

Templates for Using SOFR

David Bowman, Senior Associate Director
Board of Governors of the Federal Reserve

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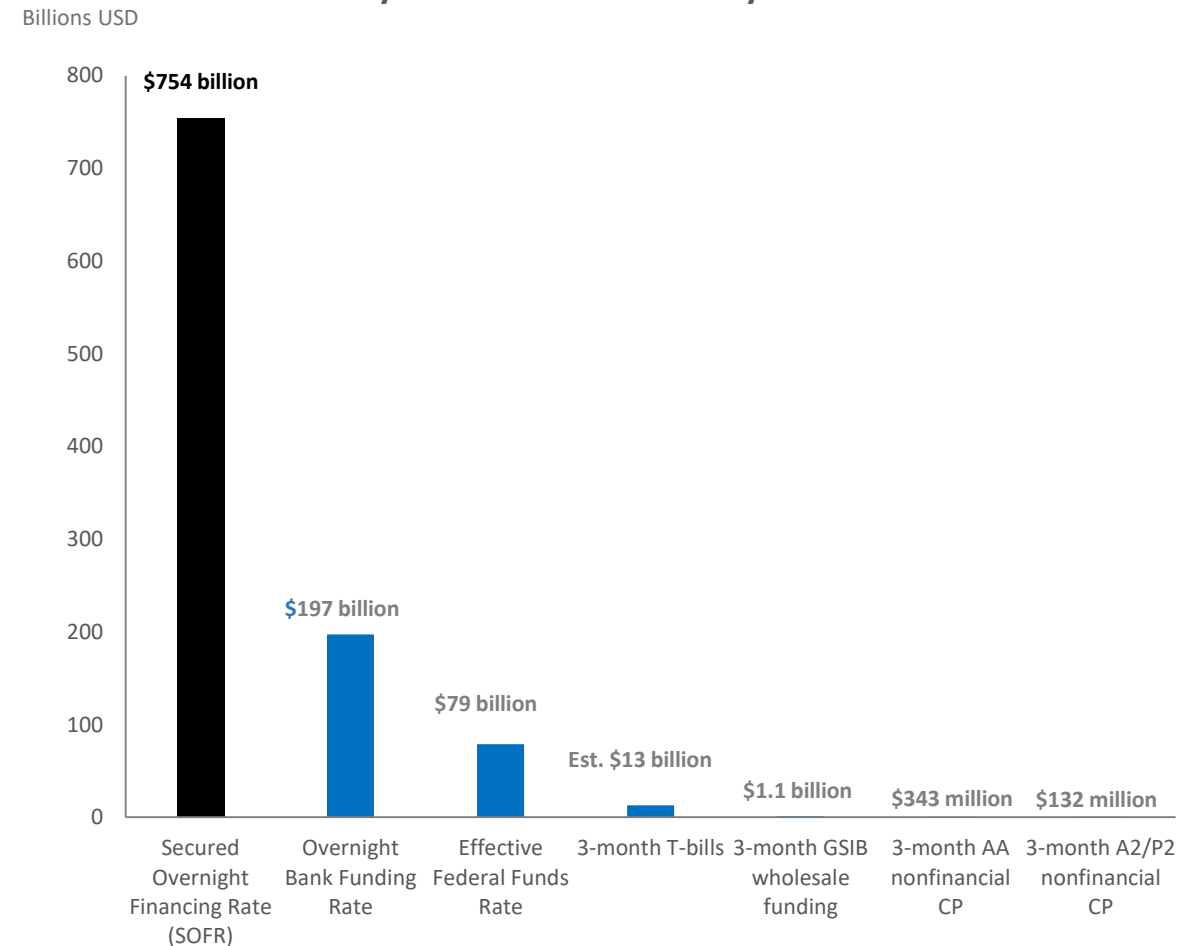
The Secured Overnight Financing Rate (SOFR)

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

- It is a rate produced by the Federal Reserve Bank of New York (FRBNY) 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.

Daily Volumes in U.S. Money Markets



Source: ARRC Second Report

SOFR Publication

SOFR is published on the Federal Reserve Bank of New York’s website (<https://apps.newyorkfed.org/markets/autorates/sofr>) every U.S business day at approximately 8am EST. FRBNY’s revision policies state that SOFR may be revised up to 2:30pm EST.

SOFR is also available on Bloomberg and Reuters and can additionally be accessed through an API offered by FRBNY (<https://www.newyorkfed.org/markets/effr-obfr>)

The rate published each day represents the rates on overnight repo transactions that were entered in to the previous business day and that are to be repaid on the current business day. So, for example, on April 16, the rate for transactions entered in to on April 15 would be published.

This is similar to how the effective federal funds rate (EFFR) and risk-free rates (RFRs) in other jurisdictions are published.

Table 3: 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

Secured Overnight Financing Rate Data

The Secured Overnight Financing Rate (SOFR) is a broad measure of the cost of borrowing cash overnight collateralized by Treasury securities. The SOFR includes all trades in the [Broad General Collateral Rate](#) plus bilateral Treasury repurchase agreement (repo) transactions cleared through the Delivery-versus-Payment (DVP) service offered by the Fixed Income Clearing Corporation (FICC), which is filtered to remove a portion of transactions considered "specials".³

The SOFR is calculated as a volume-weighted median of transaction-level tri-party repo data collected from the Bank of New York Mellon as well as GCF Repo transaction data and data on bilateral Treasury repo transactions cleared through FICC's DVP service, which are obtained from DTCC Solutions LLC, an affiliate of the Depository Trust & Clearing Corporation. Each business day, the New York Fed publishes the SOFR on the New York Fed website at approximately 8:00 a.m.⁵

For more information on the production of the SOFR, please see [Additional Information about the TGCR, BGCR and SOFR](#).

To access historical data, please see: [Repo Rates Data Historical Search](#)

Download daily historical indicative SOFR and accompanying volumes from August 2014 – March 2018 [EXCEL](#)

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SECURED OVERNIGHT FINANCING RATE DATA

Statistics on the Secured Overnight Financing Rates
See [Secured Overnight Financing Rates Chart](#)

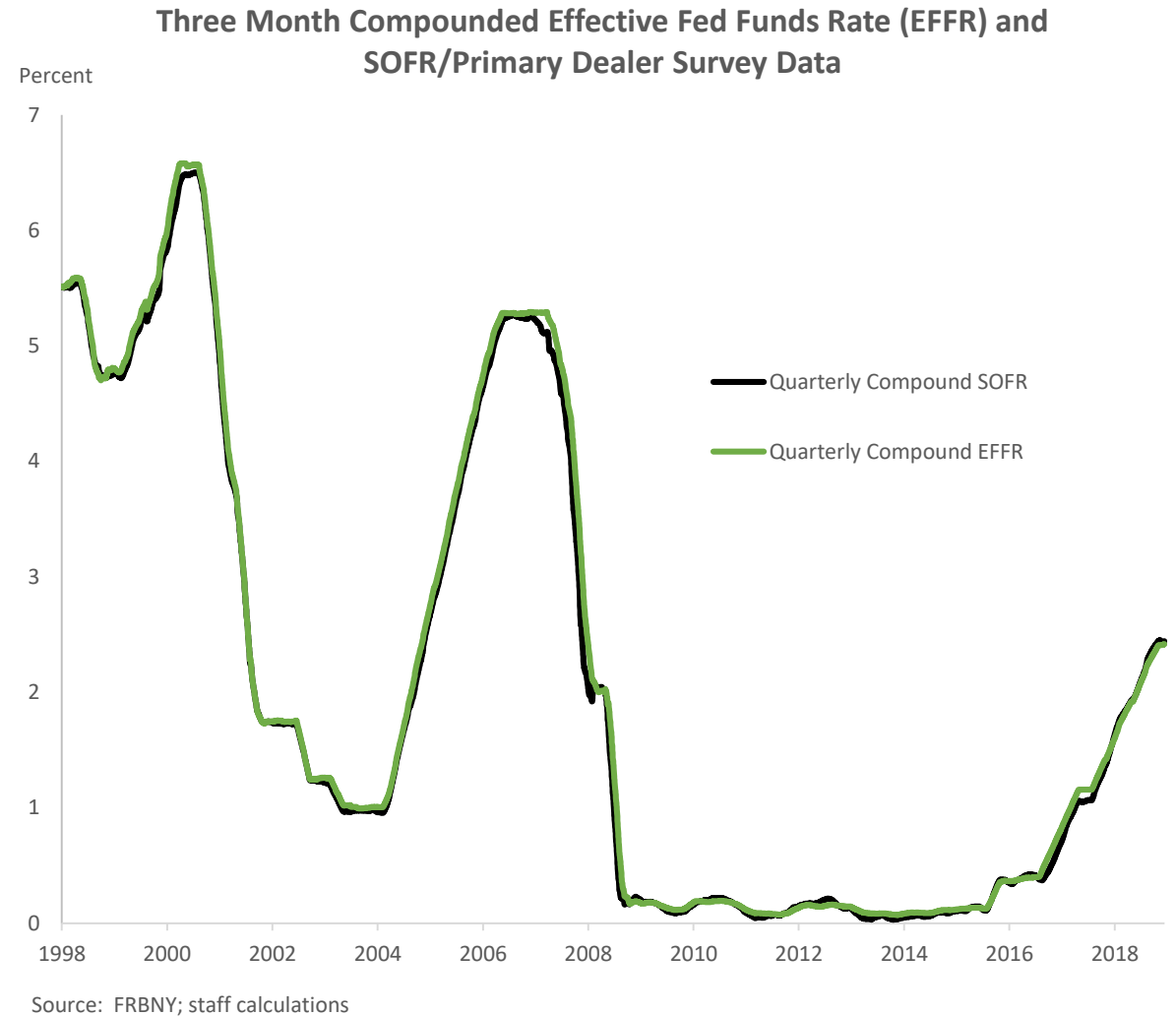
Export to: [Excel](#) | [XML](#) | [Volume](#) | [Rates](#)

DATE	RATE (PERCENT)	PERCENTILES				VOLUME (U\$ BILLION \$)
		1ST (PERCENT)	25TH (PERCENT)	75TH (PERCENT)	99TH (PERCENT)	
04/15	2.47	2.40	2.43	2.52	2.60	968
04/12	2.44	2.39	2.40	2.49	2.55	955
04/11	2.44	2.39	2.40	2.49	2.55	974

4/16/2019

SOFR Data

- FRBNY, in cooperation with the Office of Financial Research, began publishing SOFR on April 3, 2018.
- Prior to the start of official publication, FRBNY released data from August 2014 to March 2018 representing modeled, pre-production estimates of SOFR that are based on the same basic underlying transaction data and methodology that now underlie the official publication.
(https://www.newyorkfed.org/newsevents/speeches/2017/fr_o171108)
- FRBNY has also separately released a much longer historical data series based on primary dealers' overnight Treasury repo borrowing activity. (https://www.newyorkfed.org/markets/opolicy/operating_policy_180309)
- A forthcoming note I have written argues that the historical survey data is an adequate proxy for SOFR for risk modelling or other purposes



Three Key Basic Choices in Determining How to Use SOFR:

- **Averaging: Compound or Simple**

Compound averaging is used in OIS swaps and some futures. However, many loan and FRN systems currently use simple averaging, largely because of historical precedent. There is some basis between the two types of averaging, although it is generally small. Use of simple averaging may be an expedient to begin using SOFR, but most ARRC members tend to feel that moving toward compounding over time is sensible since it better interest reflects the time value of money.

- **Payment Notice: In Advance, In Arrears, or Hybrid**

An *in advance* payment structure based on SOFR 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 rates over current the interest period and would only be fully known at the end of the interest period. 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.

- **Underlying Market: SOFR (U.S. Treasury Repo Market) or SOFR Derivatives (SOFR futures or OIS)**

The U.S. Treasury Repo Market underlying SOFR is already deep and highly liquid. SOFR futures and OIS are growing but still at early stages and are not yet deep or highly liquid enough to produce a robust, IOSCO-compliant rate). Many market participants would prefer term rates based on derivatives, but at the same time, the ARRC and the FSB have warned that people should not simply wait for term rates and that those who are able to move to SOFR should seek to do so if they can.

The Different Potential Versions of SOFR-Based Rates

For derivatives, it is fairly clear that the market will be based on compound SOFR in arrears. For cash products, ARRC Working Groups have so far gravitated toward four basic models of SOFR use:

- **Published Simple or Compound Average of SOFR Set *in Advance***

Should require few or no changes to existing systems to use.

- **Published Forward-Looking Term SOFR set *in Advance***

These rates may not come until 2021, but they should require few or no changes to existing systems to use.

- **Simple Average of SOFR Set *in Arrears***

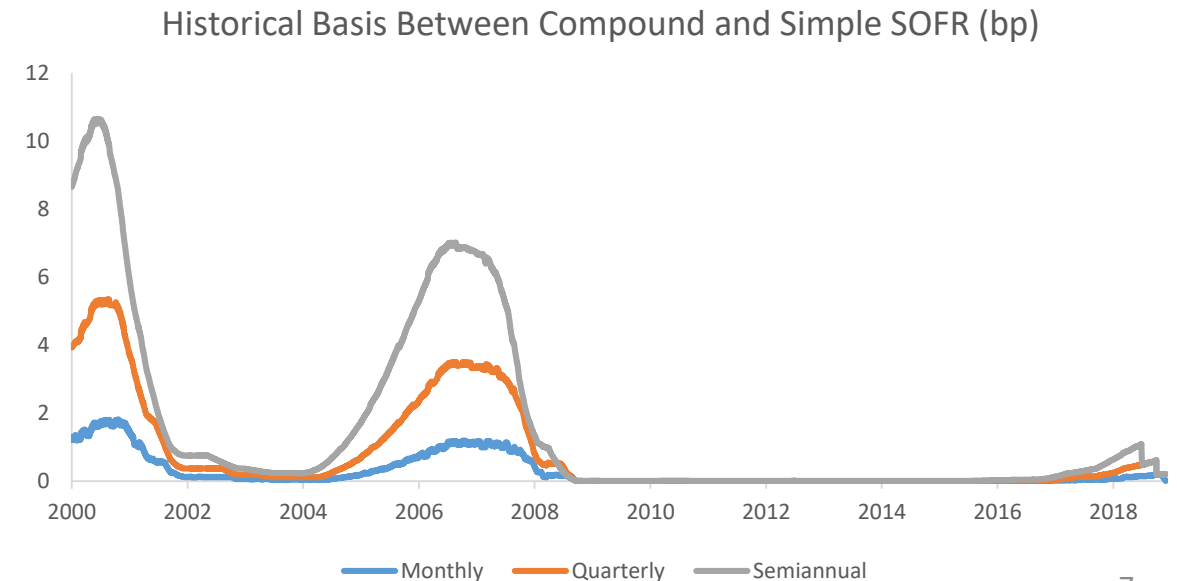
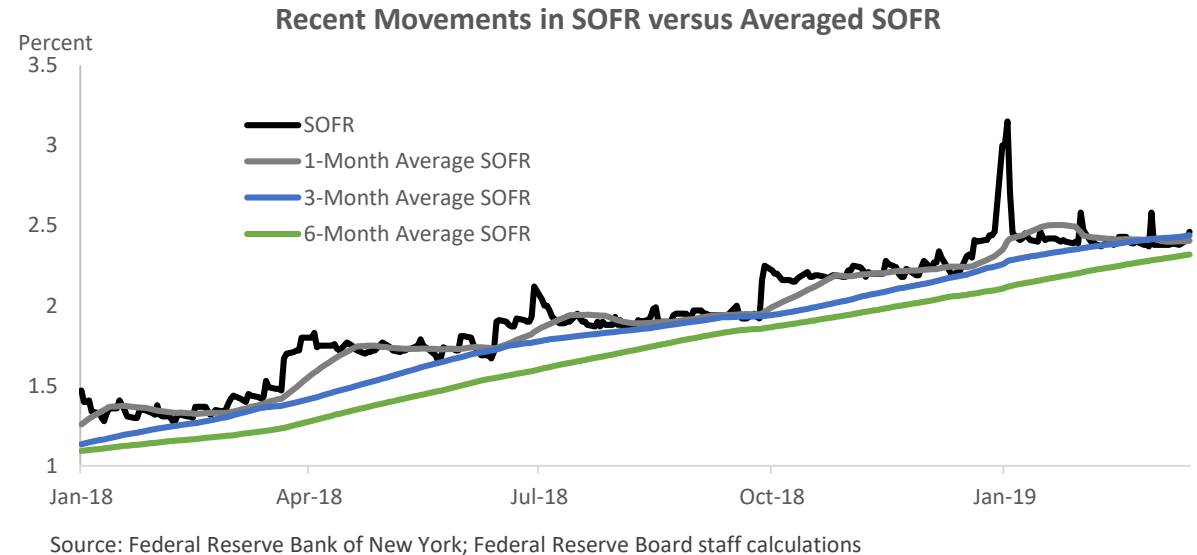
Would require few or manageable changes to existing systems to use

- **Compound Average of SOFR Set *in Arrears***

Will require more changes to existing systems to use.

Published SOFR Averages

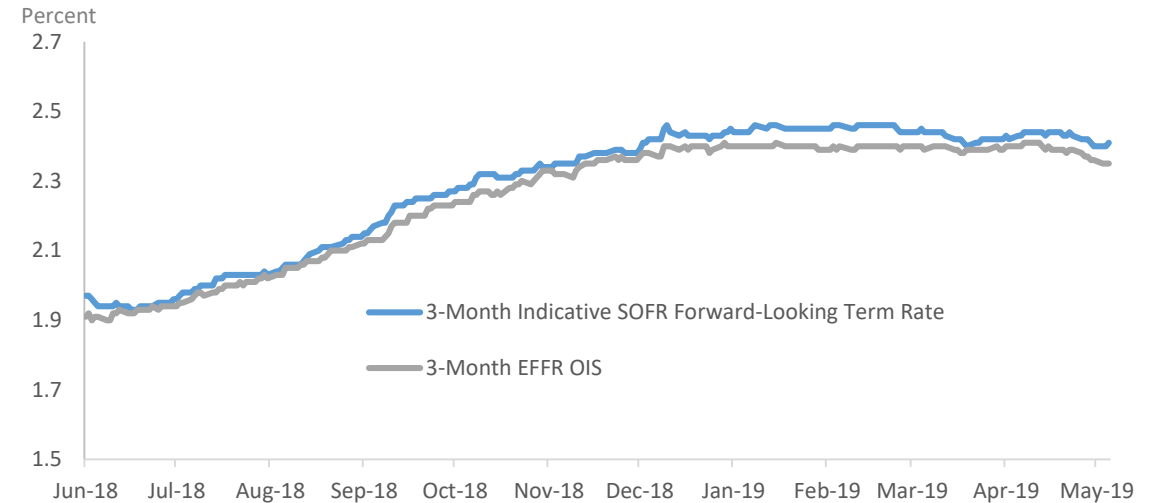
- The Federal Reserve Bank of New York has indicated that it plans to publish averages of SOFR in the first half of next year.
- Averages of SOFR show very little or no impact from these kinds of temporary, day-to-day volatility that can be seen in overnight SOFR around year/quarter-ends.
- A 3-month average of SOFR is less volatile than 3-month LIBOR, even over the last year end.
- FRBNY has not stated whether it will publish compound or simple averages, but the differences between the two choices would typically be small.
- Further details on the average rates that FRBNY would produce should follow, but from a systems perspective, using these rates in advance would be easily implemented.



Forward-Looking Term Rates

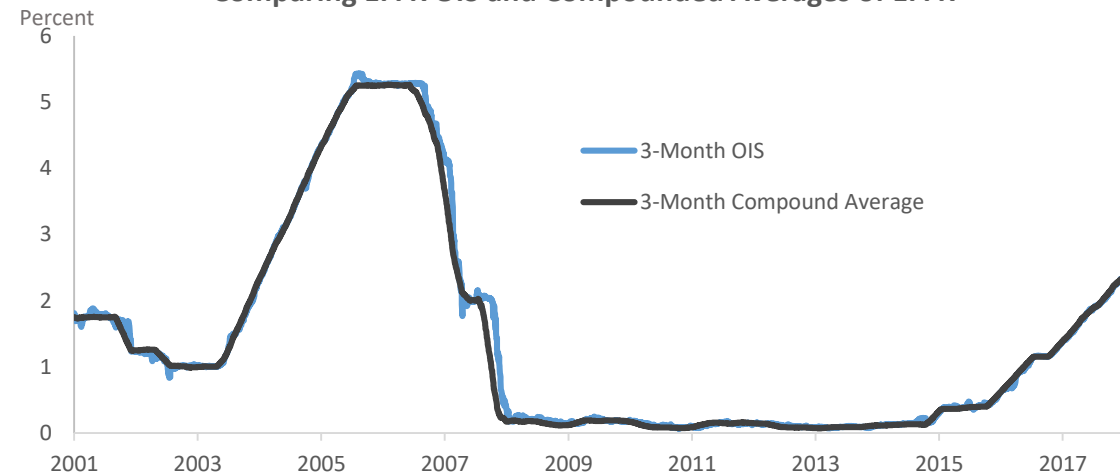
- Federal Reserve staff members are producing “indicative” forward-looking term rates that are not meant to be used in contracts and are not IOSCO compliant, but may help provide a sense as to how the term rates will behave (a link to this data, which are periodically updated, is on the ARRC’s website).
- The forward-looking term rates that the ARRC envisions will effectively be segments of the SOFR OIS curve, and as such should behave much like EFRR OIS rates do today.
- The forward-looking term rates should also be tightly linked to compound averages of SOFR, just as EFRR OIS rates are tightly linked to compound averages of EFRR.

Comparing an Indicative SOFR Term Rate to EFRR OIS



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

Comparing EFRR OIS and Compounded Averages of EFRR



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

Simple Averages of SOFR in Arrears

Monthly SOFR Futures and a number of SOFR FRNs are based on simple averages of SOFR in Arrears. FRN issuance systems had already been developed for the effective fed funds rate based on simple interest, making it easier for initial SOFR FRNs to use simple interest.

Loan systems that use overnight LIBOR, Prime, or the effective fed funds rate based on simple interest are also already frequently in place if not all that regularly used.

Compound Averages of SOFR in Arrears

Three-month SOFR futures, SOFR OIS, and some recent SOFR FRNs are based on compounded averages of SOFR in Arrears, but in general these systems are not yet in place for cash products

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

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 is $N = 360$)

This term is to translate the annualized overnight rate into an effective daily/next business day rate

This term is to annualize the compounded rate

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

An Example of the ISDA Compound Average Formula

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

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

Making Compound Calculations Easier – a SOFR Compound Index

An Index would compound daily SOFR every day, similar to a price-level index. It could serve as a trusted key allowing people to calculate compound averages over any period they wanted. It could be used with a “calculator” front end if desired.

$$I_0 = 1$$

$$I_1 = \left(1 + \frac{r_1 \times n_1}{N}\right)$$

$$I_2 = \left(1 + \frac{r_1 \times n_1}{N}\right) \left(1 + \frac{r_2 \times n_2}{N}\right)$$

$$I_3 = \left(1 + \frac{r_1 \times n_1}{N}\right) \left(1 + \frac{r_2 \times n_2}{N}\right) \left(1 + \frac{r_3 \times n_3}{N}\right)$$

⋮

$$I_T = \left(1 + \frac{r_1 \times n_1}{N}\right) \left(1 + \frac{r_2 \times n_2}{N}\right) \left(1 + \frac{r_3 \times n_3}{N}\right) \dots \left(1 + \frac{r_{T-1} \times n_{T-1}}{N}\right) \left(1 + \frac{r_T \times n_T}{N}\right)$$

Or, recursively $I_T = I_{T-1} \times \left(1 + \frac{r_T \times n_T}{N}\right)$

Taking the ratio of two Index values automatically calculates compounded interest over the period between the two dates

$$\begin{aligned} \frac{I_{t+n}}{I_t} - 1 &= \left(1 + \frac{r_{t+1} \times n_{t+1}}{N}\right) \left(1 + \frac{r_{t+2} \times n_{t+2}}{N}\right) \dots \left(1 + \frac{r_{t+n} \times n_{t+n}}{N}\right) - 1 \\ &= \prod_{i=1}^n \left(1 + \frac{r_{t+i} \times n_{t+i}}{N}\right) - 1 \end{aligned}$$

Deciding Which Segments to Compound

One issue is whether to compound any margin or to only compound the rate and add margin separately

- Compound both rate and margin:
$$\left[\prod_{i=1}^{d_b} \left(1 + \frac{(r_i + \text{margin}) \times n_i}{N} \right) - 1 \right] \times \frac{N}{d_c}$$

Pros: Economically pure – in theory, both rate and margin should compound

Cons: Harder to calculate, cannot rely on an Index to compound both rate and margin, will have some basis relative to OIS

- Compound rate but not margin
$$\left[\prod_{i=1}^{d_b} \left(1 + \frac{r_i \times n_i}{N} \right) - 1 \right] \times \frac{N}{d_c} + \text{margin}$$

Pros: Easy to calculate, can rely on an Index to compound the rate, will be fully hedged relative to OIS

Cons: Not economically pure

ARRC Working Groups have gravitated toward compounding the rate but not margin

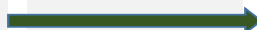



Models for Using RFRs in Arrears

The FSB and National Working Groups are looking at several models for using overnight risk-free rates in cash products. There are several different variants of both in Arrears and in Advance conventions, as well as potential hybrid conventions that attempt to bridge the difference between the two by allowing for advance notice while also allowing for complete or almost complete hedging of contemporaneous rate movements.

- **In Arrears**

- *Plain*: Used averaged rate over current interest period, paid on last day of the period (day T)
- *Payment Delay*: Use averaged rate over current interest period, paid k days after day T (Note: ISDA's conventions for SOFR swaps use a 1-day payment delay)
- *Lookback*: Use averaged rate over current interest period lagged k days (a 3-5 day lookback has been used in SONIA FRNs)
- *Lockout*: Use averaged rate over current period with last k rates set at the rate for day $T-k$ (a 3-5 day lockout has been used in most SOFR FRNs).

Models for Using SOFR in Arrears

	Day 1 (First Day of Interest Period)	Day 2	...	Day T-2	Day T-1	Day T (Last Day of Interest Period)	Day T+1 (First Day of Next Period)	Day T+2
		SOFR for Day 1 Published		SOFR for Day T-3 Published	SOFR for Day T-2 Published	SOFR for Day T-1 Published	SOFR for Date T Published	
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 <u>Payment Delay</u>	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 at T+2	Payment Due
Arrears with <u>1-Day Lockout</u>	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 <u>1-Day Lookback</u>	 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	

A Few Convention Issues for Lookback Structures

Convention #1: A lookback uses the rate from k days ago to calculate today's interest owed. For example, in a 2-day lookback, if today were Friday, one would use Wednesday's rate in calculating today's interest. A narrow definition might be taken to imply that you should apply Friday's weighting ($n_i = 3$ since Friday covers three calendar days until payment is due) to Wednesday's rate, but a more sensible reading would be to apply Wednesday's weighting to Wednesday's rate, which has been called an "observation shift"

Lookback (narrowly defined):
$$\prod_{i=1}^T \left(1 + \frac{r_{i-k} \times n_i}{N} \right) \text{ paid on } T + 1$$

Lookback with observation period shift:
$$\prod_{i=1}^T \left(1 + \frac{r_{i-k} \times n_{i-k}}{N} \right) \text{ paid on } T + 1$$

A lookback/observation shift will be fully hedged relative to OIS while a lookback with no observation shift will have some basis.

Convention #2: Is using the SOFR rate published today for the business day's rate a lookback? The SOFR rate published today represents that market rate for borrowing on the previous business day to be repaid today, and FRBNY post it as the rate for the previous business day. OIS markets would not refer to this as a lookback, and some recent FRNs have taken the same convention, but some of the early FRN issuances did call this a 1-day lookback. The payments and when they are to be made regardless, but potential differences in what constitutes a lookback can cause confusion if not understood.

For Those Who Like Math

Pure Arrears:

$$\prod_{i=1}^T \left(1 + \frac{r_i \times n_i}{N}\right) \text{ paid on } T + 1$$

Payment Delay:

$$\prod_{i=1}^T \left(1 + \frac{r_i \times n_i}{N}\right) \text{ paid on } T + k$$

Lookback (narrowly defined):

$$\prod_{i=1}^T \left(1 + \frac{r_{i-k} \times n_i}{N}\right) \text{ paid on } T + 1$$

Lookback with observation period shift:

$$\prod_{i=1}^T \left(1 + \frac{r_{i-k} \times n_{i-k}}{N}\right) \text{ paid on } T + 1$$

Payment Delay with interest period shift:

$$\prod_{i=1-k}^{T-k} \left(1 + \frac{r_i \times n_i}{N}\right) \text{ paid on } T + 1$$

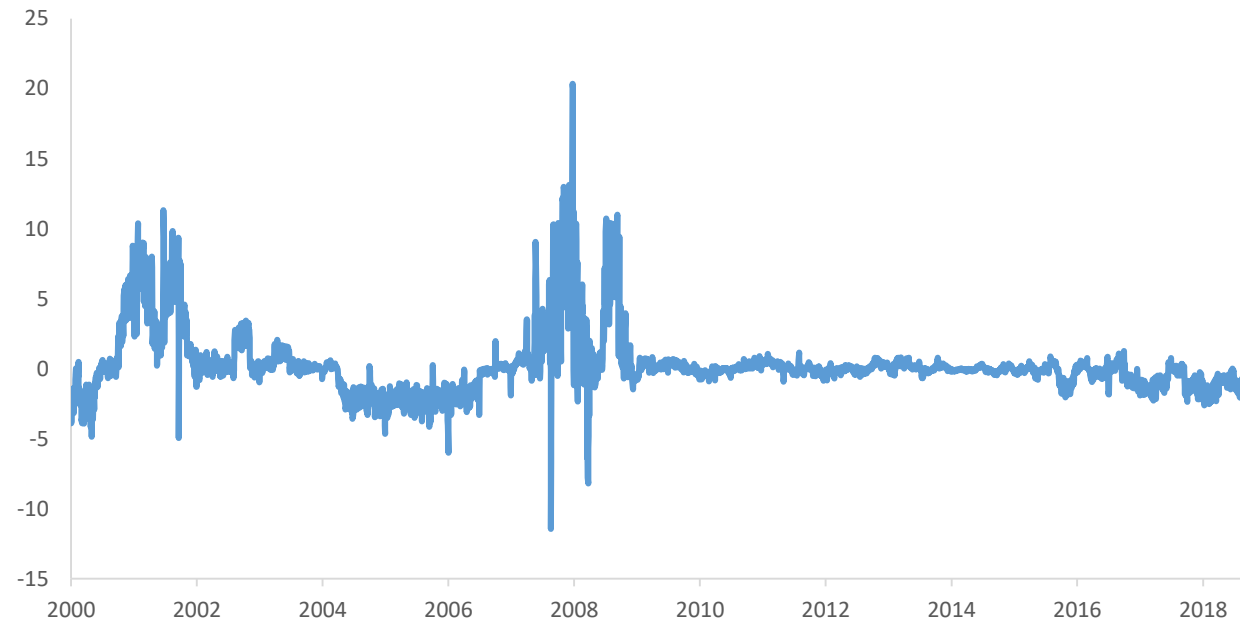
Lockout:

$$\prod_{i=1}^{T-k-1} \left(1 + \frac{r_i \times n_i}{N}\right) \prod_{i=T-k}^T \left(1 + \frac{r_{T-k} \times n_i}{N}\right) \text{ paid on } T + 1$$

In Arrears: Lockout Versus Lookback

Payment Delays or Lookbacks with observation shift are consistent with ISDA compounding definitions and more easily hedged and does not skip any interest days. A lockout does skip some days and has some basis to the In Arrears model used in OIS swaps (below), On the other hand, for most of the interest period, the daily interest rate will correspond to the most recent published value of the RFR, which may be important to certain investors who do not have hedging needs.

Basis between Quarterly Compounded 3-day Lockout vs Pure Arrears (bp)



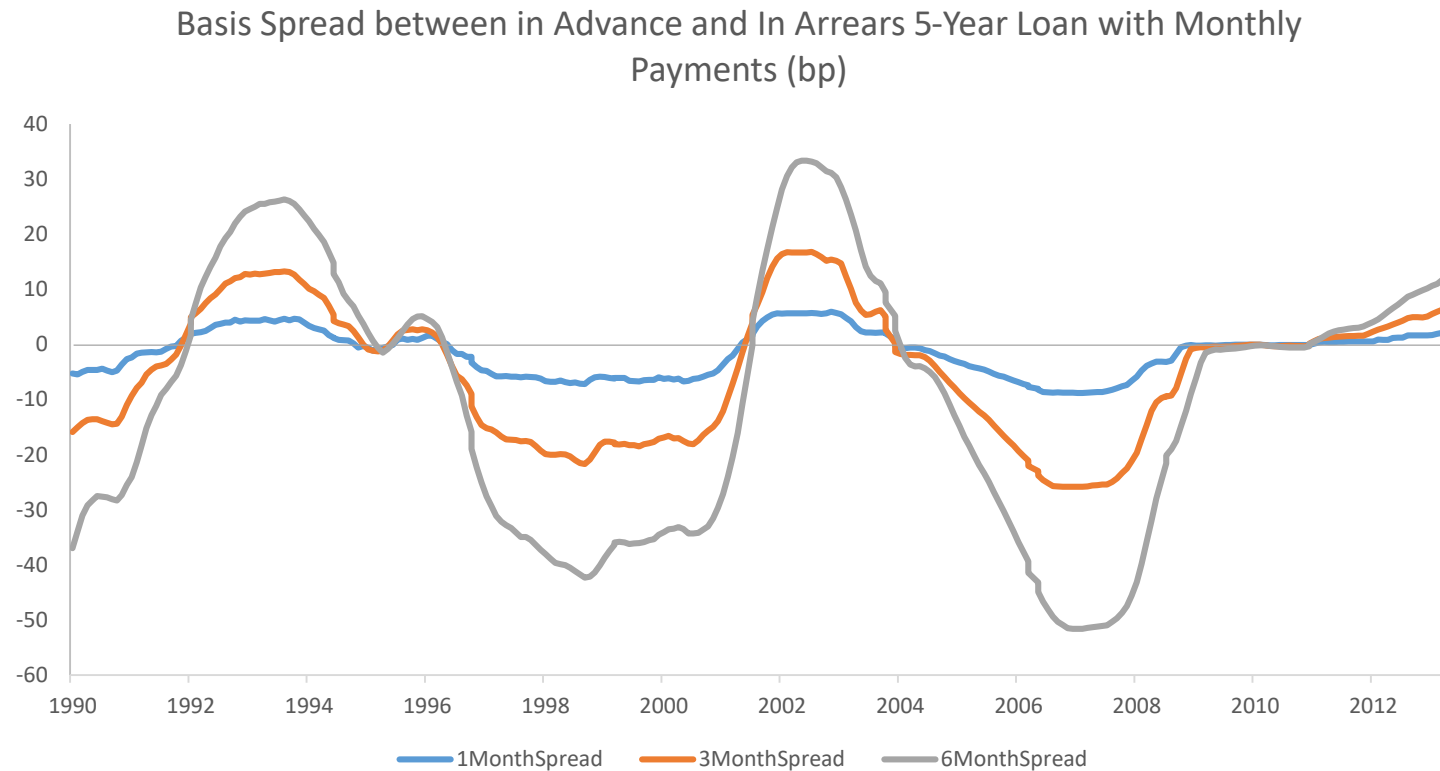
Models of In Arrears (Continued)

Most cash product issuances have used in Arrears frameworks, but there have been a wide array of choices between lookbacks, payment delays, and lockouts as well as compounding versus simple averaging.

Comparing Typical Conventions for RFR-Based FRNs and OIS				
	SOFR FRNs	SONIA FRNs	Swiss Working Group FRN Recommendations	OIS
In Arrears/In Advance	In Arrears	In Arrears	In Arrears	In Arrears
Averaging	Generally simple average, but several recent issuances have used compound averages	Compound Average	Compound Average	Compound Average
Payment Delay	Generally none (Payment due next business day after Accrual Period ends), although one recent issuance employed a payment delay except for the final payment	None (Payment due next business day after Accrual Period ends)	None (Payment due next business day after Accrual Period ends)	One business day (Payment due two business days after accrual period ends)
Lookback	0-2 business days	5 business days	3-5 business days	None
Lockout/Suspension Period	Generally 2 business days	None	None	None

In Arrears/In Advance (continued)

The amount of basis between In Advance and In Arrears depends on the frequency of interest periods. With a one-month reset, the basis is comparable to the amount of basis between simple and compound averaging. Even at 3- or 6-month resets the basis is limited and averages out to zero over longer periods of time.



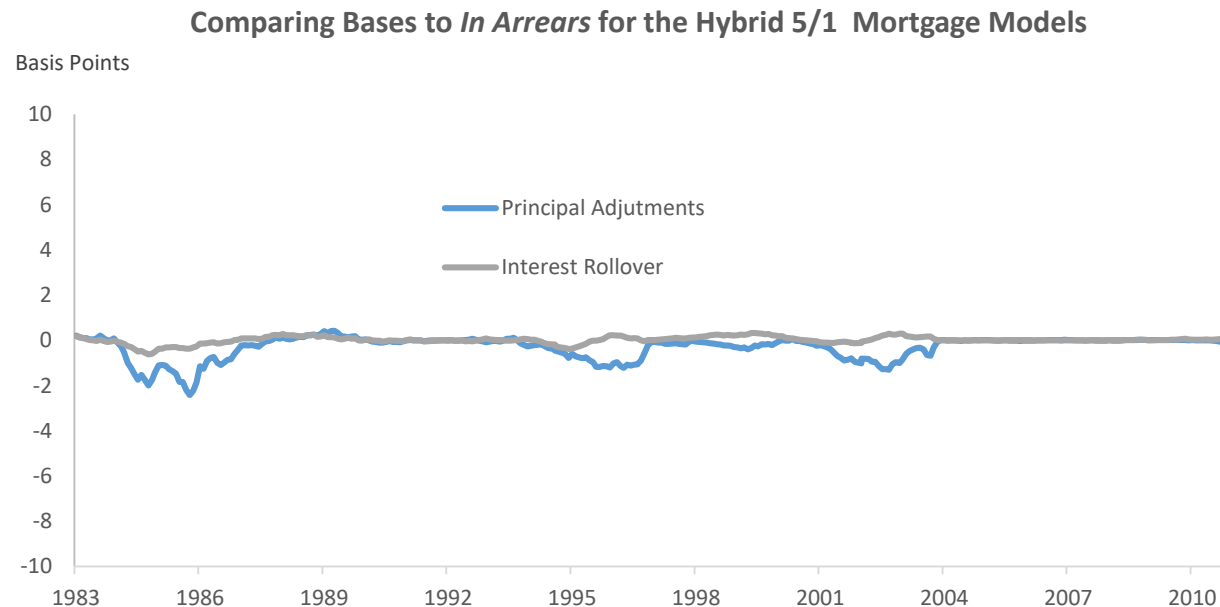
Hybrid Models

Hybrid Models mix an *In Advance* payment structure with *In Arrears* accrual of principal/interest owed:

Principal Accrual: Payments set *In Advance*, principal and interest accrue *In Arrears*

Interest Rollover: Payments set *In Advance*, any missed interest relative to *In Arrears* is rolled over into the next payment period.

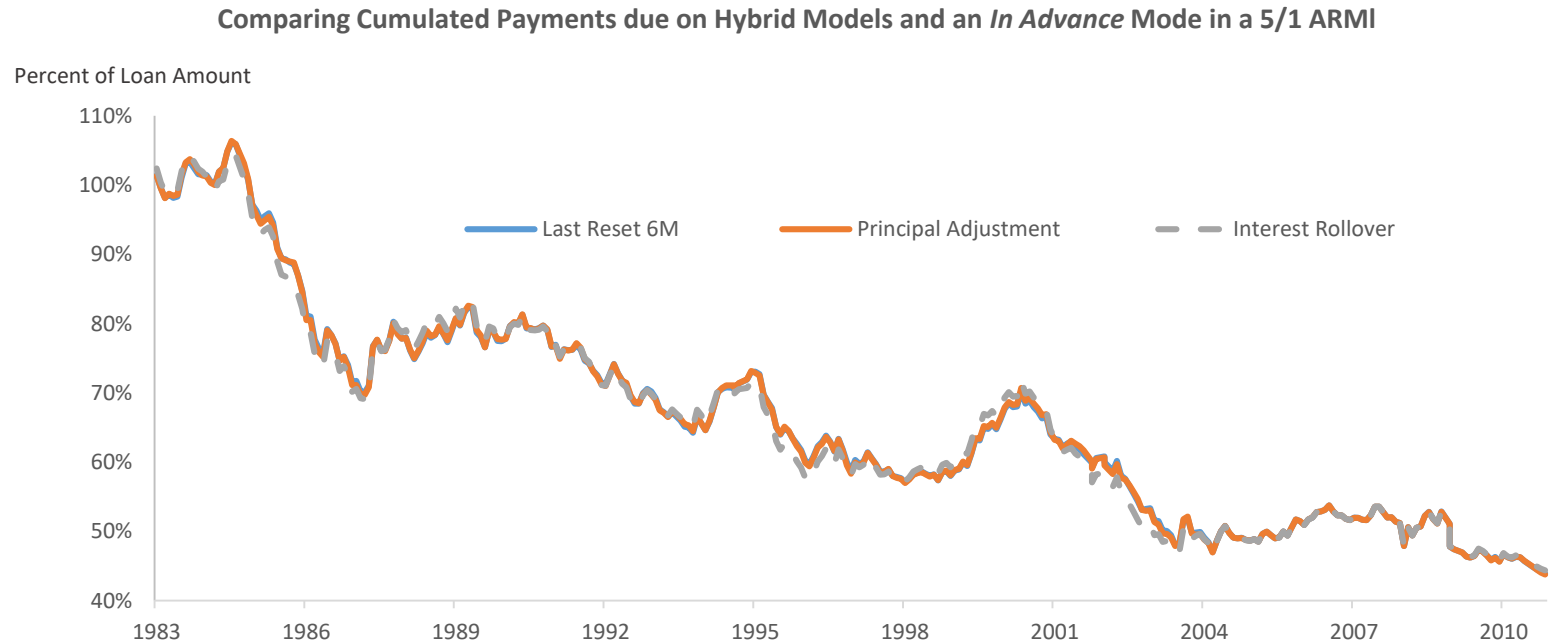
Either of the Hybrid Models can substantially further cut the basis relative to a pure *In Arrears* baseline, even for a product with a less frequent reset such as 5/1 ARM, while still allowing borrowers to know their payments at the start of the interest period



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

Hybrid Models (cont'd)

These models don't materially alter the cumulated payments that a borrower would make relative to a basic Last Reset In Advance Product. They could be fairly easy to incorporate in to some business loans, and from a systems perspective, all that would be needed is the ability for systems to accrue interest and billing or principal accumulation accordingly.



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

Questions?