

# Second Report

The Alternative Reference Rates Committee

March 2018

## I. Background

The Financial Stability Board (FSB) and Financial Stability Oversight Council (FSOC) have both publicly recognized for some time that the secular decline in wholesale unsecured term money market funding by banks poses serious structural risks for unsecured benchmarks such as ICE LIBOR (LIBOR).<sup>1</sup> Although significant progress has been made in strengthening the governance and processes underlying LIBOR, the scarcity of underlying transactions poses a continuing risk of a permanent cessation of its production.<sup>2</sup>

Because U.S. dollar (USD) LIBOR is used in such a large volume and broad range of financial products and contracts, the risks surrounding it pose a potential threat to the safety and soundness of individual financial institutions and to financial stability. Without advanced preparation, a sudden cessation of such a heavily used reference rate would cause considerable disruptions to and uncertainties around the large gross flows of USD LIBOR–related payments and receipts between many firms. It would also impair the normal functioning of a variety of markets, including business and consumer lending.

In its 2014 report, the FSB’s Market Participants Group estimated that, as of 2012, contracts referencing USD LIBOR totaled roughly \$160 trillion in gross notional exposure. Updated estimates show that, as of the end of 2016, the total exposure to USD LIBOR was closer to \$200 trillion (**Table 1**), roughly equivalent to 10 times U.S. Gross Domestic Product. The notional size of the derivatives market accounts for 95 percent of the outstanding gross notional value of all financial products referencing USD LIBOR.<sup>3</sup> However, USD LIBOR is also referenced in several trillion dollars of corporate loans, floating-rate mortgages, floating rate notes (FRNs), and securitized products.

These LIBOR exposures dwarf the volumes underlying the wholesale unsecured term bank funding markets that LIBOR is meant to represent. The distribution of daily volumes of term unsecured funding transactions by the global systemically important banks (GSIBs) since money market fund reforms were put in place in October 2016 is shown in **Figure 1**. The median daily volume of three-month funding transactions (three-month LIBOR is the most heavily referenced tenor of USD LIBOR) is less than \$1 billion, and there are many days with volumes of less than \$500 million. The number of banks submitting to USD LIBOR is about half the number of

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<sup>1</sup> See Financial Stability Board, [Reforming Major Interest Rate Benchmarks](#), July 2014, and Financial Stability Oversight Council, [2013 Annual Report](#), June 2013.

<sup>2</sup> [Ice Benchmark Administration Roadmap for ICE LIBOR](#), March 2016, relays the many steps that have been taken to strengthen LIBOR.

<sup>3</sup> Although net exposures in derivatives contracts would be much smaller, gross exposures are still critical from a financial stability perspective. Netting opportunities would be uncertain in the event that LIBOR ceased publication because existing derivatives contracts do not in general have robust fallback arrangements for such an event. Untangling the numerous cross-institution financial obligations that would result from such an event would be operationally complicated and possibly contentious. In the interim, individual banks would not have certainty about the value of their positions as it would be unclear what rate should be paid or what rate would be received on any contract.

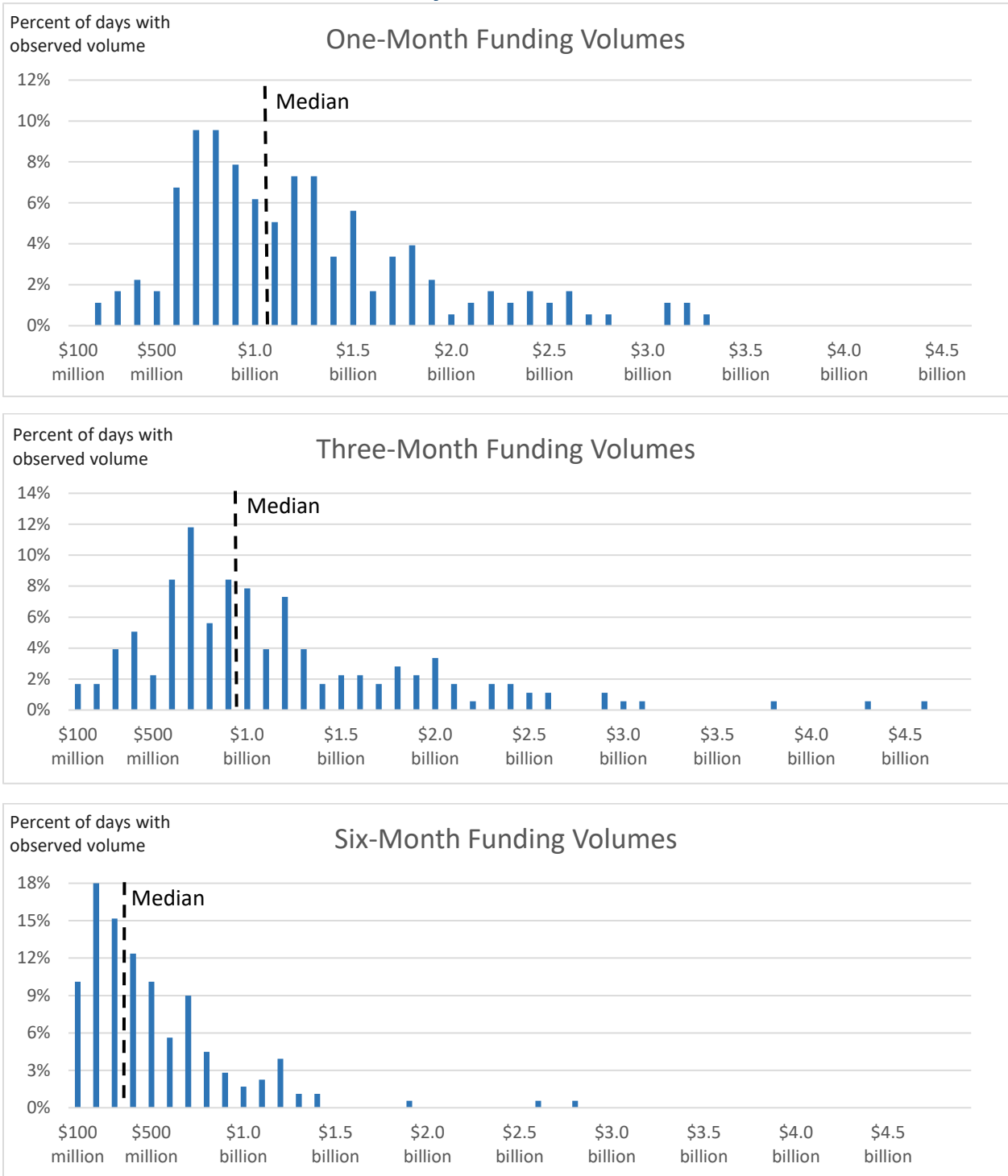
GSIBs, and so the actual volumes underlying USD LIBOR are likely to be about half of those shown here.

**Table 1: Estimated USD LIBOR Market Footprint by Asset Class<sup>1</sup>**

		Volume (Trillions USD)	Share Maturing By:			
			End 2021	End 2025	After 2030	After 2040
<b>Over-the-Counter Derivatives</b>	Interest rate swaps	81	66%	88%	7%	5%
	Forward rate agreements	34	100%	100%	0%	0%
	Interest rate options	12	65%	68%	5%	5%
	Cross currency swaps	18	88%	93%	2%	0%
<b>Exchange Traded Derivatives</b>	Interest rate options	34	99%	100%	0%	0%
	Interest rate futures	11	99%	100%	0%	0%
<b>Business Loans<sup>2</sup></b>	Syndicated loans	1.5	83%	100%	0%	0%
	Nonsyndicated business loans	0.8	86%	97%	1%	0%
	Nonsyndicated CRE/Commercial mortgages	1.1	83%	94%	4%	2%
<b>Consumer Loans</b>	Retail mortgages <sup>3</sup>	1.2	57%	82%	7%	1%
	Other Consumer loans	0.1	---	---	---	---
<b>Bonds</b>	Floating/Variable Rate Notes	1.8	84%	93%	6%	3%
<b>Securitizations</b>	Mortgage -backed Securites (incl. CMOs)	1.0	57%	81%	7%	1%
	Collateralized loan obligations	0.4	26%	72%	5%	0%
	Asset-backed securities	0.2	55%	78%	10%	2%
	Collateralized debt obligations	0.2	48%	73%	10%	2%
<b>Total USD LIBOR Exposure:</b>		<b>199</b>	<b>82%</b>	<b>92%</b>	<b>4%</b>	<b>2%</b>

<sup>1</sup> Source: Federal Reserve staff calculations, BIS, Bloomberg, CME, DTCC, Federal Reserve Financial Accounts of the United States, G.19, Shared National Credit, and Y-14 data, and JPMorgan Chase. Data are gross notional exposures as of year-end 2016. <sup>2</sup> The figures for syndicated and corporate business loans do not include undrawn lines. Nonsyndicated business loans exclude CRE/commercial mortgage loans. <sup>3</sup> Estimated maturities based on historical pre-payment rates

**Figure 1: Distribution of Daily Unsecured Funding Volumes of the G-SIB Firms Post Money-Market Fund Reform**



Source: FR2420 Report of Selected Money Market Rates and DTCC. Federal Reserve staff calculations based on daily volumes aggregated across fed funds, Eurodollar, certificates of deposit, and unsecured commercial paper transactions of the 30 global systemically important banks with tenors between 25 and 35 calendar days (for one month), 80 and 100 calendar days (three month), or 150 and 210 calendar days (six month) over the period October 15, 2016 to June 30, 2017.

In response to recommendations and objectives set forth by the FSOC and FSB to address these risks, the Federal Reserve convened the Alternative Reference Rates Committee (ARRC) on November 17, 2014, with the support of the U.S. Department of the Treasury, the U.S. Commodity Futures Trading Commission (CFTC), and the Office of Financial Research (OFR). The ARRC was convened to identify a set of alternative USD reference rates that are more firmly based on transactions from a robust underlying market than USD LIBOR and that comply with standards such as the International Organization of Securities Commissions' (IOSCO) *Principles for Financial Benchmarks* and to identify an adoption plan to facilitate the voluntary acceptance and use of these alternative reference rates.<sup>4</sup> Specifically, the ARRC was given four objectives:

- *Identify best practices for alternative reference rates.* The ARRC was asked to consider the range of existing and potential reference interest rates and identify a risk-free (or nearly risk-free) rate or rates that in the consensus view of the members would represent best practice for use in certain new derivatives and other contracts. Considerations were to include, but not be limited to, the liquidity of the underlying market, the likely robustness of the market over time, market functioning issues, usefulness to all market participants, ability to produce and maintain the alternative rates, feasibility and viability of developing a robust market of financial instruments that reference the alternative rates, accounting and tax issues that might facilitate or hinder adoption, and whether the identified alternative rates are consistent with the *Principles for Financial Benchmarks* outlined by IOSCO.
- *Identify best practices for contract robustness.* The ARRC was asked to consider the best practices related to robust contract design in order to ensure that contracts are resilient to the possible cessation or material alteration of an existing or new benchmark.
- *Develop an adoption plan.* The ARRC was asked to identify the factors that would either facilitate or impede the adoption of the alternative rates identified or the adoption of best practices related to robust contract design, and to outline the necessary steps that the official sector and market participants could take to make the adoption more successful. Considerations were to include, but not be limited to, the creation of the necessary liquidity in contracts referencing the alternative rates, accounting or tax issues such as the use of simplified hedge accounting, industry-wide protocols, complementary uses of the rates such as for discounting, and back-office or record-keeping issues.
- *Create an implementation plan with metrics of success and a timeline.* The ARRC was asked to identify observable metrics that reflect the successful adoption of the best practices and the alternative reference rates that are consistent with those best practices, and to identify how participating firms will work to achieve these best practices over time. These metrics could include, for example, quantitative measures for the dollar value or share of new derivatives or other contracts that are linked to such alternative

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<sup>4</sup> International Organization of Securities Commissions, [Principles for Financial Benchmarks](#), July 2013.

reference rates. The recommendations should include an expected timeline and clear measures of success for the implementation.

The ARRC's focus was directed toward identifying alternatives to USD LIBOR and developing plans to encourage voluntary adoption of its recommended rate rather than a mandated transition away from USD LIBOR. At the same time that the FSB recommended seeking alternatives to benchmarks such as LIBOR, the FSB also recommended that those benchmarks be strengthened to the fullest extent possible, and FSB members have actively engaged with the administrators of these rates to accomplish this.<sup>5</sup> And the FSB report, *Reforming Major Interest Rate Benchmarks*, explicitly recognized that market participants' uses of interest rate benchmarks are diverse and that they should be allowed to choose amongst rates that meet the IOSCO *Principles for Financial Benchmarks*.<sup>6</sup>

Similar private-sector groups were convened in the other currency areas for which LIBOR is quoted.<sup>7</sup> In the **United Kingdom**, the Bank of England convened the [Working Group on Sterling Risk-Free Reference Rates](#) to select an alternative reference rate for sterling markets. In **Japan**, initiatives by major market participants led to the establishment of the [Study Group on Risk-Free Reference Rates](#) in order to facilitate the identification of potential alternative risk-free rate designs and administrators. In **Switzerland**, the [National Working Group](#) was recognized as the key forum for interest rate reform proposals. And in the **euro area**, a similar [Working Group on Euro Risk-Free Reference Rates](#) has now been formed. To the extent possible, the ARRC has sought to coordinate its plans with these other groups.

The ARRC held its first meeting in December 2014 and has met regularly since then to work toward these objectives. At the time of its inception, the ARRC consisted of representatives from 15 large global interest rate derivatives dealers.<sup>8</sup> As its work progressed, the ARRC invited several central counterparties (CCPs) and other organizations to join as non-voting members. The Board of Governors of the Federal Reserve System, Federal Reserve Bank of New York (FRBNY), U.S. Department of the Treasury, CFTC, and OFR have served as ex officio members of the ARRC. Following the release of its [Interim Report and Consultation](#) in May 2016, the ARRC formed an Advisory Group of key end users across a variety of market sectors in order to ensure that its recommendations reflected a wide consensus of market participants.<sup>9</sup> The ARRC also held two public roundtables, in June 2016 and November 2017, to inform market participants and seek their views. Minutes and agendas of the ARRC's meetings are posted on its [website](#).

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<sup>5</sup> As part of this process, the Federal Reserve has participated as an observer to ICE Benchmarks Administration's LIBOR Oversight Committee since 2014.

<sup>6</sup> At the same time, the report recognized that authorities have a responsibility for ensuring that the financial institutions they regulate do not use reference rates in ways that pose undue risk to the institutions themselves, to market integrity or to overall financial stability.

<sup>7</sup> LIBOR fixings are set for five currencies: the euro, Japanese yen, pound sterling, Swiss franc, and U.S. dollar.

<sup>8</sup> See Appendix 1.

<sup>9</sup> See [ARRC Announces the Formation of an Advisory Group](#).

The ARRC has completed the tasks and deliverables requested by the official sector in November 2014:

- On June 22, 2017, the ARRC identified the secured overnight financing rate (SOFR), which the Federal Reserve Bank of New York [will publish](#) in cooperation with the Office of Financial Research, as the rate that, in its consensus view, represents best practice for use in certain new U.S. dollar derivatives and other financial contracts. The ARRC considered a variety of factors in selecting SOFR, including the depth of the underlying market and its likely robustness over time; the rate’s usefulness to market participants; and whether the rate’s construction, governance, and accountability would be consistent with the IOSCO *Principles for Financial Benchmarks*. The ARRC also considered the input of a wide range of market participants, including feedback from its Advisory Group, in making its recommendation. The official sector has supported the ARRC’s choice: in an editorial following the decision, Jerome Powell and Christopher Giancarlo noted that the choice of SOFR “*resolves the central problem with LIBOR, because it will be based on actual market transactions currently reflecting roughly \$800 billion in daily activity. That will make it far more robust than LIBOR.*”<sup>10</sup>
- On October 31, 2017, the ARRC [adopted a Paced Transition Plan with specific steps and timelines](#) designed to encourage use of its recommended rate (see Table 3).
- ARRC members have been actively engaged in work led by the International Swaps and Derivatives Association, Inc. (ISDA, itself a non-voting participant in the work of the ARRC) to consider best practices for contract robustness in derivatives contracts. ISDA has outlined a proposed process for making those contracts resilient to the possible permanent cessation of LIBOR or other prominent interbank offer rates and is now focused on the specific implementation details of that process.

Taken together, these steps represent substantial progress and much work has gone in to realizing them. When the ARRC was first convened, neither SOFR nor the other leading alternative considered by the ARRC existed.

However, while the ARRC has made substantial progress, the instabilities inherent in LIBOR have also progressed. The scarcity of underlying transactions has made it increasingly difficult and uncomfortable for panel banks to submit to LIBOR, and since 2016 two panel banks have stopped contributing submissions to USD LIBOR altogether. The U.K. Financial Conduct Authority (FCA, the regulator overseeing LIBOR) has publicly discussed the efforts that the official sector has had to exert in order to persuade banks to continue to submit to LIBOR in recent years.<sup>11</sup> Recognizing that applicable regulations do not allow it to compel submissions indefinitely, last

<sup>10</sup> Jerome Powell and J. Christopher Giancarlo, [How to Fix Libor Pains](#), Wall Street Journal, August 3, 2017.

<sup>11</sup> See [The Future of LIBOR](#), FCA, July 27, 2017. The U.K. Financial Conduct Authority’s statement confirming the agreement of LIBOR panel banks to support LIBOR until end 2021 can be found at [www.fca.org.uk/news/statements/fca-statement-libor-panels](http://www.fca.org.uk/news/statements/fca-statement-libor-panels).

year the FCA sought voluntary agreements with banks submitting to LIBOR panels to continue their submissions through the end of 2021. While LIBOR may continue publication past this date, it cannot be guaranteed to do so.

The announcements from the FCA sparked wider awareness of the risks that the FSOC and FSB warned of, and participants in many cash markets using USD LIBOR are now actively seeking to mitigate their risks both by seeking more robust contract language and considering transitions away from LIBOR. The ARRC's work has thus proved to be timely, and more necessary than many had previously considered.

## II. The Recommended Alternative

In June 2017, the ARRC announced a broad Treasury repo financing rate, SOFR, as its recommended alternative to USD LIBOR. The ARRC considered a comprehensive list of potential alternatives, including other term unsecured rates, overnight unsecured rates such as the effective fed funds rate (EFFR) and overnight bank funding rate (OBFR), secured repo rates, Treasury bill and bond rates, and overnight index swap (OIS) rates linked to EFFR.<sup>12</sup> After extensive discussion, the ARRC preliminarily narrowed this list to two types of rates that it considered to be the strongest potential alternatives: an overnight unsecured rate (the OBFR) and some form of overnight Treasury repo rate. The ARRC discussed the merits of and sought feedback on both rates in its 2016 [Interim Report and Consultation](#). The ARRC made its final choice of SOFR after incorporating feedback from the consultation and from the members of the Advisory Group.

SOFR will be published on a daily basis by FRBNY beginning on April 3, 2018.<sup>13</sup> SOFR is a fully transactions-based rate incorporating tri-party repo data, the Fixed Income Clearing Corporation's (FICC) GCF Repo data, and bilateral Treasury repo transactions cleared through FICC (the structure of the U.S. Treasury repo market is discussed in **Box 1**). It will have the widest coverage of any Treasury repo rate available. As shown in **Figure 2**, taken together, the transactions underlying SOFR regularly exceeded \$700 billion in daily volumes last year and have been growing. Over the first half of 2017, the average daily volume of transactions underlying SOFR was \$754 billion, representing the largest rates market at any given tenor in the United States (**Figure 3**). The volumes underlying SOFR are far larger than the transactions in any other U.S. money market and dwarf the volumes underlying LIBOR or other term unsecured funding rates.

Because of its range of coverage, SOFR is a good representation of general funding conditions in the overnight Treasury repo market. As such, it will reflect an economic cost of lending and borrowing relevant to the wide array of market participants active in these markets, including not

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<sup>12</sup> The ARRC's [Interim Report and Consultation](#) discusses the range of rates considered in more detail. The range of rates considered is similar to that discussed in the FSB's [Final Report of the Market Participants Group on Reforming Interest Rate Benchmarks](#), March 2014.

<sup>13</sup> See [Statement Regarding the Initial Publication of Treasury Repo Reference Rates](#).



only broker-dealers, but also money market funds, asset managers, insurance companies, securities lenders, and pension funds. FRBNY has released roughly three years of historical data for SOFR and the other repo rates that it will produce. Recognizing that a longer history will aid in modeling SOFR, FRBNY has also announced that it is considering ways to release additional historical data.<sup>14</sup> Based on the historical data released thus far, SOFR can be seen to move closely with other available repo rates (**Figure 4**). It has tended to lie in the middle of the range between other available repo rates: it is generally a few basis points higher than rates based only on tri-party transactions (such as the Bank of New York Mellon's Treasury Tri-Party Repo Index or the tri-party general collateral rate that will be produced by FRBNY) but is generally lower and less volatile than DTCC's Treasury GCF Repo Index.

Although the ARRC seriously considered OBFR as its other leading candidate, a Treasury repo rate like SOFR was seen as potentially more resilient both by the ARRC and by the ARRC's Advisory Group of end users, a clear majority of whom preferred a repo rate. While both EFR and OBFR are IOSCO compliant rates, most overnight transactions in fed funds and Eurodollar markets at this stage are arbitrage trades involving a fairly limited set of cash providers who are ineligible to earn the interest rate on excess reserves (IOER) rate paid on funds deposited at the Federal Reserve and instead lend money to financial institutions that *can* deposit and earn the IOER rate at the Federal Reserve. Money market fund reforms have also led to some decline in unsecured overnight transactions volumes since 2016. In contrast, Treasury repo markets were seen as more resilient and an active source of funding for a wide range of market participants. The alternative reference rate selected by the ARRC must be able to withstand the weight of potentially having hundreds of trillions of dollars of contracts referencing it and must remain durable over time, a standard clearly met by SOFR.

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<sup>14</sup> See [The Role of the New York Fed as Administrator and Producer of Reference Rates](#), Lorie Logan, January 2018.

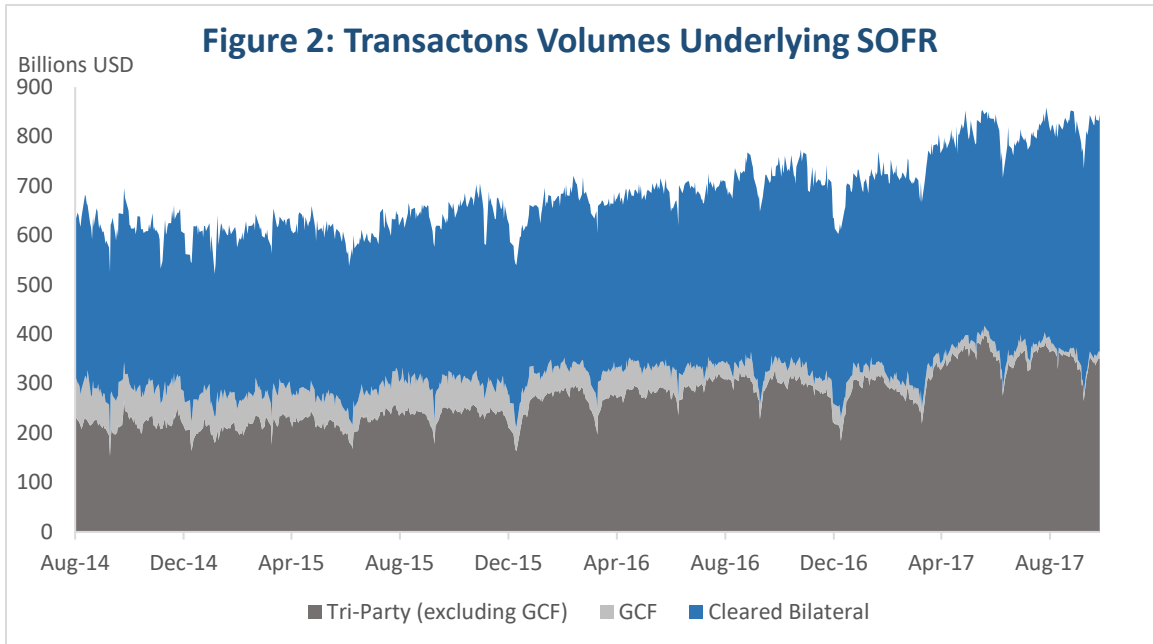
**Box 1: The Treasury Repo Market**

The U.S. Treasury repo market is composed of several segments:

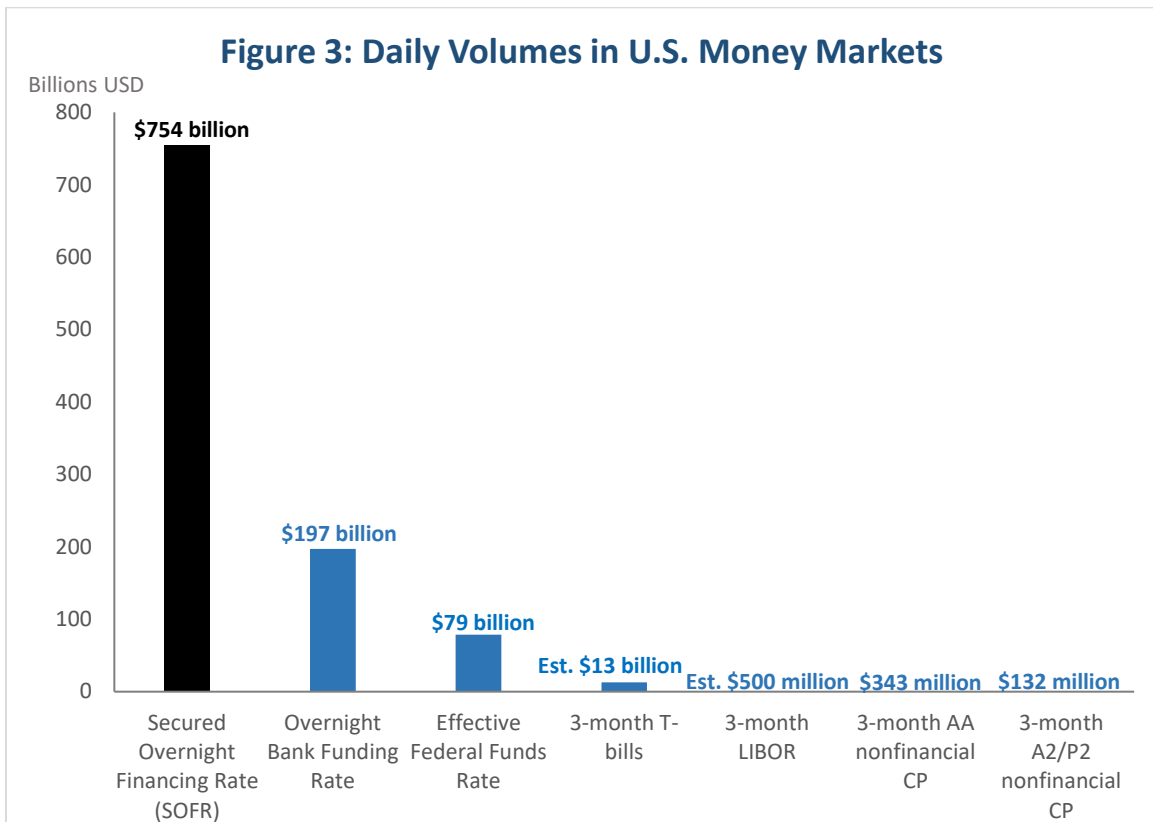
- The **tri-party repo market** is used to finance general collateral pools rather than specific securities, and trades in this portion of the market are primarily settled on the books of Bank of New York Mellon.\* General collateral repo (GC repo) Treasury transactions are secured by a range of Treasury securities that are accepted as collateral by the majority of intermediaries in the repo market. Money market mutual funds and securities lenders are among the most prominent cash providers in this segment, while securities dealers are the primary borrowers of cash. Dealers may use this cash to fund their own portfolios or they may also lend it to other participants in the repo market.
- While most tri-party repo transactions are not centrally cleared through a CCP, one segment of this market is. The **General Collateral Finance (GCF) repo market** is the segment of the tri-party repo market cleared through FICC. GCF trades are blind brokered (meaning that the counterparties to the trade do not know who they are trading with) among clearing members of FICC.
- In the **bilateral repo market**, participants designate the specific securities to be used for collateral, but many trades are still primarily intended to lend and borrow cash on a secured basis (cash trades) rather than to obtain a particular security (specials). In this portion of the market, cash providers tend to be professional investors such as asset managers or securities dealers themselves, while cash borrowers include prime brokerage clients. As in the tri-party repo market, securities dealers may also borrow cash in this market, or may borrow it and then lend it to other market participants.
- As with the tri-party repo market, there is a segment of the bilateral repo transactions that is centrally cleared through a CCP, the bilateral Treasury repo transactions cleared through **FICC's Delivery-versus-Payment (DVP) service**. Unlike the GCF market, DVP trades are not necessarily blind brokered.

SOFR will be based on three of these segments – the tri-party market settled at the Bank of New York Mellon, the GCF market, and cleared DVP bilateral repo market. Data on the remaining segment, uncleared bilateral repo transactions, are not presently available, although such data could be considered for inclusion in SOFR if it became available at a later time.

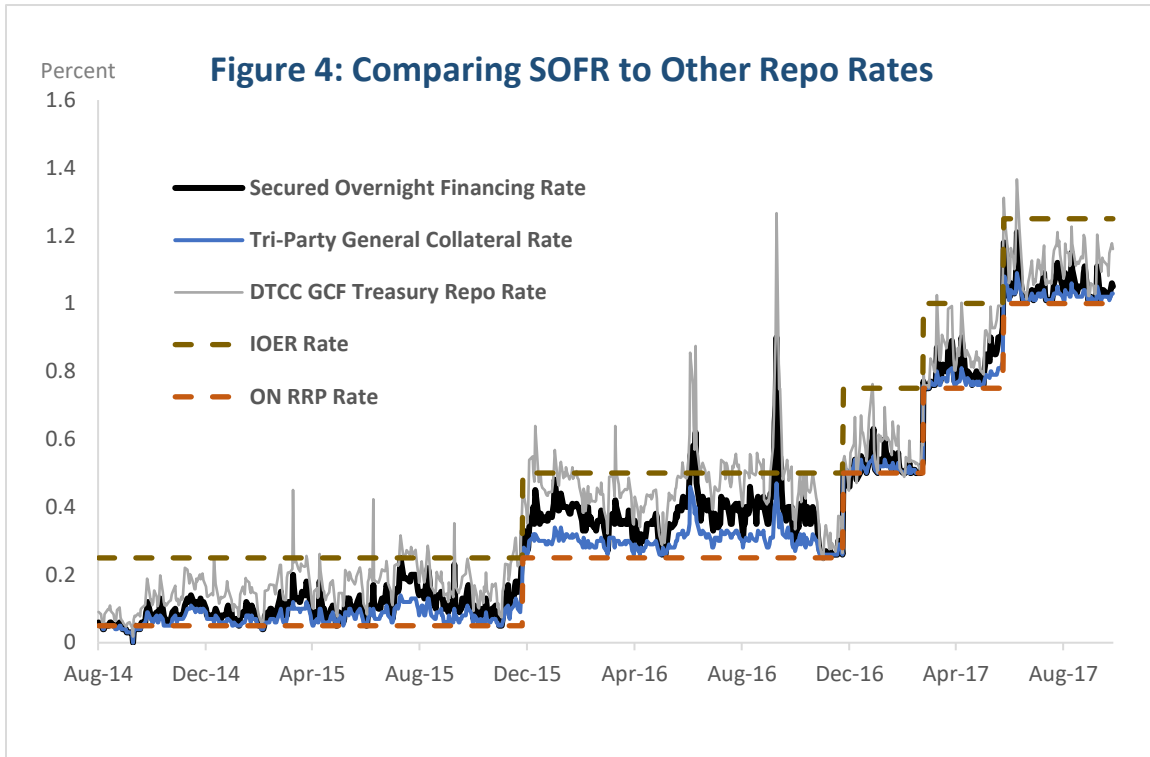
\* JPMorgan Chase also currently settles some tri-party transactions but has announced that it intends to cease providing these services. Broker-dealers using JPMorgan's government settlement services are in the process of transferring those transactions to Bank of New York Mellon.



Source: Federal Reserve Bank of New York ([link to data](#)).



Average volumes over 2017H1, with the exception of 3-month T-bills, which are preliminary estimates from available FINRA Trade Reporting and Compliance Engine (TRACE) data over August and September 2017. 3-month volumes are based on all transactions with remaining maturities between 80 and 100 calendar days or 41-80 business days. Source: Federal Reserve Bank of New York; Financial Industry Regulatory Authority; DTCC Solutions LLC, an affiliate of the Depository Trust & Clearing Corporation; and the Board of Governors of the Federal Reserve System.



Source: Federal Reserve Board, Federal Reserve Bank of New York ([link to data](#)), and DTCC Solutions, LLC.

### *The Choice of an Overnight Rate*

The ARRC's Interim Report and Consultation described the potential alternatives identified by the ARRC and the criteria it used to evaluate them. As noted in Section I, many of the official sector's concerns regarding LIBOR were driven by the secular decline in banks' short-term wholesale unsecured borrowing – the markets that LIBOR is meant to represent. In convening the ARRC, the Federal Reserve asked the committee to consider potential alternative rates based on more active and robust markets. According to these criteria, the markets considered should be highly liquid, with a large set of daily transactions, and that one should reasonably expect them to remain in this condition under all but the most extreme circumstances.<sup>15</sup>

With these considerations in mind, ARRC members began their deliberations by creating a list of criteria to judge potential rates against (**Table 2**). The ARRC criteria rely heavily on the IOSCO Principles, with the view that any chosen alternative should meet those principles. This is in line with the work of the Treasury Markets Practices Group, which has likewise recommended the use

<sup>15</sup> Given its paramount role in setting U.S. monetary policy, the Federal Reserve also requested that the ARRC avoid choices that could be seen restricting its flexibility in changing the monetary policy framework in the event that changes to the framework were considered in the best interest of meeting the Federal Reserve's congressionally-mandated policy goals.

of financial benchmarks that are consistent with the IOSCO Principles into its Best Practice Guidance.<sup>16</sup> The choice of SOFR provides market participants with an IOSCO compliant alternative to LIBOR available for their use.

LIBOR is used as a forward-looking term rate in financial markets, and recognizing this, the ARRC also included the existence or potential for a term market to develop among the criteria that it judged would ease the transition to any potential alternative. Nonetheless, as the ARRC considered possible term rates as potential alternatives to USD LIBOR, none was judged to satisfactorily meet its criteria. With nearly \$200 trillion in financial contracts referencing USD LIBOR, the need for a reference rate based on a deep and robust underlying market was paramount, and this essentially limited the set of credible alternatives to overnight rates, which were judged to be based on the only markets with a deep enough set of transactions to support a rate as heavily used as USD LIBOR.

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**Table 2: ARRC Criteria for Potential Alternative Reference Rates**

- **Benchmark Quality**

The degree to which the benchmark design ensured the integrity and continuity of the rate. The underlying market was evaluated according to its:

- Liquidity
- Transaction volume
- Resilience through periods of illiquidity
- Resilience to changes in regulatory approach
- Potential that the benchmark may constrain or be adversely affected by changes in the monetary policy framework

- **Methodological Quality**

The degree to which the benchmark construction could satisfy the IOSCO Principles for soundness and robustness. Rates were also evaluated according to:

- Standardized terms for data inclusion
- Transparency of data
- Availability of historical data

- **Accountability**

Evidence of a process that ensures compliance with the IOSCO Principles

- **Governance**

Evidence of governance structures that promote the integrity of the benchmark

- **Ease of Implementation**

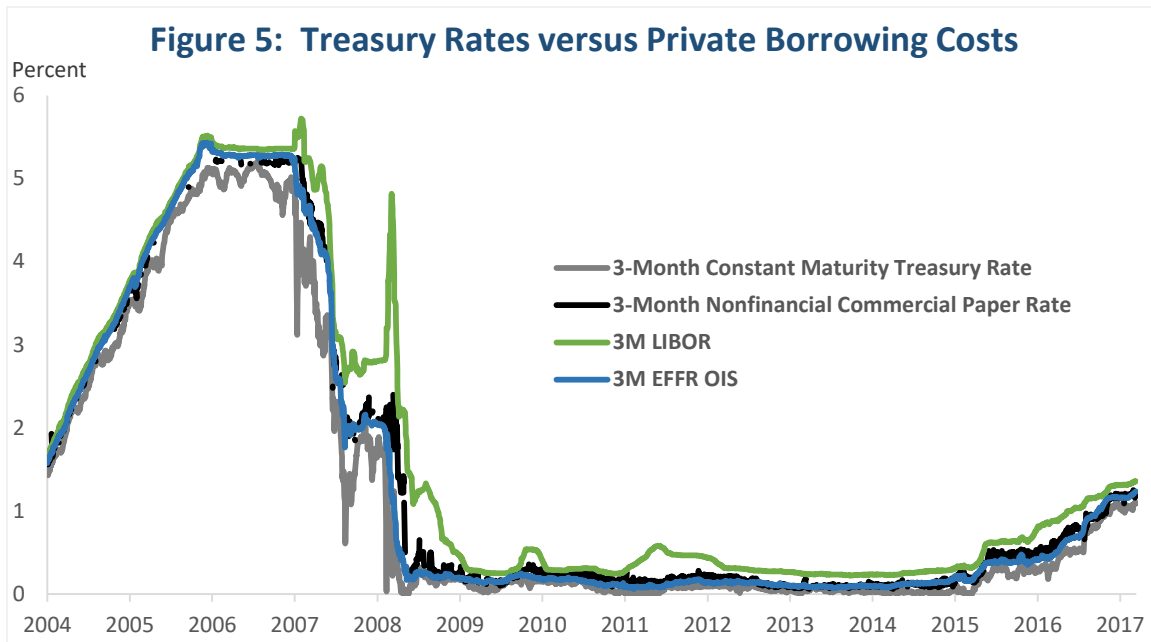
Assessed ease of transitioning to the rate, including:

- Anticipated demand for and relevance to hedging/trading
  - Existence of or potential for a term market in the underlying rate
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<sup>16</sup> [TMPG Releases Updated Best Practice Guidance to Address the Use of Financial Benchmarks](#), February 2016.

Because this is an important point, it is worth discussing the types of term rates that the ARRC considered and why each was ultimately seen as unsuitable for the ARRC's recommendation:

- The ARRC considered several types of term unsecured lending rates – financial commercial paper (CP), certificates of deposit, term Eurodollar or term federal funds transactions – but did not view them as leading candidates because they share the same key structural difficulties as LIBOR. As discussed in Section I, even in normal times, short-term wholesale unsecured transactions are now relatively sparse. Further, term wholesale unsecured borrowing is typically substantially less frequent during periods of stress, particularly at longer maturities. For example, the Federal Reserve was able to publish its three-month AA-rated financial commercial paper rate series for only 10 of the 40 trading days over November and December 2008.
- The ARRC also considered term Treasury rates. There are precedents for the use of Treasury rates as term benchmarks; for example, historically, some floating-rate mortgages were based on the U.S. Treasury's Constant Maturity Treasury (CMT) rates, although almost all new floating-rate mortgages now reference LIBOR. And, as shown in Figure 3, the average daily volume of transactions in 3-month Treasury bills is larger than the volumes for 3-month unsecured funding, although still much smaller than volumes in overnight repo or unsecured markets. However, while Treasury bill or bond rates scored highly against several of the ARRC's main criteria (liquidity, robustness, existence of a term market), there are several criteria that the ARRC felt were not met. Most importantly, Treasury rates are not well correlated with measures of either private-sector financial or nonfinancial corporate borrowing costs (**Figure 5**). Treasury rates can also move idiosyncratically based on fluctuations in technical supply and demand factors that are not reflective of the true risk-free rate relevant to the market. ARRC members felt that these considerations made Treasury rates less appealing to most market participants because these rates are less effective in hedging private-sector risks and funding costs. Therefore, the ARRC believed it would be difficult to implement a transition from LIBOR to a Treasury benchmark.
- The ARRC also considered the potential to use term OIS rates linked to EFR (the fixed rates negotiated to receive the floating compound average EFR over a specified period). This OIS market is highly liquid, in the sense that trades of good size may be executed with little price impact, deriving in part from the market's tight links with other interest rate swap (IRS) and the Fed Funds futures markets. However, on a daily basis, there are relatively few transactions in this market at any given maturity, making it impossible to calculate a robust, fully-transaction based OIS rate linked to EFR under current market conditions.



Source: Bloomberg, Ice Benchmarks Administration, and Federal Reserve Board.

The private-sector groups in the other currency jurisdictions each independently reached the same conclusion that there were no viable robust term rate alternatives to LIBOR. Like the ARRC, each has chosen either an unsecured or secured overnight rate, depending on the characteristics of their national markets.<sup>17</sup> For example, the Swiss National Working Group [chose the Swiss Average Rate Overnight \(SARON\)](#), an overnight repo rate, as its preferred alternative; this choice was simplified by the fact that the predominant Swiss unsecured rate, the TOIS rate, ceased publication at the end of last year as the panel of banks that had submitted to it had fallen to too low a level for the rate to be viable. In the United Kingdom, the Working Group on Sterling Risk-Free Reference Rates [selected the reformed Sterling Overnight Interbank Average \(SONIA\)](#), the overnight unsecured rate, as it was deemed more robust and afforded a simpler transition than the repo rates the group considered. The Japanese group [selected the unsecured overnight call rate](#) (although the government securities repo market is fairly large in Japan, there is no transaction-based overnight repo reference rate currently in production).<sup>18</sup>

Although it is an overnight rate rather than a term rate like LIBOR, SOFR should be easily incorporated into IRS and other derivatives contracts. Market participants are already familiar with OIS and futures contracts referencing EFRR, and derivatives contracts that reference SOFR can be structured similarly. While overnight repo rates are more volatile than term LIBOR rates on a day-to-day basis (a fact that is not only true of the available repo rates – the overnight unsecured rates such as EFRR and OBFR are also more volatile than term LIBOR, especially on month ends), derivatives contracts referencing SOFR would use an average of daily SOFR rates

<sup>17</sup> Further information on the work of each of the currency groups can be found in the FSB's [Progress Report on Reforming Major Interest Rate Benchmarks](#), October 2017.

<sup>18</sup> The Working Group on Euro Risk-Free Rates is expected to make the selection of its recommended alternative euro reference rate by the end of 2018.

over a fixed period of time as the floating rate paid under the terms of the contract, not a single day's realization of SOFR. For example, the floating rate on these instruments might be a 3-month compound average of daily SOFR rates. Those averages are similar to the averages of EFFR paid in current OIS contracts. They are much less volatile than the daily realizations of SOFR and are typically only minimally impacted by any volatility on quarter ends. In fact, a 3-month average of SOFR is less volatile than 3-month LIBOR (**Figure 6**).

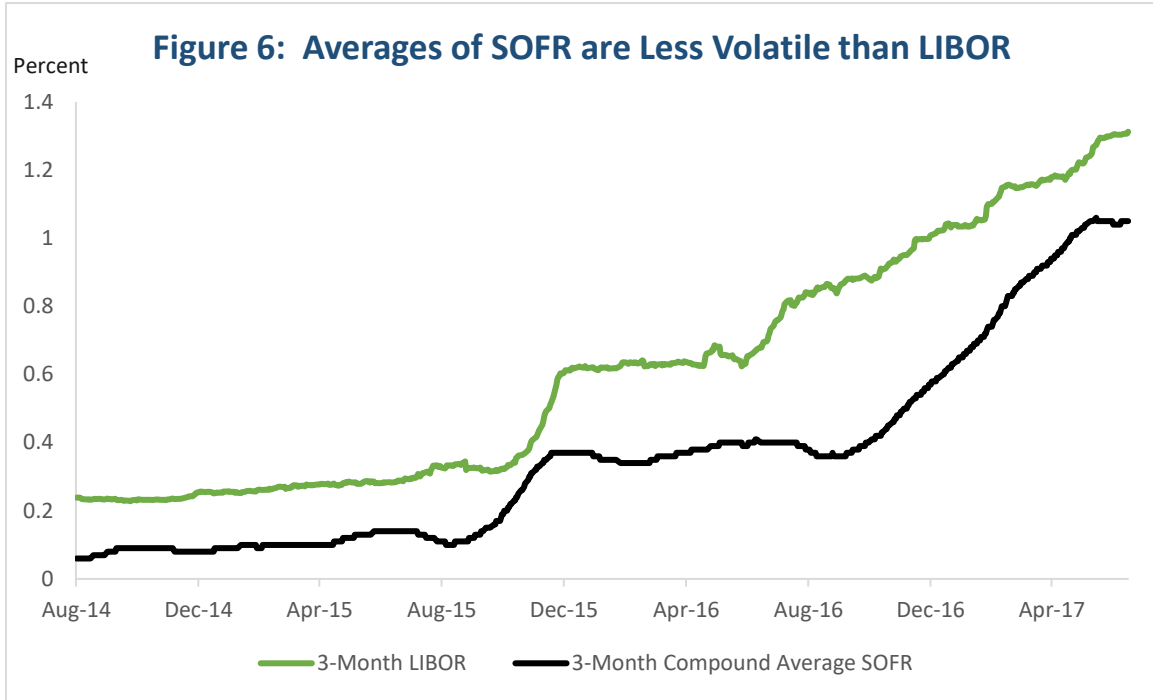
Publicly available Treasury repo rate series extend back more than 10 years and appear to be reasonable proxies for modelling how a rate like SOFR would have behaved historically.<sup>19</sup> Based on such historical data, averages of overnight repo rates like SOFR and overnight unsecured rates like the EFFR have tended to move together fairly closely over longer periods of time (**Figure 7**). Neither overnight unsecured rates nor overnight secured rates have much credit risk, and hence they will both generally move closely with the Federal Reserve's monetary policy target. Thus, the economic differences between current OIS contracts referencing EFFR and future OIS contracts that will reference SOFR should be relatively small.

But while SOFR should be relatively easy to incorporate into derivatives, instruments in which many market participants are already familiar with contracts that reference an overnight rate rather than a term rate, participants in many cash products may find use of an overnight rate unfamiliar, even if it is averaged over time. Some participants and products might be able to adapt to the use of an overnight rate, perhaps especially larger firms with more sophisticated financing infrastructures or in consumer products, which require a safe and robust rate but not necessarily a forward-looking rate. But other market participants might find this type of transition more difficult. To address this issue, the ARRC has explicitly included a goal of producing a forward-looking term rate for use in cash products in its Paced Transition Plan, which is discussed in the next section.

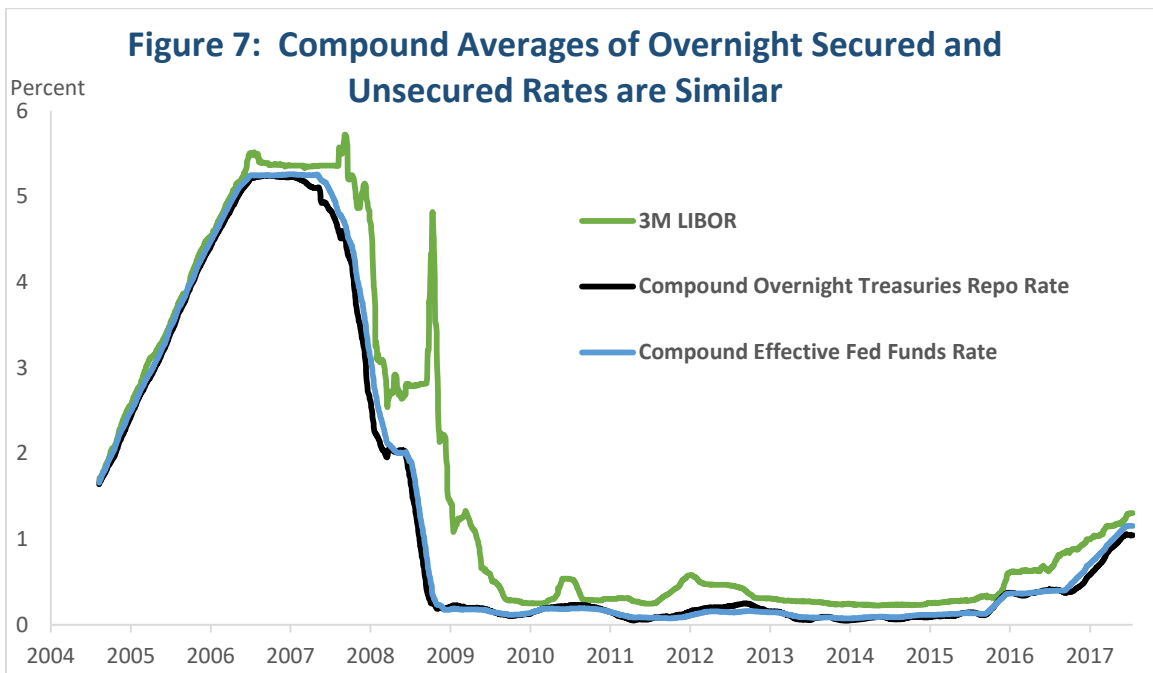
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<sup>19</sup> Prior to 2015, there were smaller differences across the different segments of the U.S. Treasury repo market, so that these publicly available rates are likely to be close to what a rate like SOFR would have been. See the materials included in the [Presentation](#) to the August 1, 2017 ARRC meeting.





Compound Average SOFR is a compound geometric average of daily rates over the subsequent quarter. Source: Federal Reserve Bank of New York ([link to data](#)) and Ice Benchmarks Administration.



Forward Compounded Repo and Fed Funds Effective Rates are compound geometric averages of daily rates over the subsequent quarter. Repo rate data: Aug 2014-2017 from the Federal Reserve Bank of New York ([link to data](#)), prior data from ICAP/NEX (source: Bloomberg series IREBUSOP Index); Effective Fed Funds Rate: Federal Reserve Bank of New York; LIBOR: ICE Benchmark Administration.

### III. The Paced Transition Plan

Because of the prevalence of LIBOR in USD interest rate markets, planning for any transition poses a host of challenges. The first of those challenges will be creating a baseline level of liquidity for derivatives contracts referencing SOFR. End users cannot be expected to choose or transition cash products to a benchmark that does not have at least a threshold level of liquidity in derivatives markets. The ARRC’s Paced Transition Plan (outlined in **Table 3**) is intended to progressively build the liquidity required to support the issuance of and transition to contracts referencing SOFR, and to create conditions in which a robust term reference rate based on derivatives referencing SOFR could be constructed and itself used in some cash products.

**Table 3: The Paced Transition Plan**

Step	Anticipated Date of Completion
1. Infrastructure for futures and/or OIS trading in SOFR is put in place by ARRC members.	2018 H2
2. Trading begins in futures and/or bilateral, uncleared, OIS that reference SOFR.	End 2018
3. Trading begins in cleared OIS that reference SOFR in the current (EFFR) PAI environment.	2019 Q1
4. CCPs begin accepting new or modified swap contracts (swaps paying floating legs benchmarked to EFFR, LIBOR, or SOFR) that pay SOFR as PAI and are discounted with a SOFR curve. In this stage, market participants are allowed a choice at the time of execution of each trade between clearing contracts that calculate PAI and discounting using either EFFR or SOFR, with both types of contracts cleared within the same clearing guarantee fund. CCPs would gradually lengthen the maturity of contracts accepted for clearing in the new SOFR PAI/discounting environment to ensure that liquidity was adequate to support the new discount curve.	2020 Q1
5. CCPs no longer accept new swap contracts for clearing with EFFR as PAI and discounting except for the purpose of closing out or reducing outstanding risk in legacy contracts that use EFFR as PAI and discount rate. Existing contracts using EFFR as PAI and discount rate and new contracts using SOFR as PAI and discount rate continue to exist in the same pool. Existing contracts roll off over time as they mature or are closed out. Methods for accelerating this close out, and the potential to pre-announce the closure of the CCPs’ EFFR-based PAI and discount rate capability, may play a part.	2021 Q2
6. Creation of a term reference rate based on SOFR derivatives	End 2021

*Initial Steps: PAI and Discounting*

The initial steps of the Paced Transition Plan map a strategy for migrating price alignment interest (PAI) and discounting (both described in **Box 2**) to SOFR. This planned migration is designed to create a robust source of demand for derivatives referencing SOFR, consistent with the FSB's recommendations, while avoiding any disruptive changes in existing contracts. It accomplishes this by focusing on a gradual transition for new transactions rather than a “big bang” that would seek to change PAI on existing trades or alter their discounting.

There were several reasons that made the Paced Transition Plan's focus on PAI and discounting natural to consider. First, because SOFR is an overnight rate, the need to build an initial level of demand and liquidity in derivatives markets referencing it will necessarily involve transitioning some current private-sector uses of EFFR, the current overnight index used for PAI and discounting, to SOFR. And second, as SOFR becomes a widely used alternative to USD LIBOR, it will be natural for market participants to seek to align PAI and discounting with the new rate.

**Box 2: PAI and OIS Discounting**

**Price alignment amount or price alignment interest (PAI):** PAI for a centrally cleared derivative is an amount calculated by applying an overnight interest rate to the variation margin (VM) for the derivative in order to align the economics of the cleared derivative with the economics of uncleared derivatives (for which interest is paid on cash VM postings). The position holder who has a cleared derivative contract with positive net present value (NPV) – i.e. “in the money” – pays PAI and, conversely, the position holder who has a cleared derivative contract with negative NPV – i.e., “out-of-the money” – receives PAI. For USD denominated derivatives, the PAI amount is calculated by applying the EFFR, which is annualized on an actual/360 basis, to contract NPV. Since PAI is a cost-of-funding adjustment, the interest rate is chosen in conformity with the currency denomination of the derivative contract. For centrally cleared derivatives, each CCP's rules dictate the legal and regulatory treatment of both variation margin and PAI.

**OIS discounting:** OIS discounting refers to the discounting of expected cash flows of a derivative using a nearly risk-free curve. Most dealers and CCPs now use interest rates based on EFFR OIS rates for discounting of derivatives. Under OIS discounting, the specific reference rates linked to a particular swap are used to generate expected future cash flows, but the NPV of these cash flows is calculated using an OIS discount curve. In the past, the conventional way for pricing IRS was to discount the cash flows of the swap by using the LIBOR curve, but since the 2008 financial crisis, there has been a shift toward using EFFR OIS discount factors as market participants recognized that LIBOR and EFFR OIS rates had diverged and that EFFR OIS discounting was more appropriate. With this switch, USD PAI and discounting were linked to the EFFR, and many market participants now see a tight link between PAI and discounting as crucial to the effectiveness of their hedging strategies and accounting requirements.

Under the Paced Transition Plan, CCPs would announce that, as of a specified future date, PAI and discounting on newly registered IRS contracts for clearing would be calculated on the basis of SOFR. These new trades would exist within the same clearing pool as existing IRS contracts with PAI and discounting calculated using EFR. In this scenario, as legacy contracts using EFR for PAI and discounting matured, or were closed out or liquidated, over time, the clearing pool would consist of only IRS that use SOFR for PAI and discounting.

Successful implementation of this plan will require voluntary trading by ARRC member banks and other market participants in order to achieve a critical mass of liquidity in futures contracts and/or OTC derivative contracts that reference SOFR. This will first require financial intermediaries to build internal infrastructures to support trading SOFR futures and swaps (Step 1 of the Paced Transition Plan). Progress is already underway: for example, the CME Group (CME) has publicly announced that it will introduce trading in SOFR futures and options and is preparing the systems necessary to do so.<sup>20</sup> ARRC members believe that many of these infrastructures can be substantially built by the end of the second quarter of 2018. With these infrastructures in place, it is anticipated that futures trading and trading in uncleared OIS referencing SOFR will begin by the end of 2018 (Step 2), with cleared OIS trading beginning – subject to regulatory approval – by the end of the first quarter of 2019 (Step 3).

Over 2019, trading activity in futures and OIS markets should foster an accumulation of price histories that will help market participants develop an understanding of the term-structure dynamics of longer-dated exposures in SOFR. This would allow CCPs to provide their members with a choice of clearing some instruments into a PAI/discounting environment based on SOFR by the first quarter of 2020 (Step 4). CCPs would then gradually lengthen the maturity of contracts allowed to clear into the new environment as liquidity in longer-term SOFR derivatives developed. After liquidity and the availability of adequate historical data for risk modelling have sufficiently developed, market acceptance of the new rate would allow CCPs to require that all new trades clear in to the SOFR-based PAI/discounting environment (Step 5). Assuming that the necessary market conditions have been met, this step could be taken by the second quarter of 2021. Although the plan refers specifically to PAI and discounting used by the CCPs given that most new standardized IRS contracts are now cleared, it is expected that counterparties will also seek to adjust the interest on collateral specified in their credit support annexes (CSAs) for uncleared derivatives to the new rate. This may take a longer period of time because amendments to these agreements must be negotiated bilaterally (although CSAs referencing LIBOR as the interest rate paid on collateral could be covered by the work that ISDA is considering on fallback language discussed in Section IV).

Under the Paced Transition Plan, legacy contracts cleared in the current PAI and discounting environment based on EFR would gradually roll off. Mechanisms for closing out legacy contracts will need to be devised in order to both meet likely market demand and ensure the safety

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<sup>20</sup> See [www.cmegroup.com/media-room/press-releases/2017/7/26/cme\\_group\\_to\\_developderivativesonbroadtreasuriesrepofinancingrat.html](http://www.cmegroup.com/media-room/press-releases/2017/7/26/cme_group_to_developderivativesonbroadtreasuriesrepofinancingrat.html) and [www.cmegroup.com/trading/interest-rates/secured-overnight-financing-rate-futures.html](http://www.cmegroup.com/trading/interest-rates/secured-overnight-financing-rate-futures.html)

and soundness of the CCPs in case of a member default involving a significant legacy book. Some ARRC members have expressed interest in exploring mechanisms to accelerate the closing of legacy contracts in the EFR-based PAI/discounting environment, but this has not been incorporated into the Paced Transition Plan itself and the feasibility of such mechanisms would depend on individual capabilities and interests.

The initial steps in the ARRC's Paced Transition Plan are intended to develop futures and OIS trading in SOFR. If the resulting futures and/or OIS markets were active and robust enough, then a forward-looking term reference rate could be created based on those markets as a final step (Step 6). Other cash products could then directly reference these term rates rather than directly referring to SOFR if some participants in those markets find it useful to do so.

Contracts for loans or other cash products could be written on either a backward-looking average of SOFR or on a "in arrears" arrangement in which the floating rate is based on realized average of the overnight rate over the period (as in OIS and futures contracts). However, the floating-rate payments in these contracts would be different than the floating-rate payments in contracts that currently reference LIBOR because they are either (a) not predetermined at the start of the period, or (b) not a forward-looking term rate (OIS payouts reflect the ex-post actual movement in rates, while LIBOR reflects the ex-ante expectation at the given time of its fixing). These differences may pose difficulties to some customers who have grown accustomed to or whose systems require a pre-determined, forward-looking floating rate payment structure. In order to accommodate these participants and to ensure the possibility of a smoother transition for many cash products, the ARRC considers it important that a forward-looking term rate based on SOFR be created.

#### ***Final Step: Creating a Term Reference Rate***

Once the initial steps in the Paced Transition Plan are successfully accomplished and liquid derivatives markets referencing SOFR have developed, the final step (Step 6) in the Paced Transition Plan, the creation of a forward-looking term rate based on SOFR derivatives markets, should be possible. For the framework underlying the term rate to work well and to have enough underlying transactions to construct a term rate, the bulk of derivatives transactions would need to be based on the underlying OIS and futures markets. As a result, broker-dealers offering clients contracts on a term reference rate for other non-derivatives products would still need to hedge the positions in the underlying OIS or futures market. Nonetheless, the forward-looking term rate could provide a useful "front end" allowing many users of cash products to transition away from LIBOR more easily.

The ARRC has discussed several different potential methods for creating a forward-looking term rate:

### 1. *Futures-Based*

A synthetic constant-maturity term rate could be imputed by bootstrapping between the prices of nearby SOFR futures contracts. The exact details would depend on the structure of SOFR futures and SOFR OIS contracts; Appendix 3 provides an example of a potential methodology based on EFR futures.

Currently, near-term federal funds futures contracts offered by CME average around \$100 billion in daily trading volume (averaged across contracts). Eurodollar futures contracts have \$100-\$300 billion in daily trading volume. If futures contracts on SOFR were expected to inherit these volumes, then a robust reference rate could likely be constructed using this data. Since the data underlying this rate would be bona fide transactions from a regulated exchange with governance and data control measures already in place, it should be feasible for a private administrator of such a rate to meet the IOSCO principles.

### 2. *OIS-Based*

A constant maturity term rate could also be constructed directly from OIS transactions. Those transactions could potentially include both new swap or other related trades and pre-existing trades that are closed out or renegotiated at a market rate. Swap execution facilities (SEFs) that provide trading platforms or CCPs that provide clearing for OIS transactions could potentially provide the underlying data. Banks could also potentially submit transactions data to an administrator, however strong governance and data control measures would need to be put in place internally at each bank submitting data, similar to the governance and control measures in place for LIBOR submitters, in order for the reference rate to be IOSCO compliant.

Confidential internal data shared by some ARRC members indicates that it might be difficult to create a robust term rate using only OIS transactions with maturities near to any given fixed term under current market conditions (e.g., there did not appear to be enough 3-month OIS transactions to robustly impute a 3-month rate on a daily basis). However, if the market for SOFR OIS developed sufficiently then this may become feasible. It may also be feasible to create a robust term rate based on a curve fit across all OIS transactions at a range of money-market maturities, with constant maturity rates then imputed from the fitted curve.

### 3. *Actionable Market Quotes*

A term reference rate could in principle also be created based on the order books of one or more trading platforms, as is done with the ICE Swap Rates (formerly ISDAfix).<sup>21</sup> ARRC members have expressed some preference for the other alternatives proposed rather than this type of system. The IOSCO Principles do allow for reference rates based on actionable quotes, but only in liquid markets in which transactions are regularly executed. And in the

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<sup>21</sup> See [www.theice.com/iba/ice-swap-rate](http://www.theice.com/iba/ice-swap-rate)

presence of high-speed trading, order books taken at fixed points in time are not necessarily representative of actual trade prices. Hitting a quote on a given platform can quickly lead to changes in order books across multiple platforms so that “theoretically” filling a trade based on a snapshot of one or more order books can generate a fairly different implied price than would be obtained by actually executing a trade. Care would also need to be taken to ensure that quotes were not submitted and then quickly withdrawn in an attempt to influence the reference rate without incurring much risk of being executed. However, notwithstanding those potential hurdles, a term rate based on central limit order books approach may still be feasible. One consideration that would help to make this approach more robust would be to sample order books over a longer period of time, for example the full trading day or many hours over the day.

In considering any of these methodologies, a few caveats should be recognized:

- The term reference rate must be IOSCO compliant.
- Because the term reference rate would be based on SOFR derivatives, the SOFR-derivatives market would need to be highly robust, with a significantly larger volume of transactions than any activity referencing the term rate. If the volume of transactions referencing the term benchmark exceeded or even rivaled trading in the underlying OIS or futures market, then there would not be enough activity in the underlying market to actually support the term benchmark as a reference rate. It would also create many of the incentive problems associated with basing a substantial amount of transactions on a reference rate based on less robust underlying activity.
- The actual swap rate that brokers would be able to obtain in the market on a given day at a given point in time would in most cases not equal the fixing for the term reference rate. This would create some basis between the rates paid on contracts referencing the term rate and the actual rates that dealers obtained in hedging those contracts in the underlying SOFR derivatives market. (This basis risk could be eliminated if the term reference rate was calculated based on a batch auction, in which all orders were submitted and the clearing price was taken as the benchmark fixing. This idea has not been taken up in other markets, but could be considered here as another potential method for calculating the term rate.)
- Finally, it is important to note while these methodologies can potentially be used to create a forward-looking term rate that can complement SOFR, none of the methodologies can be used to create a forward-looking term reference rate that embeds credit risk. As discussed in Section II, the ARRC concluded that a term unsecured lending rate would not be a robust alternative to LIBOR given the limited transactions, unstable samples of borrowers, and sensitivity to market stress that these markets exhibit. And other than those rates, none of the other potential alternative rates (overnight repo rates, OBFR or EFR, Treasury rates, central bank policy rates, and term OIS) include a meaningful credit component.

Because a transactions-based term rate will depend on an active trading market in SOFR derivatives, it will take some time to develop. The ARRC believes that this final step could be accomplished by the end of 2021. However, even under this timeline, it may be possible to build a demonstration rate earlier in the process that could help market participants to understand how the eventual term reference rate would likely behave. Further, it would still be possible to create a pre-determined, forward-looking payout structure in contracts referencing SOFR even prior to the creation of the term reference rate. For example, a party due to pay the average of SOFR in arrears at the end of the year could convert that payment to a set of pre-determined, forward-looking quarterly payments by entering into a set of rolling quarterly OIS contracts. Thus, parties potentially paying or receiving a floating rate based on a compound average of SOFR do not necessarily need to wait for a term reference rate in order to maintain a LIBOR-like payment structure.

### *Discussion*

The Paced Transition Plan maps out a clear and achievable strategy for creating a robust demand for trading SOFR derivatives. However, as already noted, the plan can only be successfully implemented if ARRC members and key end users and other market participants recognize their own interest in voluntarily helping to establish markets for SOFR instruments and building a critical mass of liquidity in them. To the extent that these goals are achieved quickly, a term reference rate based on SOFR derivatives could potentially be established earlier than the end of 2021, which would enable many users of cash products to transition away from LIBOR at a faster pace if they chose to do so. If these conditions are met and there is demand to do so, the Paced Transition Plan could eventually be updated to incorporate faster adoption timelines or to incorporate explicit transition goals for some cash products.

Successful implementation will require thoughtful adjustments to firms' internal operational constructs to support the Paced Transition, and accepting SOFR OIS for clearing by CCPs and offering a SOFR-based PAI/discounting environment will require the support of clearing members and other liquidity providers. Regulators and self-regulatory organizations will also need to work cooperatively with market participants to ensure that there are no inadvertent hurdles that could inappropriately impede the development of SOFR markets.

The ARRC has formed a Regulatory Issues working group, which has identified several areas in which regulators and self-regulatory organizations could aid the implementation of the Paced Transition Plan. Expedited regulatory approvals for CCPs that seek to clear new OTC products referencing SOFR would help to speed the transition plan. Releasing a longer history of repo data (which FRBNY has discussed doing) could aid in internal risk-modelling and potentially also in the capital treatment of SOFR-based instruments. And SOFR OIS will need to be added to the recognized list of benchmarks appropriate for hedge accounting, a step that the Financial Accounting Standards Board (FASB) is already actively proposing for consultation and expects to



publish a final decision on in the near term.<sup>22</sup> The decision by FASB to consider this step so quickly is a crucial one, and helps to set an example as to how much can be accomplished if the official sector and private market participants work cooperatively to support a smooth transition.

Establishing new basis markets will also be important. Robust basis markets between SOFR, LIBOR, and EFFR will be needed to aid in a smooth transition and to support liquidity, and will require the support of ARRC members and all major market participants. Basis markets would also help to facilitate the voluntary closing out of legacy contracts. Cross-currency swaps and options referencing SOFR will also need to be established to help market participants hedge risks. The ARRC has formed a Market Structures working group to help establish basic prototypes for these new contract structures referencing SOFR and is working with ISDA and the Securities Industry and Financial Markets Association's Asset Management Group to consult with market participants in designing them. A number of other infrastructures will need to be put in place, including establishing sources for market pricing and ensuring that SOFR derivatives are available for trading on SEFs and exchanges.

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<sup>22</sup> See

[www.fasb.org/jsp/FASB/Document\\_C/DocumentPage?cid=1176170063556&acceptedDisclaimer=true](http://www.fasb.org/jsp/FASB/Document_C/DocumentPage?cid=1176170063556&acceptedDisclaimer=true)

#### IV. ISDA's Work on Contract Robustness for Derivatives

As discussed in Section I, the ARRC was tasked with considering best practices for contract robustness, and the ARRC has explored potential fallbacks for the rates it considered as alternatives to LIBOR. ISDA, a participant in the work of the ARRC, is leading a review of its documentation in order to improve contract robustness for derivatives, and many members of the ARRC are participating in ISDA working groups as part of this review.

The FSB's Official Sector Steering Group (OSSG) has recommended that market participants both understand the contractual fallback arrangements that would apply if a benchmark such as LIBOR were permanently discontinued and ensure that those arrangements be robust enough to prevent potentially serious market disruptions in such an event. Current contract language for derivatives, which typically incorporate ISDA definitions, does not meet that standard. Under ISDA's current definitions for interest rate derivatives, counterparties are directed to seek quotes from London or New York reference banks if LIBOR is not published. If two or more such quotes are obtained, the contract will pay the average rate, but if one or no quotes are received then the payment obligations are not specified. Most observers have noted that it seems unlikely that banks would be willing to provide these quotes, potentially leaving hundreds of trillions of dollars in outstanding derivatives contracts with no clarity on what they should pay or receive.

Given that there are an estimated \$190 trillion in outstanding derivatives contracts referencing USD LIBOR, this presents a key financial stability risk. Without a clear and practicable arrangement determining the rate that payments are to be based on, firms could be left with both potentially large and unplanned exposures, uncertain payment obligations, and many potentially mismatched hedges. As LIBOR remains the dominant reference rate, new contracts are being written under the current ISDA definitions on a daily basis, adding to this risk. Market participants could mitigate this risk by closing out their current LIBOR transactions and moving new transactions to other rates, but to the extent that they continue to hold and use LIBOR instruments, it is important that more robust contract language be put in place.

These issues are not specific to USD LIBOR. They are common across all of the currencies that LIBOR is quoted in as well as other benchmarks such as EURIBOR and TIBOR. Accordingly, in July 2016, the OSSG requested that ISDA lead a cross-currency initiative to improve derivative contract robustness to address risks of discontinuance of widely-used interest rate benchmarks.<sup>23</sup> This work has two components: first, appropriately updating the ISDA definitions so that new trades would have more robust arrangements embedded in the documentation protecting investors against the risk that LIBOR may cease publication, and, second, to develop a method for incorporating similar types of arrangements into legacy contracts referencing LIBOR.

ISDA has formed several working groups to consider these issues. They have identified appropriate conditions that should trigger a fallback and have identified SOFR and the similar alternative rates selected by each of the working groups in other jurisdictions as the appropriate

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<sup>23</sup> See Appendix C of the FSB's 2017 [Progress Report on Reforming Major Interest Rate Benchmarks](#).

primary fallback rate.<sup>24</sup> Regardless of what rate was chosen as a fallback, it would be different from LIBOR, and there thus would need to be some method for adjusting for the difference between LIBOR and the fallback rate. Determining appropriate methods for calculating a spread or any other necessary adjustments to compensate for those differences is a key issue that ISDA is considering and will consult on before making any final recommendations.

Although complex, this work is crucial and progress needs to be made with due speed, both for overall financial stability and for the mitigation of the risks faced by ISDA's own members. Although many legacy derivatives contracts are due to roll off before the end of 2021 (Table 1), more risk is put into the system as new contracts continue to be written using the current ISDA definitions. If this language is not updated, it will be difficult for end users to mitigate their risks to LIBOR except by closing out their current positions.

While the work that ISDA is undergoing will help to address a key financial stability risk regarding LIBOR in particular, the issue of contract robustness is more general. Users of financial benchmarks should seek to incorporate more flexible language that allows for practicable arrangements that are minimally disruptive in the event that the benchmark fails, especially in long-term contracts. ISDA's work on LIBOR and other IBORs can potentially help set an example that may be useful in other contracts.

As with the Paced Transition Plan, regulators can facilitate the adoption of more robust contract arrangements. The ARRC's Regulatory Issues working group has noted several issues that regulators should consider, including whether adopting more robust contract language in legacy contracts would lead them to be treated as new trades, thereby triggering requirements to clear, post margin, or be treated as a tax event. Hurdles of these types could impede the adoption of more robust contract language and thereby leave the system less safe overall.

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<sup>24</sup> See [ISDA's Benchmarks Initiatives](#), 2017 remarks by Scott O'Malia and Katherine Darras.

## V. Transition Issues for Cash Products

Since the announcement that FCA had sought to secure voluntary agreements from panel banks to continue submitting to LIBOR only through the end of 2021, participants in the many cash markets that use USD LIBOR are now searching for more robust contract language and considering transitions away from LIBOR.

Although LIBOR was first created for use as a reference rate in pricing syndicated loans, over time its use expanded, and with that expansion its liquidity increased. Due to that liquidity, LIBOR became the dominant USD reference rate and is used in a wide array of cash instruments beyond syndicated loans, including many corporate loans, FRNs, securitizations, and some consumer mortgages and other loans. Much of USD LIBOR's use in these instruments is due to the ease of hedging LIBOR in derivatives markets rather than any inherent need for a reference rate based on the cost of unsecured bank borrowing. Indeed, while the use of financial products referencing LIBOR has steadily grown, the actual volume of unsecured borrowing transactions underlying LIBOR has been in decline. And as shown in Figure 5, LIBOR has not historically been a very effective hedge of nonfinancial corporate borrowing rates. However, users of cash products have constructed complicated financing systems that rely on LIBOR in interconnected ways, and it will not be a simple task to orient those systems to a new rate. In particular, dealing with legacy contracts that reference LIBOR will be challenging, because most contracts for these cash products do not envision the possibility that LIBOR might permanently cease and have fallbacks that would not be economically appropriate if such an event occurred. And, unlike derivatives covered by ISDA documentation, these instruments are not generally covered by a standardized documentation. Changing contract language in these cash products will require many bilateral negotiations.

To better understand these issues, the ARRC formed working groups related to:

- i. Business Loans and Collateralized Loan Obligations
- ii. Mortgages and Other Consumer Loans
- iii. Floating Rate Notes
- iv. Securitizations

Those working groups have already conducted initial research into exposures to USD LIBOR and the common forms of contract language in each of these sets of products. The groups' initial findings for each of these sets of products are outlined below.

## i. Business Loans

### *Estimated Exposure to USD LIBOR*

Among cash products, business loans have the highest exposure to USD LIBOR.

According to data from the Financial Accounts of the United States, as of the end of 2016, there were \$3.4 trillion in outstanding private-sector loans to U.S. nonfinancial businesses (this figure excludes commercial mortgages and does not include committed lines of credit that have not been drawn on). Of the amount outstanding, \$2.1 trillion are syndicated loans – loans that are jointly provided by a group of lenders to a borrower – according to Shared National Credit data.

Based on Federal Reserve staff estimates, roughly 85 percent of corporate business loans are floating rate.<sup>25</sup> A somewhat higher proportion of syndicated floating-rate loans appear to be tied to LIBOR than non-syndicated floating rate loans. As shown in Table 1, there are an estimated \$1.5 trillion in outstanding syndicated loans referencing USD LIBOR and \$0.8 trillion in non-syndicated loans. It is likely that there is also a roughly equal amount of exposure to USD LIBOR in committed lines that have not been drawn.<sup>26</sup>

As of the end of 2016, there were also \$4.1 trillion in outstanding commercial mortgage loans to U.S. nonfinancial businesses.<sup>27</sup> As shown in Table 1, Federal Reserve staff estimates indicate that \$1.1 trillion of this is tied to USD LIBOR.

Many, though not all, business loan borrowers and lenders rely on USD LIBOR to hedge or offset their exposures in other products. For, example, in some instances borrowers are expected to also enter into derivatives contracts in order to limit the volatility of their floating rate payments. And there are an estimated \$425 billion outstanding in collateralized loans obligations (CLOs) that securitize business loans (**Table 4**).

### *Typical Contract Language*

The contract language in business loan documentation may include instructions to seek quotes from a set of reference banks in the event that LIBOR is not published, similar to language in the ISDA definitions for derivatives, but if quotes are not obtained, then the language appears to typically imply that the rate paid on these loans would convert to an alternative base rate – either the prime rate or a rate which is typically close to the prime rate and set at a fixed spread over EFFR. Because the prime rate is typically well above LIBOR (currently, 3-month USD LIBOR is

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<sup>25</sup> The estimate of the proportion of floating rate debt is taken from [The Potential Increase in Corporate Debt Interest Rate Payments from Changes in the Federal Funds Rate](#) by Kumbhat, Palomino, and Perez-Orive, 2017. Estimates of the proportion of loans tied to LIBOR are from Federal Reserve staff estimates based on proportions calculated using FR Y-14 data.

<sup>26</sup> The amount of undrawn committed lines appears to be slightly larger than the amount drawn; for example, the amount of committed but undrawn syndicated loans is \$2.2 trillion according to Shared National Credit data, while the amount drawn is \$2.1 trillion.

<sup>27</sup> [Financial Accounts of the United States – Z.1](#)

near 2 percent and the prime rate is 4.5 percent), this would entail a significant and unplanned increase in borrowing costs.

In bilateral loans (the segment of loans that are not syndicated), the borrower and lender could directly negotiate to change this term of the loan agreement. But while most details in syndicated loan agreement can be changed with the agreement of a majority of lenders, certain changes, including altering the rate, require unanimous lender consent. Thus it may be difficult to change these terms in some legacy syndicated loans, particularly in loans involving a larger number of lenders or institutional lenders that may not have a close relationship with the borrower.<sup>28</sup>

However, roughly 80 percent of currently outstanding business loans will mature by the end of 2021, and syndicated loans are amended fairly frequently, so it is very likely that most or all of the outstanding stock of loans would be amended before the end of 2021. New or amended contracts could include more robust fallback language or could be altered to refer to a specific fallback rate and method for determining adjustments to the spread on the loan in order to prevent a significant change in borrowing costs.

Working group members noted that they were beginning to see some variation in loan contract language at the initiation of both borrowers and lenders. Those variations were intended to introduce more robust language that would allow for a choice of economically appropriate fallbacks while seeking to minimize value transfers – for example, the type of transfers that would occur if the fallback caused a jump in rates paid by borrowers as in current language. Some of the language considered seemed to be aimed at limiting the discretion of the calculation agent, seeking to specify that the spread or margin of the loan should be adjusted to limit the valuation change from a change in reference rate. There was also a push by some market participants to move away from requiring unanimous consent to majority consent of the lenders to change the rate in syndicated loans.

## ii. Floating Rate Notes

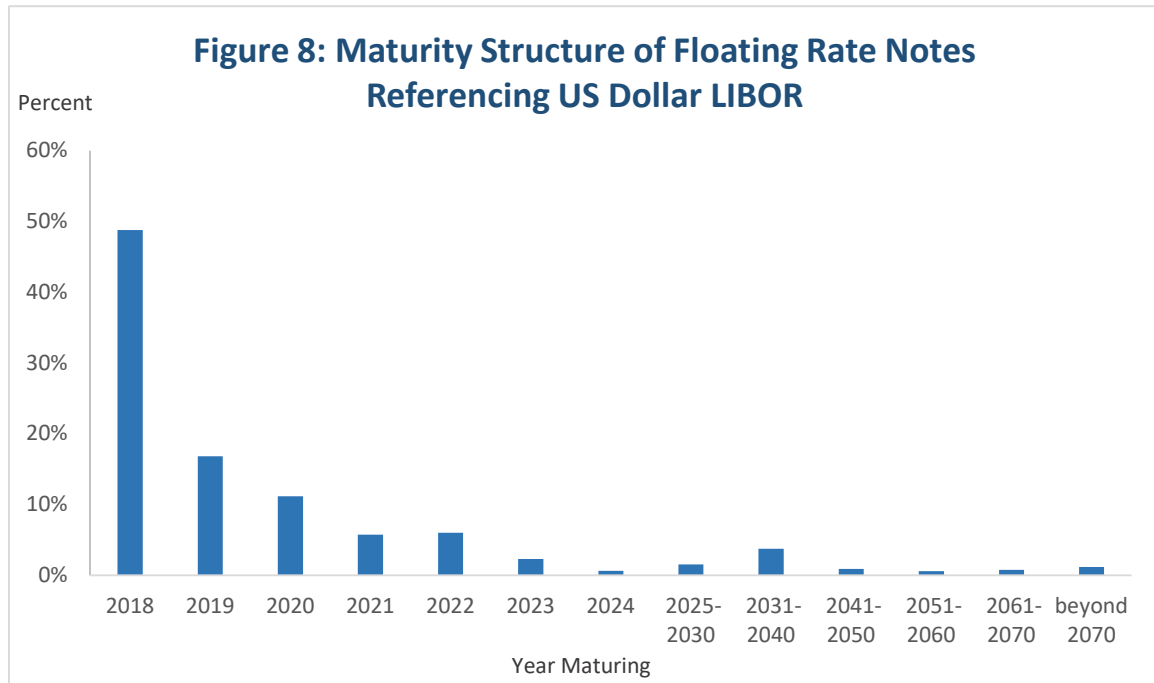
### *Exposures to LIBOR*

As noted in Table 1, as of last year, there were an estimated \$1.8 trillion in FRNs referencing USD LIBOR. Of that amount, \$1.1 trillion was debt issued by private sector businesses, with government-related entities (sovereigns, local governments, supranationals, and government-sponsored agencies) having issued roughly \$700 billion in floating-rate debt tied to USD LIBOR. A substantial portion, nearly \$1 trillion, was issued by entities outside the United States. Issuance of USD LIBOR-tied FRNs is widespread across a range of countries, with the most significant amounts linked to entities from Europe, Japan and Canada.

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<sup>28</sup> Considering committed but undrawn credit agreements, borrowers would not be required to draw on those lines if the fallback rate was considered unfavorable, and uncommitted facilities would not pose problems since the lender would not be obligated to extend a loan.

However, while the outstanding stock of FRNs tied to USD LIBOR is substantial, roughly 84 percent of those instruments are due to mature before the end of 2021 and 92 percent before the end of 2024 (**Figure 8**). Thus, there is scope to institute more robust contract language or to migrate away from LIBOR for a large proportion of this debt. Nonetheless, there is a small but still significant amount of debt that does not mature for very long periods of time, including existing notes that do not mature for 70 years or longer.



Source: Bloomberg.

### *Typical Contract Language*

Typical contract language in FRNs directs the calculation agent (often the issuer or the trustee) to first poll a sample of banks (similar to the fallback language in ISDA’s interest rate definitions for derivatives) if LIBOR is not published, and if quotes are not received then the note would convert to a fixed-rate instrument at the last published value of LIBOR. These terms can currently only be changed with the unanimous consent of all noteholders, which would likely be difficult to secure. In many instances, it might not even be feasible to locate the full set of noteholders.

The inadvertent conversion of FRNs to fixed-rate instruments could be quite disruptive, both for the issuers and the holders of these notes, introducing a number of potential basis risks, less effective hedges, and potentially dramatically affecting valuations and the expected path of payments. In addition, some FRN investors, including money market funds, may be prohibited from investing in fixed-rate, long-term instruments. If LIBOR ceased to exist and FRNs

converted to fixed, those investors would be forced to sell their notes, resulting in losses to investors and a decline in the value of the notes.

In the absence of unanimous consent of note holders to change the terms of the contract, it is unclear how to avoid these disruptions. Issuers could attempt to buy back the current notes and issue new ones, but for some issuers, the current FRNs may be used as capital instruments and there might be nontrivial capital implications for the issuer in buying the notes back. Apart from buying back the notes, the best hope for addressing legacy contract risks in longer-dated FRNs might be some form of industry-wide solution.

Market participants are considering a variety of contract language in new issuances. Some notes, for example recent FRNs issued by Goldman Sachs, JPMorgan Chase, and Morgan Stanley have offered different variations allowing the issuer, an affiliate, or a non-affiliate third party the right to name a market-accepted successor rate as calculation agent if any of the others fallbacks specified, including potential fallbacks to SOFR, were exhausted. Some other FRNs specified that the rate would fall back to the initial rate of the bond rather than to the last value of LIBOR. In those cases, participants preferred a fallback to a known rate rather than to some future value of LIBOR that was unknown at the date of issuance.

### iii. **Securitizations**

#### *Exposures to LIBOR*

Amongst securitizations, mortgage-related products, including mortgage backed securities (MBS) and collateralized mortgage obligations (CMOs), have the largest exposure to USD LIBOR, although most MBS and CMOs are fixed rate instruments and less than 10 percent (\$967 billion) are tied to LIBOR (Table 4). In contrast, most collateralized loan obligations (CLOs) are tied to LIBOR, and CLOs represent the next largest amount of exposure to USD LIBOR at \$425 billion. Asset backed securities (ABS) related to student loans, credit cards, and auto and other loans and collateralized debt obligations (CDOs) together account for another \$395 billion in exposure.



**Table 4: Estimated Volumes of Outstanding Securitizations (Billions USD)**

	<b>MBS and CMOs</b>	<b>CLOs</b>	<b>ABS</b>	<b>CDOs</b>	<b>Total</b>
<b>Total</b>	10,298	503	725	182	11,708
<b>of which:</b>					
<b>FIXED</b>	9,217	22	444	24	9,707
<b>LIBOR</b>	967	425	243	152	1,787
<b>Other</b>	114	56	38	6	214

Source: SIFMA

*Typical Contract Language*

There is some variation in contract language across different types of securitizations. Agency MBS and CMOs constitute the largest share of securitizations; if LIBOR were permanently discontinued and other fallback methods such as polling reference banks fail to provide a fallback rate, these securitizations appear to generally allow the noteholder (Fannie Mae or Freddie Mac) to name a successor rate.<sup>29</sup> Contract language in non-agency MBS is likely to be more varied, but it appears that typical contract language would require a poll of banks and then convert to fixed-rate at the last published value of LIBOR if quotes are not received. This language also appears to prevail in most ABS. Some ABS specify the trustee may have authority to name a successor rate, although it is unclear whether the trustee would consider itself able to do so. Changing the language in non-agency MBS or ABS would have to be approved by a noteholder vote, with different deals having different voter thresholds, but typically unanimous consent appears to be required. As with FRNs, securing unanimous consent, or even locating the full set of noteholders, would likely be quite difficult. Many securitizations also involve several different tranches, making the problem even more complicated.

Standard contract language in CLO documentation similarly appears to imply that the CLO obligations currently paying LIBOR would become fixed rate instruments, paying the last published value of LIBOR, if LIBOR stopped publication. This would create potentially disruptive mismatches between the rate paid in the underlying loan securities (which would convert to the prime or a similar rate based on current contract language) and the rate paid on the CLO (which would convert to fixed) if LIBOR stopped. As with ABS and non-agency MBS,

<sup>29</sup> See for example, [www.fanniemae.com/syndicated/documents/mbs/remicpros/SF\\_FM\\_June\\_1\\_2014.pdf](http://www.fanniemae.com/syndicated/documents/mbs/remicpros/SF_FM_June_1_2014.pdf)

language in legacy CLO contracts would be difficult to change. However, while some CLOs can have maturities of 12+ years, most can typically be called after an initial 1-2 year period and almost always are, at which point more robust contract language could be included. For CLOs, one possible change in language might be to set the fallback rate equal to the rate specified in the majority of underlying loans, but market participants are still only beginning to explore these issues.

#### iv. **Mortgages and Other Consumer Products**

##### *Exposures to LIBOR*

As of the fourth quarter of 2016, the total amount of outstanding single-family residential mortgages was roughly \$10.3 trillion.<sup>30</sup> About 83 percent of these were fixed-rate mortgages and 17 percent were adjustable-rate mortgages. An estimated \$1.2 trillion of these adjustable rate mortgages are tied to USD LIBOR. According to data from the Financial Accounts of the United States, other consumer credit – which includes credit cards, auto loans, consumer loans and student loans – totaled \$3.6 trillion, but the estimated exposure to LIBOR in these categories is relatively low.

##### *Typical Contract Language*

Initial research indicates that mortgages generally have fairly robust language allowing the noteholder to choose a new rate if LIBOR was permanently discontinued. Language in conforming mortgages held or packaged in MBS by Fannie Mae and Freddie Mac give those agencies the authority to name a successor rate in the event that LIBOR stopped publication.

Mortgages not held by Fannie Mae or Freddie Mac also appear to typically have similar language giving the noteholder authority to name a successor rate, although there may be more variation in contract language in non-conforming mortgages.

However, while contract language for most mortgages may give the noteholder the ultimate right to choose a successor rate, typical language is silent on how or if the margin or spread to the reference rate could be adjusted. Thus, if the noteholder named a successor rate that was higher than LIBOR, households could see an increase in their mortgage costs unless the margin was cut. There is no known precedent for raising the margin, but noteholders might have scope for cutting margin if the successor rate was higher. Fannie Mae has switched rates two times in recent history when minor reference rates were discontinued.<sup>31</sup> In one case, the successor rate was slightly lower. In the other, the successor rate was very slightly higher and in that instance a servicer purchased all of the affected MBS pools, dissolved the MBS, and then modified the loans to avoid any increase in the loan rates to consumers.

<sup>30</sup> [Financial Accounts of the United States – Z.1](#)

<sup>31</sup> See [www.fanniemae.com/portal/funding-the-market/mbs/news/2014/announcement-031214.html](http://www.fanniemae.com/portal/funding-the-market/mbs/news/2014/announcement-031214.html).

## VI. Conclusion – Looking Beyond LIBOR

As noted in Section I, the ARRC's focus was directed toward developing plans to encourage voluntary adoption of its recommended rate rather than a mandated transition. Thus, while the Paced Transition Plan is designed to create a liquid alternative to LIBOR, it did not necessarily look beyond LIBOR in the sense that it envisioned that SOFR and LIBOR contracts might run in parallel for the foreseeable future. The work by ISDA to implement more robust fallbacks obviously acknowledges the risk that LIBOR could stop, but neither the ARRC nor ISDA took an end to LIBOR as a base expectation. And while the ARRC considered the potential for cash products to transition toward the rate that it would select, its work was focused on derivatives because they represent the vast majority of overall gross exposure to USD LIBOR and because, despite the warnings of the FSB and FSOC as to risks inherent to LIBOR, many market participants seemed likely to prefer to continue to reference LIBOR in cash products.

However, the announcements from the FCA regarding the future of LIBOR have highlighted to many market participants the risk that LIBOR may cease publication at some point after 2021. The increased instability apparent in LIBOR has altered the trajectory of what market participants seek and need to accomplish. In some respects, this may encourage more active participation in the Paced Transition Plan as more market participants now understand that they may need to transition away from LIBOR. To the extent that more market participants begin to trade SOFR derivatives at earlier stages of the plan, the plan may proceed more quickly and a term rate could potentially be created before the end of 2021. At the same time, the potential that LIBOR might stop obviously accentuates the importance of the work by ISDA and the need to make contracts referencing LIBOR more robust, and has brought about a host of complicated decisions for users of cash products referencing LIBOR.

Although creating a financial system that does not rely on LIBOR may seem impossible to some, it is important to remember that LIBOR has only existed for 30 years. Transitioning away from LIBOR will pose many challenges, but it should be possible to do so in a way that minimizes more serious disruptions if market participants work cooperatively to avoid them. A clear, coordinated, and thoughtful process that openly engages with all market participants and involves the support of regulators in establishing fallbacks and transition plans is the best way to ensure that this occurs.

The official sector has clearly supported this type of process. The Federal Reserve Board's Chairman Powell and CFTC's Chairman Giancarlo have publicly pledged to work together with market participants in dealing with these transitions, and the FSOC has recommended that regulators and market participants collaborate in taking steps in mitigating any potential disruptions.<sup>32</sup> The ARRC will continue to serve as a forum for encouraging this type of industry-wide effort. As announced at the ARRC's November 2017 roundtable, the Federal Reserve

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<sup>32</sup> See [How to Fix Libor Pains](#), Wall Street Journal, August 3, 2017 and the [FSOC 2017 Annual Report](#).

intends to reconstitute the ARRC in order to widen its membership and working groups to better coordinate between users of a variety of financial instruments who are now interested in mitigating their risks to USD LIBOR.<sup>33</sup>

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<sup>33</sup> The plan to reconstitute the ARRC was also announced on the ARRC's website. See [www.newyorkfed.org/arrc/announcements.html](http://www.newyorkfed.org/arrc/announcements.html)

## Appendix 1

With the support of a number of agencies including the U.S. Department of the Treasury, the U.S. Commodity Futures Trading Commission (CFTC), and the Office of Financial Research, the Federal Reserve Board and Federal Reserve Bank of New York convened the ARRC.<sup>34</sup> The group was charged with identifying one or more alternative risk-free or nearly risk-free USD reference rates that both fit the needs of the market and meet standards of best practice, and with developing plans for the adoption of these rates.

### Membership of the Alternative Reference Rates Committee

#### Chair

Sandra O'Connor  
Chief Regulatory Affairs Officer  
JP Morgan Chase & Co.

#### Voting Members

Bank of America  
Barclays  
BNP Paribas  
Citigroup  
Credit Suisse  
Deutsche Bank  
Goldman Sachs  
HSBC  
JP Morgan Chase & Co.  
Morgan Stanley  
Nomura  
RBS  
Société Générale  
UBS  
Wells Fargo

#### Nonvoting Members

Bank of New York Mellon  
CME Group  
DTCC  
ISDA  
LCH Clearnet

#### Ex Officio Members

Board of Governors of the Federal Reserve System  
Federal Reserve Bank of New York  
U.S. Commodity Futures Trading Commission  
U.S. Department of the Treasury  
Office of Financial Research

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<sup>34</sup> More information on the ARRC is available at the [ARRC's website](#).

## Appendix 2

The ARRC formed an advisory group in November 2016 as part of its efforts to solicit feedback from a broad range of market participants. The advisory group provided input to the ARRC as it finalized its recommendations for an alternative reference rate and transition strategy.

### Membership of the ARRC Advisory Group:

BlackRock  
Brevan Howard Asset Management  
Citadel  
GE Capital  
Manulife  
Met Life  
Office of the NYC Comptroller, Bureau of Asset Management<sup>35</sup>  
Pacific Investment Management Company  
PNC Bank  
Quicken Loans  
The Federal Home Loan Bank of New York  
The Federal Home Loan Mortgage Corporation  
The Federal National Mortgage Association  
The International Bank for Reconstruction and Development – World Bank  
Verizon

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<sup>35</sup> On behalf of NYC Pension Funds

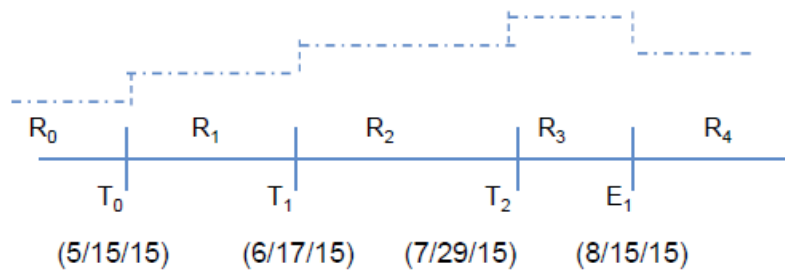
Appendix 3

This appendix illustrates a sample methodology for constructing a constant-maturity term rate from SOFR futures. As an example, we consider the construction of a 3-month rate on May 15, 2015.

The 3-month period in question (May 15 to August 15) included 2 Federal Open Market Committee (FOMC) meeting dates, June 17 ( $T_1$ ) and July 29 ( $T_2$ ). Allowing for discrete shifts in the overnight night rate after FOMC meetings, we can break the overnight interest rate into five distinct regime as shown in the figure below:

- $R_0$  denotes the average of the overnight index in May up to the 15<sup>th</sup>.
- The overnight rate is assumed to be  $R_1$  every day between May 15 and June 17
- It is assumed to be  $R_2$  after June 17 until the next meeting on July 29
- It is assumed to be  $R_3$  subsequently until the end date (Aug 15)
- The overnight rate is assumed to average  $R_4$  for the portion of August after the 15<sup>th</sup>.

Illustration of the timeline and overnight rate regimes associated with a 3M term rate



For each rate  $R_i$  and calendar month  $M_j$  we denote by  $f_{ij}$  the fraction of month  $M_j$  that has the overnight rate equal to  $R_i$  (e.g.,  $f_{01}$  equals  $14/31$ , since  $R_0$  spans 14 days in the month of May (month  $M_1$ ) and  $f_{11}$  equals  $17/31$ , since  $R_1$  spans the remaining 17 days in the month).

If we denote by  $FF_1, FF_2, FF_3$  and  $FF_4$  as the values of 100 minus the futures prices for May, June, July, and August respectively, we can setup a system of equations linking the overnight rate regimes with observed forward rates from the calendar month futures contracts. The equations can be written in matrix form as  $Ax = b$ , as shown below. The first equation also requires  $R_0$  to take the value of the observed historical average of the overnight rate in the current month, which we denote as  $FF_{act}$

Equations linking the various overnight rate regimes to the rates corresponding to calendar-month futures contract yields

Matrix A					x	=	b
1	0	0	0	0	R <sub>0</sub>		FF <sub>act</sub>
f <sub>01</sub>	f <sub>11</sub>	f <sub>21</sub>	f <sub>31</sub>	f <sub>41</sub>	R <sub>1</sub>		FF <sub>1</sub>
f <sub>02</sub>	f <sub>12</sub>	f <sub>22</sub>	f <sub>32</sub>	f <sub>42</sub>	R <sub>2</sub>		FF <sub>2</sub>
f <sub>03</sub>	f <sub>13</sub>	f <sub>23</sub>	f <sub>33</sub>	f <sub>43</sub>	R <sub>3</sub>		FF <sub>3</sub>
f <sub>04</sub>	f <sub>14</sub>	f <sub>24</sub>	f <sub>34</sub>	f <sub>44</sub>	R <sub>4</sub>		FF <sub>4</sub>

Based on the data prevailing on May 15, 2015, the equation would look like this:

Numerical specifics for the 3M rate\*

Matrix A					x	=	b
1	0	0	0	0	R <sub>0</sub>		0.130
0.45	0.55	0	0	0	R <sub>1</sub>		0.128
0	0.53	0.47	0	0	R <sub>2</sub>		0.135
0	0	0.90	0.10	0	R <sub>3</sub>		0.140
0	0	0	0.45	0.55	R <sub>4</sub>		0.155

\* Based on market data as of COB 5/14/2015. Source: JPMorgan, Bloomberg

Once the equation is solved, the overnight rates can be compounded daily over the desired term to produce the necessary term rate. However, in general, the equation may not be always directly solvable – there may be more variables than equations, or the matrix A may have properties that admit no solution or infinite solutions. Even when the system can be directly solved, it may be that small variations in futures prices can produce big swings in solved rates, particularly when the trade date is close to a meeting date or month end.

In this example, we use an approach that seeks to *approximately* solve  $Ax = b$ , while also imposing additional structure on the solution. Solutions where the overnight rate shifts up after one meeting, while shifting materially down after the next, are rather unlikely to be baked into expectations. Such solutions can be penalized by solving the problem

$$\begin{aligned} \min: & 0.5x^T Hx + M e^T u + M e^T v \\ \text{subject to: } & Ax + u - v = b \\ & x, u, v \geq 0 \end{aligned}$$

Where M is a constant, e denotes the vector of ones and H denotes the Hessian matrix associated with the penalty function.

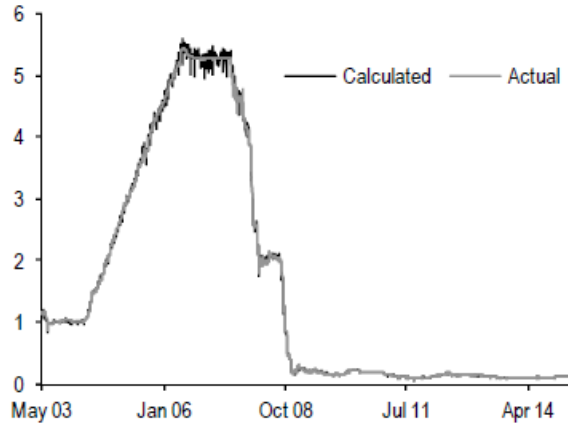
$$\sum_{i=1}^{n-2} (R_{i+2} - 2R_{i+1} + R_i)^2$$



We also modified entries in A so that values below a threshold (0.1) were rounded down to zero, and the remaining elements in the row were scaled up so the sum equaled 1.

This methodology was implemented for 3-month and 6-month tenors, with results shown below. As can be seen, the results are quite close to historical EFRR OIS rates.

3M OIS rates – actual, versus the result of the proposed calculation methodology; %



6M OIS rates – actual, versus the result of the proposed calculation methodology; %

