Is SOFR better than LIBOR?

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Abstract

In the near future, USD LIBOR is likely to be replaced by a rate based on SOFR. Loans indexed to LIBOR offer lenders insurance against funding shocks; SOFR does not have this property. In this paper, I develop a stylized model to study this mechanism and to take a first look at quantitative magnitudes. In my model, under normal conditions, an economy using SOFR behaves similarly to an economy using LIBOR. Under more extreme financial conditions, differences can be nontrivial. Keywords: LIBOR, floating rates, TED spread. JEL: G21, G29, E32.

After 2021, the Financial Conduct Authority will no longer require banks to participate in LIBOR panels. This makes it likely that LIBOR will be discontinued. As LIBOR is the main reference interest rate in the U.S. economy, it seems crucial to better understand the potential impact of such a change.

The Alternative Reference Rate Committee (ARRC), a group of private-market participants convened by the Federal Reserve, has recently identified SOFR as a potential replacement for LIBOR. SOFR is the Secured Overnight Financing Rate based on Treasury repo transactions. SOFR is supported by very liquid markets and can be determined based on market transactions, contrary to LIBOR which is often based on banks' guesses. Treasury repo markets have shown their resilience during the recent financial crisis. SOFR is therefore expected to be a reference rate that is more robust to market disruptions and manipulation than LIBOR.

SOFR differs from LIBOR in fundamental ways. As an overnight rate, there are some challenges replacing term LIBOR rates in cash products and derivative contracts. Maybe

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more importantly, SOFR is based on secured borrowing while LIBOR is based on unsecured borrowing. As closely representing banks' unsecured funding costs, LIBOR as a loan rate can provide a hedge for lenders' fluctuating funding costs. SOFR does not have this property. Based on repo rates' behavior during the recent financial crisis, SOFR can even be expected to decline at times when banks' default premiums increase. A priori, this dimension can be less attractive. SOFR was selected primarily for its property to be robustly determined, it remains an open question to what extent this change could fragilize banks' balance sheets and what the macroeconomic effects might be.

In this paper, I am considering the consequences of replacing a rate index based on unsecured borrowing by one based on secured borrowing, as SOFR does with LIBOR.[1] I develop a stylized model that focuses on the market for floating rate business loans. At the end of 2016, outstanding business loans indexed to USD LIBOR amounted to 3.4 trillion. For syndicated loans, amounting to 1.5trn USD, loans indexed to LIBOR represent well over 90% of the overall loan volume. (ARRC, 2018). In the model, banks lend to firms with long-term floating rate loans (FRL). Bank funding is unsecured and subject to a model determined default premium. For LIBOR FRL, the bank funding rate is the rate index. For SOFR FRL, the model-implied risk-free rate is the index. Firms funded with FRLs invest and produce. The model economy is closed with a household sector who is the ultimate owner of banks, firms and debt issued by banks.

The model is used to compare economic scenarios for the two reference rates. In particular, I consider shocks to banks' riskiness and aggregate productivity. The model is used to compute the welfare gain or loss from a macroeconomic perspective from switching from LIBOR to SOFR. The model is also used to study the counterfactual of how an economy with SOFR as a reference rate would have performed during the financial crisis 2007-2009.

In the model, there are two dimensions to the main model mechanism in response to a shock increasing banks' riskiness. First, at impact of the shock increasing banks' current and future funding costs, LIBOR FRL offer insurance while SOFR FRL do not. Therefore, in a SOFR economy bank default rates increase by more. Second, with banks' funding spreads increased, firms in the real sector face higher implied borrowing costs and reduce productive investment. In an economy with SOFR FRL this effect and the decline in investment is worse than in an economy with LIBOR FRL, despite the fact that LIBOR as a loan index rate increases relative to SOFR.

[1] A model period corresponds to three months. The key distinction between the two cases is whether a *term* default premium is included in the benchmark or not. The distinction between a benchmark that is a secured overnight rate and one that is an unsecured overnight rate is not important for the main point of this paper. Indeed, a three-month (term) Overnight Index Swap rate against an unsecured overnight rate such as the effective federal funds rate does not include a term default premium.

The paper contributes to the literature by developing a dynamic equilibrium model where banks with limited liability lend with long-term floating rate loans. To the best of my knowledge, this is also the first study to analyze the role of LIBOR and its replacement within a dynamic equilibrium model.

This paper is related to a large literature that has developed models to study the role of financial frictions and financial intermediaries for economic fluctuations. A small sample includes Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999), Cooley, Marimon and Quadrini (2004), Gertler and Karadi (2011), and Jermann and Quadrini (2012). These papers did not consider the role of banks' limited liability. My model shares features with models of equilibrium default of firms or sovereigns as, for instance, in Miao and Wang (2010), Gomes Jermann and Schmid (2016), Gomes and Schmid (2017), Aguiar and Gopinath (2006), and Arellano (2008). The role of capital requirements has been studied in quantitative models featuring bank default, for instance, Begenau and Landvoigt (2018), Mendicino et al (2018), and Xiang (2018). Unlike in my paper, these studies do not include long-term bank loans or a time-varying interest rate index. Elenev, Landvoigt and Van Nieuwerburgh (2018) features long-term loans but no floating interest rates. Greenwald, Landvoigt and Van Nieuwerburgh (2018) features mortgages with amortization rates contingent on house price appreciation.

1 Model

The model focuses on floating rate loans, FRL, that represent the largest share of corporate bank lending. This is multiperiod debt with coupons that are adjusted periodically to current market conditions. A period in the model is taken to be a quarter of a year. As of 2019, such loans have coupons indexed mostly to LIBOR, with a fixed spread that represents an individual firm's credit risk. The model focuses on the aggregate component of interest payments to banks and abstracts from firm specific credit pricing.

Loans. The owner (a bank) of a FRL is entitled in the next period to a coupon payment i_{t+1}, with this index determined at t, and an amortization λ of the outstanding notional, in addition to the non-amortized notational valued at q_{t+1},

$$i_{t+1} + \lambda + (1 - \lambda)\, q_{t+1}.$$

Geometrically amortizing debt is chosen for numerical tractability. This debt does not age, and a single state variable can summarize the total amount outstanding. I consider two separate model economies, each with its own rate index. LIBOR represents banks' one period funding rate, SOFR is assumed to be the risk-free one-period rate. Both rates are endogenously determined in the model,

$$
\begin{aligned}
i_{t+1}^{S} &= 1/E_t M_{t+1} - 1, \text{ and} \\
i_{t+1}^{L} &= 1/p_t - 1,
\end{aligned}
$$

for SOFR and LIBOR, respectively, with M_{t+1} the stochastic discount factor of the representative household and p_t the price of one-period risky bank debt.

The prices of FRL, q_t, are determined in the lending market between banks and firms. Firms use loans to finance real investment, and their valuation is driven by the marginal productivity of investment. Banks value FRL for their coupons as well as a collateral asset for their own funding.

Banks. We assume banks that invest in FRL and finance themselves with defaultable debt and with equity. The defaultable debt has a one-period maturity. A bank enters the period with some FRL from the previous period and some outstanding one-period debt (or deposits). Conditional on not defaulting, the bank buys new FRL, and issues new short-term debt. The payout to its shareholders (dividend) is given by

$$
\left[i_t + \lambda + (1-\lambda) q_t\right] b_t - q_t b_{t+1} - d_t + p_t d_{t+1} (1+\tau) - \Psi_t z_t b_t,
$$

with b_t the notional amount of FRL. Banks are subject to idiosyncratic shocks, $z \in [\underline{z}, \bar{z}]$, with CDF $\Phi(z)$ and $E(z) = 0$. This captures gains and losses that are not necessarily directly connected to the FRL but are assumed to scale with the volume of loans. This could include gains and losses on mortgages, derivatives or other projects. The idiosyncratic shock is also scaled by the exogenously specified aggregate risk shock Ψ_t. The shock is specified as $\Psi_t = \bar{\Psi} \exp(\psi_t)$, with the constant $\bar{\Psi}$ set so as to keep risk levels unaffected by index changes. In particular, I set $\bar{\Psi} = q_{ss}$, with q_{ss} the price of FRL in the deterministic steady state, that is, the model without aggregate shocks. As shown in more detail below, this scaling makes the deterministic steady state of the model homogenous to the index level i.

Banks can default. The term $(1+\tau)$, with $\tau \geq 0$, makes short-term borrowing attractive. Without it, a bank would be entirely equity financed to avoid the deadweight default costs. This wedge can be interpreted as a tax advantage for borrowing or some other subsidy (subsidized deposit insurance). Alternatively, it can also be viewed as the liquidity value of short-term bank debt (deposits) to its owners.

Bank debt is fairly priced (with the SDF of the representative household)

$$
\begin{aligned}
p_t d_{t+1} &= d_{t+1} E_t \int_{\underline{z}}^{z^*} M_{t+1} d\Phi\left(z_{t+1}\right) \\
&+ E_t \int_{z^*}^{\bar{z}} M_{t+1} \max\left(\kappa\left\{\left[i_{t+1} + \lambda + (1-\lambda) q_{t+1}\right] b_{t+1} - \Psi_{t+1} z_{t+1} b_{t+1}\right\}, 0\right) d\Phi\left(z_{t+1}\right),
\end{aligned}
$$

with z^* the default cutoff realization, and $\kappa \in [0,1]$ the asset recovery rate on the FRL holdings net of the profit shock z. With $\kappa < 1$ there is a deadweight default cost. The debt advantage and recovery rate parameters, τ and κ, respectively, are calibrated to produce outcomes for which $b > 0$ and $d > 0$.

There is a continuum of banks. The value of bank j is defined as

$$
J_{t,j}\left(b_{t,j}, d_{t,j}, z_{t,j}\right) = \max\left\{0, V_t\left(b_{t,j}, d_{t,j}\right) - \Psi_t z_{t,j} b_{t,j}\right\},
$$

with $V_t\left(b_{t,j}, d_{t,j}\right)$ the value conditional on survival. For a given leverage ratio $d_{t+1,j}/b_{t+1,j}$, an individual bank's value increases linearly with its choices of $b_{t+1,j}$ and $d_{t+1,j}$. To resolve the indeterminacy of a bank's scale, it is assumed that banks chose $d_{t+1,j}$ individually, taking as given $b_{t+1,j}$, and $b_{t+1,j}$ is determined by the banks collectively. This can be interpreted as each bank receiving an allocation of syndicated loans. For the problem to be well-defined, it is also assumed that banks need a minimum asset to debt ratio or maximum leverage ratio. This is required to rule out a strategy of setting $b' = 0$ and then being able to issue an infinite amount of "subsidized" debt. With these assumptions, and for an appropriately specified distributions for z, equilibrium bank behavior is specified by the first-order conditions with respect to $d_{t,j}$ and $b_{t,j}$ of

$$
V\left(b, d_j\right) = \max\left\{\begin{array}{c} [i + \lambda + (1-\lambda) q] b - d_j - qb' + p_j d_j' (1+\tau) \\ + E_t M_{t+1} \int_{\underline{z}}^{z^{*\prime}(.)} \left[V\left(b', d_j'\right) - \Psi' z_j' b'\right] d\Phi\left(z_j'\right) \end{array}\right\}.
$$

The debt pricing schedule p_j and the price q_t are taken as given.

Bank $j's$ first-order condition is

$$
p_j (1+\tau) + \frac{\partial p_j}{\partial d_j'} d_j' (1+\tau) - E\left\{M' \int_{\underline{z}}^{z^{*\prime}(,)} d\Phi\left(z_j'\right)\right\} = 0,
$$

and for b' we have

$$
-q + \frac{\partial p_j}{\partial b'} d_j' (1+\tau) + E\left\{M' \int_{\underline{z}}^{z^{*\prime}(.)} \left[i' + \lambda + (1-\lambda) q' - \Psi' z_j'\right] d\Phi\left(z_j'\right)\right\} = 0.
$$

I focus on a symmetric equilibrium, and going forward, the index j is dropped from the exposition. Defaulting banks are restructured within the period and end up facing the same decision problem as the non-defaulting banks.

The first-order condition for d' displays the trade-off between the price received from selling debt, net of the price effect $\frac{\partial p_j}{\partial d'_j} d'_j (1+\tau)$, and next period reimbursement in the no-default states. The first-order condition for b' shows that buying FRL increases the price received from selling short-term debt $\frac{\partial p}{\partial b'} d' (1+\tau)$, and that FRL are only valued in no-default states; in addition to internalizing the impact on risk exposure.

Production. It is assumed that firms are financed with FRL exclusively, and the payouts to their owners are given as

$$A_t f(k_t) - b_t^f (i_t + \lambda)$$

with $f(k)$ a concave production function with capital input k, A the exogenous productivity shock, and b_t^f the stock of debt from the previous period. Capital investment is financed through issuing new debt, $inv_t = q_t(b_{t+1}^f - (1-\lambda)b_t^f)$, so that

$$k_{t+1} = q_t(b_{t+1}^f - (1-\lambda)b_t^f) + (1-\delta)k_t.$$

For the sake of parsimony the frictions affecting firm financing are not explicitly modelled.

Firms' objective is to maximize

$$\begin{aligned} W\left(b^f, k\right) &= \max_{b^{f\prime}, k'} \left\{ A f(k) - b^f (i+\lambda) + EM' W\left(b^{f\prime}, k'\right) \right\} \\ 0 &= q(b' - (1-\lambda)b) + (1-\delta)k - k'. \end{aligned}$$

The first-order and envelop conditions combined are

$$EM' \left[(i' + \lambda) + \mu' q' (1-\lambda) \right] = \mu q$$

$$EM' \left[A' f_k(k') + \mu'(1-\delta) \right] = \mu$$

with the shadow value for capital $\mu = EM' W_k\left(b^{f\prime}, k'\right)$.

Market clearing requires

$$b^{f\prime} = b'.$$

Equilibrium consumption and SDF. Households receive the dividends from banks and firms, own bank-issued debt and suffer default losses. Aggregate output is given by

$$y = A f(k) - \xi \left(1 - \Phi(z^*)\right)(1-\kappa)\, b \left[i + \lambda + (1-\lambda) q \right]$$

with the second term measuring realized default losses on FRL. With $\xi > 0$, this implies that the reduction in the value of loans caused by the bankruptcy process corresponds to real economic losses. This captures in a reduced form way the various costs and distortions of bank failures and the restructuring process beyond the modelled distortions in current and future markets for FRL. As banks fail, intangible capital is destroyed (organizational capital, customer relationships and brands). Bank employees search for new jobs, assets used by banks are unused, or used by less efficient owners. Additionally, this could capture a reduction in firm access to other bank services, for instance working capital or trade credit, or workers' mobility being reduced through supply disruptions in mortgage markets. Real default costs are a standard feature of general equilibrium default models (Aguiar & Gopinath (2006), Arellano (2008), Gomes & Schmid (2017), Begenau & Landvoigt (2018)). One could include the realized risk shocks, but this would have the unpalatable property that bad economic shocks are truncated in default.

Consumption is given by

$$c = y - inv,$$

based on this the SDF is

$$M_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)},$$

with $u(c)$ momentary utility.

2 Qualitative model properties

2.1 Banks make zero profit in equilibrium

Banks make zero profit in equilibrium and the value of a bank (net of the current z) is

$$V(b, d) = [i + \lambda + (1 - \lambda) q] b - d,$$

which equals its book value, assets minus liabilities. This follows from combining the two first-order conditions and some algebra. The key driver of this result is the constant returns to scale property of the bank value.

Equivalently, the value created by the bank for its shareholders going forward is zero, that is

$$b' \left[-q + p \frac{d'}{b'} (1 + \tau) + E \left\{ M' \int_{\underline{z}}^{z^{*\prime}(.)} \left[[i' + \lambda + (1 - \lambda) q'] - \frac{d'}{b'} - \Psi' z' \right] d\Phi(z') \right\} \right] = 0.$$

Substituting out the price of bank debt and rewriting yields

$$\begin{aligned}
&\tau EM'\Phi\left(z^{*\prime}\right)\frac{d'}{b'} = \\
&\left(1-\kappa\left(1+\tau\right)\right)EM'\int_{z^{*\prime}}^{\bar{z}}\left\{\begin{array}{c} i'+\lambda+\left(1-\lambda\right)q' \\ -\Psi' z' \end{array}\right\}d\Phi\left(z'\right) \\
&+q-EM'\left[i'+\lambda+\left(1-\lambda\right)q'\right].
\end{aligned} \tag{1}$$

The debt funding advantage (the left hand side) contributes positively to banks' profits (this is similar to a tax shield). This is offset by the net losses from the deadweight default costs (first term on the right hand side), in addition to the loss (or gain) from investing in loans (last two terms). From this equation, I can derive a key property of the model summarized by the following proposition.

Proposition 1 *If* $\tau > 0$ *and* $(1-\kappa(1+\tau)) > 0$*, for in interior equilibrium with* $d' > 0$ *and* $b' > 0$*,*

$$q - EM'\left[i'+\lambda+\left(1-\lambda\right)q'\right] > 0.$$

Starting from equation (1), the proof is straightforward; the first minus the second term has to be positive for an interior equilibrium with $\frac{d'}{b'} > 0$, because $\frac{d'}{b'} = 0$ is a feasible choice where both terms are zero. The proposition states that banks pay more for loans than what the representative household would, implying that banks get relatively low return on their loans. As an implication derived below in subsection (2.3) the steady state capital stock is increased relative to an economy without financial frictions.

2.2 Deterministic steady state is homogenous with respect to the interest rate index

Assume we shut down aggregate shocks to bank risk and productivity, $\Psi_t = \Psi$ and $A_t = A$, and we focus on the steady state. Combining the equations characterizing firms and banks yields 5 equations in 5 unknown variables: $\left(p, \frac{d}{qb}, \frac{i+\lambda}{q}, z^*, qb\right)$, where i , q and b do not enter separately. Considering different levels of the index i leaves $\frac{i+\lambda}{q}$ and qb unchanged, that is q and b adjust. From that perspective, we can consider i a normalization. In particular, the default probability in steady state is determined uniquely by the default cutoff level z^*. Model economies with SOFR and LIBOR differ from each other due to differences in the responses to shocks and the effects on the levels of variables induced by terms of second-order or higher in the dynamic equations representing the model solution.

One can view $\frac{i+\lambda}{q}$ as a dividend-price ratio. Assume some gross discount rate $\tilde{R}$ and a price $\tilde{q}$, with $\tilde{q}\tilde{R} = i + \lambda + (1-\lambda)\tilde{q}$. Then $\tilde{R} - (1-\lambda) = \frac{i+\lambda}{\tilde{q}}$, and the index i level does not matter separately for the dividend-price ratio.

2.3 Banks' funding advantage increases capital relative to first best

Steady state firm first-order conditions imply that

$$k = \left\{ \frac{R-(1-\lambda)}{\tilde{R}-(1-\lambda)} \frac{Aa}{R-(1-\delta)} \right\}^{1/(1-a)},$$

with R the discount rate implied by the representative SDF and $\tilde{R}$ the implied equilibrium discount rate relevant in the loan market.

Without frictions for bank financing,

$$\frac{R-(1-\lambda)}{\tilde{R}-(1-\lambda)} = 1,$$

and

$$k = \left\{ \frac{Aa}{R-(1-\delta)} \right\}^{1/(1-a)},$$

which is equivalent to a frictionless first best capital level (that is, the firms' financing friction does not affect the steady state).

A direct consequence of Proposition 1 is that

$$\frac{R-(1-\lambda)}{\tilde{R}-(1-\lambda)} > 1,$$

so that the economy with financial frictions features a higher capital stock. This can be interpreted as banks passing on their funding advantage to the firms, which stimulates investment. Whether output is increased, depends on the level of the default costs measured by ξ. For $\xi = 0$, output is also higher, as ξ gets larger, more resources are lost.

2.4 Pricing FRL: No arbitrage and equilibrium pricing

Start with the no-arbitrage pricing of FRL paying SOFR and LIBOR. A SOFR FRL assumed to pay the short rate priced with the representative SDF follows

$$q_t^{NoS} = E_t M_{t+1} \left\{ i_{t+1}^S + \lambda + (1-\lambda) q_{t+1}^{NoS} \right\},$$

with $i_t^S = 1/E_{t+1}M_{t+1} - 1$. After some algebra we have

$$q_t^{NoS} = 1,$$

which is the well-known property that a FRL indexed to the risk-free rate is priced at par. Buying such a FRL creates no risk exposure.

A LIBOR FRL priced by the SDF satisfies

$$q_t^{NoL} = E_t M_{t+1} \left\{ i_{t+1}^L + \lambda + (1-\lambda) q_{t+1}^{NoL} \right\}$$

with

$$i_{t+1}^L = 1/p_t - 1 \equiv 1/E_{t+1}M_{t+1} + \theta_t - 1,$$

and $\theta_t \equiv i_{t+1}^L - 1/E_{t+1}M_{t+1}$ can be viewed as the TED spread (given our assumption that SOFR is the risk-free rate). In this case

$$q_t^{NoL} = 1 + \sum_{j=0}^{\infty} (1-\lambda)^j E_t M_{t,t+1+j} \theta_{t+j},$$

so that the loan price incorporates the present value of the TED spreads. This FRL is exposed to current and future TED spreads, that is, banks' risk spreads. In general, this risk exposure does not perfectly match the risk from short-term unsecured debt on a period by period basis, but the two exposures can at least partially offset each other. The quantitative model can tell us how well this insurance mechanism works.

In the model, markets are segmented, and the price of the loan is determined in equilibrium between banks and firms, both are subject to financial frictions. Consider how these frictions affect the equilibrium price. From the banks perspective, the loan price satisfies

$$q = \frac{\partial p}{\partial b'} d' (1+\tau) + E\left\{ M' \Phi(z^{*\prime}) \left[i' + \lambda + (1-\lambda) q' \right] \right\} - E\left\{ M' \Psi' \int_{\underline{z}}^{z^{*\prime}(.)} z' d\Phi(z') \right\}.$$

The first term captures the impact on banks' funding cost from a marginal unit of the loan, this can be thought of as capturing the collateral value of the loan. The second term captures the interest and amortization, that is however only valued by the banks' shareholders in the no-default states, that have probability $\Phi(z^{*\prime}) < 1$. This can be thought of as capturing debt overhang, because in default, the additional asset is lost to the banks' creditors (here this is internalized through the price effect). While the collateral benefit increases the value of the loan, $\frac{\partial p}{\partial b'} > 0$, the associated debt overhang effect lowers its value to the banks' shareholders.

The last term is the risk scaling effect. In this economy, even a SOFR FRL is subject to price risk unlike in the no-arbitrage case. A LIBOR FRL should mostly maintain its exposure to current and future TED spreads.

On the firm side, the debt price satisfies

$$q = EM' \left[\frac{i' + \lambda}{\mu} + \frac{\mu'}{\mu} q'(1 - \lambda) \right],$$

with η the shadow value of capital at the end of the period

$$\mu = EM' \left[A' f_k (k') + \mu'(1 - \delta) \right].$$

A temporarily high shadow value of capital μ drives down the equilibrium price q the firm is willing to accept for its debt, and this increases its implied borrowing cost. Equivalently, everything else equal, a currently high loan price q will incentivize the firm to drive down the expected marginal product of capital by increasing investment. In equilibrium, banks' and firms' pricing equations hold simultaneously, capturing the interaction of these effects.

3 Quantitative analysis

For additional model properties and to get a sense of quantitative magnitudes, values are assigned to model parameters. A period in the model is a quarter of a year. I calibrate the model to match a TED spread in steady state of 5 basis points (bps), that is 20 bps in annualized terms. This corresponds to the average TED spread in the first three months of 2019. The steady state default rate is set to 0.5% per quarter. These two choices jointly determine κ and τ, the debt recovery parameter and bank funding advantage parameter. The probability density function for the bank profit shock, z, is represented by a symmetric quadratic polynomial. The free shape parameter η is set to 0.7, which implies a distribution not far from uniform. The range of values for these three parameters for which a qualitatively reasonable equilibrium exist is narrowly restricted.

The exogenous shocks are represented as AR(1) in logs. The shock innovation volatility and persistence parameters are set to replicate the properties of the realizations required to match GDP and TED for the period 2003-2013 (which is used for the counterfactual crisis simulation). The default cost parameter $\xi = 1$. Loan maturity $1/\lambda$ is 3 years, that is 12 quarters. The rest of the parameters are standard in business cycle models. Parameters are summarized in Table 1.

Figure 1 displays the impulse responses to a one standard deviation shock in bank risk,

Symbol	Parameter / Model implied	Value
	TED spread	0.0005
	Default rate	0.005
κ	Recovery	0.9177
τ	Debt advantage	0.0088
η	Distribution parameter	0.7
σ_ψ	Risk shock innov. SD	0.0127
ρ_ψ	Risk shock persistence	0.833
σ_a	TFP shock innov. SD	0.0075
ρ_a	TFP shock persistence	0.95
$R = 1/\beta$	Discount rate	1.01
$1/\lambda$	Loan maturity	12
γ	Risk aversion	2
δ	Capital depreciation	0.025
α	Capital curvature	0.5
q_{ss}	Loan price SOFR	1.02
	Loan price LIBOR	1.0257

Table 1: Model parameters

Ψ. Plots are shown for responses in economies using either SOFR or LIBOR. The shock implies that the realizations of z are spread out. Therefore, at impact, the default rates for banks increase. TED spreads increase as default rates are expected to be higher for several periods; correspondingly debt prices, p, decline. Banks reduce their funding, d, and loans. Firms cut investment and output declines.

Comparing LIBOR and SOFR economies, a key difference is the response of loan prices q. In the LIBOR economy, the interest rate index increases driven by bank defaults and so does the loan price q. The risk free rate declines mildly, so that in the SOFR economy loan prices q decline mildly. In the LIBOR economy, the capital gain on outstanding loans offsets partially the negative effects of the bank risk shock. Banks default less, cut loan volumes by less, and firms cut investment by less in the LIBOR economy. Clearly, for this type of shock, a LIBOR index would be a better choice than SOFR.

Quantitatively, the effects of a shock of this magnitude are quite small. TED moves by about 6 and 4 bps (in quarterly terms) for the SOFR and LIBOR economies, respectively. Aggregate investment declines by about 46 and 39 bps (in quarterly terms) for the SOFR and LIBOR economies, respectively. The impact of larger shocks is considered below.

Figure 2 displays the impulse responses to a one standard deviation shock to total factor productivity (TFP), A. For the main macroeconomic quantities, responses are as expected for this class of real business cycle models. There is essentially no difference between the SOFR and LIBOR economies.

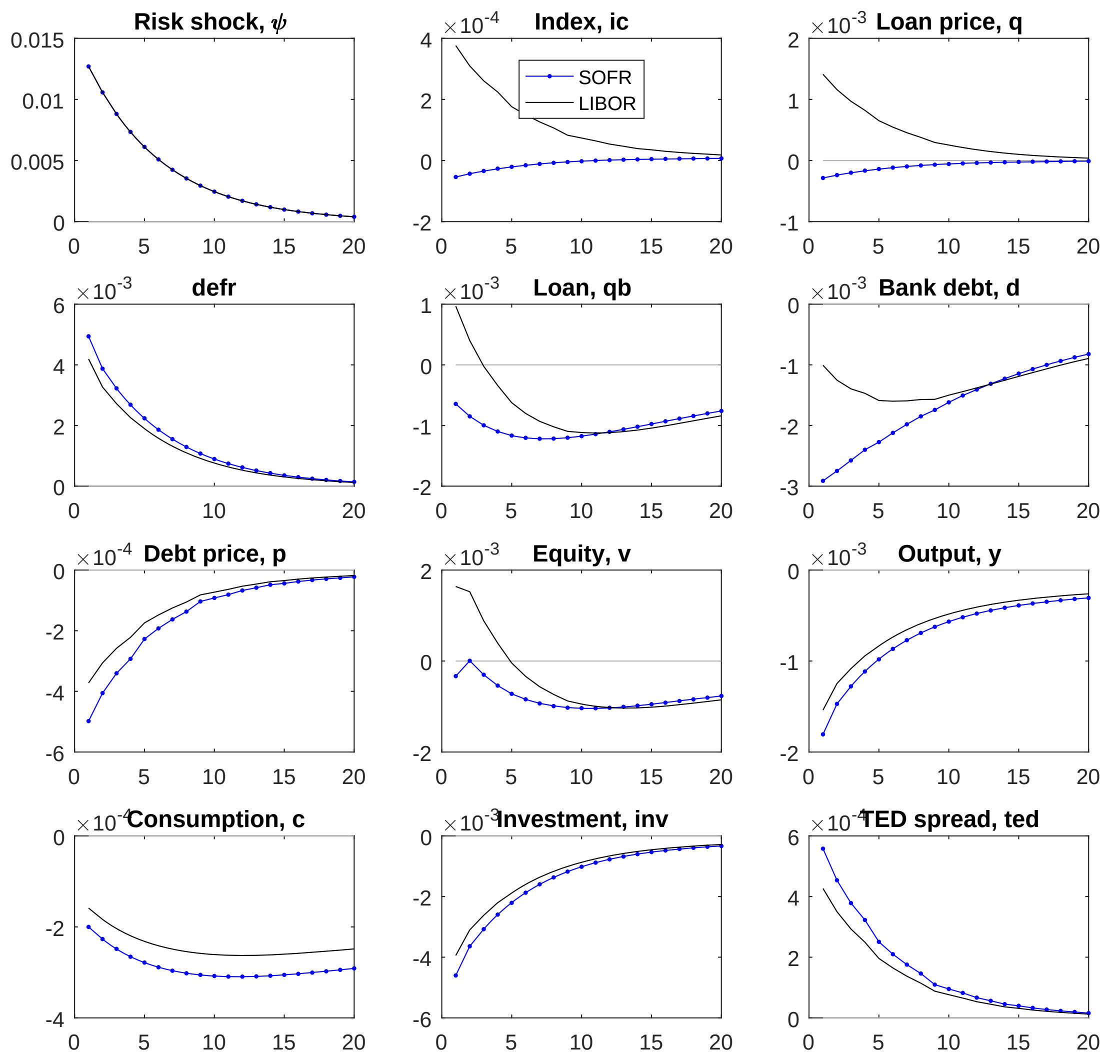

Figure 1: Impulses responses to a one standard deviation innovation in bank risk shocks.

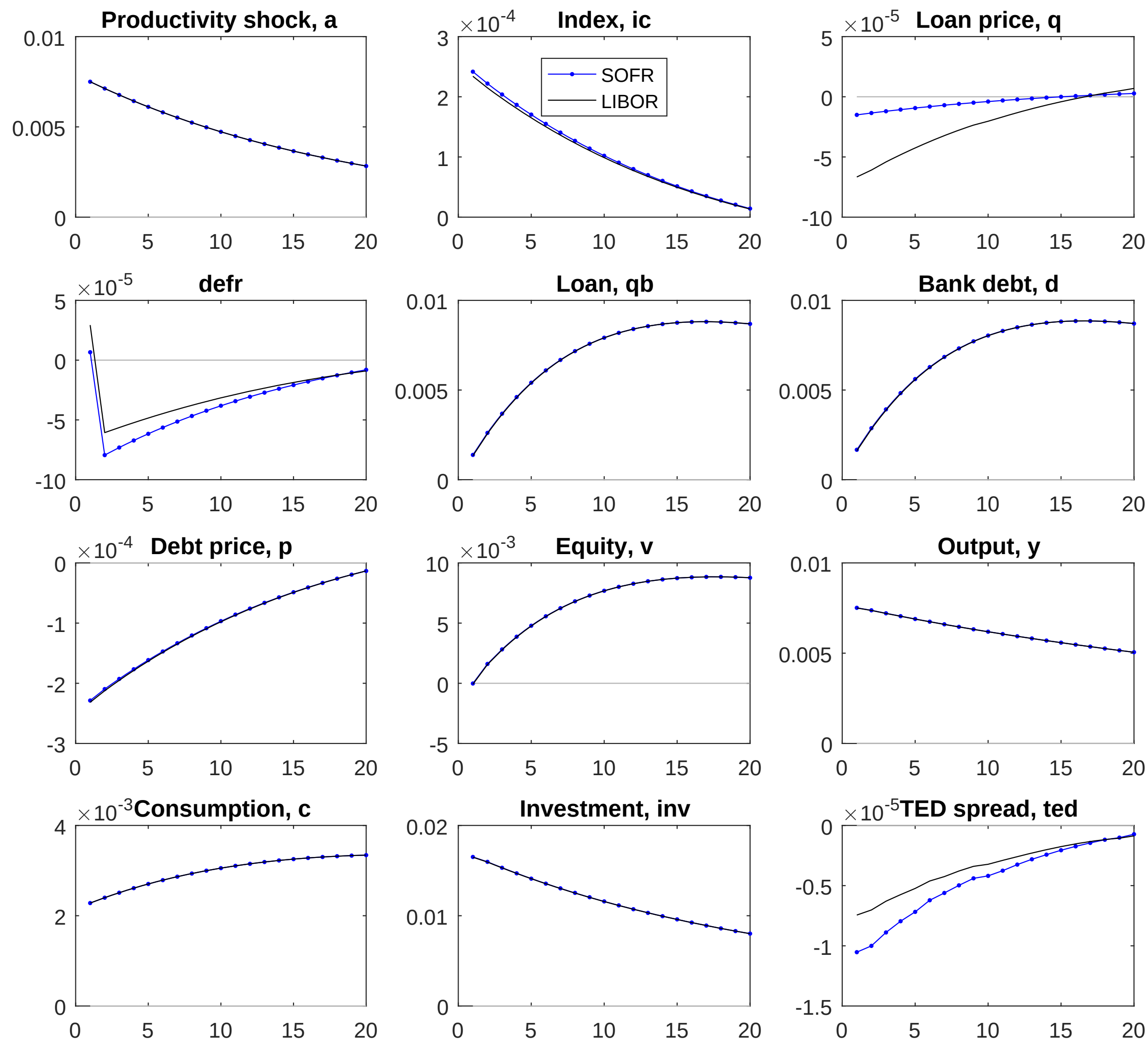

Figure 2: Impulses responses to a one standard deviation innovation in total factor productivity.

As a second experiment, I consider the transition from a LIBOR economy to an economy where FRL are indexed to SOFR. Starting from the stationary point of the LIBOR economy (which, with a third-order perturbation approximation, is slightly different from the deterministic steady state), the economy is switched to SOFR. I assume that as loans are redenominated from LIBOR to SOFR, banks are compensated for the capital loss of moving to a lower coupon. This compensation is based on the pre-transition ratio of the no-arbitrage prices of LIBOR and SOFR loans. Without this compensation, there would an increase in bank defaults in the period of the switch and a decrease in output, but the responses of aggregate consumption and welfare would be essentially unaffected. It is expected that outstanding contracts that have their coupon index changed from LIBOR to SOFR would be subject to an adjustment of the spread relative to the index.

Figure 3 displays the SOFR economy's transition to its new stationary point compared to a hypothetical LIBOR economy (which is at its stationary point from the beginning). The interest index in the SOFR economy is about 5 bps lower, and loan prices decline by about 70 basis points. This change in the loan price includes a small change in the risk premium, as coupons indexed to LIBOR covary positively with the marginal utility of consumption. Default rates in the SOFR economy are higher and consumption is lower. Welfare, as measured by a permanent consumption differential, declines by about 3 bps of consumption.

The third experiment revisits the period of the global financial crisis around 2008, and tries to answer the question how an economy with SOFR instead of LIBOR would have lived through that period. For this counterfactual experiment, I recover the shock realizations to TPF and bank risk, A and Ψ, for which the LIBOR economy matches the data on GDP deviations from a linear trend and the TED spread for the period 2003-2013.[2] These shock realizations are then run through an economy that uses SOFR as the interest index.

Figure 4 compares the two scenarios. By assumption, the LIBOR economy matches the empirical paths of GDP and TED for 2003-13, which are displayed in the two panels in the top row. The implied shocks are displayed in the bottom panels. Clearly, GDP mostly identifies the TFP shocks, and the TED spread identifies mostly the bank risk shocks. As shown in the plots, bank default rates and TED spreads would have been significantly higher in a SOFR economy. The highest average quarterly TED spread was at about 2.5% (in annualized terms) in Q4 2008. An economy with SOFR would have had a TED spread way beyond 3% during that quarter. The differences in GDP are more moderate, but not entirely trivial. For

[2] I implicitly assume that published LIBOR rates fully reflected the severity of the crisis. Due to the potential impact of reputation-based manipulation of LIBOR submissions, this may not be an accurate assumption.

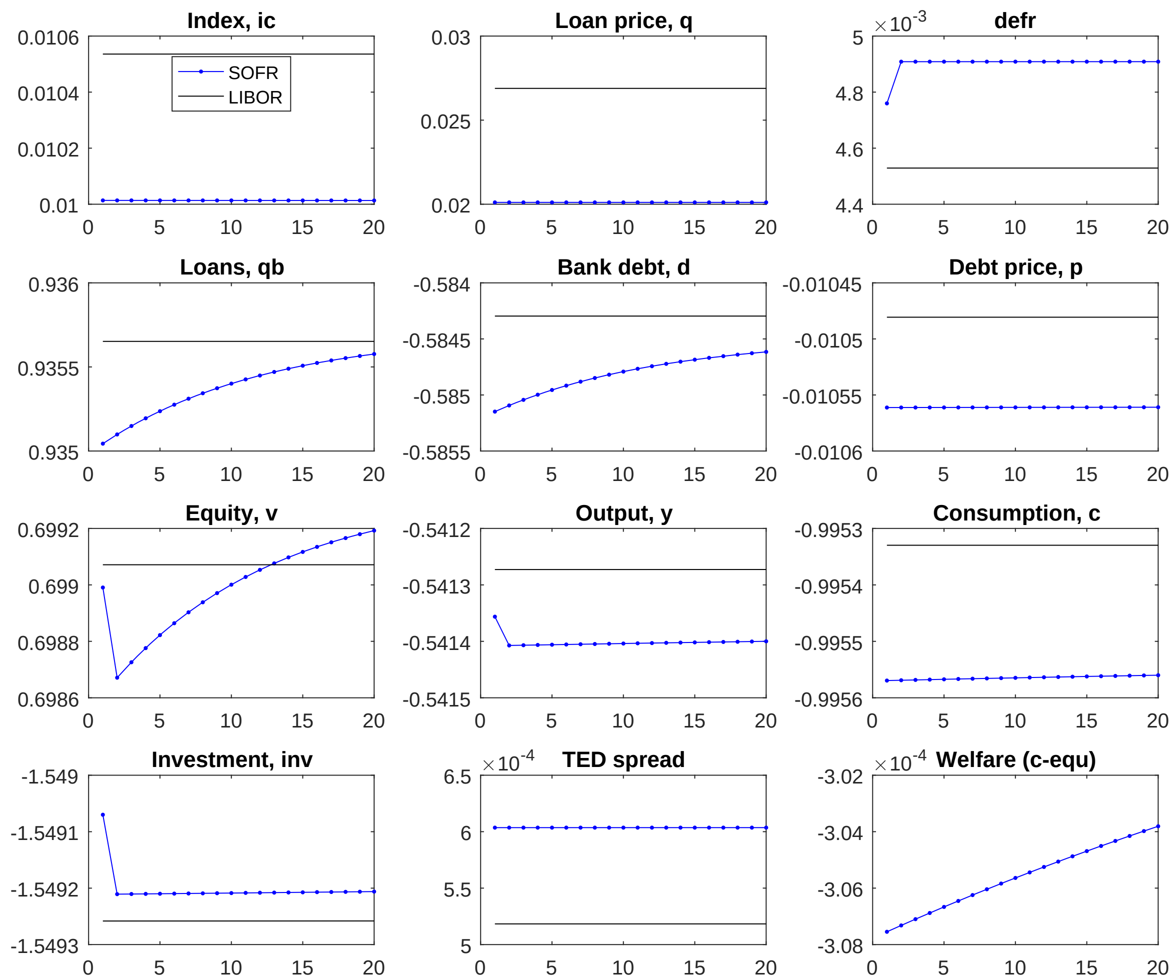

Figure 3: Transition from a LIBOR to a SOFR economy.

2008, relative to its trend level, GDP in the SOFR economy would have been about 0.2% lower than in the LIBOR economy. The output loss in the model depends crucially on the specification of the real costs of bank defaults.

4 Conclusion

Loans indexed to LIBOR can offer insurance to lenders against adverse funding shocks. Indexing loans to a rate that does not reference bank funding costs directly, such as SOFR, does not have this property. I have developed a stylized model to study this mechanism and to get a sense of quantitative magnitudes. For the aggregate economy under regular conditions, this mechanism should not have first-order effects if LIBOR is replaced by SOFR. However, for extreme conditions such as those experienced in 2008, the loss of this automatic stabilizer may not be trivial. In an economy that uses SOFR for indexing loan rates, banks may need to change risk management practices with respect to their loan exposures. Alternatively, LIBOR (or a similar rate including a term default premium) could continue to be used by banks for indexing loans in an economy that would use mostly SOFR as its benchmark rate for derivatives and other cash products.

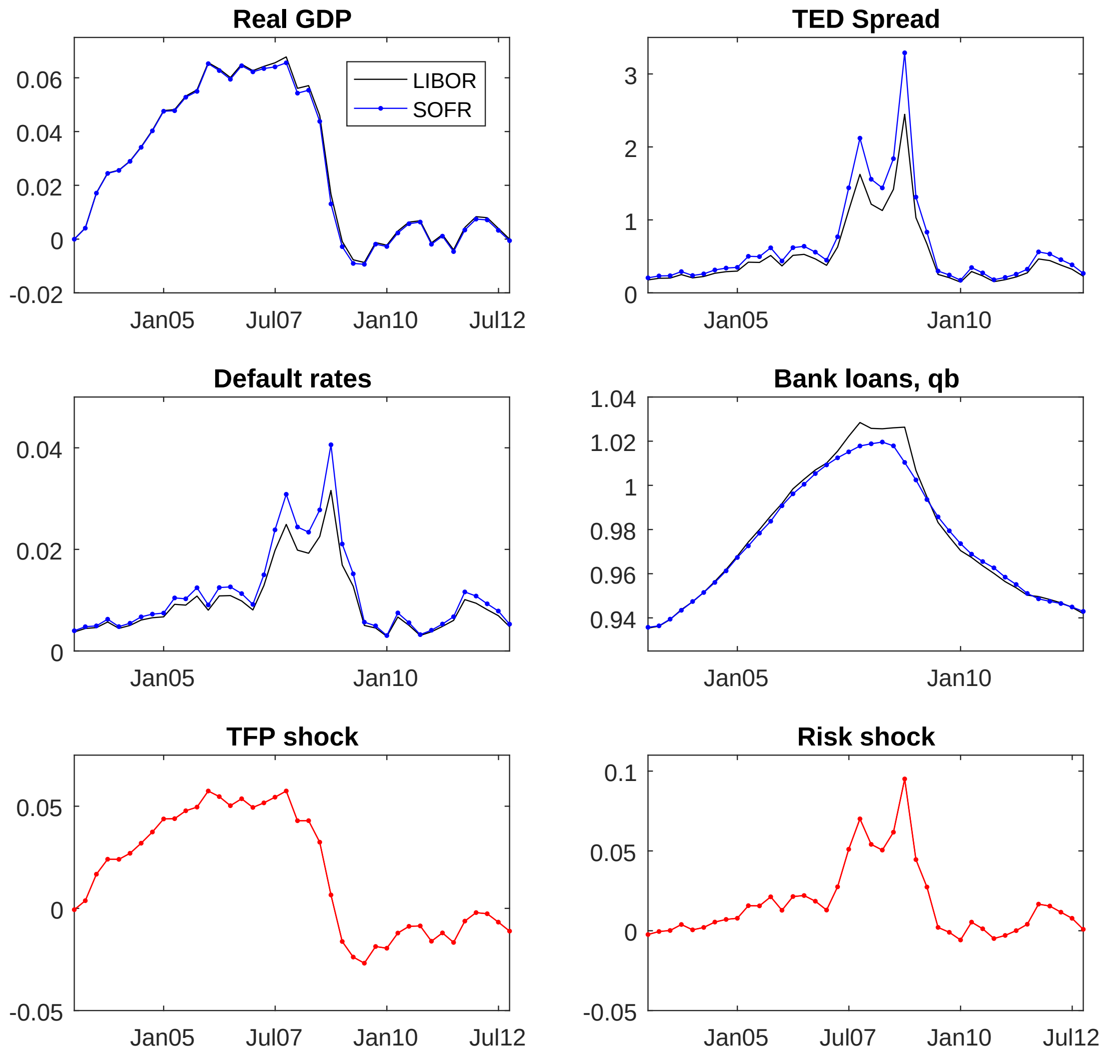

Figure 4: Counterfactual financial crisis with SOFR.

References

Aguiar, Mark, Gopinath Gita. “Defaultable Debt, Interest Rates and the Current Account,” Journal of International Economics , 2006, vol. 69, 64-83.

Arellano Cristina. “Default Risk and Income Fluctuations in Emerging Economies, ” American Economic Review , 2008, vol. 98, 690-712.

Alternative Reference Rates Committee, https://www.newyorkfed.org/arrc

Bernanke, Ben, Mark Gertler, and Simon Gilchrist, 1999, “The Financial Accelerator in a Quantitative Business Cycle Framework”, Handbook of Macroeconomics, Edited by Michael Woodford and John Taylor, North Holland.

Elenev, Vadim, Tim Landvoigt and Stijn Van Nieuwerburgh, 2018, "A Macroeconomic Model with Financially Constrained Producers and Intermediaries," working paper.

Gertler, Mark and Karadi, Peter, 2011. “A model of Unconventional Monetary Policy,” Journal of Monetary Economics, vol. 58(1), pages 17-34.

Gomes, Joao, Urban Jermann and Lukas Schmid, 2016, "Sticky Leverage," American Economic Review, VOL. 106, NO. 12, (pp. 3800-3828).

Gomes, Joao and Lukas Schmid, 2017, Equilibrium Asset Pricing with Leverage and Default, Journal of Finance, forthcoming.

Greenwald Daniel, Tim Landvoigt and Stijn Van Nieuwerburgh, 2018, "Financial Fragility with SAM?," working paper.

Jermann, Urban, and Vincenzo Quadrini, 2012, “Macroeconomic Effects of Financial Shocks”, American Economic Review 102(1), 238–271.

Juliane Begenau and Tim Landvoigt, 2018, "Financial Regulation in a Quantitative Model of the Modern Banking System," working paper.

Kiyotaki, Nobuhiro and John Moore, 1997, “Credit Cycles”, Journal of Political Economy, 105, 211-248.

Mendicino, Caterina, Kalin Nikolov, Javier Suarez, and Dominik Supera, 2018. “Optimal Dynamic Capital Requirements.” Journal of Money, Credit and Banking, 1271-1297.

Miao, Jianjun and Pengfei Wang, 2010, ”Credit Risk and Business Cycles”, working paper, Boston University

Xiang, Haotian, 2018, Corporate Debt Choice and Bank Capital Regulation, working paper, University of Pennsylvania.