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Keywords

LIBOR, SOFR, benchmark rate, ARRC

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HOW IS SOFR DIFFERENT FROM LIBOR?

By

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SOFR is expected to phase out USD LIBOR in the near future. The two rates are intrinsically different and are affected by various idiosyncratic features. Recently, the relevance and long-term effects of these differences have received increased academic interest. I begin by synthesizing the literature on meaningful ways in which the two rates are distinct. Then, I contribute to this knowledge by studying the SOFR-LIBOR spread more closely. Fundamentally, LIBOR includes term structure and risk SOFR lacks, and the rates have underlying markets of drastically different liquidity. I regress the daily spread of 1M LIBOR and 3M LIBOR to overnight SOFR on metrics for liquidity, term structure and credit risk, achieving significance on all three variables. I also regress a monthly average of the above spreads on monthly averages of the above metrics, as well as other relevant economic variables. Results show the spread is also significantly affected by variables measuring economic outlook, equity market volatility, monetary policy, and treasury trading volumes. These findings suggest a framework to understand the ways in which SOFR and LIBOR differ more precisely, and support observations by other academics that LIBOR and SOFR behave very differently under extreme economic circumstances.

Introduction

The USD LIBOR is the most used reference rate in the world, with over 220 trillion dollars in notional amount. It is a crucial feature in a multiplicity of financial markets, such as certain derivatives, mortgage products and business loans in the United States. Historically, LIBOR rates represent interbank unsecured lending over different terms and are computed every day by surveying participating "panel" banks. Nonetheless, the declining volume of lending in this market, particularly for longer terms, has led to increased discretion by bank officials in providing survey responses. In the financial crisis of 2008, several cases of LIBOR rigging were made public, resulting in billions of dollars in fines to panel banks (Burgess, 2019). These events put the viability of LIBOR to question, as the underlying market and method to compute LIBOR lacked robustness. The series of manipulation lawsuits made increasingly clear that LIBOR was a major legal liability for panel banks. Thus, several voices from the Financial Stability Board, the Financial Stability Oversight Council (FSOC) and academia called for LIBOR reform. In response, the Federal Reserve Board convened the Alternative Reference Rates Committee (ARRC), a group of private market participants tasked with the designation of a more appropriate reference rate for the financial system and the development of a plan to implement this transition with minimal disruption.

In 2017, the ARRC identified the Secured Overnight Financing Rate (SOFR) as the best fit to take over LIBOR. SOFR is a fully-transaction based overnight rate based on the Treasury repo market, with over $750 billion in underlying transactions every day (The Alternative Reference Rates Committee, 2018). It has been published daily since the second quarter of 2018. Furthermore, the ARRC published a series of target dates for the cessation of new use of LIBOR in May 2020, with the earliest deadline targeting September 30, 2020. Nonetheless, public data on daily transactions reveals LIBOR is still widely utilized, although SOFR-based contracts are increasing in popularity.

To facilitate the transition, the ARRC has made available recommended product-specific fallback language guidelines for existing LIBOR contracts, as well as extensive recommendations on how to structure new products using SOFR. In September 2020, Bloomberg published an overview of the recommended fallback methodology as the ARRC's designated vendor for adjustment services (Bloomberg Professional Services, 2020). In essence, the document suggests that market participants adjust LIBOR contracts by replacing LIBOR with (1) a compound average of overnight SOFR over the tenor of LIBOR involved, denominated the "adjusted" SOFR, plus (2) a spread adjustment. The spread adjustment is calculated as the median of the spread between LIBOR and its corresponding "adjusted"

SOFR during a five-year period prior to a fixing date. On March 5, 2021, ICE announced it would cease to produce USD LIBOR's 1-week and 2-month tenors after December 31st, 2021, and all other tenors by June 30th, 2023 (ICE Benchmark Administration, 2021). This announcement constituted a trigger event that set the fixing date to March 5, prompting Bloomberg to publish spread adjustments for all USD LIBOR tenors (Bloomberg Professional Services, 2021). Even though this implies the popular 1-month and 3-month LIBOR tenors will be produced for over 2 more years than expected, the ARRC has restated the urgency of halting new use of LIBOR and incorporating robust fallback language into longer-dated contracts.

Much of current academic and industry concern about SOFR stems from the fact that SOFR and LIBOR are inherently different in several ways. For instance, LIBOR is a term rate (with the 1-month and 3-month LIBOR as the most used) while SOFR is an overnight rate and does not have a "natural" term structure. Moreover, LIBOR is unsecured and reflects banks' funding costs, while SOFR is fully secured and thus a "risk-free" rate. Besides these explicit differences, each rate has its own set of idiosyncrasies that prevent a straightforward answer to the question asked in the title. For instance, recent literature has dived deeper into very interesting and relevant phenomena. Jermann (2019) showed the difference between the two rates may be non-trivial in periods of financial distress. He found SOFR-indexed business loans would have returned lower interest payouts to banks during the 2008 Financial Crisis. In a recent paper, Klingler & Syrstad (2020) found financial variables such as government debt and bank reserves have significant effects in SOFR. These findings motivate our research question and suggest methods we can use to further study the differences between the two rates. Ultimately, we want to know whether these differences will amount to a meaningful shift that requires non-trivial adaptation by industry players. This concern remains a topic of active academic debate, and we hope to contribute directly to this discussion.

This paper will attempt to answer the title question holistically. Firstly, we will present a comprehensive synthesis of available information about how the rates differ, from players in the transition as well as from academic literature. As the transition to SOFR is an ongoing process, relevant context will be included in our discussion. Secondly, we will present simple quantitative analyses to better understand how SOFR and LIBOR differ. We will study the spread of 1M and 3M USD LIBOR to overnight SOFR in daily and monthly frequencies. We will regress the spreads on relevant economic and financial variables that have a fundamental relation to the spread. Through our analysis, we hope to arrive at a more precise understanding of what makes SOFR and LIBOR different.

Moving away from LIBOR

Early literature identified the likely future need of a transition away from USD LIBOR. Early papers and reports described LIBOR's problematic features and suggested many pathways for a possible transition to alternative benchmark rates. In one of the earliest paper on the topic, Duffie & Stein (2015) thoroughly elaborate on LIBOR's importance in the financial market, present issues affecting it – such as manipulation and a thin underlying market – and suggest possible solutions to these issues.

Duffie & Stein contributed to reports commissioned by the Financial Stability Board about how to improve on benchmark rates such as LIBOR. A key feature of a good benchmark rate is that it is transaction-based. The discretion of market participants when submitting LIBOR surveys introduces an opportunity to falsify the submission to manipulate LIBOR. However, a transaction-based LIBOR would necessitate enough interbank wholesale lending at each currently published tenor. As we have alluded to earlier, there are not enough interbank loans to support a daily transaction-based LIBOR fixing, an inherent flaw that would eventually lead to the introduction of a new benchmark.

Despite market participants' awareness of its flaws, LIBOR has continued to grow in use, with USD LIBOR used in transactions with combined nominal value of over $220 trillion by 2021. LIBOR's importance in the financial markets is clear. The TED spread, defined as the spread between 3M USD LIBOR and the current 3-month treasury yield, is widely used to gauge general credit risk and economic health, even though technically LIBOR only measures bank's credit risk. Moreover, the use of LIBOR in the large interest rate derivatives market was born out of convenience over any judgement of adequacy. Interest rate derivatives are meant to transfer risk related to changing market-wide interest rates, having little to do with the bank credit risk embedded in LIBOR. As such, derivative markets may be better served by a risk-free benchmark, such as SOFR.

From LIBOR to SOFR

After identifying SOFR as the unique rate to succeed LIBOR, the ARRC (2018) published its Second Report, in which it provides thorough justification of its decision and points toward next steps and key milestones necessary for implementation. Some of the main concerns mentioned were deciding on the proper spread adjustment, the creation of a market that provided forward-looking SOFR term rates analogous to LIBOR, and the development of a standard legal language to deal with the transition of existing long-dated contracts (a fallback language). A paper from the Bank of International Settlements (BIS) extends the above discussion to an international setting by addressing a worldwide trend of phasing out LIBOR-like reference rates and replacing them with more robust, market-based and usually risk-free options (Schrimpf & Sushko, 2019). The authors also suggest LIBOR may have a desirable behavior for banks, as it tracks their own cost of funding. Burgess (2019) provides an overview and discussion of the transition and introduces concerns over yield curve calibration methods and requirements for the new reference rates, including SOFR. Lastly, Klingler & Syrstad (2020) compare SOFR with their British and European counterparts, SONIA and ESTR. They find that several financial variables, such as government debt, transaction volume and bank reserves, have diverse effects on the new reference rates.

A major point of concern is whether the unsecured nature of SOFR can have unwanted consequences for the financial stability of banks in distress. Jermann (2019) claims LIBOR provides a hedge to banks' fluctuating funding costs. In periods of financial crisis, LIBOR rises with banks' funding costs because of an increased default risk premium; as a secured rate, SOFR does not exhibit this behavior and would in fact be expected to fall due to monetary policy measures. In principle, this means switching to SOFR for business loans could weaken bank's balance sheet resilience during crises, which could have significant macroeconomic effects. To measure these effects, Jermann employs a dynamic equilibrium model of an economy in which banks lend to firms through floating rate loans indexed to their own funding rate (representing LIBOR) or to the model-implied risk-free rate (representing SOFR). He studies the effects of shocks to bank credit risk and aggregate productivity in bank defaults, firm investment, and consumption under the two rates. He finds that switching from LIBOR to SOFR in business loans would induce an increase in bank defaults, and a decrease in investment and consumption. While he reports that the effects of the change under normal financial circumstances are negligible, they become significant when the shocks are large enough, such as during the 2008 financial crisis. In his conclusion, he proposes the use of different benchmarks for different purposes: a funding cost-based rate for business loans with similar properties to LIBOR and risk-free SOFR for interest rate derivative applications. In a different paper, Jermann presents an estimate of the additional interest banks have received by using LIBOR versus counterfactual SOFR indexing methods during the financial crisis. He considers two possibilities for a SOFR-indexed counterfactual: a compounded SOFR over the term of the LIBOR tenor, or a matching term SOFR, for which he uses OIS term rates as proxies. He also takes an expected spread adjustment into account for his analysis. Considering outstanding LIBOR-indexed loans from 2007 to 2009, he estimates banks would have missed $33.3 billion if they used a compounded SOFR, and $26.7 billion if they used a term SOFR. These cash flows represent between 1% and 2% of the total business loan notional balance (Jermann, 2020). As of now, the ARRC has moved forward with compounded SOFR in their fallback recommendations.

Other scholars do not consider this feature of SOFR to be cause for greater concern. Bowman et al. (2020) respond to the general concerns raised by Shrimp & Sushko (2019) and Jermann (2019) that LIBOR may have some desirable characteristics for banks and their financial health. First, they examine whether LIBOR has historically risen higher than a comparable term risk-free rate during periods of recession. They construct a series of OIS rates that extends to the 1990s, using fed funds futures and the method described in Heitfield & Park (2019). The authors then examine how the LIBOR-OIS spread reacted to periods of recession, finding that although it widened significantly during the 2007-2009 financial crisis, it only widened moderately during the 1990-1991 recession and the recent but brief height of the COVID-19 scare in March-April 2020. They point out the spread did not widen during the 2001 recession. With this analysis, they intend to show that the difference between LIBOR and a comparable risk-free rate during recessions are moderate to insignificant for recessions outside of the financial crisis, which was affected by idiosyncratic events that explicitly hurt banks' credit worthiness. Furthermore, they point out that regulatory reforms and higher reserve requirements for banks following the financial crisis may have contributed to shorter and more moderate period of widening in the case of the COVID-induced shock. Moreover, they point out that LIBOR is not a better indicator of banks' overall cost of funding than other secured rates, as wholesale unsecured borrowing no longer represents a significant part of banks' financing. Even though they concede the average cost of funding does not necessarily represent banks' marginal funding costs, they do note that LIBOR funding for banks played a significantly smaller role in banks' balance sheets since the financial crisis. That said, they argue that banks' overall funding costs have been closer related to risk-free rates since before the crisis. They present a correlation table that shows a hypothetical 3-month SOFR would have been more correlated to banks' overall funding costs than 3-month LIBOR during the 2006-2011 window, which includes the financial crisis (Bowman et al., 2020). Lastly, they consider that banks do have some LIBOR exposure not directly tied to wholesale unsecured borrowing, such as issuances of senior or subordinated floating rate debt that is indexed to LIBOR. The authors report that the total outstanding LIBOR-indexed debt of this kind amounts to ca. $412 billion (Bowman et al., 2020). However, they argue these securities could instead reference risk-free rates such as SOFR to reduce exposure to LIBOR.

As certain deadlines for SOFR adoption approach us, there has been increased attention to modeling concerns under the new rate, motivated by uncertainties surrounding SOFR's implementation in practice. To replace a benchmark such as the 3-month LIBOR, either a 3-month backward-looking compound average of SOFR or a 3-month SOFR forward-looking term rate would be needed. It has been shown in literature that the traditional LIBOR Market Model (LMM) can be naturally extended to the backward-looking case (Lyashenko & Mercurio, 2019).

Another point of contention in the transition context has been the prospect of compound averaging of SOFR versus a true term SOFR for inclusion in fallback language and market use beyond the transition period. In a recent conference organized by the ARRC, multiple market participants expressed their specific concerns on this controversy. While derivative users are keen on accepting average compounding of SOFR to replace LIBOR, some industry players that hold LIBOR-indexed business loans are not fond of this option, as the required interest payment is not known until a few days before the payment is due, due to compounding in arrears over the corresponding LIBOR tenor (Wipf & Morzaria, 2021). However, a proper SOFR term rate is not available for use by market participants at the time of writing. Heitfeld & Park (2019) presented a method to compute implied SOFR term rates from future contract prices, while caveating such an estimate was not appropriate for use as a benchmark. Instead, the ARRC (2020) announced in April of 2020 that it would work toward fostering a more robust SOFR derivatives market to make possible transaction-based SOFR term rates, and has already requested proposals from parties interested in publishing these rates daily. Nonetheless, the ARRC has moved forward with their initial recommendation of SOFR compound averages over LIBOR tenors plus a spread adjustment for use in fallback language.

Due to the recent and emerging nature of this topic, a multiplicity of questions remains unanswered. For instance, recall the observation that LIBOR offers an "insurance" to banks with LIBOR-indexed exposure (this is assumed for most banks, as they usually hold LIBOR-indexed business loans). This is because LIBOR rises in times of financial distress, increasing cash inflows to banks when needed the most (Jermann, 2019). A study providing a theoretical valuation of this insurance may suggest an alternative way to adjust the spreads. Furthermore, many of the observations presented by Jermann focus on the US case. Future research could attempt to replicate his results in other economies undergoing similar LIBOR reforms to find out if international markets and their respective new reference rates show the same dynamics. We expect that the idiosyncratic regulatory framework of other economies will affect the degree to which the local IBOR is affected by financial distress.

What we know about SOFR

SOFR is usually characterized as a risk-free rate derived from transactions in the large and highly liquid repo market. That said, SOFR is affected by a set of idiosyncrasies it inherits from the repo market. Klingler & Syrstad (2020) present a thorough analysis and discussion of some factors that uniquely affect SOFR and other similar benchmarks abroad. They point out that the SOFR-Overnight LIBOR spread fluctuates significantly between -15 and +15 basis points, even though they both represent overnight lending by low-risk borrowers and should be close to the risk-free policy rate. This observation underscores the importance of understanding the factors driving SOFR's movements away from the policy risk-free rate, as even small movements can have large effects in valuation of interest-rate derivatives of huge notional values.

Klingler & Syrstad (2020) note that repo market underlying SOFR comprises of collateralized transactions consisting of bank-to-bank, non-bank-to-bank, and bank-to-non-bank lending. From this observation, the authors first hypothesize that, under tighter regulatory constraints banks' need for cash and reluctancy to lend would drive rates up in a market where banks are lenders. Second, they hypothesize that increases in government debt will drive increases in SOFR, as (1) lenders prefer Treasuries over lending to banks, which decreases supply, and (2) more government debt in the system induces higher demand for collateralized borrowing. Third, they hypothesize that, absent ample reserves, a decrease in bank reserves with the Fed will increase bank's demand for borrowing and drive rates higher. The authors use regression analysis to test their hypothesis. They find that SOFR is indeed higher by 20.25 basis points on average on quarter-end regulatory reporting dates. Across several tests, they find a strong positive link between SOFR and government debt, measured as total Treasuries outstanding, as well as a negative link between SOFR and bank reserves.

While Klingler & Syrstad focus on the new reference rates and compared their relations to key financial variables, they do not center their analysis around how the new rates are different from their respective IBOR rates. That said, their methods suggest a simple way to study the spread between the old and new reference rates, such that the quantitative results can drive useful insights on the differences between new and old rates, as well as help assess the overall significance of this transition for market participants.

Analysis

Our objective is to further the understanding of how SOFR and LIBOR differ. To this purpose, we present a regression analysis of the historical LIBOR-SOFR spread. We consider the two most used LIBOR tenors: the 3-month and 1-month term LIBOR rates. We form our dependent variables by calculating their difference to SOFR at a daily frequency, and then compute monthly averages of the two spread to analyze them at a monthly frequency. In total, we perform 2 daily regressions and 2 monthly regressions – 1 per LIBOR tenor per frequency. We include details about our daily and monthly frequency analyses below.

Daily Analysis

For our daily frequency analyses, we only consider metrics directly related to the interest rate environment. We first identify three ways in which SOFR and LIBOR are fundamentally different:

1. LIBOR is a term rate, while SOFR is an overnight rate. Thus, LIBOR is affected by term structure while SOFR is not.
2. LIBOR mostly affected by bank liquidity while SOFR is mostly affected by liquidity in the Treasury markets.
3. LIBOR reflects unsecured borrowing by banks, and thus includes a bank credit risk premium, while SOFR is collateralized and thus virtually risk-free.

We assume the following equation describes the relationship between the above factors and the LIBOR-SOFR spread:

$$1 + s_{t,T} = (1 + \tau_{t,T})(1 + \lambda_{t,T})(1 + \rho_{t,T})(1 + \epsilon_{t,T})$$

The subscript t corresponds to each day. The variable $s_{t,T}$ corresponds to the spread of USD LIBOR of tenor T to overnight SOFR. The variables $\tau_{t,T}$, $\lambda_{t,T}$, and $\rho_{t,T}$ represent appropriate measures for term structure, liquidity and bank credit risk expressed as rates, which vary each day and with their corresponding tenor. The error variable $\epsilon_{t,T}$ represents random noise in the LIBOR-SOFR spread. To study this relationship through a linear regression, we apply a logarithmic transformation to obtain the following expression:

$$\ln(1 + s_{t,T}) = \ln(1 + \tau_{t,T}) + \ln(1 + \lambda_{t,T}) + \ln(1 + \rho_{t,T}) + \ln(1 + \epsilon_{t,T})$$

$$\ln(1 + s_{t,T}) = \ln(1 + \tau_{t,T}) + \ln(1 + \lambda_{t,T}) + \ln(1 + \rho_{t,T}) + u_{t,T}$$

We study the last equation by a regression analysis. If our metrics for term, liquidity and risk are appropriate, we would expect coefficients next to the logarithmic terms to be close to 1.

As SOFR is only formally available since April 2018, we use SOFR proxies to study the behavior of the spread before 2018 and include the financial crisis years. We use a hypothetical SOFR rate provided by the Federal Bank of New York to cover the months starting August 2014 to March 2018. For all previous dates, we use the Prime Dealer Survey rate. For our independent variables that account for LIBOR and SOFR's inherent differences, we pick three metrics that represent each one. To capture term structure, we compute the difference between 3-month and 1-month OIS rates and the Fed Funds rate. This is a measure of prevailing term structure of the risk-free interest rate. To capture liquidity differences, we compute the difference between 3-month and 1-month OIS rates and 3-month and 1-month Treasury yields. This spread is a proxy for banks' liquidity penalty over the hyper-liquid treasury markets. Lastly, to account for bank credit risk, we introduce risk premium metric based on LIBOR panel banks' CDS spreads, computed in an analogous fashion to LIBOR. We choose CDS spreads to account for bank credit risk as they have been shown to reflect the risk implied by key balance sheet ratios (Chiaramonte & Casu, 2010). We note that our CDS measure is based almost fully on 1-year CDS spreads for senior unsecured bank debt. The mismatch in term is likely to negatively affect the fit – however, we lack other widely available measures of bank default risk, especially for 1-month and 3-month tenors. We thus use a single risk premium metric for both tenors, i.e., we impose $\rho_{t,\,1M} = \rho_{t,\,3M} = \rho_t$. Moreover, data for all LIBOR panel banks is not included, due to lack of availability. The banks included in the calculation of our CDS-based risk measure are Citibank, Credit Suisse, J.P. Morgan, UBS, Bank of America, Barclays, and RBC. Our full range of data for the daily analysis covers the dates from January 1st, 2002 to December 18th, 2020, which accommodates recent data availability.

A table with each variable included in our daily regression analyses, a detailed description, predicted sign of coefficient, and data source is included below:

Table 1. Daily Frequency Analysis: Variable Descriptions

Variable	**Description**	**Source**	**Predicted Sign**
DEPENDENT VARIABLES			
$s_{t,\,1M}$	Spread of the 1-month USD LIBOR to overnight SOFR or its proxies.	Bloomberg, Federal Reserve of New York	N/A
$s_{t,\,3M}$	Spread of the 3-month USD LIBOR to overnight SOFR or its proxies.	Bloomberg, Federal Reserve of New York	N/A
INDEPENDENT VARIABLES			
Term (1M) $\tau_{t,\,1M}$	Difference between the 1-month OIS rate and the Federal Funds rate.	Bloomberg	(+)
Term (3M) $\tau_{t,\,3M}$	Difference between the 3-month OIS rate and the Federal Funds rate.	Bloomberg	(+)
Liquidity (1M) $\lambda_{t,\,1M}$	Difference between the 1-month OIS rate and the prevailing 1-month Treasury bill yield.	Bloomberg	(+)

Liquidity (3M) $\lambda_{t,3M}$	Difference between the 3-month OIS rate and the prevailing 1-month Treasury bill yield.	Bloomberg	(+)
Risk ρ_t	A CDS-based measure of bank default risk. We consider the CDS spreads of LIBOR panel banks. We include only CDS spreads that are based on contracts referencing senior unsecured debt. For each day, we use a waterfall method to compute the daily risk metric. First, we average the CDS spreads of contracts available for each bank, for each date. If no 1-year quotes for a given bank are available, we look for 5-year CDS quotes and take their mean when available. Then, we take the mean of the interquartile range of banks' average CDS spreads each day. This procedure is analogous to the one used to calculate LIBOR daily, for each tenor.	IHS Markit	(+)

Monthly Analysis

Our monthly analysis is two-folds. First, we repeat the idea in our daily analysis on a monthly frequency, by regressing the monthly average of the LIBOR-SOFR spread on monthly averages of the fixed-income factors identified above. Second, taking into consideration remarks in Shrimpf & Sushko (2019) and Jermann (2019), we hypothesize that LIBOR's spread to a risk-free rate such as SOFR is affected by conditions in the economy and financial markets. In a second regression, we consider metrics to account for each of the following economic dimensions:

1. Forward-looking economic sentiment
2. Real economic activity
3. Financial market volatility
4. Monetary policy and reserves
5. Treasury market liquidity

We include (1) the month-over-month change in the Consumer Confidence Index to account for forward-looking economic sentiment, (2) month-over-month change in Industrial Production to account for real economic activity, (3) the VIX index to account for financial markets' volatility, (4) month-over-month changes in bank reserves with the Federal Reserve system, and (5) total Treasury market trading volumes as a measure of liquidity in the Treasury and money markets. To correct for any end-of-month idiosyncrasies, we take the monthly average of the LIBOR-SOFR spread and other daily variables included in our second regression.

The following equations describe the proposed relationship between the LIBOR-SOFR spread and dependent variables:

$$s_{t,T} = \tau_{t,T} + \lambda_{t,T} + \rho_t + \epsilon_{t,T} \quad \text{(I)}$$

$$s_{t,T} = b_0 + b_1 \cdot \Delta CC_t + b_2 \cdot \Delta IP_t + b_3 \cdot VIX_t + b_4 \cdot \Delta BR_t + b_5 \cdot \Delta TV_t + \epsilon_{t,T} \quad \text{(II)}$$

A table listing each variable included in our monthly regressions, a detailed description, predicted sign of coefficient, and data source is included below:

Table 2. Monthly Frequency Analysis: Variable Descriptions

Variable	**Description**	**Source**	**Predicted Sign**
DEPENDENT VARIABLES			
$s_{t,1M}$	Monthly average of the daily spread of the 1-month USD LIBOR to overnight SOFR or its proxies.	Bloomberg, Federal Reserve of New York	N/A
$s_{t,3M}$	Monthly average of the daily spread of the 3-month USD LIBOR to overnight SOFR or its proxies.	Bloomberg, Federal Reserve of New York	N/A
INDEPENDENT VARIABLES			
Term (1M) $\tau_{t,1M}$	Monthly average of the difference between the 1-month OIS rate and the Federal Funds rate.	Bloomberg	(+)
Term (3M) $\tau_{t,3M}$	Monthly average of the difference between the 3-month OIS rate and the Federal Funds rate.	Bloomberg	(+)
Liquidity (1M) $\lambda_{t,1M}$	Monthly average of the difference between the 1-month OIS rate and the prevailing 1-month Treasury bill yield.	Bloomberg	(+)

Liquidity (3M) $\lambda_{t,\,3M}$	Monthly average of the difference between the 3-month OIS rate and the prevailing 1-month Treasury bill yield.	Bloomberg	(+)
Risk ρ_t	Monthly average of our daily CDS-based measure of bank default risk. Computed as described above.	IHS Markit	(+)
ΔCC_t	Month-over-month percentage change in the Consumer Confidence Index	Bloomberg	(−)
ΔIP_t	Month-over-month percentage change in Industrial Production	Bloomberg	(−)
VIX_t	Monthly average of the CBOE Volatility Index	Bloomberg	(+)
ΔBR_t	Month-over-month percentage change in bank reserves with the Federal Reserve system.	Bloomberg	(+)
ΔTV_t	Month-over-month percentage change in Treasury volumes.	Bloomberg	(−)

The justification for the predicted sign for each new variable is as follows. Consumer Confidence and Industrial Production increase when economics are good, while LIBOR tends to decrease in such times as bank default risk subsides. At the same time, the risk-free rate also tends to increase during booms. Thus, the expected sign of coefficients next to ΔCC_t and ΔIP_t is negative. The VIX, which measures volatility in the equity markets, tends to shoot upward in times of financial distress, which usually coincides with falling rates and rising default risk. Thus, we expect its coefficient to be positive. Bank reserves have at least two effects over the LIBOR-SOFR spread. First, during periods of financial distress, the Federal Reserve tends to increase bank reserves to prevent liquidity shortages. This effect suggests bank reserves increase as LIBOR increases. Second, bank reserves are somewhat negatively correlated with SOFR, as banks with higher reserves have lower demand for borrowing in the repo markets, as shown by Klingler & Syrstad (2020). Both effects amplify the LIBOR-SOFR spread, so we expect the coefficient of ΔBR_t to be positive. Lastly, liquidity in the treasury markets is usually higher in financially healthy periods, and Klingler & Syrstad (2020) show treasury volumes are positively correlated with SOFR. Thus, the coefficient of ΔTV_t is expected to be negative.

Results

Daily Analysis Results

The results of our daily regressions are found in the tables below. *T*-statistics appear below each coefficient in parentheses, and *, **, and *** denote coefficients significantly different from zero at the 10%, 5%, and 1% level, respectively.

Table 3. Daily, 1M regression results

Independent Variable	$\ln(1 + s_{t,1M})$
Intercept	–0.000438***
	(–7.39)
$\ln(1 + \tau_{t,1M})$	0.3595***
	(9.80)
$\ln(1 + \lambda_{t,1M})$	0.8471***
	(56.68)
$\ln(1 + \rho_t)$	0.2187***
	(21.81)
Years	2002–2020
R^2	0.43

Table 4. Daily, 3M regression results

Independent Variable	$\ln(1 + s_{t,3M})$
Intercept	0.000124*
	(1.90)
$\ln(1 + \tau_{t,3M})$	0.7138***
	(25.60)
$\ln(1 + \lambda_{t,3M})$	1.110***
	(49.79)
$\ln(1 + \rho_t)$	0.4711***
	(42.32)
Years	2002–2020
R^2	0.46

All three variables are significant at the even stricter 0.001 level, for both terms. We show that liquidity and term structure differences between LIBOR tenors and SOFR are significant as captured by our liquidity and term premium metrics. As expected, both variables have positive coefficients, so relative term structure and relative liquidity in the OIS market are acceptable proxies for equivalent features determining LIBOR. Moreover, our CDS-based risk premium measure is also highly significant in both regressions, even though CDS spreads used to compute it correspond to 1-year term credit risk.

Despite the achieved significance, our coefficients are mostly significantly different from one. An exception may be our liquidity measure, whose coefficient is closest to one. In general, excess noise in our metrics may not only hurt the overall fit but dampen the coefficients. Moreover, our risk measure has a term that does not match that of either LIBOR tenor. We achieve an R^2 of 0.426 in our 1M spread regression, and an R^2 of 0.466 in our 3M spread regression. The slightly higher R^2 in the 3M case may be driven by the fact that the risk measure is based on 1-year CDS contracts, closer to 3 months than 1 month. Indeed, the risk measure coefficient moves closer to 1 at 0.47 versus 0.22 in the 1-month case. Unfortunately, a more precise measure for 3-month or 1-month bank default risk was hard to come by, as CDS data is available for contracts with a minimum of 6 months in tenor. In fact, the spread of LIBOR to same tenor treasuries is taken as the standard measure for bank credit risk over shorter maturities.

To study where the fit is most lacking, we produce a plot of the regression residuals in the 3-month and 1-month case.

Exhibit 1. Daily, 1M regression residuals

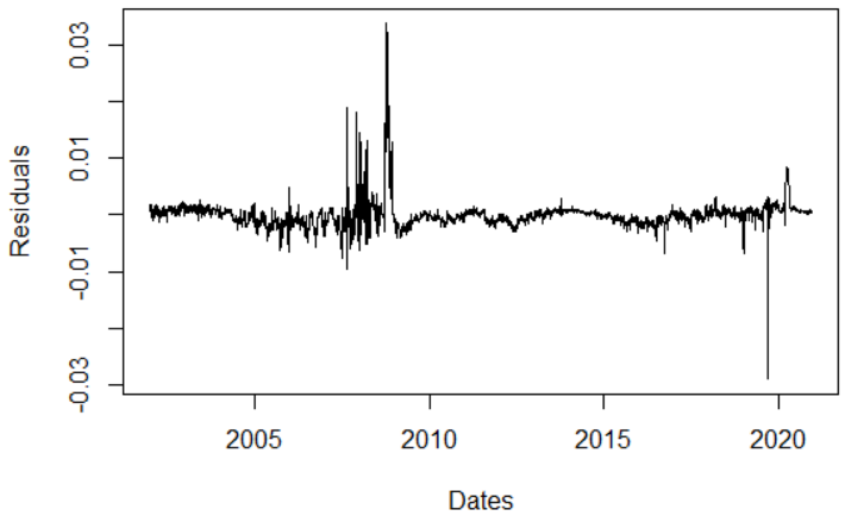
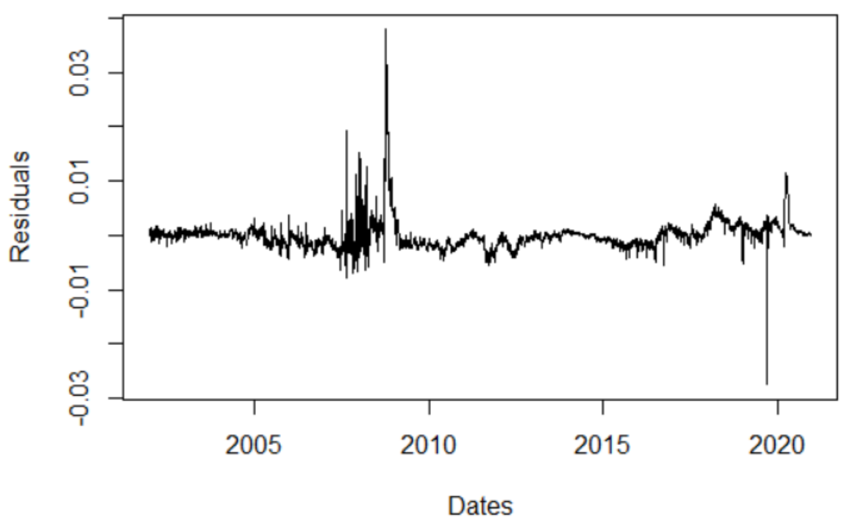


Exhibit 2. Daily, 3M regression residuals



Both graphs are rather similar and reveal lack of fit is especially severe during the financial crisis years, in 2007 and 2008. This is intuitive, as banks short term credit risk dominated the hikes in LIBOR, and we do not have a risk measure that exactly captures this risk in the appropriate tenor. There is an outlier corresponding to September 17, 2019, which corresponds to a day with an abnormal lack of liquidity in the repo markets which caused the Federal Reserve to intervene. To better understand which variables are providing the most explanatory power, we will present a variance decomposition procedure.

Daily Analysis: Variance Decomposition

We are also interested in understanding the explanatory power each variable contributes to the LIBOR-SOFR spread. To achieve this, we present a variance decomposition procedure to be conducted as follows. We record the R^2 achieved when one variable is removed, and the others are kept in the regression. The difference between this figure and the R^2 of the full regression is the contribution statistic for each variable. Proceeding in this fashion, we obtain the following tables.

Table 5. Daily, 1M variance decomposition

	Additional R^2	% of Total
$\tau_{t,1M}$	0.0111	2.53%
$\lambda_{t,1M}$	0.3706	84.89%
ρ_t	0.0549	12.57%
Total	0.4365	100.00%

Table 6. Daily, 3M variance decomposition

	Additional R^2	% of Total
$\tau_{t,3M}$	0.0710	13.31%
$\lambda_{t,3M}$	0.2687	50.34%
ρ_t	0.1940	36.35%
Total	0.5338	100.00%

We see significant differences in additional R^2 across the two tenors. The term structure term is more important in the 3-month case than in the 1-month case. This can be rationalized as a 1-month tenor is less different from an overnight tenor than a 3-month tenor is. In both cases, however, the term structure measure contributes the least explanatory power according to our decomposition method. In turn, the liquidity measure is the most important by this metric in both cases, contributing more than half the explanatory power in both cases and close to 85% in the 1-month case. The risk measure is much more important in the 3-month case than in the 1-month case, contributing over 36% of explanatory power in the former while less than 13% in the latter. We hypothesize this is due to the underlying term of the risk measure (one year). This analysis provides further evidence that liquidity is the best measured variable, with coefficients closest to one and most explanatory power.

Monthly Analysis Results

The results of our monthly regression are found in the tables below. In our monthly regression, all rate-like variables are in basis points, and all change variables are in percentage points. *T*-statistics appear below each coefficient in parentheses, and *, **, and *** denote coefficients significantly different from zero at the 10%, 5%, and 1% level, respectively.

Table 7. Monthly, 1M regression results

I. Fixed Income factors

Independent Variable	$s_{t,\,1M}$
Intercept	–6.9358**
	(–2.23)
$\tau_{t,\,1M}$	0.0926
	(0.34)
$\lambda_{t,\,1M}$	0.9476***
	(11.88)
ρ_t	0.2420***
	(4.68)
Years	2002–2020
R^2	0.50

Table 8. Monthly, 1M regression results

II. Economic factors

Independent Variable	$s_{t,\,1M}$
Intercept	–2.3608
	(–0.44)
ΔCC_t	–0.7593***
	(–3.73)
ΔIP_t	1.6213
	(1.02)
VIX_t	1.0900***
	(4.26)
ΔBR_t	0.2827***
	(6.78)
ΔTV_t	–0.1596**
	(–2.45)
Years	2002–2020
R^2	0.42

Table 9. Monthly, 3M regression results

I. Fixed Income factors

Independent Variable	$s_{t,\,3M}$
Intercept	1.7168
	(0.48)
$\tau_{t,\,3M}$	0.6857***
	(4.08)
$\lambda_{t,\,3M}$	1.1419***
	(9.65)
ρ_t	0.4494***
	(7.44)
Years	2002–2020
R^2	0.48

Table 10. Monthly, 3M regression results

II. Economic factors

Independent Variable	$s_{t,3M}$
Intercept	5.0529
	(0.83)
ΔCC_t	–0.6035***
	(–2.61)
ΔIP_t	–0.4327
	(–0.24)
VIX_t	1.4140***
	(4.86)
ΔBR_t	0.2829***
	(5.96)
ΔTV_t	–0.1584**
	(–2.14)
Years	2002–2020
R^2	0.41

On the fixed-income factor regressions, we find that our averaged risk and liquidity premiums remain significant. However, our term premium metric does not achieve significance in the 1-month spread case. The cause of weaker correlation may be averaging the variable over the term it is supposed to account for, as it could cease to be meaningful. Notably, a higher R^2 is achieved in our monthly regressions compared to our daily analysis. We attribute this phenomenon to the averaging out of noise in the spread that is not correctly captured by our fixed income factors in a daily basis.

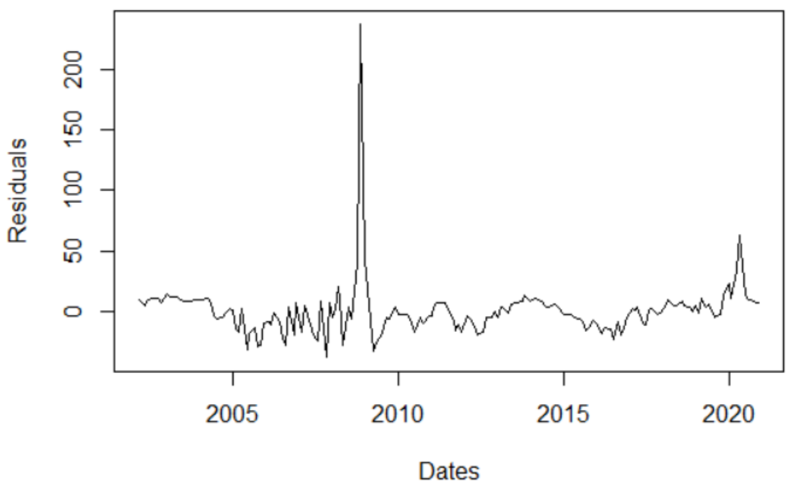
On the economic factor regressions, it is important to note that a lower R^2 is achieved on either term, as compared to our fixed-income analysis. We can infer that fixed-income factors are better at explaining the LIBOR-SOFR spread than solely economic factors. That said, the economic regressions do achieve meaningful R^2 of over 0.4 on both terms, which suggest economic variables can in fact explain much of the spread.

VIX is highly significant on both terms. VIX captures risk and “fear” in the broader financial markets, which usually correlates with the TED spread, a proxy for LIBOR’s credit risk component. Recall that VIX is calculated from S&P500 stock options over the next 30 days. Thus, the “term” in the risk measured by VIX is one month, which corresponds to 1M LIBOR tenor and is also closer to three months than one year is. We may have that VIX is a better proxy for bank credit risk over 1 or 3 months. However, we recognize VIX is fundamentally different from any direct measures of credit risk, such as bond spreads or CDS spreads. Change in Consumer Confidence is highly significant in both regressions, and bears a negative coefficient, as expected. However, change in Industrial Production fails to be significant in both regressions and its coefficients have inconsistent signs. This may be due to the fact that IP is a backward-looking variable, while 1M and 3M LIBOR are inherently forward-looking with respect to the risk they capture. Changes in bank reserves also turn out to be significant in both regressions, with positive coefficients consistent with our observation that the Fed increases bank reserves in times of financial distress, which coincide with periods of high LIBOR. We recall that Klingler & Syrstad (2020) report an moderate inverse relationship between SOFR and bank reserves, suggesting that, all else equal, the LIBOR-SOFR spread would widen with rising reserves, so both effects contribute in the same direction. Lastly, changes in treasury trading volumes are also significant in both cases, with a negative coefficient as expected. More liquidity in periods of financial health and a positive relation between SOFR and treasury volume described by Klingler & Syrstad (2020) drive the sign in the same direction.

To visualize goodness of fit, we produce residual plots for all four regressions. We then discuss how the fit differs between terms and between the two sets of factors.

Exhibit 3. Monthly, 1M regression residuals

I. Fixed Income factors



II. Economic factors

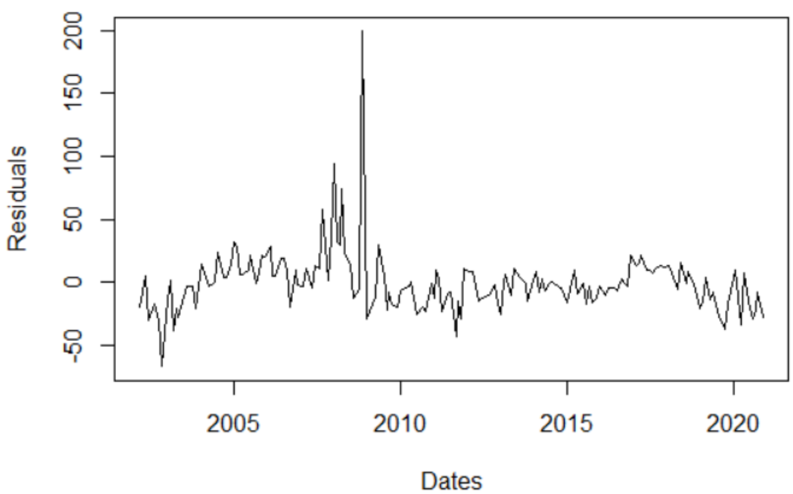
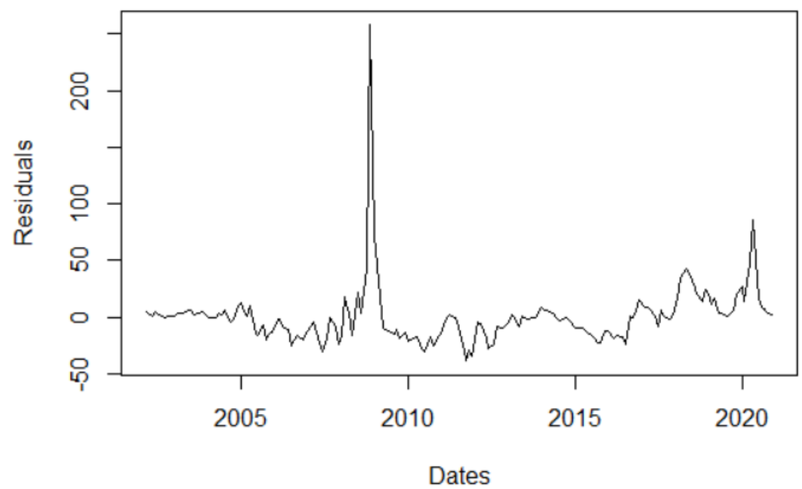
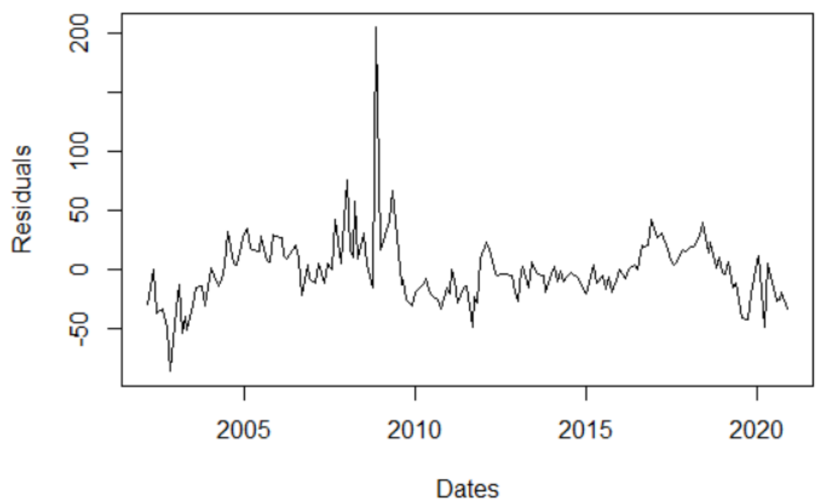


Exhibit 4. Monthly, 3M regression residuals

I. Fixed Income factors



II. Economic factors



The most extreme outliers correspond to financial crisis months and are present in all four regressions. Our observation is again that our variables cannot quite capture the extreme widening of the spread during worst months of 2008. That said, the outliers are more moderate in the economic regressions. Similarly, the 2020 COVID crisis outliers are only noticeable in the fixed-income regressions. We hypothesize this is accountable to the VIX, which captures short-term risk in the financial markets more precisely than 1-year bank CDS spreads. Monthly averaging of the spread may however dampen the spikes in LIBOR observed during the financial crisis and the spike in SOFR from September 17, 2019.

Monthly Analysis: Variance Decomposition

We are interested in the contribution of each included variable to the aggregate explanatory power of our models. Again, we present a variance decomposition procedure based on additional R^2. We record the R^2 achieved when one variable is removed, and the others are kept in the regression. The difference between this figure and the R^2 of the full regression is the contribution statistic for each variable. Proceeding in this fashion, we obtain the following tables.

Table 11. Monthly, 1M variance decomposition

I. Fixed Income factors

	Additional R^2	% of Total
$\tau_{t,\,1M}$	0.0003	0.00%
$\lambda_{t,\,1M}$	0.4500	86.07%
ρ_t	0.0698	13.93%
Total	0.5228	100.00%

Table 12. Monthly, 1M variance decomposition

II. Economic factors

	Additional R^2	% of Total
ΔCC_t	0.0525	16.49%
ΔIP_t	0.0039	1.23%
VIX_t	0.0679	21.33%
ΔBR_t	0.1716	53.91%
ΔTV_t	0.0224	7.04%
Total	0.3183	100.00%

Table 13. Monthly, 3M variance decomposition

I. Fixed Income factors

	Additional R^2	% of Total
$\tau_{t,\,1M}$	0.0555	10.07%
$\lambda_{t,\,1M}$	0.3109	56.39%
ρ_t	0.1849	33.54%
Total	0.5513	100.00%

Table 14. Monthly, 3M variance decomposition

II. Economic factors

	Additional R^2	% of Total
ΔCC_t	0.0258	9.64%
ΔIP_t	0.0002	0.28%
VIX_t	0.0896	33.47%
ΔBR_t	0.1347	50.32%
ΔTV_t	0.0174	6.50%
Total	0.2677	100.00%

We first observe that total additional R^2 is considerably lower than the R^2 of the full model in the economic regressions. This suggests there is significant correlations between our economic variables, as one might expect. In contrast, total additional R is higher than model R in the fixed income regressions. This points to lower correlation between fixed income variables. This supports our claim that the three variables represent three distinct features of fundamental difference between SOFR and LIBOR.

On the fixed income regressions, we note that the liquidity measure is again most important in explaining the LIBOR-SOFR spread given our methods. As for the risk measure, we obtain similar results to our daily analysis. It gains explanatory power in the 3-month case, as expected. Our term measure, however, suffers significantly in the 1-month case, likely due to monthly averaging. It remains a significant explanatory variable in the 3-month case, but behind liquidity and risk in importance.

On the economic regressions, changes in bank reserves are the most important factor, followed by VIX and consumer confidence. This result is sensible if we consider that changes in reserves are the most related to changes in bank liquidity our of all our economic factors, and we know this is an important differentiator between SOFR and LIBOR from our previous regressions. VIX and consumer confidence serve as proxies for the risk measure, as they capture current expectations about the near future of the economy. Changes in treasury volume also adds significant information, as it is an additional measure of liquidity in the financial markets. In contrast, change in Industrial Production does not have the same property. As we discussed earlier, this variable may be too backward looking and cannot offer additional information after forward-looking economic expectations are accounted for.

Conclusion

As LIBOR's end nears, it is increasingly important for market participants to understand how the transition will take place, as well as how is newcomer SOFR different from the old well-known rate. Fundamentally, LIBOR is different from SOFR in term, liquidity, and risk. Regressing the LIBOR-SOFR spread on measure for each of these three factors at a daily frequency shows they are all in fact significant. LIBOR users will benefit from understanding how changes in the economy's yield curve, bank liquidity and bank credit risk has affected their pricing and how this will change with the introduction of a compound average of overnight SOFR to replace LIBOR. Relating the spread to a broader set of economic variables at a monthly frequency reveals how the spread differs under different economic environments. We show the spread correlates with changes in the economic outlook, volatility in the equity markets, changes monetary policy and Fed actions, and changes in liquidity in the treasury markets. In general, our results are in line with the observations by Schrimpf & Sushko (2019) and Jermann (2019) that LIBOR is higher in economic downturns that significantly affect the financial sector.

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