a and maturing at time 2. We ignore risk aversion throughout. For the case of credit-sensitive reference rates, we take R_1 and R_a to be positively correlated with the unsecured borrowing rates of the bank, $r + S_1$ at time 1 and $r + S_a$ at time a.

The borrower will be blocked from drawing at time a if $S_a \geq \hat{S}$, for some threshold $\hat{S}$. Because we are conducting a marginal analysis, we take $\hat{S}$ as given, although it may depend on the borrower type. The spreads S_1 and S_a are affiliated, so the conditional probability at time 1 that the borrower is blocked from drawing at time a is increasing in S_1. The borrower will endogenously choose whether to deposit any funds drawn at time 1. Any drawn funds outstanding at time a are for uses by the borrower at that time, and are not left on deposit. If the borrower does not need cash at time a, any previously drawn funds are repaid.

At time 0, the bank offers the borrower a menu $\{(L, s) : L \geq 0\}$ of credit line terms distinguished by the size L of the line and the associated fixed spread s over the variable loan benchmark rate R. At time

1, information reveals the credit spread S_1 of the bank for unsecured wholesale funding maturing at time a. Likewise, at time a, the credit spread S_a of the bank for loans maturing at time 2 is observed. Information is symmetric throughout.

The borrower will use the drawn funds only at time a, if at all. At time a, the benefit to the borrower of having access to x in cash is $b(x, \psi)$, where ψ is a liquidity-preference variable that is revealed at time 1 and b is a function with the same properties assumed in the basic model. At time 1, given the committed size L of the credit line, the borrower chooses the amounts q_1 to borrow at time 1. At time a, the borrower chooses the the incremental amount q_a to borrow, if not blocked by the bank, so as to maximize the benefit of access to the cash, net of the present value of the loan repayment. We allow q_a to be negative, subject to $q_1 + q_a \geq 0$, with the idea that by time a, the borrower will either use drawn funds or pay back funds drawn at time 1. At time 2, the total assets and total liabilities of the bank are revealed and the bank is either solvent or not. For simplicity, the bank will not default before time a, for example because the bank has no liabilities maturing before time 2. If solvent at time 2, the bank pays back $q_1(1 + S_1)(1 + S_a) + q_a(1 + S_a)$. The corporate borrower repays the outstanding loan amount, $q_1 + q_a$, whether or not the bank is solvent at time 2. The proportional reputational or convenience cost to the borrower of not leaving the drawn funds on deposit at the same bank is ϵ. For simplicity, we assume that the borrower will not default on the credit line and take $R_1 = r + S_1$. We don't take $R_a = r + S_a$, because we want to allow for the risk that the bank will become much worse at time a than "LIBOR quality," which as a result could prevent the borrower from drawing or even make the bank unable to fund the draw request.

State by state, the borrower thus solves

$$V(L) = \sup_{0 \leq q_1 + q_a \leq L,\, W} E\left[b(Q + q_a, \psi) - W q_1 \epsilon - Q(1 + R_1 + s)(1 + R_a + s) - q_a(1 + R_a + s) \,|\, S_1, \psi\right], \tag{18}$$

where q_a is constrained to be non-positive on the event $\{S_a \geq \hat{S}\}$, where

$$Q = q_1(H + (1 - H)W),$$

and where H is the indicator of the event that the bank honors its deposit obligation at time a. We take $P(H \,|\, S_1)$ to be a simple given function, for example linear, assuming that S_1 has a sufficiently bounded range. Or, for another example, we can take $H = 1_{\{S_a < S^*\}}$, where S^* is a threshold above $\hat{S}$. As reflected in (18), if the borrower loses its deposits at time a, then of course it is not obligated to pay back the loan.

The problem can be solved inductively as follows. At time a, for each given amount q_1 of funding obtained at time 1, the optimal incremental borrowing amount q_a is the solution of the associated Kuhn-Tucker conditions, which have an explicit first-order interior condition whenever the solution is interior. We can thus treat q_a as an explicit function of variables observable at time a. We ignore for now cases in which the fraction W of withdrawn cash may interior, and take W to be chosen as zero or 1 for simplicity. Then, given S_1 and ψ, the optimal amount q_1 of funding at time 1 can be solved by a line search for each of two cases, $W = 0$ and $W = 1$. The better of these two cases determines W and q_1, state by state, and from these, q_a.

The marginal increase at time 1 in the equity value of the bank associated with given contractual credit line terms (L, s) is

$$g_{L,s} = E\left(1_A[q_1[(1 + R_1 + s)(1 + R_a + s) - 1] + q_a(R_a + s) - q_1((1 + S_1 W)(1 + S_a) - 1) - q_a S_a]\right). \tag{19}$$

where 1_A is the event of bank solvency at time 2. The first two terms inside the expectation of (19) are the bank's profit markups. The third and fourth terms are debt overhang costs to shareholders. For each line size L, the bank offers a competitive spread s at which the bank's shareholders break even on marginal new credit lines, meaning that $g_{L,s} = 0$. Given the resulting menu of feasible line terms, the borrower solves (18) for the optimal line amount L^*.

B Data

We make use of several confidential and public data sources to reconstruct bank balance sheets, lending terms, funding costs, and exposure to LIBOR.

- We source daily and monthly bank balance sheet information from the **FR 2052a**. This confidential regulatory report collects quantitative information on selected assets, liabilities, funding activities, and contingent liabilities on a consolidated basis and by material entity subsidiary. Banks' outstanding balances are reported at a granular level, including by counterparty type, maturity bucket, product type, and collateral category. U.S. bank holding companies designated as Global Systemically Important Banks (G-SIBs) and foreign banking organizations (FBOs) with U.S. assets greater than $100 billion are required to report.

  For our analysis, we only include line items reported for the consolidated holding company level (i.e. the highest holder). We also exclude all FBO reporting banks, as we do not observe the full asset and liability profile for these institutions (only that of their U.S. operations). Additionally, as the reporting frequency varies by the size and risk profile of the institution,[37] we create two balanced panels of banks for our analysis: the first is a daily panel of the eight largest banks in the U.S, for which we include observations between Dec. 30, 2015 and May 21, 2021. The second is a monthly panel of 24 large U.S. banks, for which we include observations between Sept. 30, 2017 and April 30, 2021. A list of banks in each sample is included in Table B.1.[38]

  We rely primarily on a few select schedules within the FR 2052a. For bank liabilities (and contingent liabilities), we focus on the Deposits-Outflow Schedule, the Wholesale-Outflow Schedule, FHLB Advances and Exceptional Central Bank Operations from the Secured-Outflow Schedule, and unfunded commitments on credit and liquidity facilities from the Outflows-Other Schedule. We exclude other secured funding and contingent liabilities from our analysis.[39] For bank assets, we restrict our attention primarily to bank loan balances—which we source from the Inflows-Unsecured Schedule (Outstanding Draws on Revolving Credit Facilities and Other Loans) and the Inflows-Secured Schedule (Margin Loans and Other Secured Loans)—and central bank reserves—which we source from the Inflows-Assets Schedule (Restricted and Unrestricted Reserve Balances). We reconcile the liabilities we collect from the FR 2052a to total liabilities reported in the FR Y-9C for the same bank and find that we cover most of our sample banks' balance sheets with these schedules; we note only one institution with a > 10% deviation between the two reports in any quarter.[40] Importantly, we do not try to reconcile to loans reported in the FR Y-9C as the FR 2052a requires banks to report the lifetime cash flows from a loan, which includes both its principal and interest payments; this is in contrast to the FR Y-9C, which reports the book (or market) value of bank loans.

[37]The largest institutions, which are those designated by the Federal Reserve as part of the Large Institution Supervision Coordinating Committee (LISCC) portfolio or have >$700 billion in assets, report the FR 2052a on a daily basis with a T+2 day lag, while smaller institutions report monthly with a T+10 day lag.

[38]For some of the analyses that we include in our appendix, we also consider a third balanced panel. This panel consists of the Consolidated U.S. Branches of 14 Foreign Banking Organizations (FBOs): BARC, BNPP, TD, SOGN, DB, UBS, BMO, BBVA, KN, CS, MUFG, SMBC, MFG, RY. These banks are not included in our main analyses, as we do not observe the full asset and liability profile of these institutions (only that of their U.S. operations)

[39]This primarily includes non-balance sheet funding, such as collateral swaps and dollar rolls, as well as certain balance sheet funding, namely repo.

[40]Specifically, we compare total deposits and wholesale funding that we source from the FR 2052a to Total Liabilities less Other Liabilities less Trading Liabilities less Repo in the FR Y-9C to construct a like-for-like comparison. We also compare component balances to the extent possible. For deposits specifically, we note only a single bank-quarter observation with a > 5% deviation between the FR 2052a and the FR Y-9C. The remaining deviations are expected, as values reported in the FR 2052a reflect contractual cash flows while values in the FR Y-9C reflect balance sheet book values (which can be adjusted for various accounting reasons, such as securities recorded at fair value).

- We also make use of the **FR Y-14Q**, a confidential supervisory data set maintained by the Federal Reserve to assess capital adequacy and to support stress testing. The FR Y-14Q data contain detailed quarterly data on: various asset classes, capital components, and categories of pre-provision net revenue; for: U.S. bank holding companies, intermediate holding companies of foreign banking organizations, and savings and loan holding companies with more than $100 billion in total consolidated assets.[41]

  We primarily make use of the FR Y-14Q corporate loan and commercial real estate schedules to analyze loan terms to C&I and CRE borrowers. For this purpose, the FR Y-14Q covers approximately two-thirds of the bank C&I lending market (Chodorow-Reich et al., 2021). It includes key information on loan-terms, including the utilized and committed amount each quarter, interest rate, interest rate index (for floating rate loans), and interest rate floors and ceilings, if they exist. For some of our analyses, we restrict to a sub-sample of Y-14. For our counterfactal analyses, we restrict to domestic C&I and CRE loans so we can compare estimated Y-14 revenues to Y-9C/call report income for the same line item. In most of our analyses, we include loans secured by owner-occupied real estate (which are reported on the Y-14Q C&I schedule) with other loans secured by real estate (loans reported on the Y-14Q CRE schedule) to align with the Y-9C reporting aggregation.

- We also utilize the **FR 2420** data collection to analyze bank funding costs prior to and at the onset of the COVID pandemic. This confidential report is filed daily by U.S. banks with greater than $18 billion in assets, and contains transaction-level information for bank wholesale Certificate of Deposit (CD) and time deposit issuances of greater than $1 million, including interest rate, maturity term, and counterparty type. It also includes transaction-level information for selected deposits of greater than $1 million with maturity between 1 and 7 days. In our analyses of interest rates at the onset of the COVID pandemic, we compute period-specific interest rates as volume-weighted means or medians among banks that reported transactions during that period. For overnight deposit rates, we include all transactions with the relevant counterparty (e.g., Bank, NBFI, or Non-Financial Corporate) that measure 1-day in term. For 3M wholesale deposit rates, we include all transactions with the specified counterparty that measures between 89- and 92-days in term. This includes transactions from banks that are both within and outside our main sample from the FR 2052a and FR Y-14 bank-level results.

- For publicly available interest rates, including LIBOR and SOFR, we source data from **FRED**. We source OIS, BSBY, and term SOFR rates via **Bloomberg**. Interest rates for Federal Home Loan Banks (FHLBs) are not publicly available for all 11 FHLBs. We rely primarly on the publicly available **FHLB Des Moines historical rate file**; however, we compared these rates to other publicly available FHLB rates for the first six months of 2020 (FHLB Boston and FHLB Pittsburgh) and note that these rates follow similar trends during the pandemic, after adjusting for required investment in FHLB activity-based capital and dividends that FHLBs pay on those investments.

  We adjust for FHLB dividends and for the cost of holding FHLB activity-based capital stock in a

[41] The size cutoff is based on: "(i) the average of the firm's total consolidated assets in the four most recent quarters as reported quarterly on the firm's Consolidated Financial Statements for Holding Companies (FR Y-9C); or (ii) if the firm has not filed an FR Y-9C for each of the most recent four quarters, then the average of the firm's total consolidated assets in the most recent consecutive quarters as reported quarterly on the firm's FR Y-9Cs." Prior to 2020Q2, the respondent panel was comprised of any top-tier BHC or IHC with $50 billion or more in total consolidated assets.

way similar to Ashcraft et al. (2010),[42] using the following formula:

$$\begin{aligned}\text{Adjusted Rate}_t = & \; r_t \times (1-h) + (h \times \text{LIBOR}_t) \\ & - (c * (1-h) * d) \\ & + (c * (1-h) * (1 - \text{CET1} * rw) * \text{LIBOR}_t) + (c * (1-h) * \text{CET1} * rw * \text{ROE})\end{aligned}$$

where Adjusted Rate_t is the all-in FHLB rate, r_t is the notional FHLB rate for a given term t, h is the collateral haircut, LIBOR_t is the LIBOR rate for term t, c is the FHLB's activity-based capital requirement, CET1 is a bank's minimum CET1 ratio target, rw is the risk weight banks must apply to FHLB stock, and ROE is the bank's cost of equity (i.e. ROE target). In essence, this formula captures the all-in interest rate for funding a dollar of collateral via the FHLB. We assume that the collateralized portion of the advance is funded at the FHLB notional rate (first term) and that the uncollateralized portion of the FHLB advance is funded via LIBOR (second term). We also account for the bank's requirement to purchase additional FHLB activity-based capital which is partially funded by unsecured funding at LIBOR (fourth term) and partially funded by equity at the bank's ROE target (fifth term). We also reduce the rate by the value of expected dividends that the bank receives from the FHLB for its activity-based capital purchase (third term).

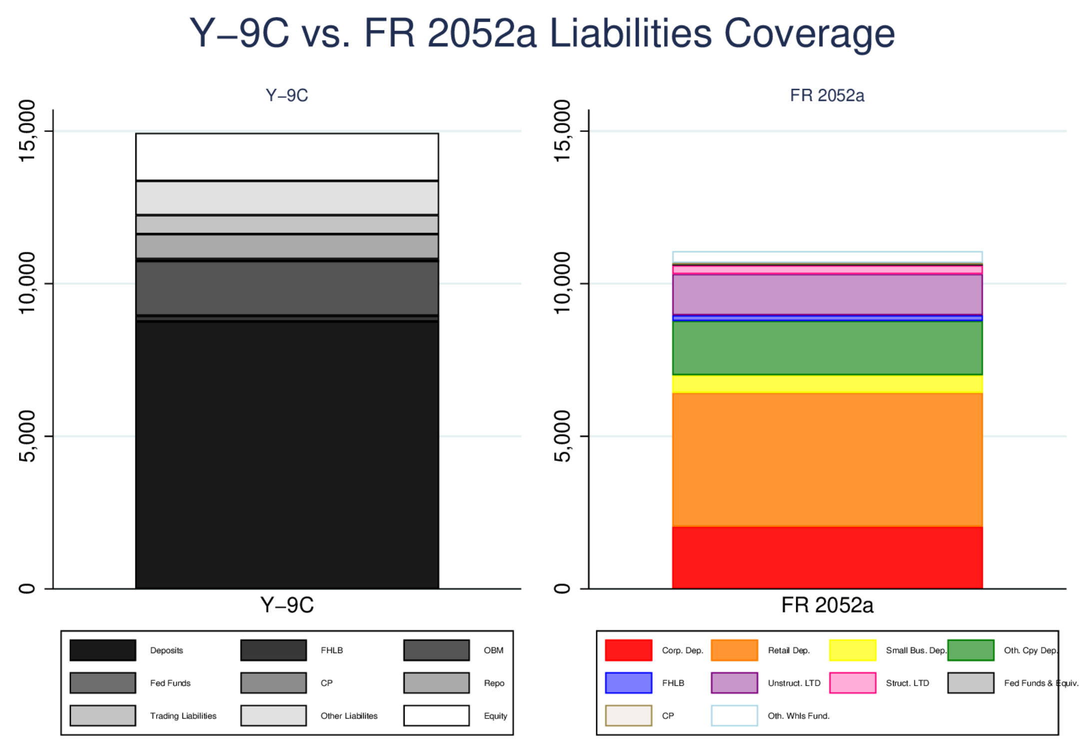
Details on our assumptions vary between the GFC and COVID period, as collateral haircuts, activity-based capital requirements, and dividend expectations have changed since the GFC. To account for these time-varying parameters, we leverage the FHLB Des Moines historical dividend file, which reports quarterly dividends on activity-based capital since 2000. We use the prior quarter's dividend rate in our calculations for the current quarter's "All-in" rate. We also assume a 4.45% activity-based stock purchase requirement until 2013, when SEC filings show the requirement decreased to 4%. For both periods, we assume a static 19% collateral haircut. We also account for the incremental cost of capital to purchase FHLB stock using static adjustment parameters: 15% minimum bank CET1 ratio, 20% FHLB stock risk weight, and 15% ROE target.[43]

- We source additional bank-level information from the **FR Y-9C** and bank **call reports**, which are public and reported quarterly. These reports include information on bank assets, capital ratios, and quarterly interest income and expenses. For certain fields only reported in the call reports, for instance small business loans, FHLB advances, and interest income on C&I loans, we aggregate across all bank subsidiaries to estimate exposure at the holding company-level.
- We leverage aggregate series from **FRED** on bank assets and liabilities during the GFC. We focus primarily on asset and liability series for large domestically chartered banks, and adjust those series for large non-bank mergers based on public notes on the Fed's H8 series.
- We also leverage data from S&P Compustat and Capital IQ to conduct firm-level analysis of drawdowns during COVID and the GFC. We source standard financial statement variables, such as cash (CHQ), cash and equivalents (CHEQ), and operating cash flow (OANCFY), from Compustat. We source credit lines outstanding (IQ_RC) from Capital IQ. As credit lines outstanding are only reported on an annual basis for most firms during the GFC, our main cross-sectional GFC analysis is conducted at an annual frequency.

[42] We build on the this adjustment by also including factors to adjust for the cost of capital for holding FHLB activity-based capital.

[43] For comparison, in December 2019 the median call report bank had a 15% CET1 ratio and 10% ROE.

Figure B.1: **Y-9C vs. FR 2052a Total Liabilities Coverage** Data Source: FR 2052a and FR Y-9C for banks in the FR 2052a monthly panel.



Values in $ B.

Table B.1: **Banks in FR 2052a and FR Y-14 samples**

Bank Name	Bank Type	Assets	% Committed	FR 2052a		Y-14
			C&I / Assets	Monthly	Daily	
JPMORGAN CHASE & CO	Universal	2687.8	0.16	Yes	Yes	Yes
BANK OF AMER CORP	Universal	2434.1	0.25	Yes	Yes	Yes
CITIGROUP	Universal	1951.2	0.19	Yes	Yes	Yes
WELLS FARGO & CO	Universal	1927.6	0.20	Yes	Yes	Yes
GOLDMAN SACHS GROUP THE	IB	993.0	0.14	Yes	Yes	Yes
MORGAN STANLEY	IB	895.4	0.11	Yes	Yes	Yes
U S BC	Regionals	495.4	0.35	Yes	No	Yes
TRUIST FC	Regionals	473.1	0.34	Yes	No	Yes
PNC FNCL SVC GROUP	Regionals	410.4	0.43	Yes	No	Yes
TD GRP US HOLDS LLC	Other	408.6	0.16	No	No	Yes
CAPITAL ONE FC	Cards	390.4	0.14	Yes	No	Yes
BANK OF NY MELLON CORP	Trust	381.5	0.03	Yes	Yes	Yes
CHARLES SCHWAB CORP	Trust	294.0	0.01	Yes	No	Yes
HSBC N AMER HOLDS	Other	249.1	0.37	No	No	Yes
STATE STREET CORP	Trust	245.6	0.02	Yes	Yes	Yes
AMERICAN EXPRESS CO	Cards	198.3	0.26	Yes	No	No
ALLY FNCL	Regionals	180.6	0.32	Yes	No	Yes
BMO FNCL CORP	Other	172.9	0.40	No	No	Yes
MUFG AMERS HOLDS CORP	Other	170.8	0.22	No	No	Yes
FIFTH THIRD BC	Regionals	169.4	0.50	Yes	No	Yes
CITIZENS FNCL GRP	Regionals	166.1	0.42	Yes	No	Yes
SANTANDER HOLDS USA	Other	149.5	0.19	No	No	Yes
KEYCORP	Regionals	145.6	0.49	Yes	No	Yes
RBC US GRP HOLDS LLC	Other	139.7	0.09	No	No	Yes
NORTHERN TR CORP	Trust	136.8	0.13	Yes	No	Yes
REGIONS FC	Regionals	126.6	0.37	Yes	No	Yes
BNP PARIBAS USA	Other	125.3	0.21	No	No	Yes
M&T BK CORP	Regionals	119.9	0.24	Yes	No	Yes
DISCOVER FS	Cards	114.0	0.00	Yes	No	No
DB USA CORP	Other	109.4	0.03	No	No	Yes
HUNTINGTON BSHRS	Regionals	109.0	0.36	Yes	No	Yes
SYNCHRONY FNCL	Cards	104.8	0.01	Yes	No	No
BBVA USA BSHRS	Other	93.6	0.33	No	No	Yes

Note: Table reflects the Bank Holding Companies (BHCs) and Intermediate Holding Companies (IHCs) of foreign banks operating in the U.S. that are present in our final balanced panel samples. As part of our data cleaning process, we drop certain banks from the FR 2052a and FR Y-14 samples even though they file the respective schedules. We exclude IHCs of FBOs from our FR 2052a panels. We also exclude some banks from the Y-14 panel due data checks we apply. Assets and C&I values sourced from the FR Y-9C as of December 31, 2019. Committed C&I is calculated as the sum of C&I loans (BHCK1763 & BHCK1764) and unfunded C&I commitments (BHCKJ457).

One additional bank included in our FR 2052a monthly balanced panel and Y-14 panel but not listed above is Suntrust; in December 2019, Suntrust merged with BB&T to form Truist (which is included). Given that we fully observe both the predecessor and successor entities for this merger, we do not drop Suntrust from our sample prior to the merger occurrence. In regressions, we often exclude the bank-month in which the Truist merger occurred.

C Drawdowns and Deposit Inflows

To tighten the empirical relationship of drawdowns and their fundings, we thus also estimate a dynamic difference-in-differences model. We use the detailed information on each bank's loan portfolio provided in the Y-14 data to construct a bank-level drawdown exposure measure that captures to which extent a bank has committed lines to firms that are adversely affected by the COVID shock and able to draw their lines (Chodorow-Reich et al., 2021).

The exposure measure is constructed as follows:

$$\text{COVID Exposure}_b = \frac{\sum_i^N \mathbb{I}[\text{Firm Size}_i > 1\$ \text{ bil}] \times \text{Industry Exposure}_i \times \text{Committed Credit Lines}_i}{\text{Total Committed Credit Lines}_b},$$

where $\mathbb{I}[\text{Firm Size}_i > 1\$ \text{ bil}]$ is an indicator that is one if firm i is larger than \$1 billion in assets. Industry Exposure_b is constructed as follows: we take the percent change in national employment in firm i's three digit industry between 2019Q2 and 2020Q2 using data from the Bureau of Labor Statistics Current Employment Statistics and use the resulting change as a proxy for the demand shock to a firm (as in Chodorow-Reich et al. (2021)). We then determine the decile of the percent change firm i's industry is and normalize Industry Exposure_b to be between 0 and 1.

Thus, COVID Exposure_b is the share of credit line commitment that bank b has to large firms—those that tend to draw their lines—that are exposed to COVID. Given the unexpected nature of COVID and that the lending decisions were made before the COVID recession, any cross-sectional variation across more or less exposed banks results from bank borrower demand shocks.[44]

We then estimate a model of the following form:

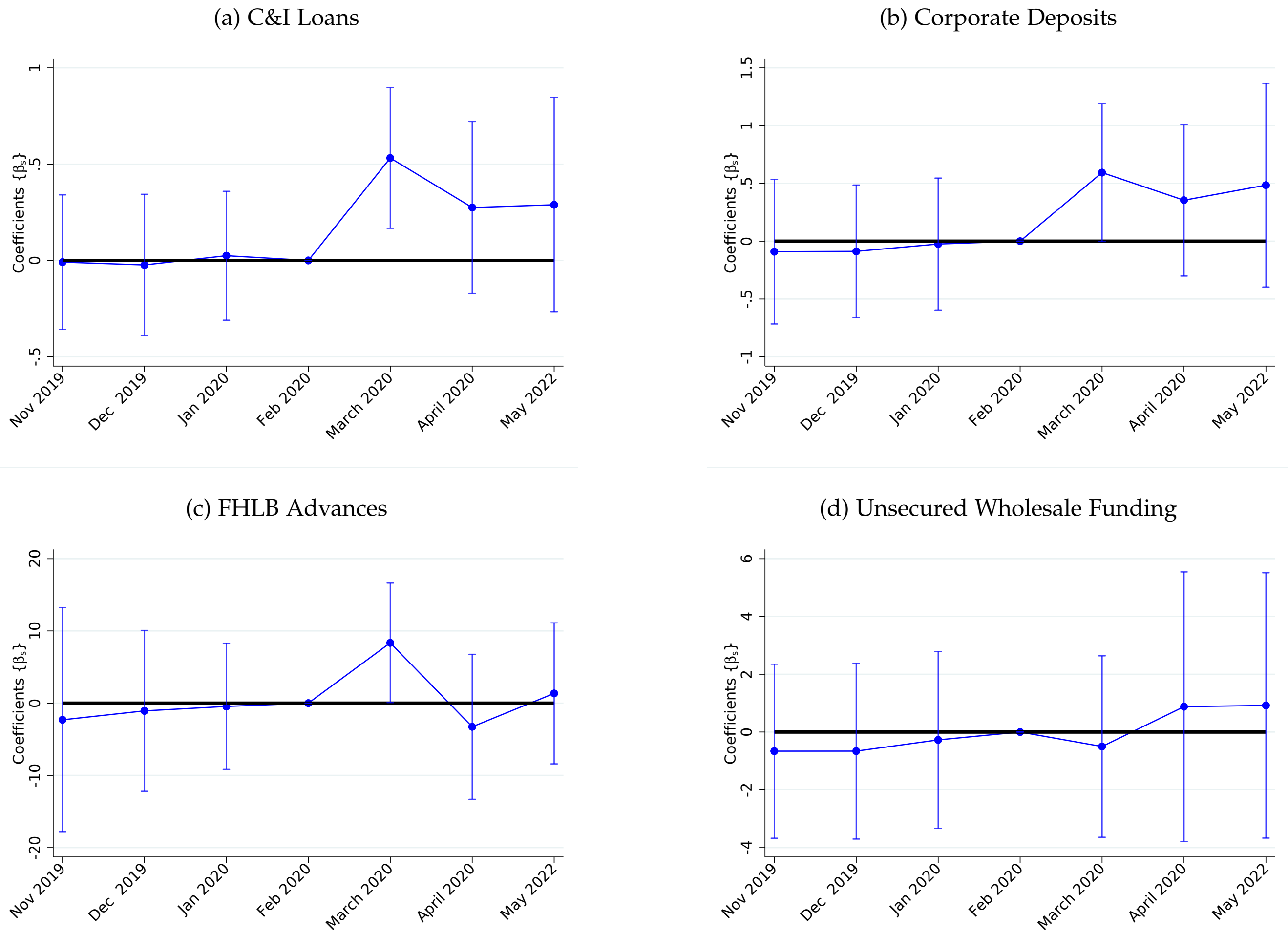
$$\ln y_{bt} = \gamma_b + \gamma_{\theta t} + \sum_{s \neq \text{Feb 2020}} \beta_s \times \mathbb{I}[s = t] \times \text{COVID Exposure}_b + \epsilon_{bt},$$

where $\ln y_{bt}$ is the natural logarithm of either bank b's corporate credit or deposits, FHLB advances, or unsecured wholesale funding. We are interested in the sequence of $\{\beta_s\}$ that allow us to understand how the respective balance sheet items evolved at relatively more exposed banks compared to less exposed banks.

Figure C.1 shows results. The coefficients plotted in Panel (a) shows that banks with more exposed C&I portfolios are subject to larger drawdowns, confirming the findings in Chodorow-Reich et al. (2021). Panel (b) and Panel (c) show that these banks are also bank with a higher increase in corporate deposits and FHLB advances. Note that corporate deposits increase in March together with drawdowns and then return to a lower level—although not exactly to the pre-pandemic level. In contrast, the relative differences in FHLB advances only increase in March and then returns to it pre-pandemic level, indicating that banks use FHLB advances to fund the marginal drawdowns at the onset of the pandemic. Finally, in line with unsecured wholesale funding playing no role in funding the drawdowns, there is no variation in unsecured wholesale funding.

[44] Note that ideally one would like to instrument drawdowns with the exposure measure and and then explain the different funding types in the next step. However, eve though the exposure measure correlated strongly with drawdowns, our sample is too small making the instrument weak.

Figure C.1: **Loans, Deposits, FHLB and Wholesale Funding during COVID by Bank Exposure.** Data Source: FR2052a.



This figure shows the sequence of $\{\beta_s\}$ for the following regression:

$$\ln y_{bt} = \gamma_b + \gamma_{\theta t} + \sum_{s \neq \text{Feb 2020}} \beta_s \times \mathbb{I}[s=t] \times \text{COVID Exposure}_b + \sum_{s \neq \text{Feb 2020}} \mu_s \times \mathbb{I}[s=t] \times X_b + \epsilon_{bt},$$

here y_{bt} is a either the natural logarithm of a bank C&I loans, corporate deposits, FHLB advances, and unsecured wholesale funding.

Data is sourced from our monthly FR 2052a balanced panel between September 2017 and April 2021. COVID exposures are calculated from the FR Y-14Q Schedule H1.

D Accounting Counterfactual Assumptions & Additional Results

We construct an "accounting" counterfactual[45] for bank loan revenues and interest expenses during the COVID recession and the Great Financial Crisis. This allows us to answer the following questions: Keeping all other outcomes fixed, how much income would banks have lost if credit lines had not been linked to LIBOR but instead were linked to a risk-free rate such as SOFR? And, what would bank interest expenses have been if drawdowns had not been pre-cautionary, causing these draws to be financed at prevailing market rates for unsecured wholesale funding?

To construct these counterfactuals, we require a series of assumptions on how bank revenues and expenses evolve over this period. For this analysis, we define the COVID shock to be between January 2020 and June 2020; we define the GFC to be between July 2007 and June 2009.

D.1 COVID Counterfactual

For our COVID counterfactual, we use the FR Y-14 to model bank-level loan revenues and we use the FR 2052a to model bank-level interest expenses. Our bank sample for this counterfactual excludes all IHCs, as well as all banks that do not file the FR Y-14Q Schedule H1.

On the loan side, we leverage the granularity of the FR Y-14Q to recalculate interest income at the loan-level for all C&I loans held by each bank. Specifically, we calculate:

$$\text{LIBOR Revenue}_{i,t} = (\text{LIBOR}_t + \text{Interest Rate Spread}_{i,t}) * \text{Utilized}_{i,t}$$

where LIBOR_t is the value of LIBOR reported at the end of the prior quarter, $\text{Interest Rate Spread}_{i,t})$ is the interest rate spread reported for loan i at time t, and $\text{Utilized}_{i,t}$ is the outstanding utilization of loan i at time t. For loans that report LIBOR as the underlying base rate, we also run a SOFR counterfactual scenario, where we calculate:

$$\text{SOFR Revenue}_{i,t} = (\text{SOFR}_t + \text{Interest Rate Spread}_{i,t} + \text{ISDA Spread Adjustment}) * \text{Utilized}_{i,t}$$

where SOFR_t is the value of term SOFR reported at the end of the prior quarter, and ISDA Spread Adjustment is ISDA- and ARRC-recommended credit spread adjustment for loans.[46] For fixed rate loans and floating rate loans not linked to LIBOR, we do not vary our calculations between scenarios. To estimate interest income from these loans, we calculate

$$\text{Loan Revenue}_{i,t} = \text{Interest Rate}_{i,t} * \text{Utilized}_{i,t}$$

where Interest Rate_t is the interest rate reported on loan i at time t.

For these scenarios, we restrict our attention to domestic C&I and CRE loans only, as it allows us to reconcile our estimated bank-level loan-revenues to the domestic C&I and CRE loan revenues reported in bank call reports.[47] We apply minor data cleaning to reported interest rates and interest rate spreads, which affect less than 0.1% of observations. We also apply additional adjustments, which affect a small portion of loans. We apply loan-level interest rate floors and ceilings if the interest rate falls below or above the respective value reported for the loan. We also assume $0 interest income in all periods when

[45] We refer to this exercise as an "accounting" counterfactual as our calculations do not take into account how agents would have adjusted as a response to changes in the reference rates. We assume that balances are unchanged regardless of the underlying loan reference rate. Our model suggests that we expect draws would comparatively increase for SOFR-linked credit lines vs. LIBOR-linked lines in periods of stress, but would decrease vs. LIBOR-linked loans in periods without stress.

[46] These values are 26.161 basis points for 3M term and 11.448 basis points for 1M term.

[47] These account for between 70% and 80% of domestic C&I and CRE loans at the banks in our sample. We do not fully capture C&I or CRE loan revenues or balances because the Y-14 only contains a subset of these loans. We do not observe small business loans or Paycheck Protection Program loans. Additionally, with respect to income, we do not observe any portfolio or loan-level hedges that would affect interest income.

a loan is flagged as non-accrual. As the Y-14 data are reported quarterly but our analysis is conducted monthly, we assume that loan balances increase or decrease linearly between quarter ends (i.e., we linearly interpolate between quarter-end balances at the loan-level). Additionally, as we do not observe to which term LIBOR a loan is linked, we run two simulations: a 1M and a 3M scenario. We further restrict our recent loan-revenue analysis to start in 2019, since that is when term SOFR rates began publication.

On the liabilities side, we calculate three alternative scenarios based on our monthly panel in the FR 2052a. These scenarios are intended to analyze the incremental cost required to fund large drawdowns in March 2020. In the first scenario, we assume that all bank-level corporate drawdowns were funded entirely by wholesale funding at the relevant term LIBOR. This provides an upper bound for the interest expense required to fund these drawdowns.

In the second scenario, we estimate actual funding costs for corporate drawdowns based on how each bank actually funded them. To do so, we assume a waterfall of funding sources, aligned with our results from Section 5.4 on how drawdowns were funded in the cross-section. We assume that corporate deposits paid the average Fed Funds rate over the month. To the extent that banks took out FHLB advances to fund these draws, we apply the average FHLB Des Moines fixed rate advance rate for that portion of funding. Finally, all remaining funding we assume is funded at term LIBOR. This scenario is intended to illustrate the actual incremental cost of borrower drawdowns between March and June 2020.

In our third scenario, we estimate the funding costs for corporate drawdowns assuming that they were entirely precautionary (meaning they were completely re-deposited at the banks from which they were drawn). Again, we assume those deposits paid the average Fed Funds rate during the month. This scenario provides a lower bound on the incremental interest expense banks would have had to pay.

D.2 GFC Counterfactual

For our GFC counterfactual, we do not have bank-loan level data to calculate counterfactual interest income by replacing LIBOR with SOFR. As a result, we estimate our counterfactual using the FR Y-9C for a subset of our main sample banks that reported the Y-9C in all quarters between July 2007 and June 2009. We also must make assumptions about the balance sheet composition of the banks in our sample. We assume that 70.21% of domestic C&I loans are LIBOR-linked, which represents the % of domestic C&I LIBOR-linked loans as of December 2019 (see Table 5). Given that term SOFR did not exist during the GFC, we proxy for it using the relevant term OIS, as in Jermann (2020). We leverage BHC subsidiary data on interest income on C&I loans to calculate base C&I loan revenues. We estimate the portion of C&I loan revenues linked to LIBOR as:

$$\text{LIBOR Revenue}_t = \%\ \text{LIBOR} \times \text{C\&I Loans}_t \times (\text{3M LIBOR}_{t-1} + \text{C\&I Spread}_t)$$

where 3M LIBOR_{t-1} the end-of quarter 3M LIBOR from the prior quarter and C&I Spread_t represents the difference between industry reported C&I rate and average 3M LIBOR in a given quarter. When calculating SOFR revenues, we estimate:

$$\text{SOFR Revenue}_t = \%\ \text{LIBOR} \times \text{C\&I Loans}_t \times (\text{3M OIS}_{t-1} + \text{ISDA Spread Adj.} + \text{C\&I Spread}_t)$$

where the additional ISDA spread adjustment term is added to account for the impact of the transition.

On the liability side, we apply the same logic as we do for the COVID counterfactual to estimate incremental funding costs under three scenarios: (1) entirely wholesale funding; (2) 85% deposits and 15% FHLB; and (3) entirely deposit funding.

D.3 Results

Table D.1 shows the results of this analysis, assuming all LIBOR-linked loans are 3M tenor and transitioned to a 3M SOFR term. Overall, we estimate that banks would have lost $1.6 billion (or 9%) of interest income on domestic C&I loans in the first two quarters of 2020 if loans had referenced SOFR instead of LIBOR.[48] Further, if we expect that banks fund these additional drawdowns entirely with wholesale unsecured market sources (at LIBOR rates), we estimate that industry interest expenses would have been $430 million above their actual estimated funding costs (or 2.4% of domestic C&I loan income over the period). Again, this is holding constant the amount of drawdowns, rather than accounting for the increased incentive to draw on SOFR-linked lines relative to LIBOR-linked lines during a stressed-market period.

By contrast, in the Financial Crisis we find that banks would have lost significantly more revenue on their C&I loan books. Given the prolonged period of stress, we calculate a decrease in interest income of $6.5 billion (or 9.1%) between July 2007 and June 2009 for the largest banks' C&I loan portfolio. This is less than the headline impact in Jermann (2020) due to differences in the portfolios that we study; our results are generally aligned for the same sub-portfolios.[49] On the liability side, we find that funding these drawdowns at 100% LIBOR throughout the entire period would have increased interest expense by $3.1 billion (or 4.4% of C&I loan revenue), compared to an entirely precautionary-draw scenario. If industry drawdowns were funded by a liability composition similar to the COVID pandemic – 85% deposits and 15% FHLB advances – incremental expenses would have been $5 billion over the period, $2.8 billion lower than if they were entirely funded via wholesale markets.

The results of these counterfactual exercises highlight how LIBOR can mitigate a bank's funding costs in periods of stress. Comparing the incremental revenue from LIBOR versus SOFR loans ($1.6 billion in COVID, $6.5 billion in the GFC) to the "worst" case incremental interest expenses from draws ($0.68 billion in COVID, $7.9 billion in the GFC), we see that incremental LIBOR-based revenues fully or almost fully cover the incremental expenses associated with drawdowns.

[48] The results are consistent but smaller for a 1M term. Additionally, we conduct a similar counterfactual for CRE loans during COVID using the FR Y-14Q. In Table D.2, we estimate that banks would have lost an additional $320 million in domestic CRE loans.

[49] Jermann (2020) found that using term SOFR during the financial crisis would have reduced overall bank loan revenues by about $26 billion. The key difference between our analysis is that we restrict our focus to large bank C&I lending, to: (1) allow for greater comparability between our COVID and GFC samples; and (2) allow for a greater focus on the impact of credit lines. Restricting to the same sub-sample of loans (in Jermann (2020), "syndicated loans" and "corporate business loans"), Jermann (2020) finds a $11.7 billion impact on $930 billion of LIBOR-linked notional, which is comparable to our $6.5 billion impact on $528 billion of LIBOR-linked notional (at peak draws).

Table D.1: **Counterfactual: Estimated Industry Impacts if SOFR replaced LIBOR during GFC and COVID ($B)**

Period	C&I Loans		Interest Income			Interest Expense on Draws		
	Start	Max	LIBOR	SOFR	Diff.	All WSF	COVID Dist.	All Precaution
GFC	498.1	752.4	71.17	64.69	-6.48	7.86	5.09	4.72
COVID	985.2	1234.0	17.60	16.01	-1.59	0.68	0.25	0.19

This table displays results from a counterfactual exercise to understand the impact of the LIBOR-SOFR replacement on banking income and expenses. All values are in $ billion. For this analysis, we define the GFC to be between July 2007 and June 2009 and COVID to be between Jan. 2020 and June 2020. We assume all LIBOR and SOFR revenues and expenses are indexed to a 3M tenor. Given the lack of data availability during the GFC, we proxy for 3M term SOFR during the GFC using 3M OIS. Interest income reflects the estimated total interest income on C&I loans–both term loans and credit lines. We assume floating rate loans reprice quarterly based on the prior month-end index rate. Interest expense for both COVID and GFC reflect the incremental interest expenses required to finance loan drawdowns during the relevant shock period. We assume interest expenses are based on average monthly (COVID) or quarterly (GFC) rates. We restrict to a balanced panel of large banks in both periods.

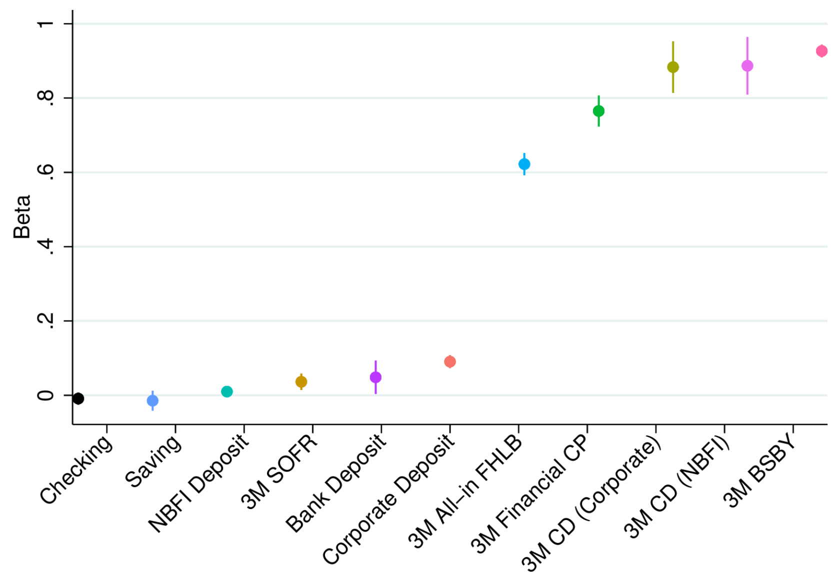
Table D.2: COVID Industry-Level Counterfactual: LIBOR vs. SOFR impact on bank revenues in recent history, across Y-14 banks

Period	Bank	Y-14 Coverage		3M Term			1M Term		
	Loans	% Balances	% Income	LIBOR	SOFR	Diff	LIBOR	SOFR	Diff
Panel A: C&I Loan Portfolio									
Pre-COVID	1129.11	82.79	69.78	38.96	39.09	0.14	38.30	38.66	0.36
COVID	1320.93	81.26	59.12	17.60	16.01	-1.59	16.71	15.56	-1.15
Post-COVID	1118.78	75.40	47.43	22.25	22.54	0.29	21.86	21.98	0.12
Panel B: CRE Loan Portfolio									
Pre-COVID	789.08	72.80	81.90	25.81	25.89	0.07	25.47	25.66	0.19
COVID	809.92	74.10	74.56	11.63	10.86	-0.77	11.22	10.65	-0.58
Post-COVID	806.81	75.01	76.10	20.80	20.94	0.14	20.61	20.67	0.06

This table displays the impact, by time period, to industry loan revenues by switching from a LIBOR-based index to a SOFR-based index. Data are restricted to 2019q1 through 2021q2: Pre-COVID is 2019, COVID is 2020q1 and 2020q2, and Post-COVID is 2020q3 and beyond. Within the Y-14Q, we restrict to domestic C&I loans (Panel A) and domestic CRE loans (Panel B) to ensure comparability with the Y-9C. From left to right, columns represent: (1) Time period; (2) Average quarterly value of outstanding loans; (3) Coverage of loan balances by the FR Y-14Q; (4) Coverage of loan revenues by the FR Y-14Q; (5) Total loan revenues in $ billion, assuming 3M LIBOR index using the Y-14 over the relevant period; (6) Total loan revenues, assuming 3M term SOFR plus ISDA spread adjustment; (7) Difference between LIBOR and SOFR for 3M term; (8) Total loan revenues in $ billion, assuming 1M LIBOR index using the Y-14 over the relevant period; (9) Total loan revenues, assuming 1M term SOFR plus ISDA spread adjustment; (10) Difference between LIBOR and SOFR for 1M term. Of note: Y-14 and Y-9C do not fully reconcile due to unobserved balances and income in the Y-14. Data sources: FR Y-14Q Schedules H1 and H2, FR Y-9C, Bloomberg, FRED.

E Additional Tables & Figures

Figure E.1: **Bank Funding Rates and LIBOR**.



Notes: This table displays the coefficient on 3M LIBOR-OIS in a regression of the form $y_t = \beta \times [\text{LIBOR}_t - \text{OIS}_t] + \epsilon_t$, where y_t is the interest rate or OIS spread on date t. Table E.5 in the Appendix also shows the corresponding detailed regression output. Confidence intervals calculated from robust standard errors. Series represent different maturities and different start dates, which are further detailed in Table E.5. Checking and Saving series represent demand deposit rates. NBFI, Bank and Corporate Deposit are spreads over the effect fed fund srate. 3M SOFR, 3M "All-in" FHLB Advance, 3M CD (corporate), 3M CD (NBFI), and 3M BSBY represent spreads over 3M OIS.

Table E.1: Bank-Level Distribution of Deposits and Wholesale Funding as of Dec. 31, 2019. Data Source: FR2052a.

Metric	25^{th} %tile	Median	Mean	75^{th} %tile
Panel A: Deposits				
% Open	82.2	93.2	85.4	95.9
% 1 Day-1 Year	2.4	5.5	10.0	11.1
% > 1 Year	0.0	1.3	4.6	6.4
% Uninsured	33.5	51.7	50.5	61.3
% Brokered	0.6	2.1	6.0	9.3
% Relationship	49.9	63.8	53.6	72.4
Counterparty Breakdown				
% Corporate	9.9	19.0	17.5	25.4
% Retail	43.3	54.1	56.9	79.5
% Small Business	0.6	4.9	5.5	10.2
% NBFI	1.7	4.1	13.3	12.1
% Other Cpy	1.5	5.7	6.8	11.1
Panel B: Wholesale Funding				
% Very Short Term (Open-30 Days)	6.5	10.8	16.1	20.2
% Short Term (1-6 Months)	8.2	11.8	11.9	16.0
% Medium Term (1-6 Months)	5.3	6.8	8.2	9.5
% Long Term (1+ Year)	58.2	67.3	63.8	75.4
% Collateralized	0.8	17.5	23.6	40.6
% Prime Brokerage	0.0	0.0	1.1	0.1
Product Breakdown				
% Unstructured LT Debt	49.2	60.1	59.4	67.1
% Structured LT Debt	0.0	0.0	4.2	3.4
% FHLB Loans	0.1	5.5	14.0	28.5
% Free Credits	0.0	0.0	6.1	3.3
% Other Product	5.0	11.1	16.3	24.4

Table represents the distribution of deposit and wholesale funding characteristics by bank across 24 banks in monthly FR 2052a panel, as of December 31, 2019. Metrics are aggregated at the bank level, and statistics are calculated across banks. Maturity information reflects remaining maturity as of Dec. 31, 2019, and not maturity at origination. NBFI reflects non-bank financial institutions and includes Supervised Non-Bank Financial Institutions and Other Financial Instiutions (as reported on the FR 2052a). Panel A reflects distributional information for deposits, while Panel B reflects information for wholesale funding.

Table E.2: Regional Bank Funding Breakdown as of Dec. 31, 2019. Data Source: FR2052a.

Counterparty	% Open	% 1 Day-1 Year	% 1 Year+	% Uninsured	% Brokered	% Relation-ship	% Total Deposits	% Total Assets
Retail	82.4	12.7	4.8	21.5	81.5	3.0	54.0	39.3
Non-Financial Corporate	96.5	3.2	0.2	96.2	46.5	0.5	24.6	17.9
Small Business	98.1	1.6	0.3	47.5	93.8	0.0	9.5	6.9
NBFI	85.3	14.7	0.0	98.2	47.8	0.0	5.4	3.9
Public Sector Entity	93.6	5.9	0.5	97.9	37.1	0.5	5.2	3.8
Bank	87.2	12.6	0.2	99.3	26.7	0.6	1.0	0.7
Other Counterparty	98.2	1.8	0.0	98.0	76.2	0.3	0.4	0.3
All Counterparties	88.2	9.0	2.7	51.5	69.4	1.8		

Product	% Open-30 Days	% 1-6 Months	% 6 Months-1-Year	% Long-Term	% Collateral-ized	% Prime Brokerage	% Wholesale Funding	% Total Assets
Unstructured LTD	0.5	7.4	8.8	83.4	0.0	0.0	59.8	6.6
FHLB	36.6	19.6	11.4	32.4	100.0	0.0	28.5	3.1
Conduit and SPV	23.6	12.1	12.8	51.5	100.0	0.0	5.1	0.6
Other Wholesale Funding	95.0	5.0	0.0	0.0	0.0	0.0	5.1	0.6
Wholesale CDs	67.7	32.3	0.0	0.0	0.0	0.0	1.2	0.1
Structured LTD	0.0	0.0	0.0	100.0	0.0	0.0	0.2	0.0
CP	85.2	14.8	0.0	0.0	0.0	0.0	0.1	0.0
Free Credits	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Products	17.7	11.3	9.1	61.9	33.6	0.0		

Table represents the distribution of deposit and wholesale funding characteristics across regional banks in monthly FR 2052a panel. For deposits: Other Counterparty includes Central Banks, Debt Issuing SPEs, GSEs, Multilateral Development Banks, Sovereigns, Other Supranationals, counterparties categorized as “Other" and deposits with missing counterparty type information. Maturity information reflects remaining maturity as of Dec. 31, 2019, and not maturity at origination. Relationship deposits include: (1) transactional and non-transactional relationship accounts for retail and small business customers; (2) operational deposits, for all other counterparty types.

For wholesale funding:Conduit and SPV financing includes asset-backed commercial paper, other asset-backed securities, collateralized CP, covered bonds, and tender option bonds. Other Wholesale Funding includes banks’ draws on committed lines, government supported debt, onshore and offshore borrowing (e.g. Fed Funds), structured notes, and unsecured notes.

Table E.3: FBO Bank Funding Breakdown as of Dec. 31, 2019. Data Source: FR2052a.

Panel A: Deposit Funding by Counterparty

Counterparty	% Open	% 1 Day-30 Days	% 30 Days-1 Year	% 1 Year+	% Uninsured	% Relation-ship	% Total Deposits	% Total Claims
Non-Financial Corporate	44.5	35.0	19.1	1.5	99.9	5.9	44.7	12.8
Bank	19.9	16.2	14.1	49.7	72.7	1.0	29.1	8.3
NBFI	28.9	52.2	17.8	1.1	99.3	5.7	16.3	4.7
Other Counterparty	10.3	40.8	42.2	6.8	100.0	3.0	6.1	1.8
Retail	42.4	52.9	4.7	0.0	100.0	16.5	3.3	0.9
Public Sector Entity	2.7	91.5	0.0	5.8	100.0	0.8	0.3	0.1
Small Business	60.4	30.7	8.6	0.3	99.9	87.6	0.1	0.0
All Counterparties	32.5	33.4	18.3	15.8	91.9	4.7		

Panel B: Wholesale Funding by Type

Product	% Open-30 Days	% 1-6 Months	% 6 Months-1-Year	% Long-Term	% Internal Debt	% Collateral-ized	% Wholesale Funding	% Total Claims
Offshore Borrowing	35.5	10.7	10.6	43.1	98.7	0.0	46.2	35.7
Wholesale CDs	12.1	58.6	27.7	1.7	0.0	0.0	32.8	25.3
Unstructured LTD	1.5	2.8	5.8	89.8	52.2	0.0	9.9	7.7
CP	22.3	68.7	9.0	0.0	0.0	0.0	6.0	4.7
Other Wholesale Funding	81.2	9.7	5.8	3.3	96.2	0.0	2.9	2.2
Onshore Borrowing	51.9	14.3	9.4	24.5	40.8	0.0	1.3	1.0
Free Credits	34.5	65.5	0.0	0.0	0.0	0.0	0.4	0.3
Conduit and SPV	27.4	71.0	0.0	1.6	0.0	100.0	0.4	0.3
All Products	25.1	29.6	15.4	29.8	54.1	0.4		

Table represents the distribution of deposit and wholesale funding characteristics across Consolidated U.S. Branches of Foreign Banking Organizations (FBOs) in a monthly balanced FR 2052a panel of 14 FBOs: BARC, BNPP, TD, SOGN, DB, UBS, BMO, BBVA, KN, CS, MUFG, SMBC, MFG, RY.

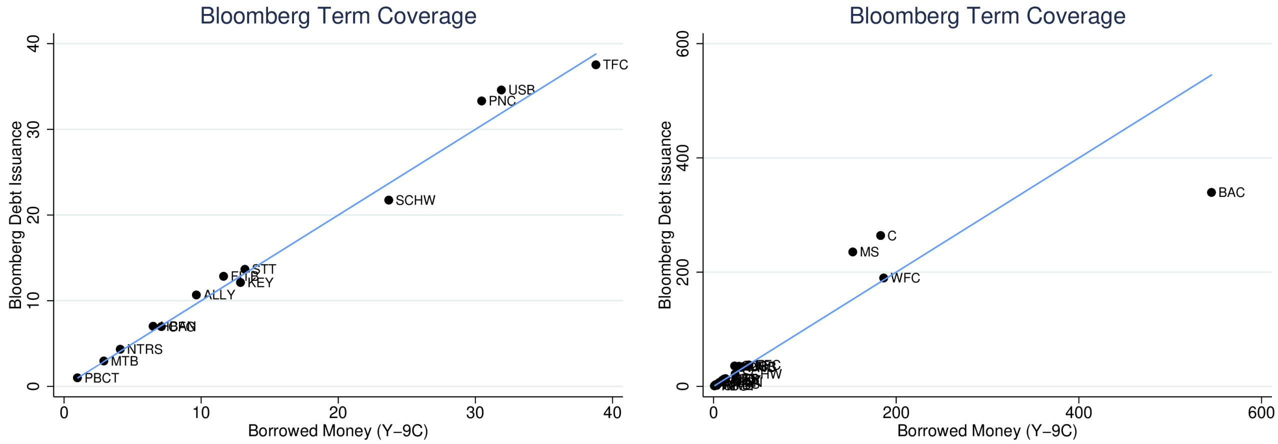
For deposits: Other Counterparty includes Central Banks, Debt Issuing SPEs, GSEs, Multilateral Development Banks, Sovereigns, Other Supranationals, counterparties categorized as "Other" and deposits with missing counterparty type information. Maturity information reflects remaining maturity as of Dec. 31, 2019, and not maturity at origination. Relationship deposits include: (1) transactional and non-transactional relationship accounts for retail and small business customers; (2) operational deposits, for all other counterparty types.

For wholesale funding: Conduit and SPV financing includes asset-backed commercial paper, other asset-backed securities, collateralized CP, covered bonds, and tender option bonds. Other Wholesale Funding includes banks' draws on committed lines, government supported debt, onshore and offshore borrowing (e.g. Fed Funds), structured notes, and unsecured notes.

The final column (far right) reflects each measure as a % of total claims on non-related parties across all U.S. branches of FBOs in our sample. We use this measure instead of assets since FBO branches may have intercompany loans that overstate total third-party assets.

Figure E.2: Bloomberg Coverage of Y-9C Bank Borrowings

(a) "Confident" Banks Only (b) All Banks



Data source: Bloomberg and FR Y-9C. These figures show our coverage of bank borrowings, as defined in the FR Y-9C, from debt issuances sourced from Bloomberg. Panel (a) shows the non-GSIBs for which we can confidently match total borrowings; Panel (b) shows our match for all banks. In addition to the banks in Panel (a), we also "confidently" match other borrowed money for WFC.

Table E.4: Bank-level distribution of Floating Rate Long-Term Debt

in %	Industry	Mean	25^{th} %	Median %	75^{th} %	No. Banks
Fixed	69.93	78.24	69.70	78.56	88.73	14
Floating	29.02	21.51	11.27	21.34	30.30	14
LIBOR	11.36	11.94	8.97	10.82	18.67	14
SOFR	11.34	5.70	0.00	0.00	9.67	14

This table displays statistics from the cross-sectional distribution of banks for which we were able to "confidently" source long-term debt issuance terms via Bloomberg. Data as of June 30, 2021. We define our "confidence" by measuring the bank-level difference between outstanding amounts as reported in Bloomberg and borrowings as reported in the FR Y-9C. Borrowing in the FR Y-9C is defined as other borrowed money plus subordinated debt less advances from FHLBs. "Confidence" is defined as matching Y-9C within 10% or matching non-deposit liabilities within 5%. Floating rate debt includes both current floating rate notes, as well as variable notes (which start paying fixed and convert to floating at a future date).

Table E.5: Interest Rate Correlations with LIBOR-OIS

	Deposit & Risk-Free Rates					
	Checking	Saving	ON Corp	ON NBFI	ON Bank	SOFR
LIBOR-OIS	-0.01	-0.01	0.09***	0.01	0.05***	0.04***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
N	447	447	696	696	693	615
Start Date	14 May 2009	14 May 2009	01 Oct 2018	01 Oct 2018	04 Oct 2018	03 Jan 2019
	Wholesale Rates					
	FHLB	FHLB Adj.	Fin. CP	Corp.	NBFI	BSBY
LIBOR-OIS	0.51***	0.62***	0.77***	0.88***	0.89***	0.93***
	(0.01)	(0.01)	(0.01)	(0.04)	(0.02)	(0.01)
N	4875	4875	4639	1340	1385	1351
Start Date	04 Dec 2001	04 Dec 2001	04 Dec 2001	15 Jan 2016	11 Jan 2016	06 Jan 2016

This table displays the coefficient on LIBOR-OIS in regressions of the form

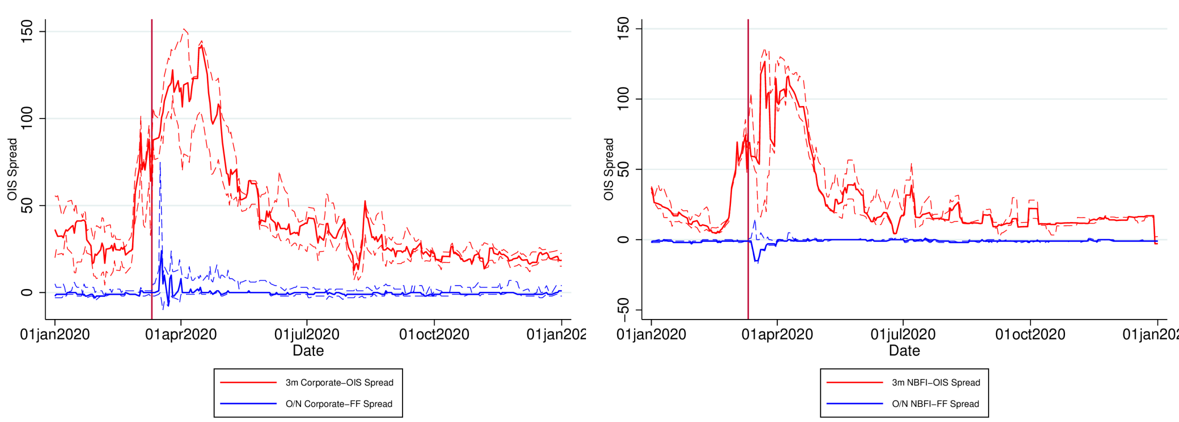
$$Y_t = \alpha + \beta \times \text{LIBOR-OIS}_t + \epsilon_t$$

where Y_t is the interest rate or OIS spread on date t. The rates displayed in this table are: Interest and Savings Rate, sourced from FDIC calculations using RateWatch Data; overnight corporate, non-bank financial, and bank deposit spread vs. Effective Fed Funds, where O/N rates are calculated by counterparty type from FR 2420 data; 3M term SOFR and 3M BSBY spreads to 3M OIS, sourced from Bloomberg; 3M Financial CP-OIS spread, sourced from FRED; the 3M FHLB Des Moines rate on fixed rate advances spread to 3M OIS; and the average 3M Non-Financial Corporate CD and Non-Bank Financial CD rates, calculated from the FR 2420, spread to 3M OIS. Regression coefficients can be interpreted as the average relationship between LIBOR-OIS and the corresponding rate or spread. Note: The relatively low observation count for savings and checking deposit rates are due to the weekly nature of the data series, comapred to other series which are reported daily.

Figure E.3: **3-Month Wholesale CD and O/N Deposit Rate Distribution During COVID**.

(a) Corporate Deposits

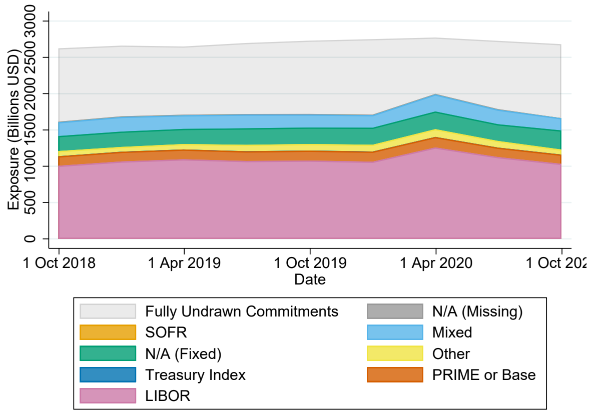
(b) NBFI Deposits



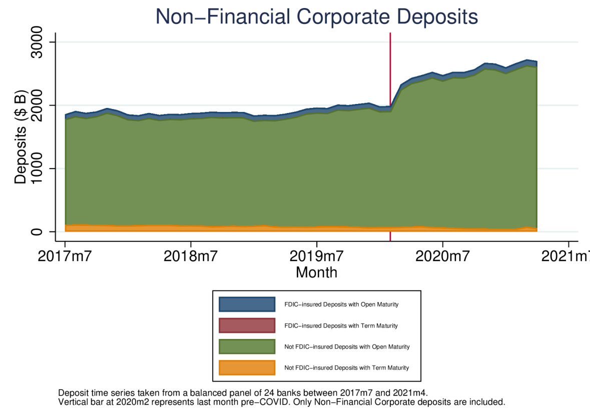
Notes: Data is sourced from FR 2420 daily trade-level reporting. Interest rates are set to missing on days we observe fewer than 10 trades. 3-Month Wholesale CD statistics are calculated by date and dollar-weighted; we include trades with original maturity between 89 and 92 days. 5-day rolling averages are then calculated after daily aggregation. Overnight deposit rates are calculated using 1-day maturities. Dotted lines represent smoothed 25^{th}% and 75^{th}% of trade distributions, respectively. In Panel (a), we restrict to non-financial corporate counterparties. in Panel (b), we restrict to non-bank finanical counterparties.

Figure E.4: **Corporate Loans & Deposits.** Data Source: FR Y-14Q, FR2052a.

(a) Aggregate C&I Loans by Reference Rate



(b) Non-Financial Corporate Deposit Funding in $



These figures display corporate loans and deposits over time. Panel (a) displays C&I loans by underlying reference rate, using the FR Y-14Q Schedule H1. Panel (b) displays corporate deposits by insurance-type and maturity (open or term), using data from our monthly balanced FR 2052a panel.

Table E.6: FHLB Drawdowns as a function of pre-positioned FHLB capacity

	Δ FHLB Capacity		Δ FHLB Capacity / Lagged Assets	
	(1)	(2)	(3)	(4)
Δ FHLB Funding	-0.65***	-0.66***		
	(0.09)	(0.09)		
Δ FHLB Funding × COVID	-0.34***	-0.33***		
	(0.09)	(0.10)		
Δ FHLB Funding / Lag Assets			-0.61***	-0.58***
			(0.15)	(0.14)
Δ FHLB Funding / Lag Assets × COVID			-0.38*	-0.42*
			(0.20)	(0.20)
No. Banks	22	22	22	22
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes
N	973	973	971	971
R^2	0.267	0.299	0.287	0.324

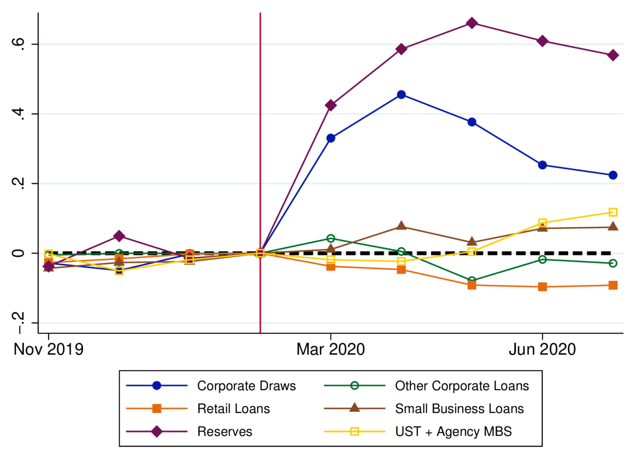
Note: Table reflects regressions of Federal Home Loan Bank (FHLB) capacity (by bank) on FHLB drawdowns. Regressions of the form:

$$\Delta y_{i,t} = \alpha + \beta_1 \mathbb{I}\{\text{COVID}\} + \beta_2 \Delta x_{i,t} + \beta_3 \Delta x_{i,t} \times \mathbb{I}\{\text{COVID}\} + \tau_t + b_i + \epsilon_{i,t}$$

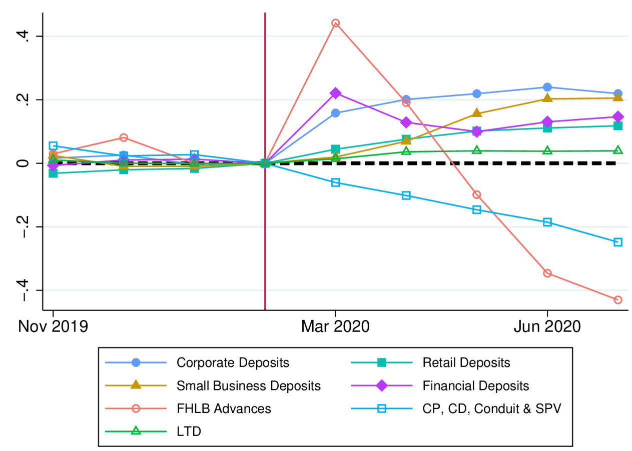
where $\Delta y_{i,t}$ is the change in FHLB capacity (in dollars or over assets), $\Delta x_{i,t}$ is the change in FHLB advances (in dollars or over assets), τ_t reflect time fixed-effects that could affect FHLB capacity, and b_i are bank fixed-effects. FHLB capacity is based on the lendable value of collateral that banks have pre-positioned with the FHLBs. Bank sample restricted to monthly panel of banks in FR 2052a that have ever received FHLB funding. In this table, we define COVID to be March 2020, which is when FHLB draws primarily occurred. Robust standard errors are clustered at the bank level in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Figure E.5: **Industry Assets & Liabilities in Periods of Distress.**

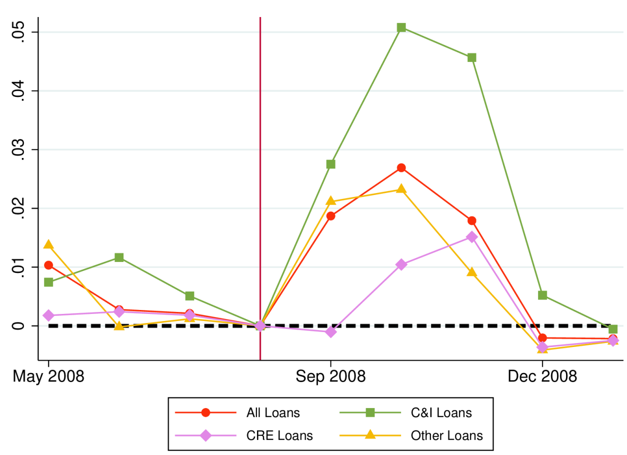
(a) Loans During COVID Recession



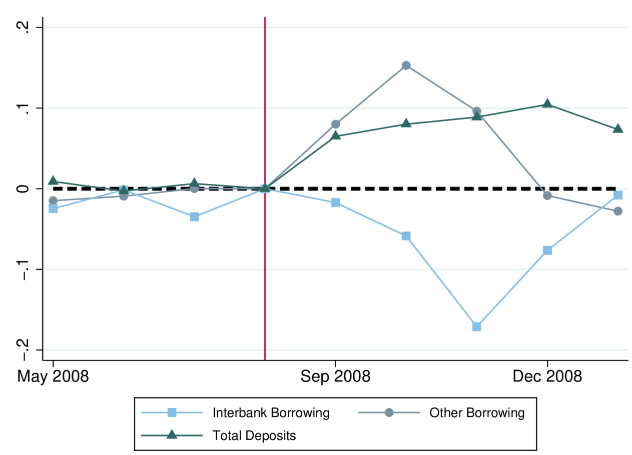
(b) Funding During COVID Recession



(c) Loans Around the Lehman Failure

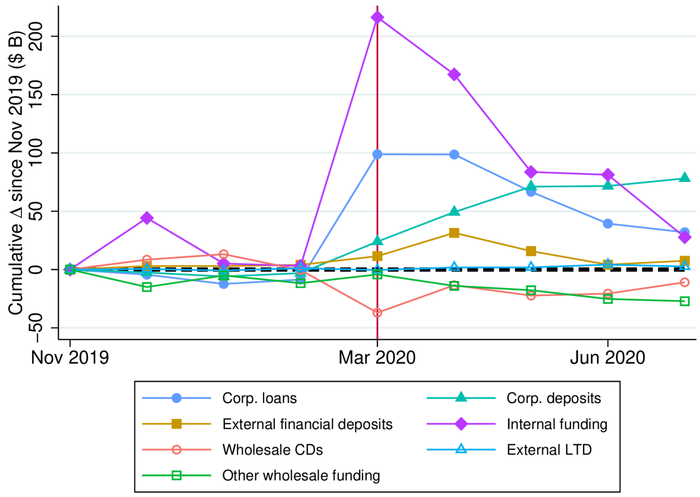


(d) Funding Around the Lehman Failure



This figure shows aggregate asset and liability evolution during the GFC (following Lehman's collapse) and during the COVID pandemic (following the declaration of the global pandemic in March 2020). Values are normalized to 0 in the month prior to the shock, and represent the log difference compared to the base month. Data from the GFC are sourced from FRED series for large domestically chartered banks, adjusted for large M&A based on public notes to H8 series. Data from COVID are sourced from the FR 2052a monthly balanced panel of 24 banks. Due to balance reclassifications between business segments in the FR 2052a, we exclude some banks (in all cases, fewer than three) from our aggregate series for: small business loans, small business deposits, corporate draws, other corporate loans.

Figure E.6: **Corporate Drawdowns & Funding Sources: U.S. Operations of Foreign Banking Organizations (FBOs).** Data Source: FR 2052a.



This figure shows aggregate asset and liability evolution during the COVID pandemic for the Consolidated U.S. Branches of a balanced panel of 14 FBOs: BARC, BNPP, TD, SOGN, DB, UBS, BMO, BBVA, KN, CS, MUFG, SMBC, MFG, RY. Values represent cumulative growth/decreases compared to the starting month in $ billion.

Figure E.7: **Deposits and Wholesale Funding During COVID** Data is sourced from our monthly FR 2052a balanced panel between September 2017 and April 2021. Data Source: FR2052a.

(a) Deposits by Counterparty in $

(b) Wholesale Funding by Type in $

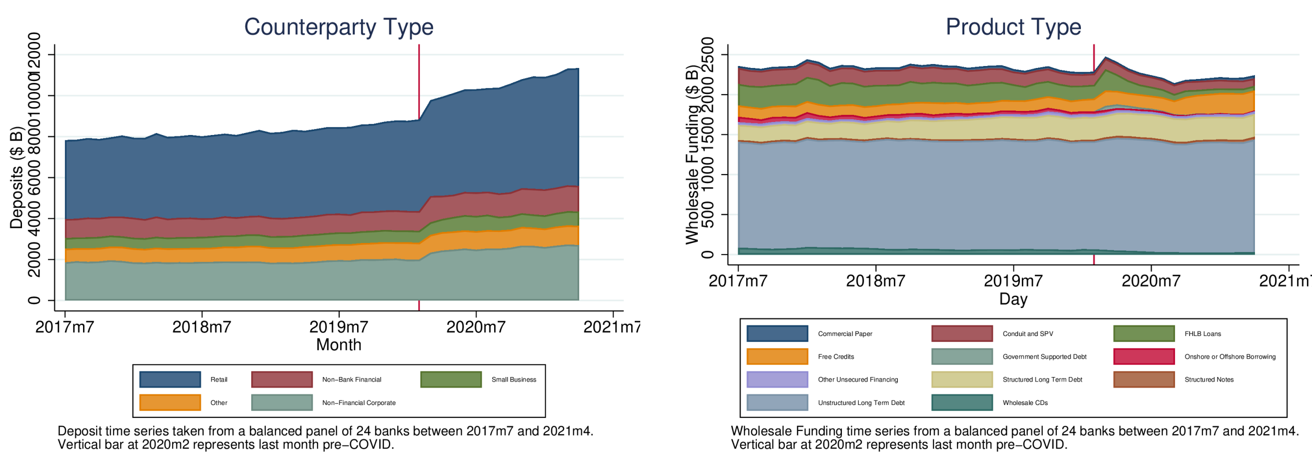


Table E.7: Precautionary Draws: COVID vs. GFC

	COVID					GFC		
	Y-14		CIQ / Compustat					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Util.	0.97***	0.97***	0.58***	0.53***	0.45***	-0.01	0.04	-0.01
	(0.07)	(0.07)	(0.06)	(0.05)	(0.06)	(0.07)	(0.07)	(0.07)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year	No	Yes	No	Yes	Yes	No	Yes	Yes
Match Quality			No	No	Yes	No	No	Yes
R^2	.275	.275	.281	.29	.379	.0791	.0859	.148
N	7130	7130	1683	1536	1020	1317	1217	811

This table provides cross-sectional evidence on drawdowns and re-depositing during the COVID pandemic (before and after March 11, 2020) and the GFC (before and after Lehman's failure in September 2008). It estimates cross-sectional regressions of the form $\Delta \text{Cash}_i = \alpha + \beta_1 \Delta \text{Drawdowns}._i + X_i + \epsilon_i$ where the dependent variable is change in cash for firm i before and after the shock, $\Delta \text{Drawdowns}_i$ is the change in credit line utilization for firm i, and X_i are firm controls. Firm controls include industry fixed effects (NAICS 2-digit codes) and cash flow controls. For COVID analysis using the Y-14, cash flow controls include EBITDA and Δ Total Debt less drawdowns. For COVID and GFC analyses using Compustat & Capital IQ (CIQ), cash flow controls include cash dividends paid (DVY), operating cash flow (OANCFY), and long-term debt issuance (DLTISY). Columns 1-2 conduct firm level analyses on quarterly data using the FR Y-14Q (aggregated by borrower TIN) using borrowers who reported financials in either 2019q3 or 2019q4 AND also in March 2020. Columns 3-5 conduct firm level analyses on quarterly data during COVID using drawdowns from Capital IQ (Δ IQ_RC) matched to financials as reported in Compustat. Columns 6-8 conduct firm level analyses on annual data during the GFC using drawdowns from Capital IQ and financials from Compustat. In Columns 2, 4, 5, 7, and 8, we restrict to borrowers whose financial statement "as-of" dates correspond to calendar year quarters (i.e. March, not February). In Columns 5 and 8, we restrict to a sub-sample of firms where we match long-term debt between Compustat (DLTTQ) and CIQ (IQ_TOTAL_DEBT - IQ_ST_DEBT) within 10% on average. We conduct annual analysis during the GFC as credit line drawdowns appear most predominantly reported on an annual basis at this time. The dependent variable in columns 1-2 is the change in cash *and cash equivalents*, as the Y-14 does not segregate cash from equivalents. By contrast, the dependent variable in columns 3-8 are the change in cash *excluding cash equivalents*. In all cases, we trim both Δ cash and Δ draws at 1% and 99% to attenuate the impact of outliers. Robust standard errors in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table E.8: Precautionary Draws: GFC Robustness

	2Q Δ Cash			1Q Δ Cash		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Util.	-0.00	-0.00	0.02	0.10	-0.07	-0.10
	(0.08)	(0.08)	(0.11)	(0.14)	(0.15)	(0.19)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Fiscal Year	No	Yes	Yes	No	Yes	Yes
Match Quality	No	No	Yes	No	No	Yes
R^2	.0985	.0985	.167	.225	.228	.329
N	283	283	177	267	206	128

This table provides cross-sectional evidence on drawdowns and re-depositing during the GFC (before and after Lehman's failure in September 2008). It estimates cross-sectional regressions of the form $\Delta \text{Cash}_i = \alpha + \beta_1 \Delta \text{Util.}_i + \gamma_i + \epsilon_i$ where the dependent variable is change in cash for firm *i* before and after the shock, $\Delta\text{Util.}_i$ is the change in credit line utilization for firm *i*, and γ_i are firm controls. Credit line data is sourced from Capital IQ (CIQ) and firm financials are sourced from Compustat. Firm controls include industry fixed effects (NAICS 2-digit), cash dividends paid (DVY), operating cash flow (OANCFY), long-term debt issuance (DLTISY), and the change in non-cash equivalents, such as monetization of U.S. Treasuries (Δ (CHEQ - CHQ)). The dependent variable is the change in cash (CHQ), which notably *excludes cash equivalents* and thus serves as a strong proxy for deposits. Firm-level analyses analyze the change between the pre-Lehman credit draws and either two (Columns 1-3) or one (Columns 4-6) subsequent quarters. In Columns 2-3 and 5-6, we require fiscal quarters be aligned to calendar quarters (i.e. we exclude companies with quarter-end in October 2008, rather than September 2008). In Columns 3 and 6, we further restrict our sample to a set of firms where long-term debt matches between CIQ and Compustat within 10% on average. For all these analyses, we restrict to the subset of firms who drew on credit lines. Further, since most borrowers that reported credit lines in Capital IQ (CIQ) during the GFC appeared to do so on an annual basis, we restrict further to borrowers who report outstanding credit lines on a quarterly basis. In all cases, we trim both Δ cash and Δ draws at 1% and 99% to attenuate the impact of outliers.

Table E.9: **Floating Rate Loans at Large US BHCs (as of December 31, 2019)**

(in %)	Industry	Bank Holding Company			No. of
		25th	Median	75th	Banks
Panel A: Credit Lines					
% LIBOR	70.51	53.75	74.95	84.79	20
% Prime	6.92	2.51	5.07	9.22	20
% Fixed	6.22	0.52	2.52	6.75	20
% Other	16.36	9.36	13.82	32.14	20
Panel B: Term Loans					
% LIBOR	72.80	51.73	84.01	89.88	20
% Prime	4.15	0.10	0.83	1.64	20
% Fixed	14.99	4.74	12.65	17.84	20
% Other	8.05	0.58	1.60	5.57	20
Panel C: Commercial Real Estate					
% LIBOR	65.61	54.82	75.06	83.27	20
% Prime	3.58	0.08	0.98	2.78	20
% Fixed	28.38	9.89	18.80	29.77	20
% Other	2.43	0.45	1.32	2.69	20

This table displays the distribution of floating rate loan terms across banks that file the FR Y-14Q Schedule H1 B (corporate loans) and FR Y-14Q Schedule H2 (commercial real estate). In Panels A and B, we restrict to domestic C&I loans only. In Panel C, we restrict to domestic loans secured by real estate. We also exclude all holding companies that are owned by foreign (non-U.S.) banks. Data is as of December 31, 2019 and reflects utilized loans (and not unfunded commitments). We define short-term wholesale funding (STWF) similarly to Bowman et al. (2020), as the sum of commercial paper, fed funds purchased, and large time deposits with remaining maturity less than one year, as reported in the FR Y-9C. We add to their definition other borrowed money maturing in one year or less.

F More details on calibration

This appendix section provides additional details on the calibration of the theoretical model.

Figure F.1 shows the modeled impact of shifting the bank's minimum equity capital from the base case of $C = 6\%$ of assets to an elevated capital requirement of 12% of assets.[50] This shift increases the debt overhang costs to the bank for offering credit lines, and thus reduces the equilibrium provision of credit lines. In equilibrium, the borrower chooses from the menu $\{L, s(L) : L \geq 0\}$ a line size that is sensitive to the capital requirement, but a spread $s(L)$ that is relatively insensitive. The impact of shifting C on the drawn amount of credit, as a function of LIBOR-OIS, is somewhat different for SOFR.

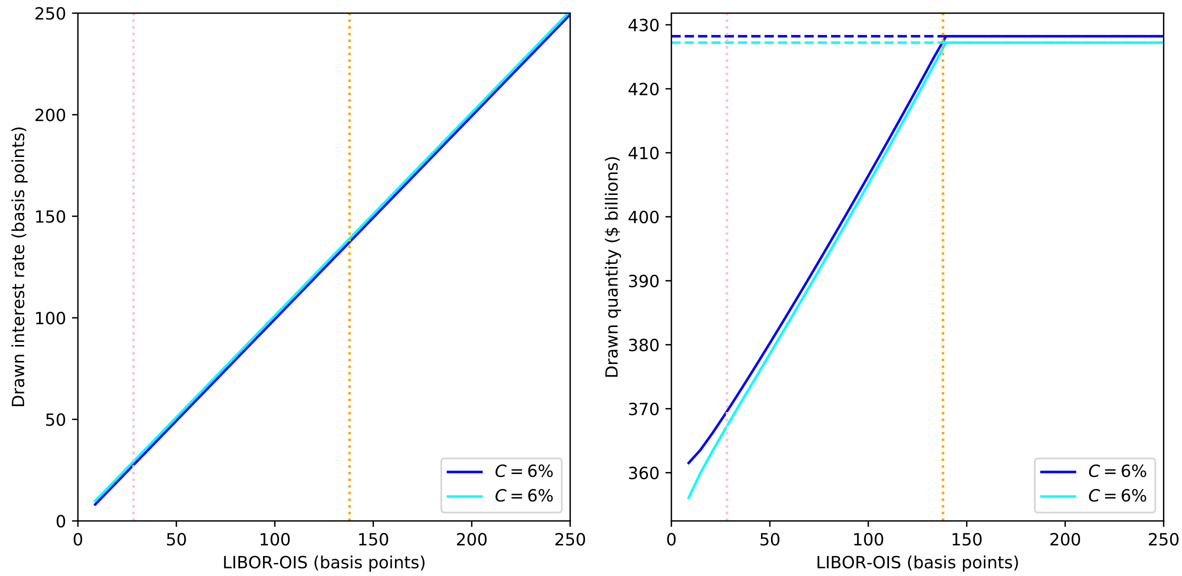


Figure F.1: **The effect of shifting equity capital requirements.** All parameters other than C are as specified in the caption of Figure 5.

[50]This requirement applies to the actual (drawn) loan amount q, and is distinct from capital requirements associated with the line size L. We recall that debt overhang costs to bank shareholders associated with the line size are assumed to be offset by the line-size fee fL.