

Short-Term Rate Benchmarks: the Post-LIBOR Regime

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Abstract

LIBOR, the predominant family of global short-term rate benchmarks for the past 40 years, ceased to exist in June 2023. Given the low volumes of interbank loans on which LIBOR had been based, the revelations that LIBOR had been manipulated, and the risks that countless LIBOR-dependent financial instruments without fallback rates would be cast into limbo, regulators over the last decade pushed to replace LIBOR with risk-free overnight rate benchmarks. In the United States, the new benchmark, SOFR, is an overnight rate based on U.S. Treasury repo transactions; use of term rates and derivatives on term rates is limited; and use of credit-sensitive term rates is discouraged. This paper recounts the rise and fall of LIBOR; reviews the academic literature on the efficiency benefits of benchmarks, the LIBOR scandal, and the pros and cons of risk-free vs. credit-sensitive rate benchmarks; and calls for further academic work on the current policy of entrenching a single-benchmark SOFR regime relative to the alternative of encouraging a two- or multi-benchmark regime of SOFR and one or more credit-sensitive term rates.

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1. INTRODUCTION

Over the last 40 years, London Interbank Offered Rate (LIBOR) was the predominant family of short-term rate benchmarks around the world. Interest rates on business loans, adjustable-rate mortgages, corporate floating-rate notes, interest rate derivatives— futures, options, forward rate agreements (FRAs), and interest rate swaps (IRS), and some retail credit products were all set off LIBOR.

LIBOR for each currency and term was fixed every day from responses to a survey asking large banks about their costs of borrowing funds from each other. In the years after the financial crisis of 2007-2009, however, LIBOR was judged to be unsustainable. First, post-crisis changes in bank regulation and quantitative easing combined to reduce the volumes of interbank borrowing dramatically. Second, it was gradually revealed that many professionals at many financial institutions had intentionally misstated their LIBOR submissions, both to understate their costs of funds during the crisis and to earn profits on LIBOR-linked positions over a longer period of time.

Regulators around the world eventually decided to abandon LIBOR and transition to risk-free rate benchmarks (RFRs) that were calculated either from overnight bank funding transactions or from overnight repo transactions, in which one party borrows from another on government collateral. Some jurisdictions, in addition to RFRs, reformed and kept LIBOR-like credit-sensitive rate benchmarks (CSRs), including the Euro Interbank Offered Rate (Euribor). In any case, once LIBOR's fate was sealed, the transition had to be pursued with urgency: vast numbers of financial instruments were linked to LIBOR without any provisions for a fallback rate.

In the United States, regulators decided to transition from LIBOR to the Secured Overnight Financing Rate (SOFR), which is a repo-based RFR. The transition is mostly accomplished in derivatives markets, but has proved more challenging in “cash” or loan markets, in which borrowers have historically preferred the certainty of term rates and

banks have wanted to keep the interest on their loans linked to a CSR that increases with their funding costs. Regulators have recently and somewhat reluctantly allowed the use of SOFR-based term rates, but have not encouraged CSRs.

Section 2 of this paper provides some necessary background on how short-term rate benchmarks are used in loans and derivatives. Section 3 recounts the history of LIBOR, and Sections 4, 5, and 6 review the academic literature on the efficiency benefits of benchmarks, the LIBOR scandal, and various aspects of RFRs and CSRs. The paper builds up to a call for academic work on a significant contemporary policy question: should short-term rate benchmark policy in the United States continue to push toward a single-benchmark, SOFR-based regime or should the development of CSRs be encouraged alongside SOFR toward a multi-benchmark regime? Section 7 concludes.

2. Primer: Euribor- and SOFR-linked Loans and SOFR Futures

This section begins with a brief and somewhat simplified description of Euribor- and SOFR-linked loans. These two benchmarks, in addition to their importance in the post-LIBOR world, illustrate the difference between calculating “set in advance” interest based on term rates and “set in arrears” interest based on overnight rates. The section then explains how term SOFR rates can be implied from SOFR futures and elaborates on the distinction between RFRs and CSRs.¹

Consider a €100 million 3-month or 92-day deposit from March 15 to June 15, and say that Euribor for settlement on March 15 is 1.50%. Then, using the appropriate conventions, the interest payable on the deposit on June 15 is €100,000,000 × 1.5% × 92/360 or €383,333. Interest on a term rate like Euribor is said to be “set in advance and paid in arrears,” which means that the interest rate is determined at the beginning of the period— here March 15— and the interest amount is payable at the end of the period— here June 15. For this reason, term rates are called forward-looking rates. Interest payments on a multi-year floating rate loan or a floating-rate note with quarterly resets are computed each quarter in the same way: the rate to be earned over each quarter is set to Euribor at the beginning of the quarter, often plus a spread, and the interest amount payable each quarter is paid at the end of the quarter.

SOFR is calculated each day by the Federal Reserve Bank of New York as a trimmed volume-weighted median of rates on government repo transactions. For the sake of example, assume that, over the 92 days from March 15 to June 15, SOFR is 2.95% on 20 of those days; 3.0% on 40 of the days; and 3.05% on 32 days. Then, a \$100 million daily-compounded SOFR loan grows over the period to

$$\$100,000,000 \left(1 + \frac{2.95\%}{360}\right)^{20} \left(1 + \frac{3.0\%}{360}\right)^{40} \left(1 + \frac{3.05\%}{360}\right)^{32} = \$100,771,260.25 \quad 1.$$

The interest earned of \$771,260.25 mathematically corresponds to a term rate of 3.018%, because $\$100,000,000 \times 3.018\% \times 92/360 = \$771,260.25$, but that term rate is not known until every SOFR rate over the period has been realized. For this reason, overnight rate benchmarks are “backward-looking” and are “set in arrears and paid in arrears”, which

¹For simplicity, this presentation abstracts from exact settlement dates and payment details. For more on this and other details, see Tuckman & Serrat (2022), Chapter 12.

means that the interest rate or payment is both set and paid at the end of the period— here June 15. Interest payments on a multi-year floating rate loan or a floating-rate note with quarterly resets are computed similarly, that is, interest is set and paid at the end of each quarter based on the daily values of SOFR, often plus a spread, that were realized over the quarter.

A SOFR futures contract can be used to hedge or lock in future lending or borrowing at SOFR. To illustrate, consider the March three-month SOFR contract. By design, if the market rate on this contract as of March 15 is 3.018%, then the profit from buying a contract on March 15 and holding it through June 15 is proportional to the difference between 3.018% and the term rate that corresponds to realized compounded overnight SOFR from March 15 to June 15. Now consider a bank that lends money from March 15 to June 15 at SOFR. This bank can lock in a rate of 3.018% by buying March contracts on March 15 and rolling daily compounded overnight SOFR loans from March 15 to June 15. If the realized term SOFR rate as of June 15 turns out to be 4.018%, the bank will have made 4.018% on its cash market lending, but will have lost 1% on its futures position, for a total of 3.018%. And if realized term SOFR as of June 15 turns out to be 2.018%, then the bank will have made 2.018% on its lending and 1% on futures, again for a total of 3.018%. Therefore, 3.018% is considered the forward-looking SOFR term rate implied by SOFR futures contracts.

The last points to be made here concern the differences between CSRs and RFRs. Three-month Euribor is a CSR or credit-sensitive rate because it represents the borrowing cost of a bank over a three-month period, which incorporates credit and liquidity risks. By contrast, SOFR is an RFR because it represents the rate on a one-day, extremely safe collateralized loan. Short-term rate benchmarks that represent the one-day borrowing costs of large banks and, as such, embed minimal credit and liquidity risks, are also called RFRs. Finally, term rates derived from futures on RFRs are in no way CSRs. The rate on an RFR futures contract represents the market's pricing of the path of the overnight RFR. But because each day's rate has essentially no credit and liquidity risk, neither does the derived term rate.

3. The Rise and Fall of LIBOR

3.1. Early History

The 1950s through 1970s saw rapid growth in the Eurodollar market. Banks in Europe, particularly in London, accepted deposits denominated in USD (United States Dollar) and made USD loans to each other and to companies and governments around the world. The initial drivers of the market were Russia's wanting to hold dollars that were beyond the reach of the U.S. government and a more general desire to circumvent various U.S. regulations that restricted the international flow of funds and the gathering of deposits.²

The Eurodollar market typically traded short-term funds, with banks paying prevailing short-term rates on their liabilities and earning those short-term rates plus a spread on their assets. In 1969, however, a London branch of the New York-based Manufacturers Hanover arranged a novel multiyear syndicated loan of \$80 million to the Shah of Iran: the interest rate on the loan was adjusted every few months to equal the average cost of funds of the

²Friedman (1971).

large banks in the syndicate plus a spread. Other similar deals soon followed, along with issues of floating-rate notes.³

The British Bankers Association (BBA) eventually standardized and formalized the averaging of bank funding costs for use as short-term rate benchmarks. A panel of large banks was set for each of 10 currencies, and each bank was asked the following question each day for each of 15 terms (e.g., 1 month, 3 months, etc.): “At what rate could you borrow funds, were you to do so by asking for and then accepting interbank offers in a reasonable market size just prior to 11am?” LIBOR for each currency and term was then fixed as the trimmed mean of survey responses, with the highest and lowest 25% of responses discarded. Referencing LIBOR grew throughout the 1980s, for both syndicated loans and floating-rate bonds, and also for the rapidly-growing derivatives market, particularly Eurodollar futures and their over-the-counter equivalents, FRAs and IRS.

At the start of the 1980s, rates on U.S. Treasury bills, or T-bills, were firmly entrenched as the predominant interest rate benchmarks in U.S. money markets. Rates on nongovernment or “private” money market instruments, like commercial paper (CP) and large certificates of deposits (CDs), were quoted and traded as spreads to T-bill rates of corresponding maturities.

Over the course of the 1980s, however, LIBOR thoroughly displaced T-bills as the predominant USD short-term rate benchmark. First, LIBOR better reflected bank funding costs. Second, volumes of LIBOR-based cash and derivative products continued to increase. Third, during “flight-to-quality” or stress events, rates on private money market instruments tended to rise, while T-bill rates tended to stay the same or fall. In this way, positions in private paper and their T-bill “hedges” both lost money through the worst of these episodes. Fourth, idiosyncratic shocks to the U.S. Treasury debt market impacted T-bill rates but not rates on private instruments, again rendering T-bills poor hedges for private instruments.⁴

Use of LIBOR continued to grow in the decades to follow, including inroads into adjustable-rate mortgages and other forms of consumer credit. A highly-cited report in 2012 compiled very rough estimates of the volume of financial contracts referencing LIBOR: \$10 trillion of syndicated loans, \$3 trillion of floating-rate notes, and \$30 trillion of exchange-traded futures and options. The report also included about \$225 trillion of notional amounts of FRAs and IRS, but this greatly exaggerates the risk exposure of these derivatives to LIBOR, which was possibly more on the order of \$30 trillion.⁵ In any case, LIBOR had become deeply entrenched in financial markets.

Euribor—distinct and significantly more popular than EUR (Euro) LIBOR—was first published in 1999 to coincide with the birth of the Euro. There were originally 15 Euribor rates with tenors ranging from one week to 12 months. Panel banks submitted rates at which European prime banks could borrow funds from one another, and the Euribor fix at each tenor was calculated as the trimmed mean of the responses, after dropping the lowest and highest 15%.

³O’Malley (2015), pp. 47–50.

⁴Gyntelberg & Wooldridge (2008), Kreicher, McCauley & Wooldridge (2014), McCauley (2001), and Stigum (1990).

⁵Wheatley (2012), Table C.1, p. 76. Notional amounts, which add long and short swap positions between pairs of counterparties, can vastly overstate exposure to LIBOR. Applying a 2019 CFTC analysis for a very rough estimate of this overstatement reduces this \$225 trillion to less than \$30 trillion. See Baker *et al.* (2021).

3.2. The LIBOR Scandal and Early Reforms

Well into the financial crisis of 2007-2009, in April and May 2008, a number of articles in *The Wall Street Journal* suggested that LIBOR submissions of panel banks understated their true costs of funds. With banks distrusting each other's credit, the volume of inter-bank lending had fallen dramatically, particularly at longer tenors, which meant that many LIBOR submissions were based on judgment rather than transactions and were difficult to verify. Nevertheless, using other money market rates and credit default swap spreads, these newspaper articles and various interest rate strategists estimated, for example, that three-month USD LIBOR was 25 to 40 basis points below banks' true cost of funds. Buttressed by anecdotal evidence, the implication was that banks were intentionally lowballing their submissions to hide how their credit and liquidity profiles were perceived by lenders.⁶

These revelations triggered regulatory investigations around the world. Evidence surfaced that some firms had indeed directed personnel to keep submissions low, from as early in the crisis as August 2007. While only a few firms were directly accused of lowballing submissions, senior market participants believed at the time that lowballing was more widespread. In fact, there were allegations that the BBA and senior regulators knew about and perhaps even countenanced lowballing so as not to disrupt already fragile markets.⁷ Furthermore, over the course of these investigations, evidence surfaced that many traders at many firms had been trying to manipulate LIBOR and Euribor fixings in several currencies to profit on their own positions, with the earliest instances as far back as 2005. Because traders did not want to attract attention, these manipulations were often on the order of a few basis points or less, but that was enough to generate meaningful profits on their large positions.⁸ In any case, as the dust settled, over a hundred traders or brokers had been implicated; more than a dozen firms involved; and fines, judgments, and settlements totaled over \$11 billion.⁹

In reaction to the scandal, regulators around the world discussed proposals for reform. The conclusions of the most notable reports might be summarized as follows: LIBOR and Euribor should be reformed rather than replaced; benchmarks should be managed by independent administrators; to the extent possible, benchmarks should be based on actual funding transactions; publication of individual submissions should be delayed, to make it harder to abuse the system; and, to reduce the pervasiveness of the "ibors," RFR benchmarks should be developed and available to those who are really interested in exposure to rates, rather than bank funding costs.¹⁰ In addition, the European Union proposed in 2013 and adopted in 2016 a broad-ranging and explicit Benchmark Regulation (BMR), which encompassed the ibors.

In pursuit of this agenda, LIBOR passed from the BBA to the independent ICE Benchmark Administration (IBA), which is regulated by the United Kingdom's Financial Conduct

⁶Mollenkamp (2008a), Mollenkamp (2008b), and Mollenkamp & Whitehouse (2008).

⁷CFTC (2018); CFTC (2014), pp. 3, 14-16; House of Commons (2012), pp. 43-58; Department of Justice (2012a), pp. 15-22; Department of Justice (2012b); de la Merced & Protesse (2012); Mollenkamp (2008a); Vaughan & Finch (2017), pp. 51, 93, 162, 182 (note 7).

⁸Department of Justice (2012a), Department of Justice (2012b), and Vaughan & Finch (2017), pp. 160-161.

⁹Cone (2016); CFTC (2018); Dealbook (2016); FINNEWS (2020); Jarvis (2022); Department of Justice (2018); McBride (2016), p. 7; Pierson (2017); Stempel (2018); Stempel (2017); Trefis Team (2016); and Williams-Grut (2016).

¹⁰Wheatley (2012), IOSCO (2013), and FSB (2014).

Authority (FCA). Individual LIBOR submissions were published only after a delay of three months, and the family of 10 currencies and 15 tenors was culled to 5 currencies and 7 tenors. The IBA also began to develop longer-term plans to make submissions more dependent on actual transactions.

As for Euribor, the number of terms was reduced from 15 to five and, to increase the volume of underlying transactions, the benchmark was redefined as the rate at which European banks could borrow funds not just from each other, but from wholesale markets more broadly. Finding that the resulting volumes of transactions were still too small, a “hybrid methodology” was introduced, in which each submission would follow a “water-fall.” At Level 1, a submission is based solely on the rates of eligible transactions of the appropriate term. If transaction volume is insufficient to support a Level 1 submission, a Level 2 submission may use rates from transactions on a prior day and from interpolating rates of nearby terms. And if insufficient data exist for a Level 2 submission, a Level 3 submission may use rates from closely-related markets in combination with submitter models and judgment. In July 2019, regulators approved use of the reformed Euribor.

3.3. Ending LIBOR and the Transition to Risk-Free Rate Benchmarks

The plan to reform LIBOR and simultaneously encourage the development of RFRs was derailed for several reasons. First, volumes of unsecured short-term bank borrowings, on which reformed LIBOR was to be based, continued to decline. Post-crisis bank regulation discouraged reliance on wholesale funding as unstable through stressed conditions, and quantitative easing by central banks around the world reduced the need for banks to raise unsecured funds. Second, as penalties from the LIBOR scandal accumulated, banks grew reluctant to submit rates. The number of Euribor panel banks, for example, fell from 44 in 2012 to a low of 18 in 2019. The BMR did give authorities the right to compel benchmark submissions, but only for a limited time. Third, working groups were concluding from studies of transaction volumes that some benchmarks might never be sustainable.¹¹

Confronted with these realities, Andrew Bailey, Chief Executive of the FCA, gave a speech in July 2017 that essentially ended LIBOR. Ironically titled “The Future of Libor,” the speech revealed that the FCA had “spent a lot of time persuading banks to continue submitting to LIBOR.” But without an underlying active market in bank borrowing, he said, LIBOR was ultimately not sustainable. And a sudden cessation of LIBOR, upon which so many financial contracts depended, was unthinkable. Therefore, the FCA persuaded the current panel banks to submit until the end of 2021, after which the FCA would not compel them to continue. Markets had until then to transition to the alternate benchmarks that were being developed around the world.¹²

Table 1 lists short-term rate benchmarks in selected currencies before and after the LIBOR transition. Note that the new benchmarks for products in CHF (Swiss Franc) and USD are repo-based RFRs, SARON and SOFR, while those in EUR, GBP (British Pound), and JPY (Japanese Yen) are overnight bank-rate RFRs, €STR, SONIA, and TONAR. Note too that products in EUR and JPY are part of two-benchmark regimes, each with a new RFR and a reformed version of a previously existing CSR, namely, Euribor and TIBOR. Generally speaking, regulator choices were informed by the liquidity characteristics of their

¹¹IOSCO (2016), p. 35; Market Participants Group (2014); and Priem & Van Rie (2020), p. 17.

¹²Bailey (2017).

respective funding markets.¹³

Table 1 Short-Term Rate Benchmarks in the LIBOR Transition. The risk-free rate benchmarks preferred by regulators are in bold.

Currency	Pre-Transition	Repo	Post-Transition	
			Unsecured Bank Borrowing Overnight	Term
CHF	LIBOR	SARON(2009)^a		
EUR	EONIA ^b , Euribor		€STR (2019)^c	Euribor
GBP	LIBOR, SONIA ^d		SONIA	
JPY	LIBOR, TIBOR ^e		TONAR^f	TIBOR
USD	fed funds, LIBOR	SOFR(2017)	fed funds	Ameribor(2015), BSBY(2021), AXI(2022)

^aSwiss Average Rate Overnight; ^bEuro Overnight Index Average; ^cEuro Short-Term Rate, also written as ESTR or ESTER; ^dSterling Overnight Index Average; ^eTokyo Interbank Offered Rate; ^fTokyo Overnight Average Rate, also called TONA.

The vast majority of derivatives contracts around the globe have migrated from their pre-transition, LIBOR-based benchmarks to their post-transition RFRs. This was an enormous operational achievement, but several background conditions were favorable. First, regulators could at least identify the handful of clearinghouses and the relatively small number of large dealers that dominate derivatives markets. Second, derivatives users tend to be operationally sophisticated and were already using backward-looking benchmarks (e.g., overnight index swaps). Third, a large portion of interest rate derivatives positions are established for exposure to rates rather than bank funding costs, for which RFRs are adequate and possibly preferred.

By contrast, the transition of cash products has been slower and more challenging. First, it is difficult for regulators to herd the very large number of bank and corporate participants in the cash market. Second, borrowers have a strong preference for set-in-advance term rates over set-in-arrears daily compounded rates, for reasons of risk management, operational capabilities, or simply familiarity.¹⁴ Third, regional and smaller banks express strong preferences to link the interest rate on their loans to a CSR, like LIBOR, which increases as bank funding costs increase. They also worry that linking loan interest to a repo-based RFR can be particularly problematic through a crisis, as discussed in the context of T-bill rate benchmarks in Subsection 3.1.¹⁵

In the United States, after Bailey’s 2017 speech, regulators were keenly aware of the huge volumes of product that had to be moved away from LIBOR in the short time before its cessation.¹⁶ As it turned out, in fact, there was not enough time: the cessation of the more popular USD LIBOR terms (i.e., overnight, one month, three months, six months, and one year) had to be postponed from the originally-planned year-end 2021 to June 2023.

Cash market participants asked U.S. regulators for a usable term SOFR rate, but were initially met with little sympathy. SOFR futures had begun to trade, but with limited

¹³Schrimpf & Sushko (2019); Tuckman & Serrat (2022), pp. 289-292, 295.

¹⁴Goyder (2022) and Hintze (2021).

¹⁵Marshall et al. (2019).

¹⁶Smith (2020).

liquidity, and regulators were wary of diverting any volumes from overnight SOFR products. Regulators insisted that the transition proceed apace without term rates. But with liquidity gradually improving in SOFR futures, and perhaps because of some growing interest in the privately-created CSR alternatives discussed below, regulators relented. Starting in 2021, a term SOFR rate, created by the CME from SOFR futures, could be used for business loans. Volumes are to be restricted, however, so as to remain proportional to SOFR futures volumes and so as not to compete materially with overnight SOFR products.¹⁷

Regulators also relented in permitting swaps to reference term SOFR, but only to hedge a direct exposure to a cash product that is linked to term SOFR. Regional banks were granted an exemption, however, which, all in all, means the following. A loan linked to term SOFR can be hedged with a swap linked to term SOFR, and a regional bank that enters into such a swap with a customer can hedge its resulting exposure with a dealer. But dealers may not hedge their net term SOFR exposures with each other using term SOFR swaps: they may hedge these net exposures only with swaps linked to overnight SOFR.

The introduction of term SOFR has indeed accelerated the transition of cash markets away from LIBOR. And the volume of loans linked to term SOFR relative to the volume of SOFR futures does not seem to be a current cause for concern. But the restrictions on derivatives linked to term SOFR is becoming problematic, as it happens that dealers are accumulating basis risk from receiving term SOFR from customers and, to hedge, paying overnight SOFR to other dealers.¹⁸

As mentioned above and as shown in **Table 1**, there exist two privately-created CSRs—the American Interbank Offered Rate (Ameribor) and the Bloomberg Short-Term Yield Index (BSBY)—and one privately-created credit-sensitive spread—the Across-the-Curve Credit Spread Index (AXI). Ameribor and BSBY are both calculated for several tenors from transactions and executable quotes, with Ameribor using data from the American Financial Exchange (AFX), on which small and regional banks trade funds, and BSBY using data from Bloomberg’s trading platform, on which large banks raise funds. Both benchmarks have been deemed compliant with regulatory principles for benchmarks by independent auditors, and both can be traded through futures contracts. But U.S. regulators have been disapproving. First, regulators do not accept that the markets underlying these benchmarks are sufficiently liquid and robust to support benchmarks. Second, as noted above, regulators do not want any diversion of liquidity from SOFR, particularly before the transition from LIBOR has been fully realized. Without a benchmark regulation as in Europe, however, U.S. regulators do not have direct authority to halt these alternative benchmarks. Furthermore, recent federal legislation prohibits regulators from taking action against banks merely for using a non-SOFR based rate in a loan contract.¹⁹

AXI is a third alternative to the exclusive use of SOFR. While AXI itself has not yet been deemed compliant with regulatory principles by an independent auditor, its administrator has been so certified. The idea behind AXI, conceived by Berndt, Duffie & Zhu (2020), is to use any bank funding transactions available, from overnight to five years, to calculate a volume-weighted bank credit spread index. Banks can scale the index to any desired term and add it to SOFR of that term to obtain a CSR for that term. In any case, AXI sacrifices

¹⁷Bartholomew (2021a) and ARRC (2021).

¹⁸Bartholomew (2022).

¹⁹Bartholomew (2021a); Bartholomew (2021b); Tuckman & Serrat (2022), p. 295; and Duffee et al. (2022).

precision with respect to the term structure of credit spreads so as to make use of relatively high volumes of transactions. Furthermore, in a two-benchmark regime comprised of SOFR and AXI, market participants would trade both SOFR- and AXI-based instruments. Hence, AXI can grow without diverting any liquidity from SOFR.

4. Literature on the Role of Benchmarks

This paper focuses on short-term rate benchmarks, but benchmarks— more generally— are ubiquitous. Early indexes include the Dow Jones Railroad Average (1894); the Dow Jones Industrial Average (1896); London Silver Fixing (1897); and London Gold Fixings (1919). Other well-known commodity indexes include Platts for oil, fuel, and iron ore; ICE Brent oil; and ICIS Heren natural gas. Other well-known financial indexes include WM/Reuters daily foreign exchange fixings and the ICE Swap Rate (previously ISDAFIX) for longer-term IRS rates.

Duffie et al. (2017) explain the popularity of benchmarks from the perspective of reducing information asymmetries. In their model, traders incur search costs to discover asset prices across dealers, which gives dealers some pricing power. When these search costs are high enough, the introduction of a benchmark of dealer prices reduces the information asymmetry between traders and dealers, which, in turn, increases trade and welfare. Dealers themselves may actually decide to introduce a benchmark, so long as the benefits from increasing trade outweigh the reduction of pricing power. And dealers able to provide assets at relatively low prices have an incentive to introduce a benchmark to take market share away from higher-priced dealers. But there are also cases in which dealers would not profit from introducing a benchmark that would increase trade and welfare. In these cases, the model justifies a governmental role in introducing benchmarks. Aquilina & Pirrone (2020) show that improving the precision of a benchmark— rather than introducing a new one— can also increase market efficiency.

A number of recent empirical papers have found that benchmarks have improved market efficiency. Aquilina et al. (2022) study the 2015 shift from ISDAFIX, which was based on panel submissions, to the ICE Swap Rate, which is based on quotes from swap execution facilities. For the portion of the market executed through order books, they show that this shift reduced spreads and generally increased market depth. Ysusi, Pirrone & Suntheim (2018) document similar improvements. Aspris et al. (2020) study the changes in 2014 to the precious-metal fixings of the London Bullion Market Association (LBMA), from closed auctions among a limited number of dealers to open and transparent electronic auctions. They find that the change decreased market spreads and improved market depth. Pirrone (2018) show that the LBMA Silver Price fixing remained representative of the underlying spot market despite a period of market dislocations in 2017. Cereda et al. (2022) study the benchmark for stock loan fees in Brazil, which changed from the mean over the prior 15 days to the mean over the prior three days. In the spirit of Duffie et al. (2017), they find that the change reduced fees, increased volumes, increased the market share of low-cost lenders, and increased price efficiency.

In deciding whether or not to use a benchmark, either directly or through traded instruments, individuals trade off the suitability of the benchmark against the liquidity with which it can be traded. The S&P 500 index is popular because it is highly correlated with the portfolios of many market participants and because S&P futures and options are very liquid. By contrast it has proven difficult to create a similarly successful index of housing

prices. An index focused on a particular locality is useful to individuals in that locality, but there are too few such individuals to support a successful index. On the other hand, a regional or national index would encompass too much basis risk: it would be too weakly correlated with prices in individual localities to be of use to a large enough number of homeowners and investors.

Gyntelberg & Wooldridge (2008), Kreicher, McCauley & Wooldridge (2014), and McCauley (2001) apply this general principle to explaining why U.S. T-bills lost their benchmark status to LIBOR in the 1980s. As mentioned in Subsection 3.1, there was too much basis risk in hedging private paper prices and bank funding costs with T-bills, both because of flight-to-quality episodes and the idiosyncrasies of government bond markets. McCauley (2001) discusses a similar trend, claiming that longer-term rate benchmarks are moving from government bonds to IRS. Kreicher, McCauley & Wooldridge (2014) explain how changing the benchmark of adjustable-rate mortgages from T-bills to LIBOR increased demand for the product in Europe without unduly reducing demand in the United States.

Several papers discuss the trade-off of liquidity and basis risk in the context of selecting panels for survey-based benchmarks like LIBOR. Gyntelberg & Wooldridge (2008) point out that adding smaller, less active banks to the panel might make LIBOR more robust, but also less representative of actual funding costs in the market. Duffie & Stein (2015) and Duffie et al. (2013) analyze broadening LIBOR beyond interbank transactions and incorporating data across multi-day windows. These changes increase the pool of underlying transactions at the expense of increased heterogeneity as to what is being measured. Kuo, Skeie & Vickery (2018) point out that the dispersion of borrowing costs across panel banks during the financial crisis casts doubt on the suitability of LIBOR for hedging individual bank funding costs.

From a public policy perspective, Duffie & Stein (2015) point out that the willingness to take on basis risk in order to trade with better liquidity resulted in a system overly reliant on LIBOR. Because LIBOR was already liquid in the 1980s, even market participants who were focused on the level of rates, for whom fluctuations in bank funding costs were actually a distraction, chose to trade LIBOR-based instruments. In other words, because liquidity begets liquidity, a system can be pushed into a suboptimal equilibrium. The authors support a two-benchmark regime as a means of balancing the advantage of gathering liquidity into a limited number of pools while avoiding the systemic risk of overreliance on a single benchmark. Hou & Skeie (2014) recognize that any benchmark can have hidden or potential flaws, but seem to argue that network effects justify a single-benchmark regime. There is no framework, however, for analyzing how slowly or rapidly the liquidity benefits of networks decline with the number of benchmarks. Zhang (2022) is motivated by the observation that manipulation of a benchmark introduces basis risk into hedges using that benchmark.

In general, the optimal number of benchmarks from the perspective of balancing liquidity and basis risk is very much an open question. And in the case of short-term rate benchmarks, as discussed further below, there is a natural partition of liquidity to be analyzed. CSRs are appropriate for market participants focused on bank funding costs and on credit or funding stresses. RFRs are appropriate for market participants focused on the general level of rates or on the evolution of rate policy, with the caveat that RFRs based on repo have exposure to the idiosyncratic features of government bond and funding markets.

5. Literature on the LIBOR Scandal

Many papers have been written about the LIBOR scandal. Some were contemporaneous with the investigations mentioned in Subsection 3.2 and others with the search for policy solutions. These papers are now somewhat moot because of LIBOR's cessation, but principles of good benchmark design and empirical methods for detecting manipulation remain relevant for the future.

5.1. Proposed Changes to LIBOR

One set of papers examined changes that could reduce manipulation with minimal changes to LIBOR's survey methodology. Eisl et al. (2017) argue that screening submissions for large single-day changes could significantly reduce manipulation. Both Eisl et al. (2017) and Youle (2014) reason that a fix at the median submission is less subject to manipulation than at the trimmed mean. Eisl et al. (2017) add that switching to the median would be much more effective than fixing LIBOR at the mean of a random draw of submissions, which was an early suggestion of regulatory working groups. Finally, Eisl et al. (2017) find that using a multi-day window of submissions can reduce the effects of manipulation, but at a cost of the fix deviating significantly from market on any particular day.

Another set of papers made suggestions for reducing manipulation through supervision and enforcement. Focusing on the problem of lowballing, the model in Chen (2021) finds that manipulation can be deterred through random audits, with probabilities that decrease with submitted rates, in combination with post-audit fines that increase rapidly enough with the extent of the discovered understatement. Coulter & Shapiro (2013) propose a regime in which banks are incentivized to be whistleblowers on each other by reporting transactions that conflict with submissions. Fletcher (2016) calls for better governance by setting up a self-regulatory organization for the administration of benchmarks, which is somewhat in the direction of the EU's benchmark regulation.

As for more significant changes to the management of the LIBOR survey, Chen (2021) suggests changing the question to asking each bank not about its own borrowing costs, but about average borrowing costs. This change would make it harder for a bank to signal its own credit, but also harder to prove that a bank is falsifying its submission. Chen (2021) also finds that delaying the release of submissions, which was recommended and implemented by regulators, may not deter sufficiently patient manipulators. Lastly, Eisl et al. (2017) consider increasing the size of the panel to reduce the potential for manipulation, but recognize that this change would add noise to the benchmark because bank profiles are heterogeneous.

The international community eventually decided to migrate to benchmarks that are more dependent or exclusively dependent on transactions or actionable quotes. Coulter, Shapiro & Zimmerman (2018) propose to start with a transactions-based benchmark and then to fine banks if their transacted rates are not consistent with a mechanism designed to elicit actionable quotes. Duffie & Stein (2015) propose making it feasible for a short-term rate benchmark to depend on transactions by broadening the set of eligible transactions from interbank trades to all wholesale bank funding trade. At the same time, they encourage moving most of derivatives trading to RFRs to lessen the incentive to manipulate the CSR benchmark.

Given that a rate benchmark does depend on transactions, each transaction needs to be assigned a weight for calculating the fixing. LIBOR, for example, was a trimmed simple

average, while SOFR is a trimmed volume-weighted median. Duffie et al. (2013) make the following suggestions for contexts with limited data: use prior dates, weighting recent transactions more heavily; adjust the window of eligible transactions times to contain a minimum threshold of volume; and impose minimum transaction sizes. Duffie & Dworczak (2021), through a model of strategic manipulation with trading costs that increase with trade size, recommend fixing the benchmark equal to a variation of VWAP (volume-weighted average price) that caps the weights of large trades. The small weights on small trades make it difficult to manipulate the benchmark without incurring significant trading costs, whereas the cap on weights discourages traders with very large incentives to manipulate from being able to do so successfully. They note that their proposal does not fully eliminate manipulation, but argue that this is too ambitious a goal for any benchmark that must also efficiently represent the market's underlying fundamentals.²⁰ By contrast, Jarrow & Li (2021), through a model in which the market is competitive apart from one large potential manipulator, recommend an equally-weighted average price. In their setting, the potential manipulator's trades are drowned out by the equal weighting of all other market participants, and the random weights of a pure VWAP fixing only add noise to the benchmark relative to its fundamental value. Finally, Frei & Mitra (2021) make the point that when the benchmark in a market is the closing price and when a large portion of trading volume targets the benchmark, then a fix derived from a closing auction performs better than a VWAP from trades over the course of the day.

5.2. Empirical Studies

Many empirical papers attempt to confirm the allegations of the LIBOR scandal, to quantify the extent to which submissions did not reflect funding costs, and to quantify the extent to which misleading submissions impacted the LIBOR fix. These studies typically compare individual bank LIBOR submissions with rates on other relevant money market and credit instruments. The challenges of these analyses, of course, are the differences between what these other rates represent and what LIBOR represents. For example, T-bill rates and CDS spreads differ from LIBOR in important ways. As discussed in Subsection 3.1, T-bills enjoy a flight-to-quality premium, which means that the spread of a LIBOR submission or the LIBOR fix to T-bills can easily rise in a crisis without any misrepresentation of bank funding costs. And because CDS spreads represent the credit but not liquidity component of bank funding costs, LIBOR might be expected to increase by more than CDS spreads in times of stress. This conceptual point does not typically matter for establishing the fact (as opposed to the quantification) of lowballing, however, because LIBOR was observed to increase by less than justified by the increase in CDS spreads.

In one of the earliest studies, Gyntelberg & Wooldridge (2008) find that the spread between eurodollar deposit rates and LIBOR increased in the second half of 2007, but because of various indirect evidence do not conclude that banks were lowballing submissions. Abrantes-Metz et al. (2012), Chua et al. (2017), Fouquau & Spieser (2015), Frunza (2013), King & Lewis (2020) all essentially find that LIBOR submissions or LIBOR do not increase

²⁰Evans et al. (2018) and Ysusi, Pirrone & Suntheim (2018) highlight a different trade-off: a 2015 methodological change that lengthened the calculation window of a foreign exchange rate benchmark increased the benchmark's representativeness and decreased its susceptibility to manipulation, but reduced its attainability, that is, the ease with which it can be replicated by traders over the calculation window.

with CDS spreads as would be expected from banks that are accurately reporting their funding costs. Monticini & Thornton (2013) find that LIBOR was understated relative to the rate on large certificates of deposit. Kuo, Skeie & Vickery (2018) find low LIBOR submissions and fixes relative to several alternative rate benchmarks, with a peak understatement of 20 to 30 basis points between the fall of Bear Stearns and the bankruptcy of Lehman Brothers. Hernando-Veciana & Tröge (2019) build a model in which banks convey their funding costs truthfully in normal times, so as to enjoy the gains to trade of funding, but round their submissions in times of stress so as to hide their costs somewhat without overly disrupting their funding activities. The paper’s empirical work shows that banks do indeed round their submissions when their CDS spreads are high. Poskitt & Dassanayake (2015) show that, over the stressed period from mid-March to mid-April 2008, high LIBOR submissions from some banks were associated with common stock price declines, which, in turn, encouraged lower submissions from those banks on the following day.

While these papers focus on banks understating their costs of funds, others focus on manipulating the fix to profit on related positions. Eisl et al. (2017) analyze the extent to which individual or small groups of banks could manipulate the fix given the submissions of all other banks. At the March 2008 peak, they find that an individual bank could manipulate AUD (Australian Dollar) LIBOR by 15 basis points, USD LIBOR by 6 basis points, and Euribor by 1.5 basis points. And from 2005-2012, they find that the potential for manipulation decreases with the size of the panel (7 banks for AUD LIBOR, 18 for USD LIBOR, and 42 for Euribor). Snider & Youle (2012) posit a framework in which banks profit from moving the LIBOR fix, but risk detection and penalties if they stray too far from the truth. The model predicts bunching of submissions around the “pivotal” submissions, that is, the submissions that are just low enough at the top of the range and just high enough at the bottom of the range to be included in the calculation of the trimmed mean. The paper’s empirical work confirms that bunching of this sort was widespread.

The last two papers discussed here encompass both lowballing and profiteering. Bonaldi (2017) estimates such a model using data on submissions alone; finds that LIBOR understates funding costs on average, from Lehman’s bankruptcy until the end of 2008, by 23 basis points; and finds that nearly all of that understatement is due to lowballing rather than profiteering. This result is consistent with some of the anecdotal evidence presented in subsection 3.2. Gandhi et al. (2022) estimate the sensitivity of a bank’s excess stock return to its LIBOR submission and to the LIBOR fix as the bank’s incentive to lowball and profiteer, respectively. The paper then finds evidence consistent with manipulation from a second-stage analysis in which a bank’s LIBOR submissions are impacted by these estimated incentives.

6. Literature on Risk-Free Rates vs. Credit-Sensitive Rates (CSRs)

As discussed earlier, regulators in Switzerland, the United Kingdom, and the United States are promoting a single-benchmark RFR regime, despite the challenges of moving cash markets into such a regime, while regulators in Europe and Japan are promoting a two-benchmark regime, with one RFR and one CSR. And the privately-created CSRs for USD may or may not grow from their currently peripheral roles. In this context, an overarching policy question in the United States is whether cash markets can or should adjust to a regime built on overnight SOFR, with some use of term SOFR, or whether the history described in Subsection 3.1, which drove the earlier regime to LIBOR, will or should push

the current regime to a two- or multi-benchmark regime, that is, SOFR and some use of term SOFR alongside one or more term CSRs.

This overarching question can be divided into several smaller questions:

1. Do cash loans really need term rates or can businesses and individuals adjust attitudes and operations to rely exclusively or mostly on overnight rates?
2. If cash loans and related derivatives do need term rates, can SOFR futures supply term rates that are robust enough to support large cash and swap markets that are linked to term SOFR?
3. From the perspectives of rates traders, is basis risk less with a CSR or with SOFR?
4. Do banks really need to link interest on their assets to a CSR or can banks link floating-rate loans to SOFR and term SOFR without a sacrifice in overall welfare?
5. If banks really do need CSRs, will Ameribor, BSBY, or AXI be able to fill that role or will another alternative be needed? Why is a reformed benchmark like Euribor not appropriate for USD products?

6.1. Do Loan Markets Need Term Rates?

There is little academic literature on this question. Schrimpf & Sushko (2019) and others note the historical preference of cash market participants for set-in-advance term rates and, in an example of how deeply this convention is embedded in the financial system, Klinger & Syrstad (2021) point out that mortgage borrowers as a matter of law have had to be told their interest rate at least 45 days in advance. For policy purposes, however, it is important to know whether or not widely-available set-in-advance term lending is necessary for an efficient financial system.

6.2. Can SOFR Futures Robustly Generate Term Rates?

Klinger and Syrstad (2021) and Liu and Bai (2022) raise concerns about setting term rates from futures rates, pointing out that a benchmark based on term loans would be much more robust. Here too, little academic work has been done. Could an idiosyncratic shock, like a hedge fund liquidating a large position, perturb a futures-implied benchmark? Could large loan and swap markets referencing term SOFR lead to the manipulation of SOFR futures contracts? Relevant to these questions is that the liquidity of short-term rate futures often depends on the uncertainty of monetary policy. Fed funds and eurodollar futures contracts, for example, have typically been much more liquid when the Federal Reserve is changing policy rates than when it is keeping rates steady. And short-term rate instruments in Japan are extremely illiquid after years of unchanging short-term rates. The liquidity of SOFR futures, therefore, along with the robustness of derived term SOFR rates, might be similarly dependent on the monetary policy cycle.

6.3. For Rates Traders, Does SOFR Have Less Basis Risk than CSRs?

Duffie & Stein (2015) and others have explained that market participants other than banks embraced CSRs in the past because of the liquidity of CSR-linked instruments. In fact, for many of these participants, who might be called rates traders, who care only about policy rates or the general level of interest rates, the linkage of benchmarks to bank funding conditions constitutes basis risk. The question, therefore, is whether or not RFRs based on repo rates, like SOFR, constitute an improvement. The argument against is that repo

rates react both to flight-to-quality trades and to factors unique to government bond and government bond funding markets. With respect to episodes of flight-to-quality, Duffie & Stein (2015) and Hördahl & King (2008) show that repo rates spiked down relative to other rates through the financial crisis, and Geissbühler & Ollivier (2021) show the same at the start of the pandemic in spring 2020. With respect to idiosyncrasies of government bond markets, Schrimpf & Sushko (2019) describe the spread of SOFR to fed funds in terms of the supply and demand for treasuries and note that the inclusion of nonbank repo transactions in SOFR can push SOFR away from policy rates. Klinger & Syrstad (2021) conduct a detailed empirical study that shows several dependencies of SOFR on flight-to-quality and on supply and demand in government bond markets. In short, from the perspective of rates traders, is the basis risk from RFRs greater or less than the basis risk from CSRs?

6.4. Do Banks Need to Link Loans to CSRs?

Most academic papers (e.g., Duffie et al. (2013), Klinger & Syrstad (2021), and Schrimpf & Sushko (2019)) recognize that banks find CSR links useful for bank risk management. Jermann (2021) shows that banks earned significantly more from their LIBOR-linked loans over the financial crisis than they would have earned from (hypothetical) SOFR-linked loans. Bowman et al. (2020) dissent from this view, noting that bank funding costs over five-year windows are more sensitive to RFRs than to CSRs; the percentage of bank liabilities from wholesale funding has declined significantly since the crisis; some existing bank liabilities can be indexed to RFRs rather than CSRs; and banks can better manage volatile rates than can nonfinancial businesses. But these arguments do not recognize the importance of tail events in risk management. The correlation of RFRs and bank funding costs over five-year windows may be high, but will fall or even reverse in a crisis. Banks in normal times may have limited volumes of liabilities linked to wholesale funding costs, but if they have to raise funds in a crisis, their costs will be high. And post-crisis macroprudential regulation strives to increase the resilience of bank funding costs in a crisis. Therefore, without extraordinarily high confidence that banks are too strong to need to raise funds in a crisis, linking earnings to CSRs can play a role in managing the risks of tail events.

An important follow-up question is whether or not there are efficiency and welfare implications of forcing banks to link the interest on their assets to RFRs rather than CSRs. Cooperman et al. (2022) argue that such costs do exist, but that they arise less from risk considerations than from the extra costs of providing credit lines linked to RFRs. Nonfinancial firms borrow from the largest banks mostly through credit lines. Furthermore, a feature of RFR-linked credit lines is that borrowers may increase their borrowings during stress scenarios in which bank funding costs (and CSRs) increase while RFR-linked rates hold steady or even fall. Consequently, banks charge borrowers *ex ante* for this feature, which, in turn, increases the costs of credit lines and lowers their utilization. Jermann (2019) sets up a framework in which unsecured bank funding costs are subject to a default premium and finds that, under stress, an economy with RFR-linked loans fares worse than one with CSR-linked loans in the sense that banks default more, bank funding spreads increase by more, and businesses face higher borrowing costs and reduce investment. Kirti (2022) posits a model in which various frictions motivate banks to use CSRs to transfer funding risk to borrowers. This increases welfare, however, only to the extent that banks—because of leverage and regulation—have less capacity than nonfinancial businesses to bear funding risk. Furthermore, manipulation of CSRs can attenuate or reverse this result by

lowering the correlation between the CSRs and individual bank funding costs.

A second important follow-up, which is relatively unexplored in the academic literature, is whether or not a two- or multi-benchmark system can be expected to improve welfare over a single-benchmark system. While network effects point to having fewer benchmarks, a regime with only two short-term rate benchmarks— one RFR and one CSR— could easily moot the difficult question of choosing one over another. A handful of papers, including Duffie & Stein (2015), Duffie et al. (2013), Liu & Bai (2022), Market Participants Group (2014), and Schrimpf & Sushko (2019), seemingly favor a two- or multi-benchmark regime, but are not designed to answer that question in a rigorous way.

6.5. Should Ameribor, BSBY, AXI, and Other CSRs, Be Encouraged?

The sponsors of Ameribor and BSBY believe that their benchmarks are robust, while regulators seem to disagree. There has not been much public discussion of the properties of AXI. Furthermore, according to Amor (2021), reformed Euribor, which uses a hierarchy of transactions, interpolations, and expert judgment (see Subsection 3.1), seems to have worked well and as intended through the pandemic. If a multi-benchmark regime is indeed advantageous, should these or other CSRs be encouraged? Duffie & Dworczak (2021) make the point that the informational efficiency of a benchmark might warrant the acceptance of some potential for manipulation. In any case, the development of CSRs is a particularly timely issue because regulators are pressing hard for a SOFR-based regime.²¹ Recalling the Duffie & Stein (2015) argument that markets settled into a suboptimal LIBOR equilibrium because liquidity begets liquidity, it may be similarly argued that the current policy path may entrench a suboptimal, exclusive SOFR-based regime.

7. Conclusion

Benchmarks can make markets more efficient by reducing information asymmetries and increasing trade and welfare. There is a trade-off between having several benchmarks to represent subsets of a market more precisely and having very few benchmarks to maximize the liquidity pool dedicated to each. The tendency of liquidity to beget liquidity bestows a first-mover advantage that may result in a regime with too few benchmarks, too much systemic dependence on those benchmarks, and— for benchmarks without sufficient volumes of underlying transactions— too great an incentive for manipulation.

With respect to short-term rate benchmarks, LIBOR had become too dominant and entrenched. Confronted with the urgency of creating an alternative to LIBOR before its cessation, U.S. regulators have been promoting SOFR in a single-benchmark regime, allowing some use of term SOFR but discouraging CSR benchmarks. Academic research can examine the implications of this policy in frameworks that account for the following trade-offs: the advantages of fewer benchmarks in terms of liquidity vs. the disadvantages of broad benchmarks with respect to basis risks; the advantages of SOFR with respect to the volumes of underlying transactions vs. the disadvantages of its being an overnight rate that is impacted by flight-to-quality trades and the idiosyncrasies of the government bond market; and the advantages of CSRs as term rates and— for banks— as reflecting funding costs, vs. the disadvantages of the relatively low volumes of transactions underlying CSRs.

²¹Jones (2021).

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