A User's Guide to SOFR

The Alternative Reference Rates Committee

April 2019

Executive Summary

This note is intended to help explain how market participants can use SOFR in cash products. In particular, those who are able to use SOFR should not wait for forward-looking term rates in order to transition, and the note lays out a number of considerations that market participants interested in using SOFR will need to consider:

- Financial products either explicitly or implicitly use some kind of *average* of SOFR, not a single day's reading of the rate, in determining the floating-rate payments that are to be paid or received. An average of SOFR will accurately reflect movements in interest rates over a given period of time and smooth out any idiosyncratic, day-to-day fluctuations in market rates.

- Issuers and lenders will face a technical choice between using a *simple* or a *compound* average of SOFR as they seek to use SOFR in cash products. In the short-term, using simple interest conventions may be easier since many systems are already set up to accommodate it. However, compounded interest would more accurately reflect the time value of money, which becomes a more important consideration as interest rates rise, and it can allow for more accurate hedging and better market functioning.

- Users need to determine the period of time over which the daily SOFRs are observed and averaged. An *in advance* structure would reference an average of SOFR observed before the current interest period begins, while an *in arrears* structure would reference an average of SOFR over the current interest period.

- An average of SOFR *in arrears* will reflect what *actually happens* to interest rates over the period; however it provides very little notice before payment is due. There have been a number of conventions designed to allow for a longer notice of payment within the *in arrears* framework. These include payment delays, lookbacks, and lockouts, and, as described in the note, different markets have successfully adopted each of these. The note also discusses conventions for *in advance* payment structures and hybrid models that can reduce the basis relative to *in arrears*.

The note also explains the interaction between SOFR and the type of forward-looking term rates that the ARRC has set a goal of seeing produced once SOFR derivative markets develop sufficient depth. While these term rates can be a useful tool for some and an integral part of the new ecosystem, hedging these rates will also tend to entail more costs than using SOFR directly and their use must be consistent with the functioning of the overall financial system. For this reason, the ARRC sees some specific productive uses for a forward-looking SOFR term rate, in particular as a fallback for legacy cash products referencing LIBOR and in loans where the borrowers otherwise have difficulty adapting to the new environment.

Background

In 2014, the Federal Reserve convened the Alternative Reference Rates Committee (ARRC) and tasked the group with identifying an alternative to U.S. dollar LIBOR that was a robust, IOSCO-compliant, transaction-based rate derived from a deep and liquid market. In 2017, the ARRC fulfilled this mandate by selecting the Secured Overnight Financing Rate, or SOFR. SOFR is based on overnight transactions in the U.S. dollar Treasury repo market, the largest rates market at a given maturity in the world. National working groups in other jurisdictions have similarly identified overnight nearly risk-free rates (RFRs) like SOFR as their preferred alternatives.

SOFR has a number of characteristics that LIBOR and other similar rates based on wholesale term unsecured funding markets do not:

- It is a rate produced by the Federal Reserve Bank of New York for the public good;
- It is derived from an active and well-defined market with sufficient depth to make it extraordinarily difficult to ever manipulate or influence;
- It is produced in a transparent, direct manner and is based on observable transactions, rather than being dependent on estimates, like LIBOR, or derived through models; and
- It is derived from a market that was able to weather the global financial crisis and that the ARRC credibly believes will remain active enough in order that it can reliably be produced in a wide range of market conditions.

However, SOFR is also new, and many are unfamiliar with how to use it. SOFR is also an overnight rate, and while the ARRC believes that most market participants can adapt to this by using compound or simple averaging over the relevant term, the ARRC has at the same time set a goal of seeing an administrator produce a forward-looking term rate based on SOFR derivatives (once these markets develop to sufficient depth) in order to aid those cash market participants who may have greater difficulty in adapting to an overnight rate.

This note is intended to help explain how market participants can use SOFR in cash products and to explain the forward-looking term rates the ARRC seeks to see published in the future and where the ARRC believes those rates can be most productively used. The term rates can be a useful tool for some and an integral part of the new ecosystem; but their use also needs to be consistent with the functioning of the overall financial system. In particular, those who are able to use SOFR should not wait for the term rates in order to transition.[1] The LIBOR transition will be challenging, and it is not in the interest of market participants to put off taking action nor can the ARRC guarantee that an administrator can produce a robust, IOSCO-compliant forward-looking term rate before LIBOR stops publication. The ARRC sees some specific uses, in particular as a fallback for legacy cash products referencing LIBOR and in loans where the borrowers otherwise have difficulty in adapting to the new environment, where the term rates can be most productively used. For many other purposes, the ARRC believes it should be possible to use compound or simple averages of SOFR and that many users will come to find it more convenient to do so once they become more familiar with the new environment.

[1] The FSB has recognized that there may be a role for these types of forward-looking term rates, but the FSB has also stated that it considers that the greater robustness of overnight rates like SOFR makes them a more suitable alternative than these forward-looking term rates in the bulk of cases.

1. How Can Financial Products Use Overnight Rates?

Although many market participants have become accustomed to using term IBORs, they are a relatively new phenomenon, and financial markets were able to function perfectly well before these rates were widely adopted. There is in fact a long history of use of overnight rates in financial instruments. In the United States, futures referencing the effective federal funds rate (EFFR) have traded for more than 30 years and overnight index swaps (OIS) referencing EFFR have traded for almost 20 years. Banks in the United States also have a history of offering loans based on the Prime Rate, which is essentially an overnight rate, or overnight LIBOR, and there have been floating rate notes issued based on the fed funds rate or, more recently, SOFR. Other countries have similar experiences; for example, in Canada, most floating-rate mortgages are based on overnight rates.

A. Averaged Overnight Rates

Many financial products have used overnight rates as benchmarks, but one key thing to keep in mind is that these financial products either explicitly or implicitly use some kind of *average* of the overnight rate, not a single day's reading of the rate, in determining the floating-rate payments that are to be paid or received.

There are two essential reasons why financial products use an average of the overnight rate:

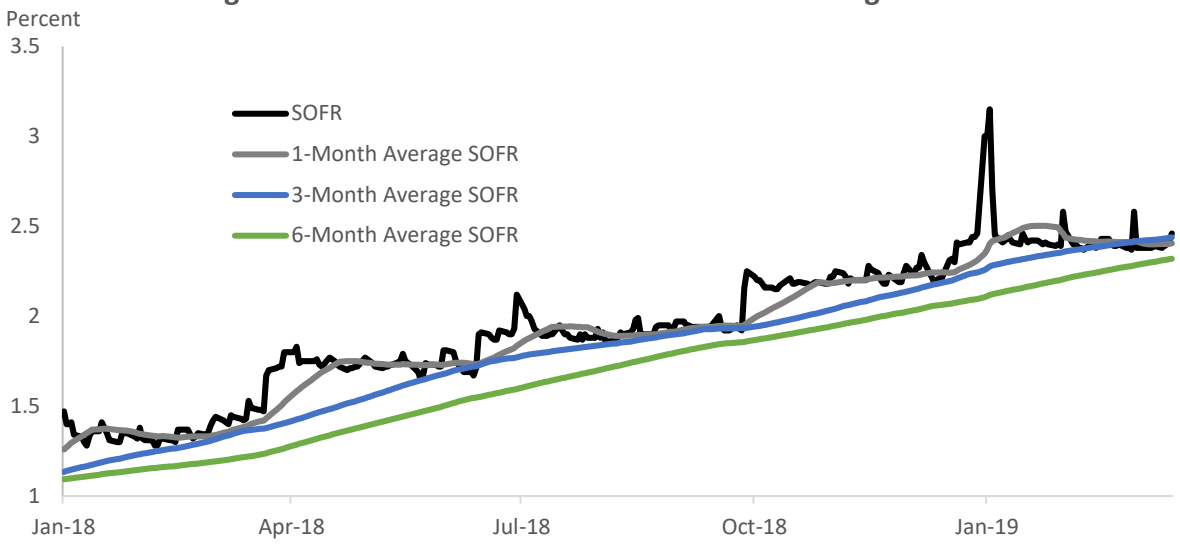
- First, an average of daily overnight rates will accurately reflect movements in interest rates over a given period of time. For example, SOFR futures and swaps contracts are constructed to allow users to hedge future interest rate movements over a fixed period of time, and an average of the daily overnight rates that occur over the period accomplishes this.

- Second, an average overnight rate smooths out idiosyncratic, day-to-day fluctuations in market rates, making it more appropriate for use.

This second point can be seen in Figure 1. On a daily basis, SOFR can exhibit some amount of idiosyncratic volatility, reflecting market conditions on any given day, and a number of news articles pointed to the jump in SOFR over the end of the year. However, although people often focus on the type of day-to-day movements in overnight rates shown by the black line in the figure, it is important to keep in mind that the type of averages of SOFR that are referenced in financial contracts are much smoother than the movements in overnight SOFR. The Federal Reserve Bank of New York has indicated that it will solicit public feedback on its plans to begin publishing averages of SOFR by the first half of 2020, which may further help market participants understand and use SOFR in cash products.[2]

[2] See reference to these plans in the January 2019 FOMC minutes.

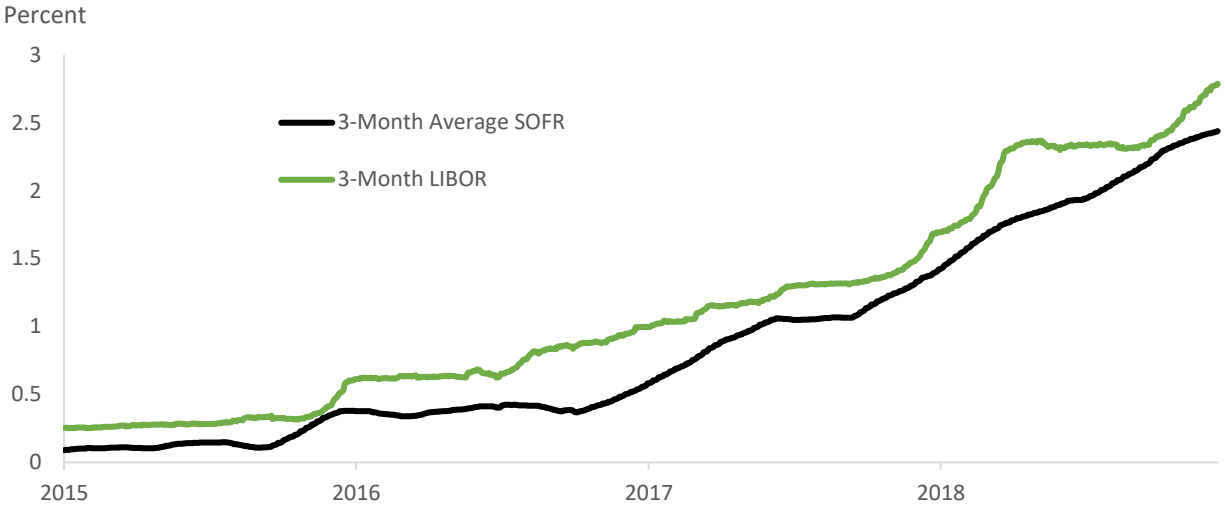
Figure 1: Recent Movements in SOFR versus Averaged SOFR



Source: Federal Reserve Bank of New York; Federal Reserve Board staff calculations

The amount of daily volatility in SOFR can change over time and depends on a number of factors, including the monetary policy framework and day-to-day fluctuations in supply and demand, but regardless of these factors, using an averaged overnight rate smooths out almost all of this type of volatility. As was emphasized in the ARRC's Second Report and is still the case today even over the year end, a three-month average of SOFR is less volatile than 3-month LIBOR (Figure 2).

Figure 2: 3-Month Average of SOFR versus 3-Month LIBOR



Source: Federal Reserve Bank of New York, ICE Benchmarks Administration; Federal Reserve Board staff calculations.
Data from August 2014 to March 2018 represent modeled, pre-production estimates of SOFR.

Compound versus Simple Averaging

Although financial products will all tend to use an averaged overnight rate, they may exhibit some technical differences in how these averages are calculated. The choice of a particular averaging convention need not affect the overall rate paid by the borrower, because the differences between them are generally small and other terms can be adjusted to equate the overall cost, but nonetheless issuers and lenders will face a technical choice between using a *simple* or a *compound* average as they seek to use SOFR in cash products. Since this is a source of confusion for some, we will explain both here.

Simple and compound averages reflect a technical difference in how interest is accrued by using either *simple* or *compound interest*. Financial markets participants have developed a number of conventions for calculating the amount of interest owed on a loan or financial instrument.[3] One area where this is the case is in the choice convention between simple versus compound interest:

- *Simple interest* is a long-standing convention, and in some respects is easier from an operational perspective. Under this convention, the additional amount of interest owed each day is calculated by applying the daily rate of interest to the principal borrowed, and the payment due at the end of the period is the sum of those amounts.

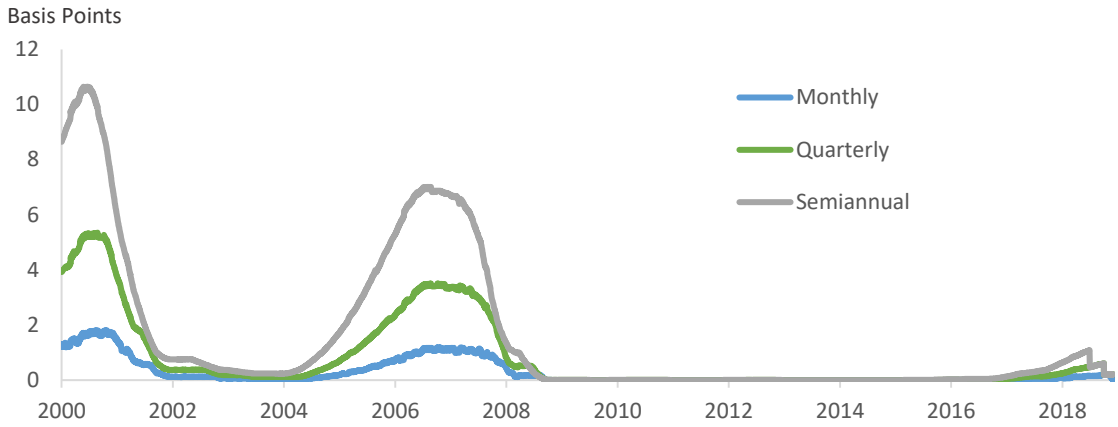
- *Compound interest* recognizes that the borrower does not pay back interest owed on a daily basis and it therefore keeps track of the accumulated interest owed but not yet paid. The additional amount of interest owed each day is calculated by applying the daily rate of interest both to the principal borrowed and the accumulated unpaid interest.

From an economic perspective, compound interest is the more correct convention. For example, if someone holds a bank account or money market fund paying overnight interest, then they receive compounded interest. OIS markets also use compound interest, and thus instruments that use compound interest will be easier to hedge. On the other hand, simple interest is easier to calculate and many systems are designed around its use, for example, in the United States loan and short-term floating rate note (FRN) systems using overnight LIBOR or EFFR were built around the use of simple interest, and those systems would require investment to change in order to incorporate compound interest calculations.

Beyond the math, it is perhaps most important to understand that the difference between the two concepts is typically quite small at lower interest rates and over short periods of time. Any differences can also be accounted for by adjusting the rate or margin. Historically, the difference between simple and compounded interest on SOFR would have ranged between 0 and 10 basis points over the last two decades (Figure 3), with the difference being larger when rates moved higher or the if payment frequency was longer.

[3] Some of those conventions were developed before modern computing made such calculations routine, at a time when interest had to be calculated manually or by looking up the answer in tables. As computing has become widespread, new conventions have developed, but in many cases both older and newer conventions coexist in the market.

Figure 3: Difference between Compound and Simple SOFR



Source: Federal Reserve Bank of New York; Federal Reserve Board staff calculations. Data from August 2014 to March 2018 represent modeled, pre-production estimates of SOFR. Historical repo data prior to August 2014 is taken from primary dealers' overnight Treasury repo borrowing activity.

In the short-term, using SOFR with simple interest conventions may be easier since many loan and FRN systems are already set up to accommodate it. However, most ARRC members believe that it will help to promote liquidity and better market functioning if market participants are able to move toward use of compounded SOFR over time. Compounded interest would more accurately reflect the time value of money, which becomes a more important consideration as interest rates rise, and it can allow for more accurate hedging. Of course, the choice between compounded and simple interest is a decision between counterparties and would entail investments to update systems in order to accommodate a compounded rate. Vendors would also need to offer solutions to allow for compounding. Steps such as producing published compound rates (i.e., a 1- or 3-month compounded average published daily or a published compounding sequence that would allow participants to calculate compounded averages over any period they wished) could be useful, as could be a compound interest "calculator" that would allow participants to calculate compound interest over any period.

Apart from the choice between simple and compound interest, there are a number of other conventions that need to be set, though they generally should have less economic impact on the amount of interest payments. Amongst others, these include the choice of day count convention (which determines how annualized rates are quoted) and how the rate to be applied over weekends and holidays are set (whether to use the rate on transactions taking place before the weekend or holiday, which mirrors how repo markets operate, or the rate after). The Appendix provides the formulation ISDA uses in its conventions and provides an example of the calculations behind compounded interest.[4]

[4] Another convention choice is whether to include the spread in compounding or to add it separately. While in theory, it would make sense to compound both interest and spread, this poses other operational difficulties and the ARRC's recommended fallback language has chosen to compound SOFR but not the spread.

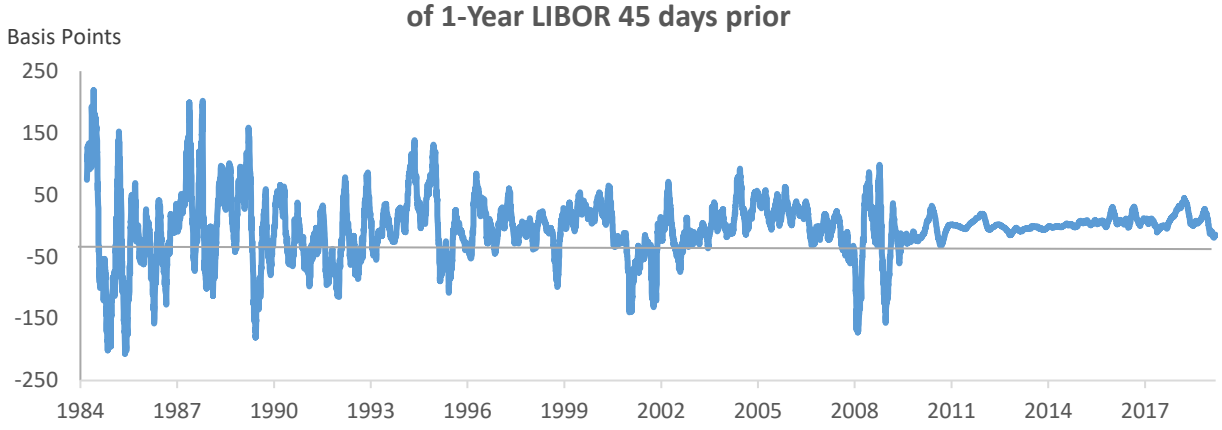
B. *Notice of Payment*

Most of the contracts that reference LIBOR set the floating rate based on the value of LIBOR at the *beginning of the interest period*. This convention is termed *in advance* because the floating-rate payment due is set in advance of the start of the interest period. But not all LIBOR contracts take this form; some LIBOR swaps reference the value of LIBOR at the *end of the interest period*. This convention is termed *in arrears*.[5]

These conventions are used with overnight rates also. An *in advance* payment structure based on an overnight rate would reference an average of the overnight rates observed before the current interest period began, while an *in arrears* structure would reference an average of the rate over current the interest period. As noted above, an average overnight rate *in arrears* will reflect what *actually happens* to interest rates over the period and will therefore fully hedge interest rate risk in a way that LIBOR or a SOFR-based forward-looking term rate will not.

The tension in choosing between *in arrears* and *in advance* is that borrowers will reasonably prefer to know their payments ahead of time – well ahead of time for some borrowers – and so prefer *in advance*, while investors will reasonably prefer returns based on rates over the interest period (i.e., *in arrears*) and will tend to view rates set *in advance* as "out of date." But this isn't an entirely new problem: LIBOR itself can often quickly become out of date, by about the same magnitude that an averaged overnight rate can. For example, in most adjustable rate mortgages (ARMs), the adjustable rate is set annually based on a 1-month average of 1-year LIBOR that is set 45 days before the start of the next reset period. The rate is forward-looking, but even in just 45 days 1-year LIBOR can change radically and can itself become "out of date." The amount of basis this creates is shown in Figure 4, and historically it has been quite large at times. Although it may seem counterintuitive, the historical magnitude of the basis that would have been caused by using a compound average overnight rate in advance in ARMs is comparable to the basis that was caused using 1-year LIBOR.

Figure 4: Difference between 1-Year LIBOR and the 1-month Average of 1-Year LIBOR 45 days prior



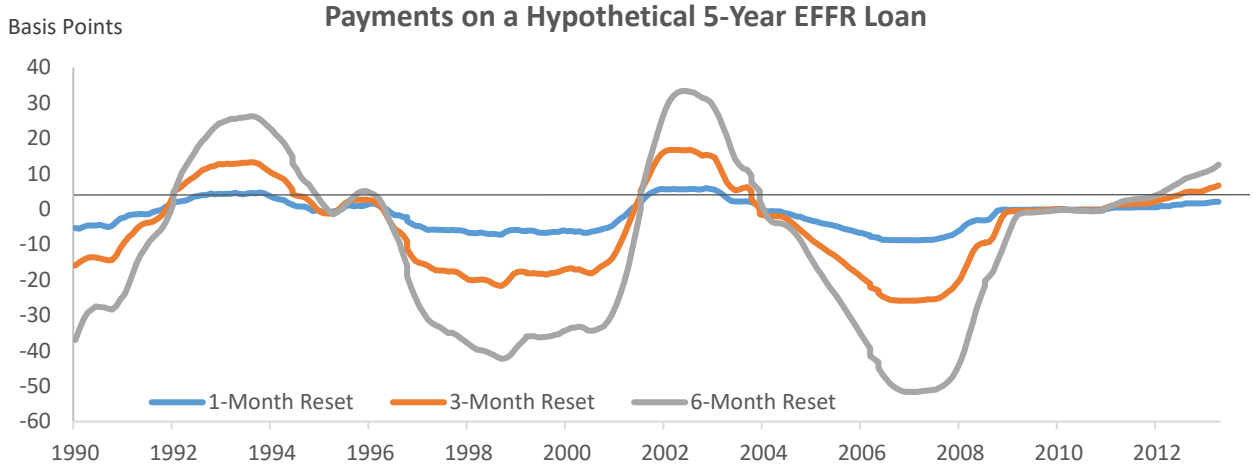
Source: ICE Benchmarks Administration; Federal Reserve Board staff calculations

[5] Although this convention doesn't necessarily have to imply that payment is made after the interest period has concluded, payment will frequently be made 1-2 days after the period has ended and in that sense is in arrears relative to the end of the interest period even though it is not legally in arrears relative to the terms of the contract.

The basis between *in arrears* and *in advance* conventions will depend on whether interest rates happen to be trending up or down over a given period. On average, any differences will tend to net out over the life of a loan or financial instrument if it lasts more than a few years, however in any given period there may be differences and investors may either gain or lose from one structure relative to the other. These differences will also depend on how frequently payments are made: the difference between an average of rates over the past month and an average of rates over the next month will typically be small, but the difference between an average of rates over this year and an average of rates over the next year may be larger just because rates can move by more over a year than they might over a month.

To quantify these effects, Figure 5 shows the ex post basis between a hypothetical 5-year loan made using EFFR *in advance* versus one made *in arrears* for different interest periods (monthly resets, quarterly, and semiannual).[6] The risk involved is on the order of ± 5 basis points with a monthly interest period, comparable to the size of the basis between simple and compound interest shown in Figure 3. The basis is larger for longer interest periods, but still contained. Any form of basis is inherently undesirable, but if market participants are generally willing to accept the kinds of potential basis that occur between simple and compound interest, then it isn't clear that the basis between *in advance* and *in arrears* payments structures should be viewed as problematic, at least for shorter payment frequencies.

Figure 5: Basis Spread between Returns on *in Advance* versus *In Arrears* Payments on a Hypothetical 5-Year EFFR Loan



Source: Federal Reserve Bank of New York; Federal Reserve Board staff calculations

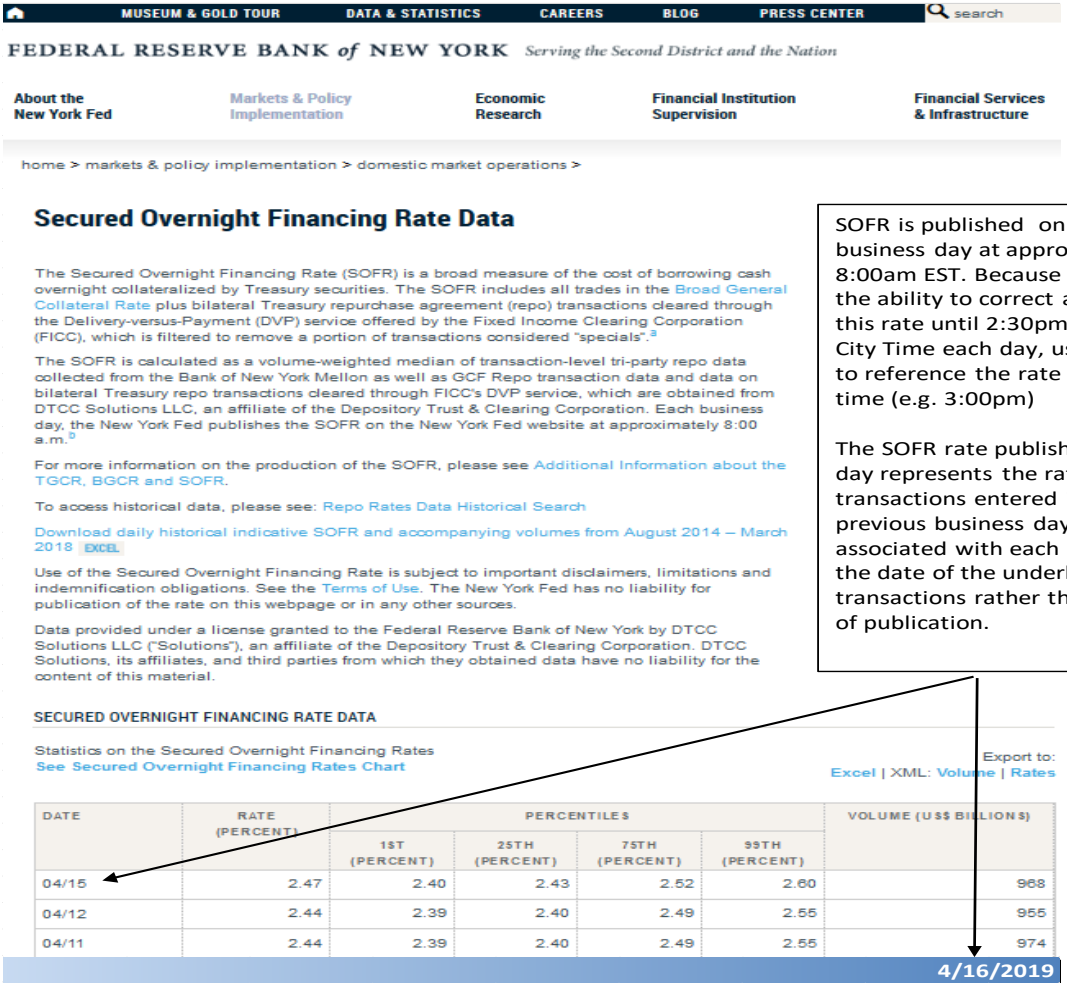
Regardless of whether one chooses *in advance* or *in arrears*, there does need to be some convention that gives borrowers sufficient notice of the amount due before they are required to make a payment. With the exception of SARON, which publishes its final fixing on the same business day after the market close, SOFR and most of the other RFRs are published on a next day basis (see Table 1 and the accompanying figure for SOFR). That is, the Federal Reserve Bank of New York publishes the daily SOFR rate one business day after the transactions underlying the rate have occurred. This is due to

[6] In these and following simulations, the basis is calculated as the spread (expressed as an annual rate) that would need to be added to the *in advance* instrument in order to equate the ex post net present value of payments received with the *in arrears* instrument. Net present values are calculated using the internal rate of return on the *in arrears* instrument. A positive basis implies that investors would have required added compensation to have broken even on the *in advance* instrument, while a negative basis implies that investors would have gained from the *in advance* instrument and would have had to rebate some of the interest received to have broken even relative to *in arrears*.

the need to receive and fully vet the large amounts of data underlying SOFR before the rate is published. Looked at another way, SOFR and these other RFRs are published on the day that the overnight repo transaction is to be repaid rather on the day that the transaction is entered into. Given this, the borrower would only have a few hours' notice before payment was due using an *in arrears* convention for calculating the average of SOFR in the absence of any modification. Many borrowers would need more time than this.

Table 1: The Publication Timing of the RFRs

SOFR	Published around 8am the next business day
SONIA	Published at 9am the next business day
TONA	Published at 10am the next business day
ESTER	Will be published at 9am the next business day
SARON	Published at 6pm the same business day



There have been a number of modifications to the conventions in order to allow for advance notice of payment within the *in arrears* framework. This isn't an issue for *in advance*, as the framework already allows for ample notice of the next payment due, but even in an *in advance* framework there are other decisions that need to be made about the period over which to calculate the averaged overnight rate. And finally, although these would be new concepts for the market in some respects, there are also potential hybrid conventions that combine aspects of both *in advance* and *in arrears* and that could prove useful. Below, we set out the different possible conventions:

In Arrears

- *Plain*: Use the averaged SOFR over current interest period, paid on first day of the next interest period.

  A plain *in arrears* structure reflects the movement in interest rates over the full interest period and payment is made on the day that it would naturally be due, but given the publication timing for SOFR and most other RFRs, this has the disadvantage of requiring payment on the same day that the final payment amount is known.

- *Payment Delay*: Use the averaged SOFR over current interest period, paid *k* days after the start of the next period (OIS swaps generally use a payment delay to settle at T+2 as shown in Table 3).

  The payment delay structure matches and is easily hedged using OIS swaps. The advantage is that it gives more time for payment while still reflecting the movements in interest rates over the full interest period. The fact that payment is delayed would be reflected in the rate charged on the instrument, but nonetheless some investors may dislike any delay or find that the payment timing introduces mismatches with other payments.

- *Lockout or Suspension Period*: Use the averaged SOFR over current interest period with last rates set at the rate fixed *k* days before the period ends (a 2-5 day lockout has been used in most SOFR FRNs).

  The lockout structure does not exactly match the basic OIS swap structure and therefore creates some hedging basis, as shown in Figure 6, and this structure will effectively skip *k* days of rates each interest period which may matter for investors given that SOFR can change from day to day.[7] On the other hand, for most of the interest period, the daily interest rate will correspond to the most recent published value of the SOFR, which brings the calculation of net asset value and discounting closer to par value, which may be important to some investors.

- *Lookback*: For every day in the current interest period, use the SOFR rate from *k* days earlier. (a 3-5 day lookback has been used in SONIA FRNs)

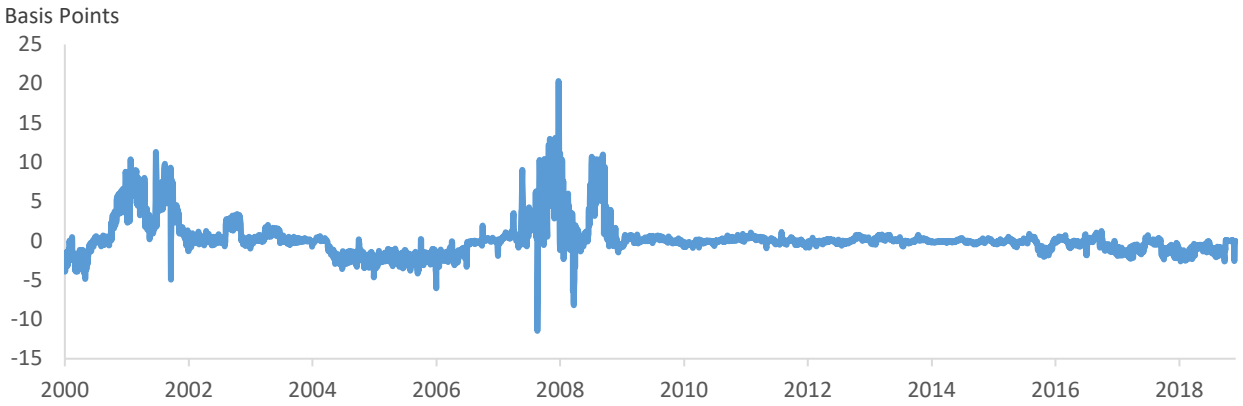
  The lookback structure (also referred to as a backward-shifted rate observation period or "lag") is similar to the structure of OIS swaps. [8] A compound average *in arrears* with a lookback has the

[7] A lockout is designed to provide timely notice of payment at the end of an interest period. If an instrument was sold or closed out before the end of the interest period, then further conventions would also be needed to determine when and how payment was to be made.

[8] In certain versions of lookback convention, the rate applied over a weekend or holiday would differ from the repo transaction rate that applied over those days. However, this can be controlled for by shifting the observation period so that each rate applies to repo transaction period it represents.

same floating rate structure as a typical OIS swap with a payment delay and so could be fully hedged in a fairly straightforward way. Market participants may also find a lookback helpful when there is a need to calculate interest accruing during an interest period, for example primary and secondary market trading or prepayments.

Figure 6: Basis between Quarterly Compounded 3-day Lockout versus Pure Arrears



Source: Federal Reserve Bank of New York; Federal Reserve Board staff calculations. Data from August 2014 to March 2018 represent modeled, pre-production estimates of SOFR. Historical repo data prior to August 2014 is taken from primary dealers' overnight Treasury repo borrowing activity.

Most U.S. dollar issuance of SOFR FRNs have used simple interest with a 1-day lookback and a lockout or suspension period, but SONIA FRNs have instead used compounded interest and a lookback (see Table 2). In part, the choice for simple interest in issuance of SOFR FRNs was driven by operational considerations – systems were already set up for issuing effective federal funds rate FRNs using simple interest. Certain investors may also have systems in place to receive simple interest. Nonetheless, the SONIA issuance demonstrates that the market can accept compounding and also demonstrates that the market can accommodate different types of conventions for using an *in arrears* payments structure.

Table 2: Comparing Typical Conventions on SOFR and SONIA Floating Rate Notes and OIS

	SOFR FRNs	SONIA FRNs	SOFR and SONIA OIS
Averaging	Generally simple average	Compound Average	Compound Average
Payment Delay	None (Payment due next business day after the interest period ends)	None (Payment due next business day after the interest period ends)	Payment due two business days after the interest period ends
Lookback	One business day	5 business days	None
Lockout/ Suspension Period	Generally 2 business days	None	None

Table 3: Models for Using SOFR in Arrears

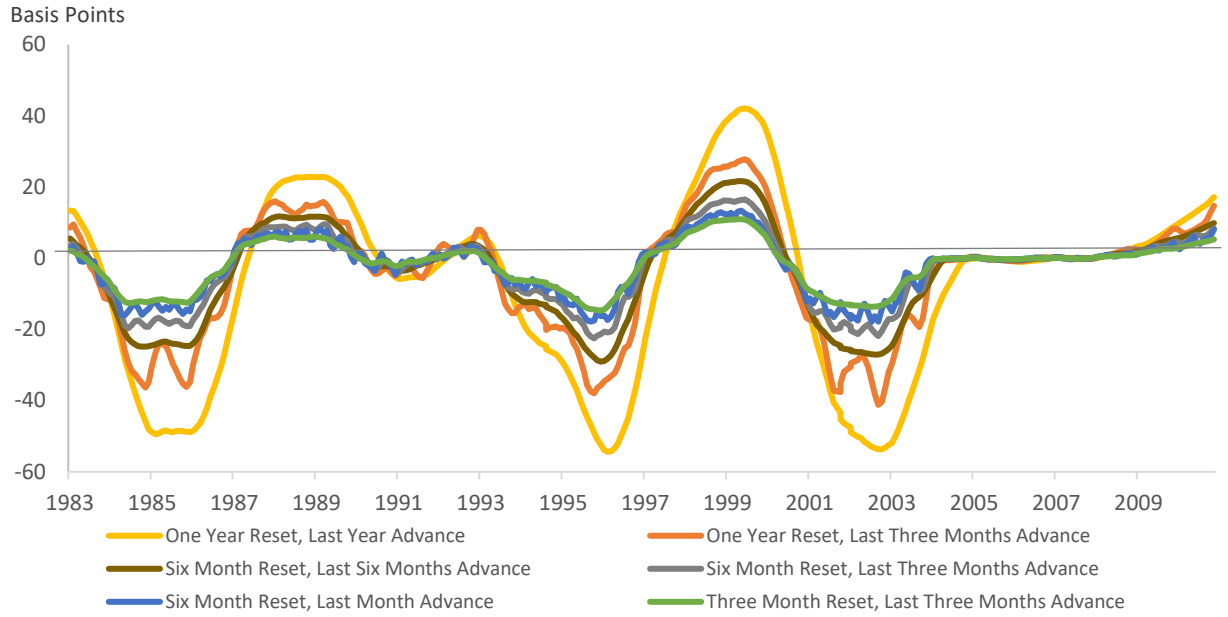
	Day 1 (First Day of Interest Period)	Day 2 SOFR for Day 1 Published	…	Day T-2 SOFR for Day T-3 Published	Day T-1 SOFR for Day T-2 Published	Day T (Last Day of Interest Period) SOFR for Day T-1 Published	Day T+1 (First Day of Next Period) SOFR for Date T Published	Day T+2
Plain Arrears	Use SOFR for Day 1	Use SOFR for Day 2	…	Use SOFR for Day T-2	Use SOFR for Day T-1	Use SOFR for Day T	Payment due	
Arrears with Payment Delay	Use SOFR for Day 1	Use SOFR for Day 2	…	Use SOFR for Day T-2	Use SOFR for Day T-1	Use SOFR for Day T → OIS generally settle on T+2		Payment due
Arrears with 1-Day Lockout	Use SOFR for Day 1	Use SOFR for Day 2	…	Use SOFR for Day T-2	Use SOFR for Day T-1	Use SOFR for Day T-1	Payment Due	
Arrears with 1-Day Lookback	Use SOFR for Day 0	Use SOFR for Day 1	…	Use SOFR for Day T-3	Use SOFR for Day T-2	Use SOFR for Day T-1	Payment Due	

In Advance

- *Last Reset*: Use the averaged SOFR from the last interest reset period as rate for current interest period
- *Last Recent*: Use the averaged SOFR from a shorter recent period as rate for current interest period

Comparing these two *in advance* conventions, the last reset model is similar to a lookback model and will more closely match the structure of an OIS (although the payment structure will be lagged). On the other hand, the last recent model is likely to have less basis relative to the *in arrears* average interest rate over the current interest period. This can be seen in Figure 7, which compares the basis between different models of Last Reset/Last Recent for different payment frequencies on a hybrid adjustable rate mortgage to a hypothetical *in arrears* structure.[9]

Figure 7: Comparing Bases to *in Arrears* for Different Models of Hypothetical EFFR *in Advance* Mortgages



Source: Federal Reserve Bank of New York, Haver; Federal Reserve Board staff calculations

Hybrid Models

- *Principal Adjustment*: Payments are set *in advance*, but principal and interest accrue *in arrears*.

  In this model, the payment for the period is set using an average of SOFR calculated at the start of the interest period (*in advance*); however the amount of that set payment that is applied to interest will be based on the average of SOFR over the interest period (*in arrears*). In this model, the remaining principal on the loan would change over time based on the difference between the *in advance* and *in arrears* calculations for each period– if rates moved up over the interest period, then

[9] In these mortgage simulations, a hypothetical 5/1 Adjustable Rate Mortgage that refinances in year 8 of the mortgage is considered, with floating rate payments based on historical values of EFFR. As described earlier, in these and following simulations, the basis is calculated as the spread (expressed as an annual rate) that would need to be added to the *in advance* instrument in order to equate the ex post net present value of payments received with the *in arrears* instrument. Net present values are calculated using the internal rate of return on the *in arrears* instrument. A positive basis implies that investors would have required added compensation to have broken even on the *in advance* instrument, while a negative basis implies that investors would have gained from the *in advance* instrument and would have had to rebate some of the interest received to have broken even relative to *in arrears*.

more of the payment would go to cover interest expenses and remaining principal would be higher, while if interest rates moved down then remaining principal would be lower.

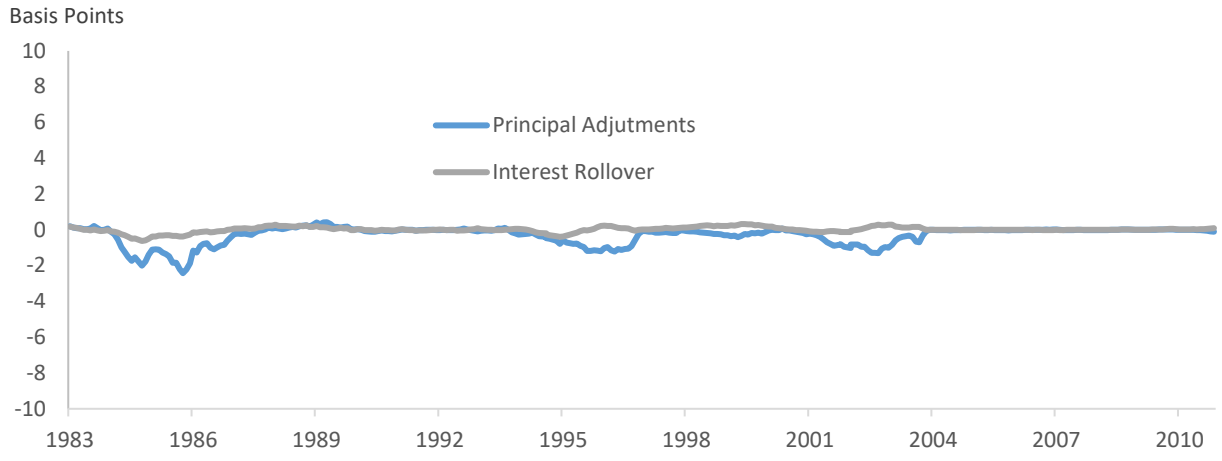
- *Interest Rollover*: Payments are set *in advance* and any missed interest relative to *in arrears* is rolled over into the next payment period.

  In this model, the payment for the period is again set using an average of SOFR calculated at the start of the interest period; however the amount of interest due is calculated based on the average of SOFR over the interest period (*in arrears*), and any difference between the amount of interest paid and the interest accrued is simply rolled over into the payment for the next interest period. In this model, the remaining principal on the loan would not change.

The hybrid models will be unfamiliar to some, although it is not unusual to roll over certain payments into the next period as suggested with the *Interest Rollover* model. Both of these hybrids are designed to give borrowers ample advance notice of the payments they will need to make, while also structuring principal and interest to match the kind of *in arrears* return that investors may prefer. As shown in Figures 8 and 9, they can potentially minimize the basis faced by investors while at the same time structuring payments in a way that borrowers should feel comfortable with. The hybrid models do come with some additional complexity, however, which could negatively affect the acceptance in the market, and both lenders and borrowers would need to explore a number of operational and other issues in considering them.[10]

There are a range of reasonable conventions to address the tension between giving borrowers sufficient notice of payment amounts and investors' desire to be fully hedged against interest rate risk. Market participants may need to update systems or adapt to these conventions, but in many cases would be able to do so with the support of vendors and through greater understanding of the issues.

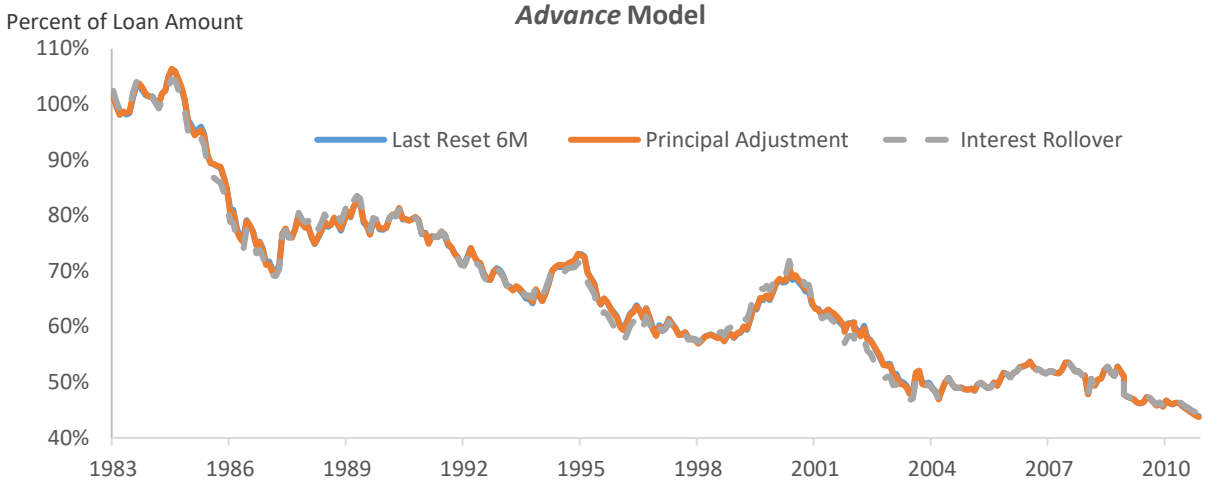
Figure 8: Comparing Bases to *In Arrears* for the Hybrid Mortgage Models



Source: Federal Reserve Bank of New York, Haver; Federal Reserve Board staff calculations

[10] Users would also need to understand the accounting treatment of these models.

Figure 9: Comparing Cumulated Payments due on Hybrid Models and an *In Advance* Model



Source: Federal Reserve Bank of New York, Haver; Federal Reserve Board staff calculations

2. The Interaction between SOFR and the Forward-Looking Term Rate

While the overnight Treasury repo market underlying SOFR is extraordinarily deep, term repo markets are much thinner, and it would not be possible to build a robust, IOSCO-compliant rate directly off the term Treasury repo market. As discussed in the ARRC's Second Report, there is really no term cash market in the United States with enough depth to build a reliable, robust, transactions-based rate produced on a daily basis that would be able to meet the criteria that the ARRC set in choosing SOFR. Therefore, the ARRC has proposed that a private administrator could construct a forward-looking term rate based on SOFR derivatives markets once those markets develop enough liquidity. Because SOFR derivative markets have developed quickly and are expected to achieve a very high degree of liquidity, it is reasonable to expect that these markets will be sufficiently liquid and robust to construct a forward-looking term rate, but the timing cannot be guaranteed.

As noted above, the FSB has been clear in its assessment that financial stability will be enhanced if most market participants move toward use of RFRs, while also recognizing the potential usefulness of forward-looking RFR-based term rates in certain circumstances. However, it is important that market participants are also clear on what the forward-looking term SOFR rate is expected to be, and its relationship to the overnight SOFR, in order to understand where use of such rates could be best made.

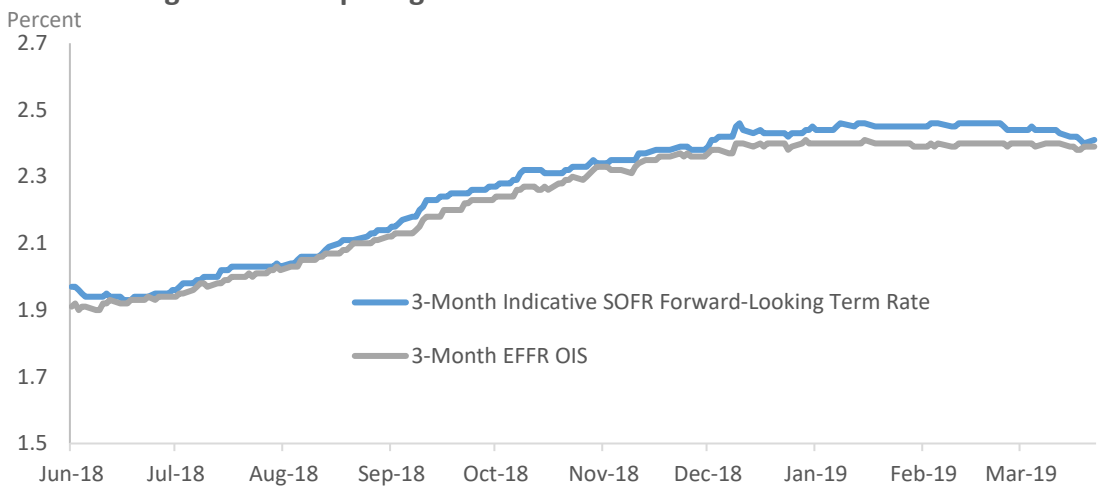
Under the ARRC's proposal, the forward-looking term rate would be based on some combination of SOFR futures and SOFR OIS transactions.[11] The ARRC has not endorsed a specific methodology for producing these rates, but a recent working paper has laid out one potential methodology and the

[11] These two markets are very tightly linked together. SOFR futures pay an average of SOFR over a given month or quarter, for example, the average of SOFR realized over the month of June or the average over the first quarter of the year. SOFR OIS pay the compounded average of SOFR over a fixed period of time, for example, a one-month OIS contract beginning on March 15 would pay the compound average of SOFR realized over the period from March 15 to April 14.

authors have released a series of "indicative" term rates that may help to promote better understanding as to how rates of this type might behave over time.[12] Eventually, as liquidity in SOFR derivatives markets develops, the ARRC anticipates that private vendors will seek to produce one or more forward-looking term rates for commercial use, which the ARRC has committed to evaluate against criteria it will develop with the aim of recommending one such rate provided that it satisfies the ARRC's criteria.

The first point to understand is this: *the forward-looking term rates are simply segments of the underlying SOFR OIS curve*. An OIS contract involves exchanging a set of fixed-rate payments for a set of floating-rate payments between two parties. The floating rate is a compound average of the overnight rate calculated over the interest period, while the fixed rate is set at the start of the period. If we call $OIS_{3m}(t)$ the fixed rate on a 3-month OIS contract entered into at date *t*, then the 3-month forward-looking term rate would be either equal to $OIS_{3m}(t)$ or extremely close to it. The same would be true for the potential 1-month or 6-month counterparts, $OIS_{1m}(t)$ and $OIS_{6m}(t)$. Figure 10 compares the indicative SOFR term rate to an OIS rate referencing EFFR, and one can see that they move quite closely together.

Figure 10: Comparing an Indicative SOFR Term Rate to EFFR OIS



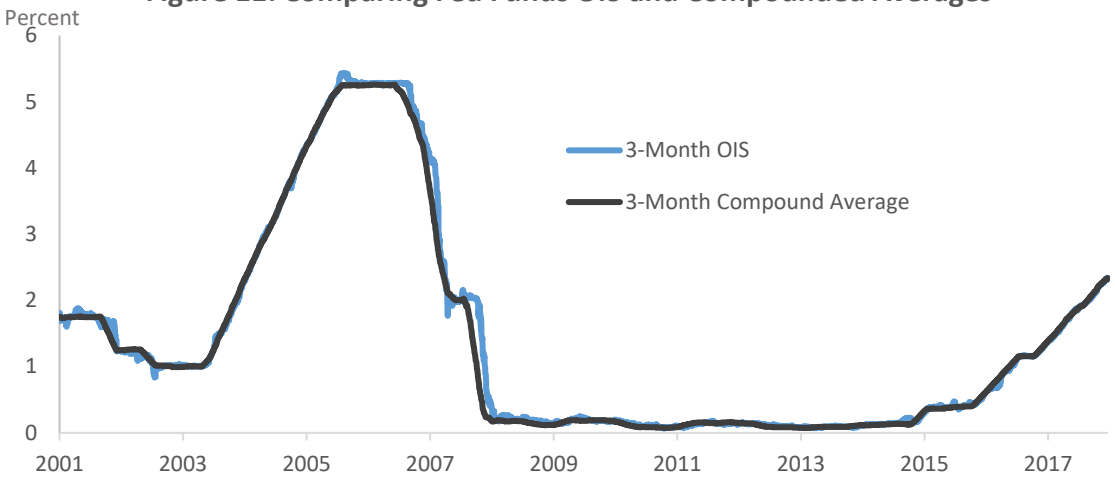
Source: Federal Reserve Bank of New York, CME, Bloomberg; Federal Reserve Board staff calculations

The second point to understand is that *there will be a tight link between the forward-looking term rate and the compound average of SOFR used as the floating rate in OIS contracts*. The fixed rate is set so that the OIS contract has zero value at the time it is entered into; that is, the value of receiving the fixed rate is exactly equal to the value of receiving the floating rate. In this sense, the fixed rate (which is the forward-looking term rate) will be economically equivalent to the corresponding expected compound

[12] See Heitfield and Park (2019), Inferring Term Rates from SOFR Futures Prices, FEDS discussion paper 2019-014. Further description of the methodology as well as a data file that presents indicative forward-looking term rates derived from end-of-day SOFR futures prices and compound averages of daily SOFR rates can be found in Heitfield and Park (2019), Indicative Forward-Looking SOFR Term Rates, a staff FEDS Note published April 14, 2019. These rates are presented for informational purposes only and are not appropriate for use as reference rates in financial contracts.

average of SOFR. We don't have a long history of SOFR OIS yet, but Figure 11 shows this same type of tight link between fed funds OIS and compound averages of the fed funds rate. Both before and after the financial crisis, the average difference between a 3-month OIS rate and the compound average was less than 1 basis point.[13] The key difference between the two rates is that the term rate reflects market *expectations* as to what will happen to interest rates, while the compound average used in OIS contracts will reflect what *actually happen*s to interest rates over the period.

Figure 11: Comparing Fed Funds OIS and Compounded Averages



Source: Federal Reserve Bank of New York, Bloomberg; Federal Reserve Board staff calculations

Many potential users of the forward-looking term rate will not seek to hedge their exposures, but for those who might seek to hedge, the third critical point to understand is that *forward-looking-term rate exposures can (and in an economic sense, will) be hedged by using SOFR OIS*. To see this, consider an example of an end user that wants to hedge a set of quarterly term SOFR payments they are required to make over the next year by converting their floating term rate payments into fixed rate. Although they are paying the quarterly term rate, they could still hedge this directly in the SOFR OIS market with the following steps[14]

- Step 1: Enter into a 12-month SOFR OIS contract at the start of the year to pay the fixed-leg rate $OIS_{12m}(t)$ and receive quarterly compound SOFR payments.

- Step 2: At the start of each quarter, enter into a 3-month SOFR OIS contract to receive the fixed-leg term rate, OIS_{3m} and pay compound SOFR over that quarter. Use the quarterly floating-rate SOFR payment from the 12-month OIS in Step 1 to pay the floating-rate leg of Step 2 and use the fixed rate payment of this swap to pay the quarterly term-rate owed.

In practice, many firms would engage a bank or a dealer to do these steps for them rather than taking it on themselves, and there would be some transaction cost to doing this. If they entered into a

[13] During the financial crisis, the difference was higher, but this is because there were two episodes during this period in which monetary policy was unexpectedly cut very sharply – by over 175 basis points within a 90-day period in each episode – thus these cuts were not captured in the OIS rate (because they were fixed before the unexpected cuts took place) but were reflected in the realized compounded fed funds rate.

[14] This example uses an OIS convention in which floating and fixed rate payments are paid quarterly.

bespoke term rate swap with their dealer instead, then the dealer would need to enter the SOFR OIS market to hedge the swap and that would involve the same basic steps. In addition, there may be some charges for any basis risk (the term rate benchmark may not precisely match the OIS rate that the dealer may be able to obtain on any given day), and there may be associated costs if the bespoke swap cannot be cleared or if the dealer needs to warehouse the swap and must charge for the associated risk. Each of these factors would result in additional transactions costs to all of the parties to the transaction.

Dealers are equipped to provide these kinds of services to their clients, and presumably they will, but they will also need to pass on the associated costs. On the other hand, many of these costs could be avoided from the start if the borrower used SOFR rather than a forward-looking term-rate. An instrument that required payments of compounded SOFR could be directly hedged in the SOFR OIS market, with far fewer steps and costs. Which leads to the final important point – *use of the forward-looking term rate will tend to involve more transactions costs than using SOFR, and if end users know that they want to hedge their floating rate payments then it would involve fewer transaction costs if they can modify their systems to be able to pay or receive the compound average SOFR rather than paying or receiving the forward-looking term rate.*

None of this is meant to contradict the idea that the forward-looking term rate can be a useful tool for some market participants, but it is also important that they understand the likely costs as well. A number of firms will likely wish to avoid these costs and use SOFR from the start. Many other firms will likely come to the same conclusion over time as they gain experience with the new market structure and are able to update their systems to accommodate using SOFR.

Appendix

For some, it may be useful to note the mathematical formulas behind compound and simple interest conventions:

$$Compound\ Interest\ Formula = \left[\prod_{i=1}^{d_b}\left(1 + \frac{r_i \times n_i}{N}\right) - 1\right] \times \frac{N}{d_c}$$

$$Simple\ Interest\ Formula = \left[\sum_{i=1}^{d_b}\left(\frac{r_i \times n_i}{N}\right)\right] \times \frac{N}{d_c}$$

Where

d_b = the number of *business days* in the interest period

d_c = the number of *calendar days* in the interest period

r_i = the interest rate applicable on business day *i*

n_i = the number of calendar days for which rate r_i applies (on most days, n_i will be 1, but on a Friday it will generally be 3, and it will also be larger than 1 on the business day before a holiday). This can also be stated as the number of calendar days from and including business day *i* to but excluding the following business day.

N = the market convention for quoting the number of days in the year (in the United States, the convention for money markets is N = 360, while in the UK it is N=365).

And *i* represents a series of ordinal numbers representing each business day in the period.

Table A1 provides an example of how these formulas would be used for a hypothetical 1-week SOFR loan.

Table A1: Calculating Simple and Compound Interest

Simple Interest on a One-Week SOFR Loan of $1 Million Drawn on Jan 7, 2019

	Secured Overnight Financing Rate (Percent, Annualized)	Number of Days Rate is Applied	Effective Rate (Not Annualized)	**Principle**	Principal + Accumulated Interest	**Interest Charge for Next Business Day (Effective Rate*Principal)**
Monday, Jan 7, 2019	2.41	1	0.0241/360 = 0.006694%	**$1,000,000.00**	$1,000,000.00	**$66.94**
Tuesday, Jan 8, 2019	2.42	1	0.0242/360 = 0.006722%	**$1,000,000.00**	$1,000,066.94	**$67.22**
Wednesday, Jan 9, 2019	2.45	1	0.0245/360 = 0.006806%	**$1,000,000.00**	$1,000,134.16	**$68.06**
Thursday, Jan 10, 2019	2.43	1	0.0243/360 = 0.006750%	**$1,000,000.00**	$1,000,202.22	**$67.50**
Friday, Jan 11, 2019	2.41	3	3*0.0241/360 = 0.020083%	**$1,000,000.00**	$1,000,269.72	**$200.83**
Monday, Jan 14, 2019	---	---	---	**$1,000,000.00**	$1,000,470.55	

Payment Due
Monday, Jan 14, 2019 **$1,000,470.56**

Annualized Simple Rate of Interest: $\left(\frac{360}{7}\right)\left[\frac{0.0241}{360}+\frac{0.0242}{360}+\frac{0.0245}{360}+\frac{0.0243}{360}+\frac{3\times 0.0241}{360}\right]$

= (360/7)*(.047056%) = 2.4200%

Compound Interest on a One-Week SOFR Loan of $1 Million Drawn on Jan 7, 2019

	Secured Overnight Financing Rate (Percent, Annualized)	Number of Days Rate is Applied	Effective Rate (Not Annualized)	Principle	**Principal + Accumulated Interest**	**Interest Charge for Next Business Day (Effective Rate*(Principal+Accumulated Interest))**
Monday, Jan 7, 2019	2.41	1	0.0241/360 = 0.006694%	$1,000,000.00	**$1,000,000.00**	**$66.94**
Tuesday, Jan 8, 2019	2.42	1	0.0242/360 = 0.006722%	$1,000,000.00	**$1,000,066.94**	**$67.23**
Wednesday, Jan 9, 2019	2.45	1	0.0245/360 = 0.006806%	$1,000,000.00	**$1,000,134.17**	**$68.06**
Thursday, Jan 10, 2019	2.43	1	0.0243/360 = 0.006750%	$1,000,000.00	**$1,000,202.23**	**$67.51**
Friday, Jan 11, 2019	2.41	3	3*0.0241/360 = 0.020083%	$1,000,000.00	**$1,000,269.74**	**$200.89**
Monday, Jan 14, 2019	---	---	---	$1,000,000.00	**$1,000,470.63**	

Payment Due
Monday, Jan 14, 2019 **$1,000,470.63**

Annualized Compound Rate of Interest: $\left(\frac{360}{7}\right)\left[\left(1+\frac{0.0241}{360}\right)\left(1+\frac{0.0242}{360}\right)\left(1+\frac{0.0245}{360}\right)\left(1+\frac{0.0243}{360}\right)\left(1+\frac{3\times 0.0241}{360}\right)-1\right]$

= (360/7)*(.047064%) = 2.4204%