FE5101: Lecture 4 – Interest Rate Derivatives

Forward Rate Analysis and Products

Lecture 4 Topics:

1. Inter-bank deposit market
2. Inter-bank short-term rate benchmarking
3. Forward Rate Calculation
4. Short-term Interest Rate Derivatives
   a. Interest Rate Futures
   b. Supplementary slides on Forward Rate Agreements, FRAs

L4: Topic 1
Inter-bank Deposit Trading

Short-term Money Market Rates

The Money Markets - Participants

- Large players
  - Banks
  - Governments
  - Corporations
  - Institutions (pensions, trusts, insurance co's)
  - Monetary Authorities
- Borrow and lend large amounts
- For short periods of time (≤ 1year)

Money Markets - Instruments

- Instruments issued and traded include:
  - Short-dated government securities (T-Bills)
  - Inter-bank deposits & certificates of deposit (CDs)
  - Trade-related "Bankers' Acceptances"
  - Commercial Paper (CP) issued directly by large corporates
- Banks are regular players in money markets and largely in the market for short-term deposits

Inter-bank Short Term Fixed Deposits

- Fast way for a bank to:
  - Cheaply borrow short term to cover funding requirement
  - Safely invest cash temporarily in surplus
- Interbank deposits are usually funded (settled) T + 2
  - E.g. fixed deposit *dealt* on Tuesday, and *funded* on Thursday
- Large banks act as deposit market makers
  - borrow funds at *bid* rate = “JIBID”, “LIBID”, “SIBID”
  - lend funds at *offered* rate = “JIBOR”, “LIBOR”, “SIBOR”
- In process, they set inter-bank benchmark rates
  - Serves as benchmark for other bank lending

Rupiah Inter-bank Deposit "Broker Run"

name	bid	ask
IDROND=	3.75	4.00
IDRTND=	3.00	4.00
IDRSND=	7.00	7.25
IDRSWD=	5.00	5.50
IDR2WD=	6.00	6.25
IDR1MD=	8.25	8.50
IDR2MD=	8.00	8.25
IDR3MD=	8.00	8.25
IDR6MD=	8.00	8.25
IDR1YD=	8.00	8.25

Source: Reuters, Aug 2008

Inter-bank Deposit Market Interest

- Usually principal funded in round amount at initiation
  - So Principal and Interest repaid at Maturity is odd amount
- Interest portion may be referred to as
  - "coupon" or "add-on"
    - $1m on deposit for 1year at 4% returns $1,040,000 at end of term (P + i)
- Market Maker quote of 3-month IDR fixed deposit
  - Bid 7.95% (borrows at this rate)
  - Ask 8.25% (lends at this rate)
- Price-taker
  - Can "*place* deposit" (lend) at 7.95 % (or look for better bid)
  - Can "*take* deposit" (borrow) at 8.25 % (or look for lower offer)

Calculate the Accrued amounts

- Funding Date: Friday 14 Sep
- Maturity Date: Friday 14 Dec
- Days between Dates: _____
- Principal funded: IDR 1bn
- Interest Rate: 8% Actual/360
- Interest Payment: At maturity, w/ principal
- How much interest is accrued over the calculation period?

- What are the *present* and *future values* of this deposit?

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Lecture 4, Exercise 1:
Inter-bank Deposit Trade

Exercise 1: Inter-bank Deposit Trade

11am Monday, Sep 12, 201X

DBS:	Your offer on 3-mo JPY Deposit in 2 billion of yen?
BTMU:	0.56
DBS:	That's done. I take funds at 0.56% p.a. actual/360.
BTMU:	OK, Sep 14 Funding of ¥2,000,000,000. Dec 14 201X Maturity with interest of ¥2,831,111
DBS:	Agreed.

Read the conversation above. Then answer the following questions:

1. Who is lending and who is borrowing? How?

2. This deposit has a stated rate of interest. Is it a zero-coupon instrument? Why or why not?

3. How are the funding and maturity dates determined, and how many days are in the calculation period?

4. Do you agree the interest amount? What formula was applied?

5. How does the borrower (deposit-taker) receive funds? When?

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L4: Topic 2:
Money-Market Rate Benchmarking

Where "LIBOR" Comes From

Daily Rate Benchmarking

- Round-date deposit offered rate benchmarked one time each day
- Contributors (major banks) show best estimates of what rate at which they can borrow as price-taker at 11am local time
  - For round-date maturities (e.g. 1 day, 1 week, 1 month, …, 1 year…) fixed deposits
- Calculation agent then posts the average (as calculated) for each maturity to serve as the benchmark for that day (corresponding to conventional funding start)

Old method of LIBOR Rate Benchmarking

- Panel Banks submit their 11am Offered Rate (as price-makers)
- British Bankers Assn (BBA) reports the 11am fixing (average)

LONDON INTERBANK OFFERED RATES EURODOLLARS — LIBO

RATES FIXED AT 11:00AM LOCAL TIME. Today's Date: 14/09/07
Value Date: 18/09/07

	1 WEEK	1M	2M	3M	6M	9M	1Y
CHASE	5.25000	5.60000	5.63000	5.64000	5.45000	5.24000	5.13000
DEUTSCHE	5.35000	5.58000	5.63000	5.65000	5.42000	5.20000	5.11000
HBOS	5.25000	5.60000	5.63000	5.64000	5.46000	5.25000	5.13000
HSBC	5.30000	5.60000	5.61000	5.62000	5.45000	5.22000	5.10000
LLOYDS	5.25000	5.65000	5.65000	5.65000	5.46000	5.26000	5.13000
WEST LB	5.20000	5.65000	5.66000	5.66000	5.46000	5.25000	5.13000
R.B. SCOT	5.30500	5.60000	5.60000	5.60000	5.43000	5.24000	5.11000
RABOBANK	5.25000	5.64000	5.60000	5.58000	5.47000	5.24000	5.10000
BTM.	5.25000	5.65000	5.67000	5.66000	5.50000	5.26000	5.13000
BARCLAYS	5.30000	5.60000	5.63000	5.66000	5.50000	5.26000	5.13000
CITIBANK	5.25000	5.58000	5.60000	5.60000	5.42000	5.20000	5.05000
CR SUISSE	5.20000	5.57000	5.60000	5.65000	5.46000	5.25000	5.13000
BOA	5.35000	5.60000	5.62000	5.63000	5.45000	5.25000	5.13000
R.B. CAN	5.23000	5.68000	5.67000	5.66000	5.49000	5.25000	5.13000
UBS AG	5.32000	5.62000	5.65000	5.65000	5.43000	5.21000	5.08000
NORIN BK	5.45000	5.72000	5.70000	5.69000	5.50000	5.25000	5.12000
AVERAGE*	5.28156	5.62125	5.63438	5.64000	5.45938	5.23938	5.11500

Negative EUR Deposit Rates

- We live in strange times….
- Short-term rates in JPY, EUR, and CHF are below zero! (Aug 2019)

EUR	08-02-2019	08-01-2019	07-31-2019	07-30-2019	07-29-2019
Euro LIBOR - overnight	-0.46529 %	-0.46143 %	-0.46300 %	-0.47143 %	-0.46629 %
Euro LIBOR - 1 week	-0.45829 %	-0.45800 %	-0.45729 %	-0.45671 %	-0.45571 %
Euro LIBOR - 2 weeks	-	-	-	-	-
Euro LIBOR - 1 month	-0.43386 %	-0.42586 %	-0.42643 %	-0.42443 %	-0.42243 %
Euro LIBOR - 2 months	-0.43000 %	-0.42400 %	-0.41929 %	-0.41857 %	-0.41271 %
Euro LIBOR - 3 months	-0.41171 %	-0.41529 %	-0.41971 %	-0.41743 %	-0.40229 %
Euro LIBOR - 4 months	-	-	-	-	-
Euro LIBOR - 5 months	-	-	-	-	-
Euro LIBOR - 6 months	-0.41886 %	-0.41600 %	-0.40786 %	-0.40943 %	-0.41029 %
Euro LIBOR - 7 months	-	-	-	-	-
Euro LIBOR - 8 months	-	-	-	-	-
Euro LIBOR - 9 months	-	-	-	-	-
Euro LIBOR - 10 months	-	-	-	-	-
Euro LIBOR - 11 months	-	-	-	-	-
Euro LIBOR - 12 months	-0.35386 %	-0.33957 %	-0.33914 %	-0.33800 %	-0.34829 %

Can Interest Rates be Negative?

- Traditionally the answer is
  - No, because people would simply hold savings in cash rather than pay "storage fees" to a bank
  - Yes, if expected inflation for a period is higher than the nominal rate for the period
    - E.g. E(Inflation) = 4% over the coming year, while the 1 year fixed deposit rate = 3%. One would lose 1% purchasing power by investing in a fixed deposit
    - So the "real interest rate" is negative here, although the nominal rate is not
- Lately the answer is "yes," because central banks have the power to force banks to accept them
  - Simply because banks have no choice but to place some deposits with the CB, and…
  - Central banks are giving an incentive to borrow by accepting negative interest rates from the banks borrowing the money
- Negative rate policy is anti-deflationary, intended to get loans out into the economy and thereby stimulate economic activity.

What Use are the Benchmarked "ibors"?

- Many loans and other transactions use the benchmark as a reference source
  - Pricing/re-pricing of bank loans to customers
  - Settlement of derivatives
  - Very basic short-term zero-coupon rate reflecting bank-quality credit
- For many valid reasons, we can consider a currency's benchmarked rate to estimate a given bank's incremental cost of short-term debt financing
  - Pricing of variable-rate and short-term loans
  - Valuation of inter-bank future cash-flows
  - Mark-to-market of Interest Rate Derivatives

LIBOR Fixing Scandal

- From 2005 to 2012
- Panel banks (12 of them) colluded in manipulating LIBOR fixing
  - To give false impression of borrowing ability
  - To report false P&L in derivatives trading books
- Fines and prison sentences, lawsuits and sanctions
- Result: Contributor submissions fundamentally changed
  - Confidential rate submission
  - Personal accountability of person providing submission
  - Price-taker perspective
- For more info on this scandal, see
  https://www.investopedia.com/terms/l/libor-scandal.asp

Post-scandal Upshot

- New methodologies in calculating the benchmarks
- Less inter-bank lending not as a result of the scandal, but because of tighter limits and new regulations that discourage it
- Higher reliance on overnight lending and the rates emanating from overnight markets
- Higher reliance on secured inter-bank lending via repo markets

New Method – ICE LIBOR

- Banks report rates that are offered to them (as price-takers)
- ICE calculates and reports the 11am fixing

USD	08-02-2019	08-01-2019	07-31-2019	07-30-2019	07-29-2019
USD LIBOR - overnight	2.10425 %	2.11225 %	2.35163 %	2.34700 %	2.34863 %
USD LIBOR - 1 week	2.18013 %	2.18825 %	2.17625 %	2.19625 %	2.23225 %
USD LIBOR - 2 weeks	-	-	-	-	-
USD LIBOR - 1 month	2.22850 %	2.24413 %	2.22425 %	2.22975 %	2.23438 %
USD LIBOR - 2 months	2.24575 %	2.27050 %	2.25288 %	2.25250 %	2.25800 %
USD LIBOR - 3 months	2.23925 %	2.28675 %	2.26563 %	2.25313 %	2.25550 %
USD LIBOR - 4 months	-	-	-	-	-
USD LIBOR - 5 months	-	-	-	-	-
USD LIBOR - 6 months	2.13300 %	2.22688 %	2.20688 %	2.19163 %	2.19625 %
USD LIBOR - 7 months	-	-	-	-	-
USD LIBOR - 8 months	-	-	-	-	-
USD LIBOR - 9 months	-	-	-	-	-
USD LIBOR - 10 months	-	-	-	-	-
USD LIBOR - 11 months	-	-	-	-	-
USD LIBOR - 12 months	2.11588 %	2.23850 %	2.18863 %	2.18850 %	2.19800 %

Source - www.global-rates.com/interest-rates/libor/libor.aspx

Migration to Overnight Rate Basis

- Central banks and regulators are encouraging the emergence of overnight inter-bank rates to replace the -*ibor* benchmarks.
- Bank of England requirement to contribute to LIBOR averages ceases in 2021
- New overnight benchmarks are being compiled and reported daily by the central banks themselves in many cases

Major Overnight Rates

- Sterling Overnight Index Average (SONIA) – weighted trimmed average of interbank overnight rates for unsecured deposits ≥ GBP 25m
- EONIA – like SONIA but for Euro
- SORA – for SGD
- TONA/TONAR – for JPY
- SOFR – Daily average of overnight rates for USD general collateral repo transactions, published by NY Federal Reserve Bank

Why SOFR instead of LIBOR?

- USD repo volume is much higher than inter-bank deposits
  - According to Investopedia.com, by a factor of 1500X!
- Data compilation is based on real transactions
- Federal Reserve Bank is pushing for the switch
- Bank of England won't require LIBOR contributions starting in 2021
- But as of 2019, there are $200 trillion open positions in derivatives based on LIBOR
  - So we're still very much in a LIBOR regime…

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L4: Topic 3:
The LIBOR Forward Yield Curve

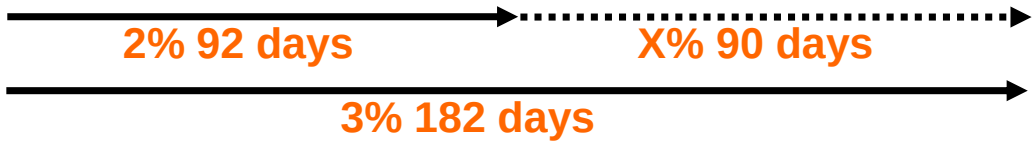
Inter-bank Rate Analytics

Forward Implied Rates

- If you know two or more spot zero-coupon rates of the same credit and different maturities, they imply forward starting rates
- Example: In 3 months time, you will borrow USD for 3 months. You don't know what the 3-month -LIBOR will be then, but do know the spot-starting 3- and 6-month rates:
  - Spot-3 months at 2% Act/360
  - Spot-6 months at 3% Act/360

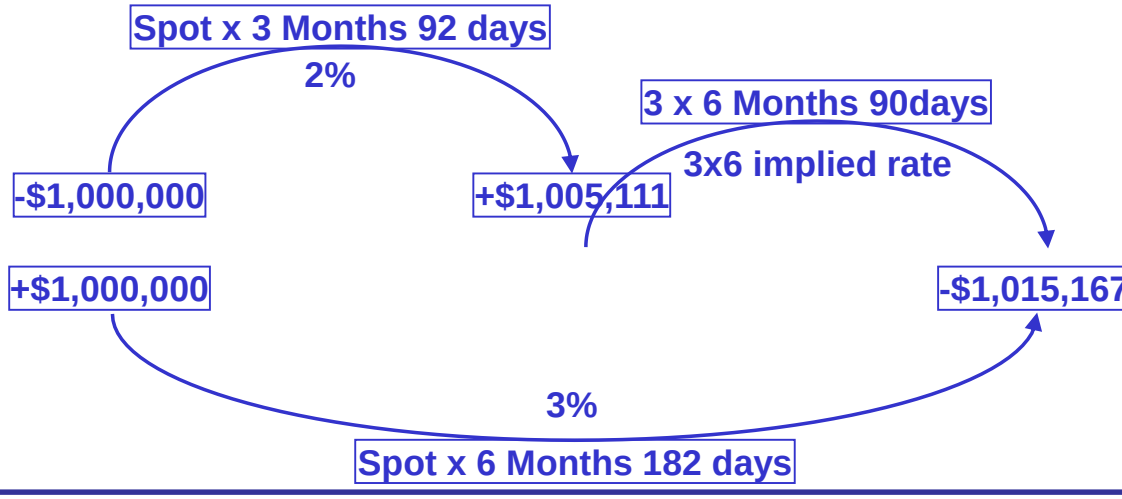
Implied Forward LIBORs

- The 3 × 6 forward rate is implicit in these 2 spot rates:
  - 0 x 3 months (Spot-3mo) at 2% (assume 92 days)
  - 0 x 6 months (Spot-6mo) at 3% (assume 182 days)
- Unbiased Expectations Hypothesis = Investing in 6-mo at 3% should give same return as investing 3-mo at 2% and re-investing P+i for the 3 x 6mo period



Synthetic 3 x 6mo forward fixed deposit

- To borrow (take deposit) 3 x 6mo forward:
  - Borrow (take deposit) $1,000,000 spot-6mo at 3%
  - And Lend (place deposit) that same $1,000,000 spot-3mo



Spot zero-rates imply the forward zero rate…

$$\left(P + i_{spotx3mo}\right) \times \left(1 + Rate_{3x6\ forward} \times Days_{3x6} / day - ct\right) = P + i_{spotx6mo}$$

$$\left(1 + Rate_{3x6} \times 90/360\right) = \frac{\$1{,}015{,}167}{\$1{,}005{,}111}$$

$$Rate_{3x6} \times 90/360 = \frac{\$1{,}015{,}167}{\$1{,}005{,}111} - 1$$

$$Rate_{3x6} = \left(\frac{\$1{,}015{,}167}{\$1{,}005{,}111} - 1\right) \times 360/90$$

$$Rate_{3x6} = 4.02\%act/360$$

3 x 6 mo rate LIBOR = 4.02% implied

+$1,005,111 -$1,015,167

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Lecture 4, Exercise 2:
USD LIBOR Forward Rates

Exercise 2: Calculating Implied Forward USD LIBORs

Today is Monday 11 Sep 201X. The following are the benchmarked spot-staring LIBORs for today, corresponding to Wed 13 Sep 201X funding:

Tenor	$LIBOR	Funding	Maturity	Accrual Days
3-month	2.25%	13 Sep 201X	13 Dec 201X	91
6-month	2.55%	13 Sep 201X	13 Mar 201Y	181
9-month	2.80%	13 Sep 201X	13 Jun 201Y	273
12-month	3.05%	13 Sep 201X	13 Sep 201Y	365

1. Calculate the following Implied Forward Rates, based on their real day-count. The first one is done for you. Here's the formula using the correct day-count ("dayct")

Forward Rate (short x long) =

[([1+(long rate x days/dayct)] ÷ [1+(short rate x days/dayct)]) – 1] x [Dayct/(Longdays-Shortdays)]

3 x 6 = [([1+(.0255 x 181/360)] ÷ [1+(0.225 x 91/360)])-1] x [360/(181-91)] = 2.8372%

Funding 13 Dec 201X, Maturity Mar 201Y, Frequency Quarterly, Day-count Act/360

6 x 9

Funding _____, Maturity _____ Frequency_____ Day-count_____

9 x 12

Funding _____, Maturity _____

2. Now calculate the following semi-annual actual/360 rates, by either using the same formula above or by compounding the corresponding forward quarterly rates

3 x 9

Funding _____, Maturity _____ Frequency_____ Day-count_____

6 x 12

Funding _____, Maturity _____ Frequency_____ Day-count_____

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L4: Topic 4:
Forward Rate Derivatives

Futures and Forwards

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L4: Topic 4a:
Short-term Rate Futures

Exchange-traded Forward Rates

Exchange-traded Rate Futures

- A financial contract between two parties through a regulated exchange to buy or sell a defined amount and standard of asset at a date in the future defined by the exchange at a price agreed **today**
  - The exchange is governed by a formal set of rules, and usually regulated by govt
  - The contracts are standardized
  - The contracts give a position in a notional amount of the underlying asset or price
  - The user places cash in a margin account, from which losses are deducted and gains are deposited each day
    - Too many losses = Margin call
  - The contracts are novated thru a clearing house
    - A position can be closed out prior to expiration by taking an offsetting position
- Futures on 3mo USD LIBOR trade on the Chicago Mercantile Exchange
  - $1m notional deposit placed for ¼ year (3mo)
  - P&L sensitivity attached to fixing of 3mo LIBOR
  - Can be used to hedge future a spot rate (e.g. 15Mar next year) at the implied forward rate

Eurodollar (3mo LIBOR) Futures

- USD Interest Rate Futures
  - 3 Month LIIBOR is the underlying value
  - USD1,000,000 of Notional Value per contract
  - Priced as 100 – 3mo LIBOR
    - E.g. if the forward rate implied for Mar-Jun accrual period is 3.10%, the Mar futures contract should have a price quote of appx 96.89 / 96.91
  - Cash Settled
    - Against 3m USD LIBOR as determined in Mar, Jun, Sep, and Dec
  - USD25 per Basis Point change in USD 3mo LIBOR interest rate
  - March, June, September & December expiries
  - Expiry on the 2nd business day preceding the 3rd Wednesday of the contract month
- Huge liquidity
  - Dec 17 CME Eurodollar contract (appx 3 x 6 forward) on 4th Sep 2017:
    - Open Interest of 2,044,803 contracts (at $1m notional each)
    - Volume 4 Sep in that contract only = 45,360 contracts ($45.36 bn)

Exercise 3: Hedging w/ CME 3mo E$ Futures

- It is Nov1X, and your bank will take a $100m deposit from mid-March 201Y for a three month period.
  - Assume your bank can borrow at spot-3mo LIBOR
  - But you are concerned that interest rates may rise between now and then, so…
- You sell 100 Mar-1Y E$ futures at a price of 96.89 as a hedge:
  - If 3mo spot LIBOR (for Mar-1Y) rises
    - Your higher borrowing cost will be offset by a profit in the futures
  - If the rate (for Mar-1Y) falls
    - Your lower borrowing cost will be offset by a loss in the futures

Exercise 3: Futures Hedging of LIBOR

Hedging with 100 E$ Futures Contracts			
Traded CME Futures Price			
LIBOR Fixing Rate (futures settlement price)	4.65% (95.35)	3.11% (96.89)	2.80% (97.20)
Interest cost of Borrowing*		$777,500	
Futures P&L Rec'd (Paid)*			
Net Cost of Borrowing (after including futures)			

Assume a perfect quarter-year of 90 actual accrual days/360. Note: Futures pay-out = $25 per tick (bp of 3mo LIBOR) x no of contracts which are sized at $1m notional, so each bp difference is appx $25 = 0.0001 x 1m x ¼

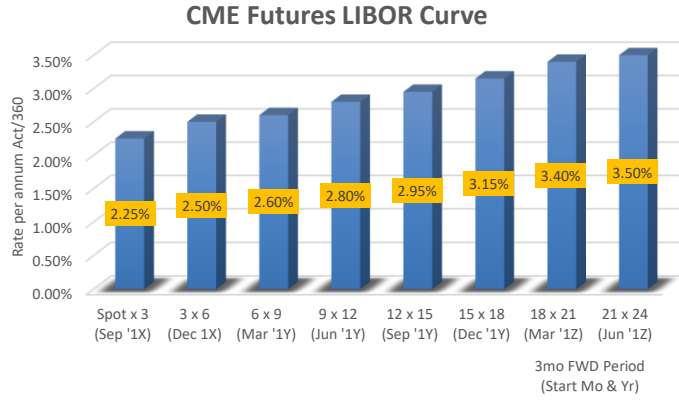
Futures Price Run and Implied Forward Rates

- Sample spot x 3mo and CME LIBOR Futures

3mo Accrual	Accrual Period	Market	Implied	
Calc Period	Start Date	Price	Rate	Act Days
Spot-3mo	20-Sep-1X	2.25%	2.25%	91
3 X 6	20-Dec-1X	97.50	2.50%	90
6 X 9	20-Mar-1Y	97.40	2.60%	92
9 x 12	20-Jun-1Y	97.20	2.80%	91
12 x 15	19-Sep-1Y	97.05	2.95%	91
15 x 18	19-Dec-1Y	96.85	3.15%	91
18 x 21	20-Mar-1Z	96.60	3.40%	91
21 x 24	19-Jun-1Z	96.50	3.50%	91
	18-Sep-1Z			

Forward LIBOR Yield-curve in *stripped* format:

- With forward rates, easier to present the yield-curve in bar-graph format:



- What is the appx average rate for the 2yr period?

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Lecture 4, Exercise 4 (Homework): Using Forward Rates to Derive Long-dated Zero-rates

Exercise 4: Calculating Long-dated Zero LIBOR Rates

Inter-bank deposit rates are typically quoted spot x 1 day to spot x 1yr. These by the nature of money market deposits are natural zero-coupon instruments. There are inter-bank deposits quoted to 18mo or even 2yr, but these conventionally require an interim payment of interest at the one-year anniversary of funding (i.e. the 18mo deposit pays interest at 12mo and at maturity)

As we know, yield-curve analytics and various fixed income products require a zero-coupon yield curve for various use-cases, including risk analysis and valuation of market-traded instruments.

With LIBOR futures, there is immense activity in these contracts, thereby establishing a highly visible and tradable forward curve. These contracts allow a user to lock in forward LIBOR rates by buying or selling futures contracts.

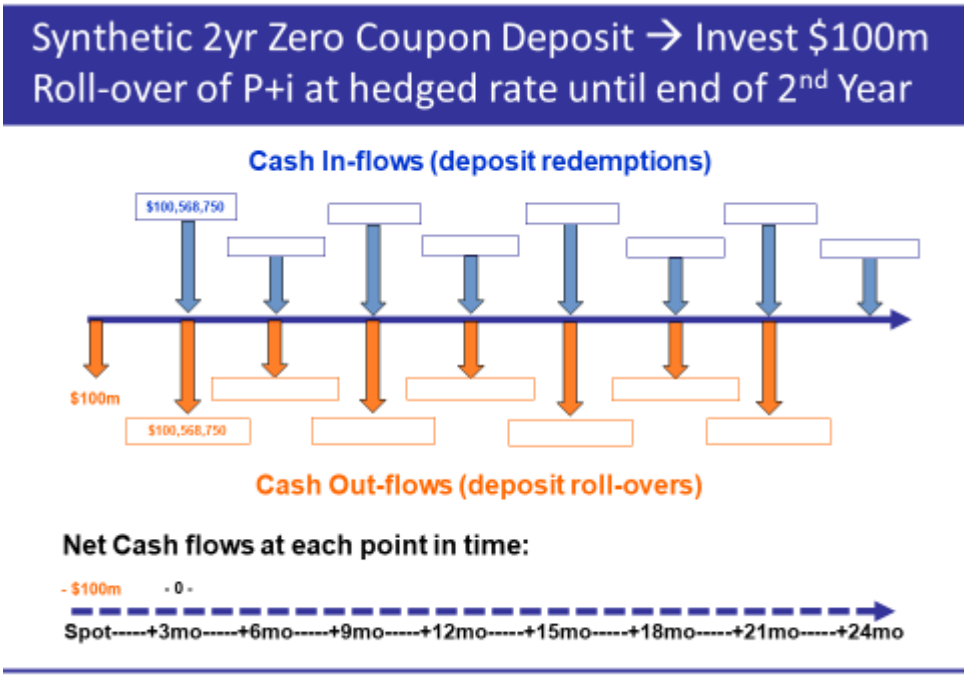
In the government bonds, you have already used bootstrapping to synthesize long-dated zero rates, and from these you were able to calculate implied forward rates. Now you'll "go the other way" and start with the forward rates to determine the zero rates.

Assume today is 18Sep1X and you face the following market, and you will invest $100m spot-3mo, and roll P+I over into new subsequent 3mo deposits at each maturity. You will use the futures market to lock in the reinvestment rates for each forward 3mo period (assume you can reinvest all odd amounts of interest at the hedged forward rate even though the min contract size is $1m).

Here are the market prices and rates

3mo	Accrual Period	Market	Implied	
Calc Period	Start Date	Price	Rate	Act Days
Spot-3mo	20-Sep-1X	2.25%	2.25%	91
3 X 6	20-Dec-1X	97.50	2.50%	90
6 X 9	20-Mar-1Y	97.40	2.60%	92
9 x 12	20-Jun-1Y	97.20	2.80%	91
12 x 15	19-Sep-1Y	97.05	2.95%	91
15 x 18	19-Dec-1Y	96.85	3.15%	91
18 x 21	20-Mar-1Z	96.60	3.40%	91
21 x 24	19-Jun-1Z	96.50	3.50%	91
	18-Sep-1Z			

Visual time-line of cash flows. Fill in all the boxes. What net cash flows are you left with? What rate does it imply?



Cash out at Spot? _____

Cash Back at Spot + 2yrs? _____

Any net cash flows occuring in between? _____

2yr Discount Factor? _____

Approximate Quarterly Equivalent Act/360 Rate per annum?_____

Congratulations, you've used the futures prices to extrapolate zero rates!

By the way, what are the following?

1yr df and zero rate in quarterly act/360?

15mo df and zero?

18mo df and zero?

End of Lecture 4

Final Q&A

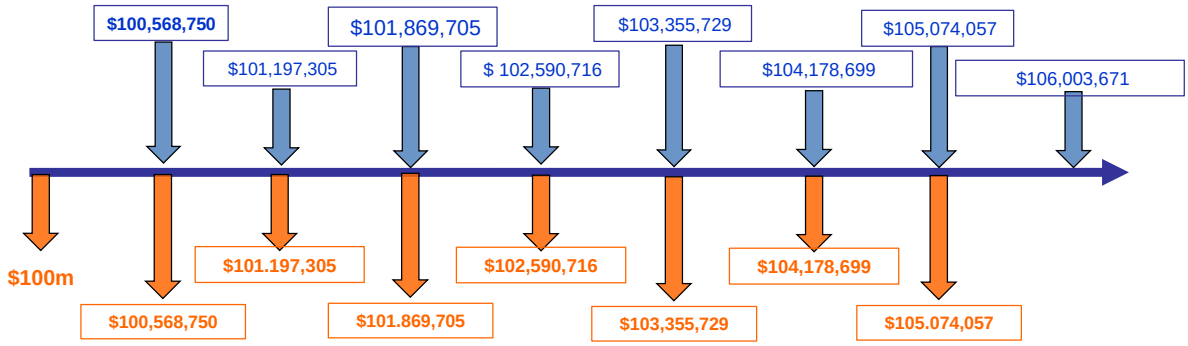
Supplementary Slides

Help with Homework

Exercise 4

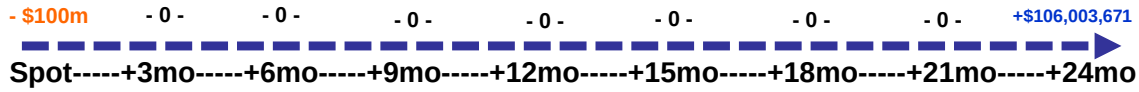
Synthetic 2yr Zero Coupon Deposit → Invest $100m Roll-over of P+i at hedged rate until end of 2nd Year

Cash In-flows (deposit redemptions)



Cash Out-flows (deposit roll-overs)

Net Cash flows at each point in time (inflows minus outflows):



Supplementary Slides

Forward Rate Agreements

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L4: Topic 4b:
Forward Rate Agreements

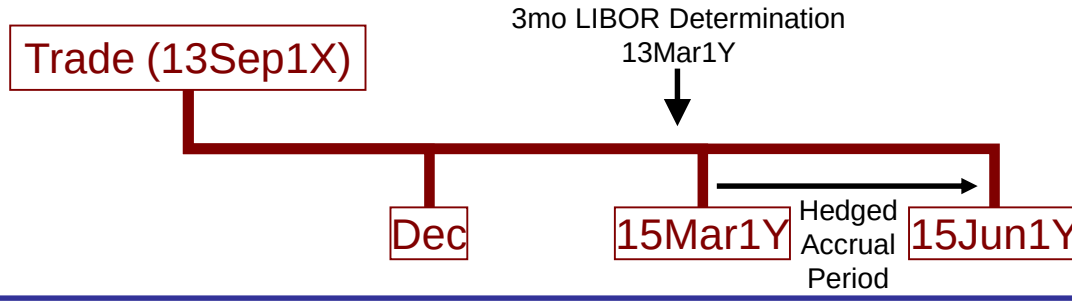
FRAs

FRA – Forward Rate Agreement

- A forward rate agreement is a contract on a forward short term interest rate to be determined by objective process
  - Usually an inter-bank benchmark rate such as LIBOR or SIBOR
  - Gives a directional position in the future of the short-term rate in question
  - Provides for cash settlement of gain or loss from the difference between the dealt rate (determined at inception) and the benchmark rate (determined in future)
- Allows rate hedging for forward-starting calculation period
  - Agreed Notional Amount (principal equivalent)
    - But there is no principal amount funded
  - Agreed future accrual period (e.g. 6 x 9 months)
    - Benchmark fixing usually 2 days before first day of calculation period
  - Agreed Fixed Rate vs. forward rate set to benchmark
    - Rates applied to Notional Amount to calculate payments

FRA Sample Application

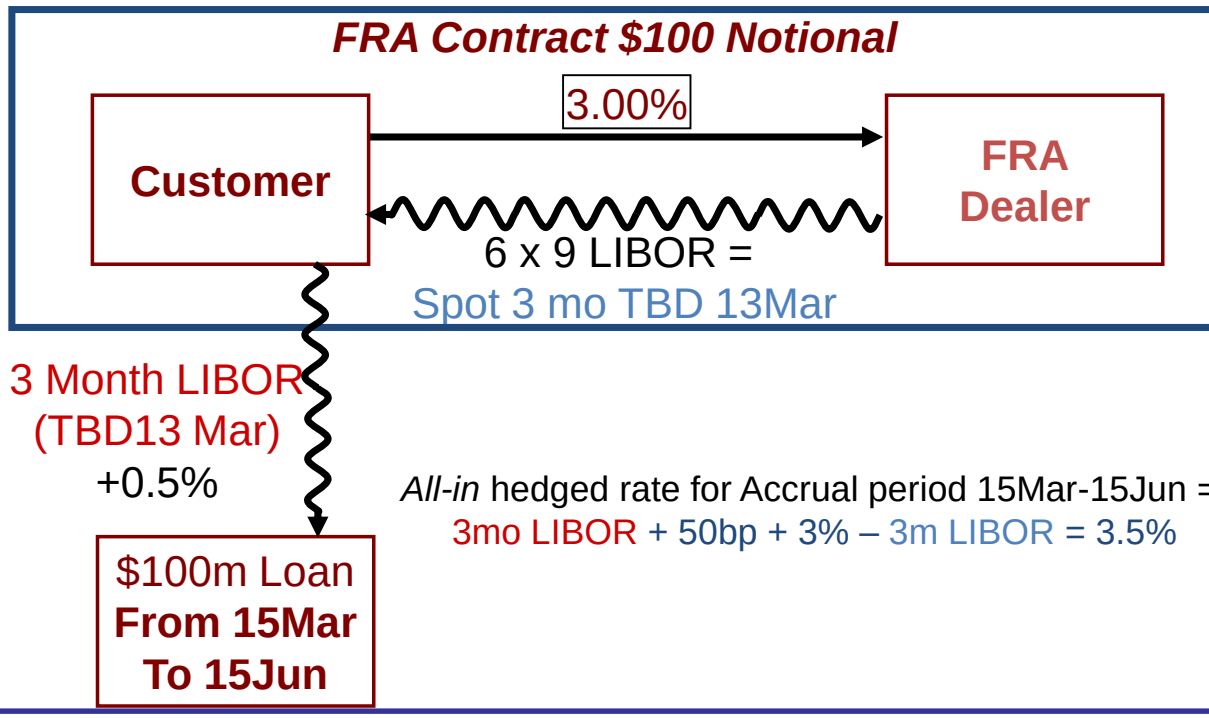
- Today (trade date) = 13Sep1X; Spot = 15Sep1X
- A borrower has a floating rate bank *line of credit* priced at 3-mo LIBOR + 50bp
  - Plan to take funding of $100m on 15Mar1Y (i.e. 6mo from today's "spot date"). But at risk as to what the 3mo LIBOR will be at that time
  - To hedge the interest rate risk for the first 3mo accrual period, they "buy" a "6x9" FRA on a notional amount of $100m
  - They pay fixed in the FRA at 3.0% vs. 3-month LIBOR (corresponding to 15Mar-15Jun1Y) to be determined on 13Mar1Y (2 days prior to funding)



Notional Amount

- With interest rate derivatives, the idea is to create a P&L that reflects interest rate risk on a funded loan or investment
- So the derivative itself involves no funding
- But in order to give the P&L a magnitude equivalent to a funded exposure…
- The derivative is given a multiplier, called the Notional Amount
  - E.g. If I agree to pay you 3% on a notional (pretend, un-funded) loan of $100m, at the end of 3mo, I would owe you $7,500 of real money!
  - Of course, it wouldn't be a loan if it had a pretend principal, but…
  - ….what if we agree to each make pretend (un-funded) forward-starting loans to each other of $100m and agreed to pay fair rates of interest on that Notional $100m:
    - I pay you fixed at 3%, agreed today to be applied 6 x 9mo, and…
    - you pay me 3mo LIBOR to be determined just before the loan begins accruing interest 6mo from now.

FRA-Hedging of the Variable Rate



All-in hedged rate for Accrual period 15Mar-15Jun =
3mo LIBOR + 50bp + 3% – 3m LIBOR = 3.5%

FRA Mechanics and Terms

- The rates paid/received are simple money market rates
  - "Fixed rate" is the rate dealt at time, T
  - "Floating rate" is the one that is set in future
  - Referenced to daily rate settings as reported on Reuters, Telerate, Bloomberg
  - Applied over the *Calculation Period* (accrual period)
- *FRA Buyer* pays (dealt) fixed rate and receives floating rate
  - Buyer gains on FRA if Floating > Fixed
- *FRA Seller* receives the dealt rate and pays the floating rate
  - Seller gains on FRA if rates Fixed > Floating
- This is a transaction type mostly used by financial institutions to hedge short-term rate exposure

FRA Settlement

- Advance FRA settlement (conventional)
  - Settle the PV of the net cash-flow resulting from the 2 interest rates, but on the first day of the accrual period

$$\text{Settlement Amount} = \frac{N \times (R - D) \times A}{(1 + [R \times A])}$$

N = Notional Amount (e.g. \$100 million)

R = Reference Variable Rate (e.g. 3 mo LIBOR)

D = Dealt Fixed Rate (e.g. 3.00%)

A = Accrual Fraction (e.g. 92/360)

- It is also possible to specify arrears settlement, on the last day of the accrual period, in which case the formula is $N \times (R - D) \times A$

FRA Quote Terminology

- Market Quotation
  - 6s 9s
  - 6-9
  - 6.9
  - 6 × 9
  - 6 vs 9
- This refers to the number of months to start and maturity of the *Calculation Period*
  - E.g. in Sep 201X, a 6s 9s advance settled FRA will cover the period starting in Mar 201Y and accruing interest for three months.....in Mar 201Y the counter-parties know both rates and *settle for differences*

Pricing and Valuation of FRAs

- If you have calculated the 6 X 9 implied forward rate to be 3% (*fair value*)
- As a FRA dealer, you make a two-way price around fair value:
  - Bid 2.98%
  - Offer 3.02%
- Drawing 2-way deal-flow from FRA users
  - You can earn the bid-offered spread
  - Have FRA sales offset FRA purchases
  - Adjust your market prices to offset any trading book mismatches

Sample Price Run of USD FRAs

maturity	bid	ask	contributor	updated	
1X4	1.238	1.258	BROKER	00:55 GMT	16 FEB 2009
2X5	1.247	1.267	BROKER	01:00 GMT	16 FEB 2009
3X6	1.2375	1.2975	BROKER	01:00 GMT	16 FEB 2009
4X7	1.2450	1.3050	BROKER	01:00 GMT	16 FEB 2009
5X8	1.2775	1.3375	BROKER	01:00 GMT	16 FEB 2009
6X9	1.325	1.345	BROKER	01:00 GMT	16 FEB 2009
7X10	1.355	1.375	BROKER	01:00 GMT	16 FEB 2009
8X11	1.453	1.473	BROKER	01:00 GMT	16 FEB 2009
9X12	1.479	1.499	BROKER	01:00 GMT	16 FEB 2009
1X7	1.72	1.78	BROKER	01:00 GMT	16 FEB 2009
2X8	1.6700	1.7300	BROKER	01:00 GMT	16 FEB 2009
3X9	1.553	1.593	BROKER	01:00 GMT	16 FEB 2009
4X10	1.5925	1.6525	BROKER	01:00 GMT	16 FEB 2009
5X11	1.566	1.606	BROKER	01:00 GMT	16 FEB 2009
6X12	1.575	1.615	BROKER	01:00 GMT	16 FEB 2009
9X15	1.645	1.685	BROKER	01:00 GMT	16 FEB 2009
12X18	1.755	1.795	BROKER	01:00 GMT	16 FEB 2009
1X10	1.980	2.020	BROKER	01:00 GMT	16 FEB 2009
2X11	1.577	1.617	BROKER	01:00 GMT	16 FEB 2009
3X12	1.499	1.539	BROKER	01:00 GMT	16 FEB 2009
6X18	1.675	1.715	BROKER	01:00 GMT	16 FEB 2009
12X24	2.016	2.056	BROKER	01:00 GMT	16 FEB 2009

Know the Difference:

- US$ (LIBOR) FRAs
  - Over the counter
  - Flexible Face
  - Flexible Dates
  - Under ISDA or similar
  - Have counter-party risk
  - Liquid to 1 year +/-
  - P&L depending on actual accrual days
  - P&L PV on settlement
- E$ (LIBOR) Futures
  - Exchange traded
  - $1m face per contract
  - Set accrual periods/expiries
  - Margined
  - No counter-party risk
  - Liquid beyond 1 year
  - Assumes exact ¼-year accrual period
  - P&L fixed at $25/tick/contract with no PV

Supplementary Information*

USD SOFR Futures

**Not required for midterm exam*

CME Group

Understanding SOFR Futures

14 May 2018 // By CME Group // Topics: #Interest Rates

This note spells out the workings of CME Three-Month SOFR futures and One-Month SOFR futures, examines how they complement the exchange's established short-term interest rate futures, and discusses intermarket spread trading.[1]

Contents

Secured Overnight Financing Rate

The Federal Reserve System convened the Alternative Reference Rates Committee ("ARRC") in November 2014 (i) to identify alternative reference interest rate benchmarks that are firmly based on transactions from a robust underlying market and that comport with the International Organization of Securities Commissions ("IOSCO") *Principles for Financial Benchmarks*, and (ii) to formulate a plan to facilitate acceptance and use of the chosen alternative. On 22 June 2017, the ARRC endorsed the Secured Overnight Financing Rate ("SOFR") as its preferred alternative reference rate. Regular production and publication of SOFR began Tuesday, 3 April 2018.

The SOFR value for any US government securities market business day ("business day") is published by the Federal Reserve Bank of New York ("FRBNY") around 8:00 a.m. New York time on the next business day.[2] SOFR comprises a broad enough universe of overnight Treasury repo trade activity to make it a benchmark for all seasons, firmly rooted in transaction data from multiple and diverse sources[3] --

- Tri-party Treasury general collateral ("GC") repo transactions cleared and settled by Bank of New York Mellon ("BNYM"), excluding repo transactions made through the Fixed Income Clearing Corporation ("FICC") General Collateral Financing ("GCF") repo market, and excluding transactions in which the Federal Reserve is a counterparty.
- Tri-party Treasury GC repo transactions made through the FICC GCF repo market, for which FICC acts as central counterparty.
- Bilateral Treasury repo transactions cleared through the FICC Delivery-versus-Payment ("DVP") service.

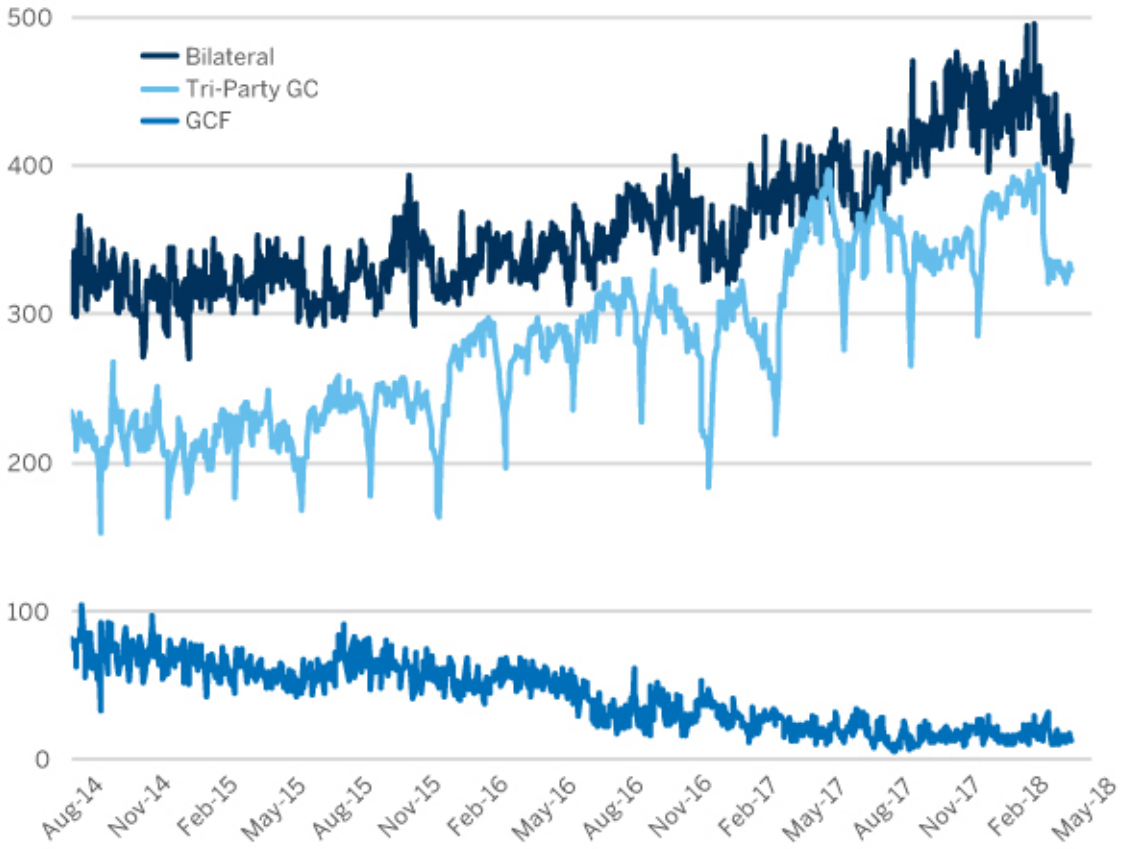
FRBNY applies various filters, trims, and inclusion rules to these data sources to isolate overnight Treasury GC repo transactions from other repo market activity, and to ensure that SOFR adheres to the IOSCO Principles.[4] FRBNY then pools them, ranks the aggregate of repo trading volumes by their transaction rates, from lowest to highest, and computes the transaction-weighted median repo rate (*ie*, the repo rate for which half of the day's trading volume is transacted at rates that are equal to it or less than it, and for which the other half of the day's trading volume is made at rates that are equal to it or greater than it). The transaction-weighted median repo rate becomes the day's SOFR benchmark value.

The trade-volume-weighted median methodology brings at least three advantages. It is a more robust statistic than alternatives such as, *e.g.*, the trade-volume-weighted average. The value it produces, moreover, is almost always an interest rate level that actually has been observed, at which business actually has been conducted. And it aligns with the calculation method for the daily effective federal funds rate (EFFR) and for the daily overnight bank funding rate (OBFR), which was adopted by the Federal Reserve in March 2016.[5]

SOFR's underlying transaction pool is massive. In 2017 average daily trading volumes ran $332 bln in BNYM tri-party Treasury GC repo, $21 bln in FICC GCF Treasury repo, and $393 bln in FICC DVP bilateral Treasury repo, making total average traffic flow of $745 bln per day (Exhibit 1).

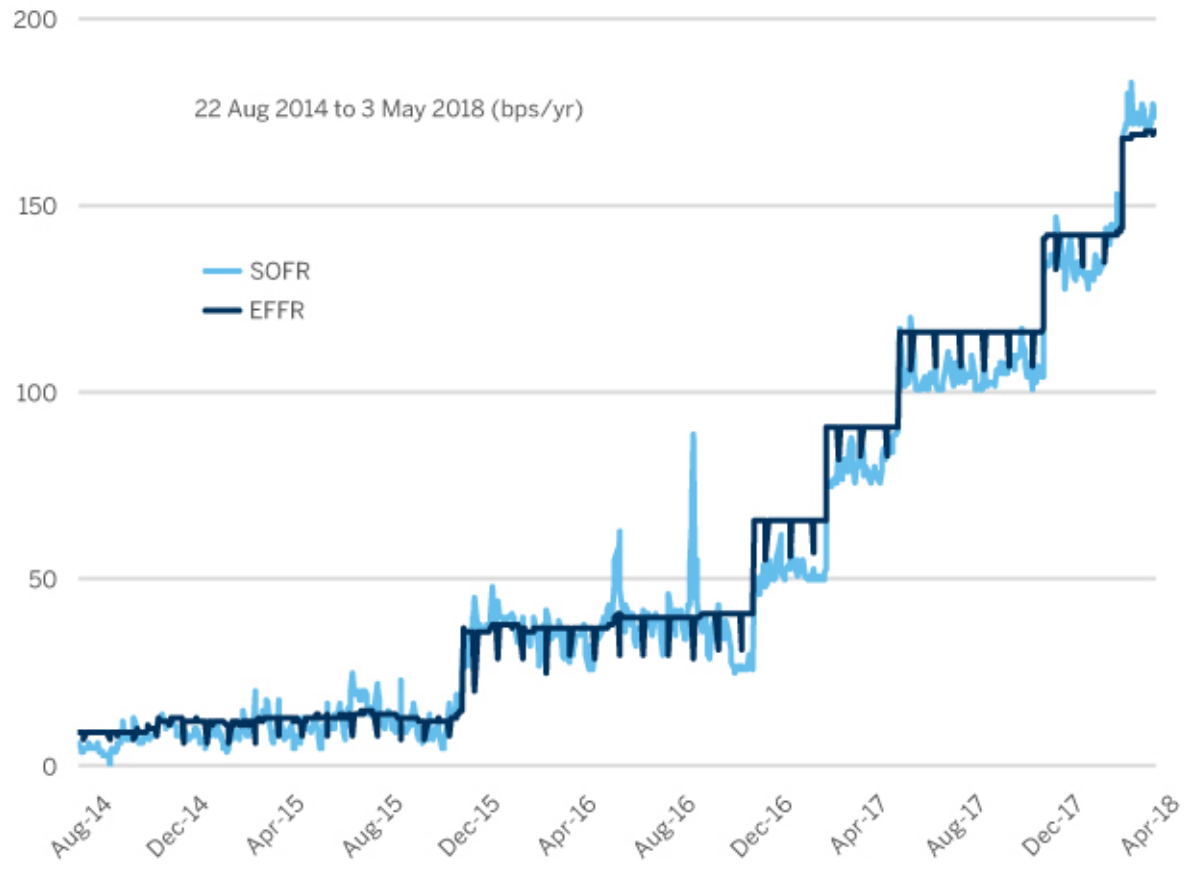
Although the available 3-1/2 years of evidence is limited, the data suggest that SOFR and EFFR share a common trend (Exhibit 2). Their short-term dynamics are quite different, however, with SOFR exhibiting noticeably more volatility. Between September 2014 and April 2018, the median absolute value of daily change in SOFR was one basis point. For EFFR it was zero. In other words, half the time, SOFR rises or falls from its previous daily level by a distance of one basis point or more, while, at least half the time, EFFR doesn't change from day to day.

Exhibit 1 -- Trade Activity ($ Billions per Day) in SOFR Data Sources, 22 Aug 2014 through 3 May 2018



Source: FRBNY

Exhibit 2 -- Daily EFFR and Estimated SOFR Values (Basis Points per Annum), 22 Aug 2014 through 3 May 2018



Source: FRBNY

CME Three-Month SOFR Futures

Exhibit 3 summarizes contract specifications for Three-Month SOFR ("SFR") futures.

Exhibit 3 -- CME Three-Month SOFR Futures Contract Specifications

Trading Unit	Compounded daily SOFR interest during contract Reference Quarter, such that each basis point per annum of interest = $25 per contract. *Reference Quarter:* For a given contract, interval from (and including) 3rd Wed of 3rd month preceding Delivery Month, to (and not including) 3rd Wed of Delivery Month.
Price Basis	Contract-grade IMM Index: *100 minus R*. *R* = compounded daily SOFR interest during contract Reference Quarter. *Example*: Contract price of 97.2950 IMM Index points signifies *R* = 2.705 percent per annum.
Contract Size	$25 per basis point per annum (or $2,500 per contract-grade IMM Index point)
Minimum Price Increment (MPI)	*Contracts with Four Months or Less Until Termination of Trading:* 0.0025 IMM Index points (¼ basis point per annum) equal to $6.25 per contract *All Other Contracts*: 0.005 IMM Index points (½ basis point per annum) equal to $12.50 per contract

Termination of Trading	*Last Day of Trading*: Exchange Business Day first preceding 3rd Wed of Delivery Month. *Termination of Trading*: Close of CME Globex trading on Last Day of Trading.
Delivery	By cash settlement, by reference to Final Settlement Price, on 3rd Wed of Delivery Month (or, more generally, first US government securities market business day following Last Day of Trading). *Final Settlement Price*: Contract-grade IMM Index (100 minus R) evaluated on the basis of realized SOFR values during contract Reference Quarter: $R = [\Pi_i \{1+(d_i/360)*(r_i/100)\} - 1] \times (360/D) \times 100$ n = Number of US government securities market business days in the Reference Quarter i ~ Running variable indexing US government securities market business days during Reference Quarter $\Pi_{i=1\ldots n}$ denotes the product of values indexed by the running variable, $i = 1,2,\ldots,n$. r_i = SOFR value for i^{th} US government securities market business day d_i = Number of calendar days to which r_i applies $D = \Sigma_i d_i$ (*ie*, number of calendar days in Reference Quarter)
Delivery Months	Nearest 20 March Quarterly months (Mar, Jun, Sep, Dec). For each contract, Contract Month is the month in which the Reference Quarter begins. *Example*: For a "Sep" contract, Reference Quarter starts on IMM Wed of Sep and ends with Termination of Trading on first US government securities market business day before IMM Wed of Dec, the contract Delivery Month.
Trading Venues and Hours	*CME Globex* and *CME ClearPort*: 5pm to 4pm, Sun-Fri.
CME Globex Algorithm	Allocation (A Algorithm, with Top Order Allocation = 100% and Pro Rata Allocation = 100%)
Block Trade Minimum Size	Asian Trading Hours (4pm–12am, Mon-Fri on regular business days and at all weekend times) 250 contracts European Trading Hours (12am– 7am, Mon-Fri on regular business days) 500 contracts Regular Trading Hours (7am–4pm, Mon-Fri on regular business days) page 3 on pdf 1,000 contracts
Product Codes	*CME*: SR3 *Bloomberg*: SFR Cmdty <GO>

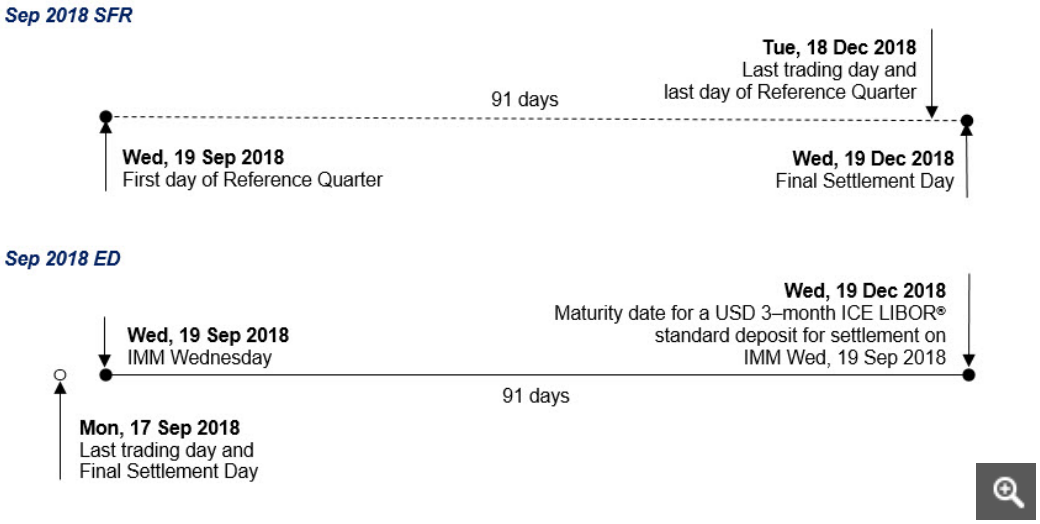
In certain important ways – contract sizing and critical dates, for instance – the contract features resemble CME's flagship Three-Month Eurodollar ("ED") futures.

Contract Critical Dates

The “contract month” convention for naming SFR futures mirrors the established convention for ED futures. To see how, consider two contracts:

- One is a September 2018 SFR future that comes to final settlement on the third Wednesday of December 2018. The interval of interest rate exposure that informs the contract final settlement price – the contract Reference Quarter -- starts on the third Wednesday of September 2018 and ends on the third Wednesday of December 2018.
- The other is a September 2018 ED future that comes to final settlement on the Monday before the third Wednesday of September 2018. The final settlement price is based on the USD three-month ICE LIBOR® corresponding to a three-month term unsecured bank funding transaction that settles on the third Wednesday of September 2018 and that matures three months later, in mid-December.

Both are referenced as “September” contracts, and the interval of interest rate exposure for one is essentially the same as for the other. Crucially, the settlement date for the ED contract’s hypothetical three-month term bank funding rate – the third Wednesday of September 2018 – is identical to the start date of the SFR contract’s Reference Quarter, the period over which daily SOFR interest is compounded --



Last Trading Day

…is the first business day before the 3rd Wednesday of the contract delivery month, *ie*, the business day first preceding the last day of the contract Reference Quarter. *Example*: For the September 2018 SFR contract, the scheduled last day of trading is Tuesday, 18 December 2018, as depicted above

Final Settlement Price

…is 100 contract price points minus daily compounded SOFR interest during the contract Reference Quarter, rounded to the nearest 1/100th of one basis point per annum. The exchange computes an expiring contract's final settlement price on the morning of the third Wednesday of the contract delivery month,[6] after FRBNY has published the SOFR value based on trade activity for the final day of the contract's Reference Quarter (typically the preceding Tuesday, more generally the first preceding business day).

> *Example*: Consider a hypothetical June 2017 SFR contract. The contract Reference Quarter spans 91 days, from (and including) Wednesday, 21 June (the third Wednesday of June), until (and not including) Wednesday, 20 September (the third Wednesday of September). Exhibit 4 details determination of the contract final settlement price on Wednesday, 20 September, when FRBNY would have published the SOFR value for Tuesday, 19 September.

Exhibit 4 -- Daily Compounding of SOFR Values for Hypothetical June 2017 SFR Futures

(Highlighted dates = business days immediately preceding US government securities market holidays)

Date	Days	SOFR (bps)	Gross Return
21--Jun	1	102	1.000028333
22-Jun	1	102	1.000028333
23-Jun	3	106	1.000088333
26-Jun	1	105	1.000029167
27-Jun	1	103	1.000028611
28-Jun	1	105	1.000029167
29-Jun	1	108	1.000030000
30-Jun	3	121	1.000100833
3-Jul	**2**	**110**	**1.000061111**
5-Jul	1	105	1.000029167
6-Jul	1	103	1.000028611
7-Jul	3	101	1.000084167
10-Jul	1	101	1.000028056
11-Jul	1	101	1.000028056
12-Jul	1	101	1.000028056
13-Jul	1	102	1.000028333
14-Jul	3	102	1.000085000
17-Jul	1	104	1.000028889
18-Jul	1	102	1.000028333
19-Jul	1	101	1.000028056
20-Jul	1	102	1.000028333
21-Jul	3	102	1.000085000
24-Jul	1	105	1.000029167
25-Jul	1	104	1.000028889
26-Jul	1	104	1.000028889
27-Jul	1	105	1.000029167
28-Jul	3	104	1.000086667
31-Jul	1	109	1.000030278
1-Aug	1	103	1.000028611
2-Aug	1	101	1.000028056
3-Aug	1	101	1.000028056
4-Aug	3	101	1.000084167

Date	Days	SOFR (bps)	Gross Return
7-Aug	1	101	1.000028056
8-Aug	1	101	1.000028056
9-Aug	1	101	1.000028056
10-Aug	1	103	1.000028611
11-Aug	3	106	1.000088333
14-Aug	1	109	1.000030278
15-Aug	1	112	1.000031111
16-Aug	1	109	1.000030278
17-Aug	1	110	1.000030556
18-Aug	3	108	1.000090000
21-Aug	1	105	1.000029167
22-Aug	1	103	1.000028611
23-Aug	1	103	1.000028611
24-Aug	1	109	1.000030278
25-Aug	3	108	1.000090000
28-Aug	1	106	1.000029444
29-Aug	1	104	1.000028889
30-Aug	1	105	1.000029167
31-Aug	1	115	1.000031944
1-Sep	**4**	**110**	**1.000122222**
5-Sep	1	105	1.000029167
6-Sep	1	103	1.000028611
7-Sep	1	104	1.000028889
8-Sep	3	105	1.000087500
11-Sep	1	105	1.000029167
12-Sep	1	105	1.000029167
13-Sep	1	105	1.000029167
14-Sep	1	109	1.000030278
15-Sep	3	111	1.000092500
18-Sep	1	104	1.000028889
19-Sep	1	101	1.000028056
20-Sep			

Data Source: FRBNY

On each Date:

"Days" =

days from SOFR trade/settlement day to next business day

"Gross Return" =

1 plus (Days/360) x (SOFR/10000)

Example:

"Gross Return" on Fri, 1 Sep = 1 plus (4/360) x (110/10000) = 1.000122222

Final Settlement Rate:

[(Product of All Gross Returns) minus 1] x (360/91) x 100

Example:

[1.002670427 minus 1]

x (360/91) x 100 =

1.056432494 pct/yr

Round to the nearest 1/100th bp:

1.0564

Final Settlement Price:

98.9436 = 100 minus 1.0564

As Exhibit 4 suggests, the computational conventions for compounding of daily SOFR values closely resemble those that apply in standard US dollar overnight index swaps ("OIS"), in which each OIS contract's floating rate leg is based on business-day-compounded EFFR. That is, SOFR will accrue as simple interest over weekends and US government securities market holidays and as compound interest otherwise.[7]

Futures Final Settlement Prices and SOFR Revisions

FRBNY normally publishes the SOFR value based on "yesterday's" transaction data at around 8:00am New York time "today". What happens if later "today" FRBNY discovers errors in those data (as provided to it by either BNYM or DTCC Solutions) or in the calculation process? Or what if transaction data that had been unavailable in time for regular publication at 8:00am "today" were to become available later in the day?

In any such instance, FRBNY may publish a revised SOFR value at approximately 2:30pm New York time, subject to two restrictions: (1) FRBNY will issue a revised SOFR value only on the same day as the initial rate value was published, and no later, and (2) it will issue a revised SOFR value only if the size of the revision – the magnitude of difference between the corrected rate value and the initial rate value that was published earlier that day -- exceeds one basis point per annum. Any time a SOFR value is revised, FRBNY will include a footnote to identify the revision.[8]

FRBNY's revision policy interacts with SFR futures final settlement prices in two ways. First, for all but the last business day in an expiring contract's Reference Quarter, the contract final settlement price calculation will incorporate any revised values that FRBNY has issued. Second, for the last business day of the expiring contract's Reference Quarter, the SOFR value that enters into calculation of the final settlement price shall be the value first published by FRBNY, irrespective of any revised SOFR value that FRBNY might publish at 2:30pm that day.

Price = 100 Minus Rate

Not just at final settlement but at all times, the SFR contract price takes the familiar IMM Index form, derived by subtracting from 100 the value (either expected or actual) of the contract's three-month SOFR interest exposure, as described above.

> *Example*: Suppose it is early August. Consider the nearby September SFR contract, which comes to final settlement in December. If the consensus view among market participants is that daily SOFR interest will compound between mid-September and mid-December (*ie*, during the contract Reference Quarter) at an annualized rate of 2 percent, then the futures contract price should trade at or around 98.00 (equal to 100.00 minus 2.00).

If any newly arrived information or change in market circumstances prompts market participants collectively to expect a rise (or fall) in SOFR by the time of the contract Reference Quarter, then the contract price will fall (or rise).

1 Basis Point = $25

Gains or losses on a contract position are calculated simply by determining the number of interest rate basis points ("bps") by which the contract price has moved, then multiplying by the value of one bp per contract. As with ED futures, *each basis point of contract interest is worth $25. Thus, SFR contract size is $2,500 x the contract IMM Index.*

Minimum Price Increment = Either ¼ Bp or ½ Bp

The price of a SFR contract trades in increments of either ¼ bp or ½ bp, depending upon the contract's proximity to its final settlement date. Generally, the minimum price fluctuation is ½ bp (equal to $12.50 per contract). Each contract's minimum price fluctuation reduces to ¼ bp (equal to $6.25 per contract), however, as of the first Trade Date following the weekend that precedes the third Wednesday of the month before the contract month. Broadly put, *this means each contract will trade in minimum price increment of ¼ bp during the four months before it comes to final settlement*.

Example: Consider the September 2018 SFR contract. Its Reference Quarter starts on (and includes) Wednesday, 19 September, and ends on (and excludes) Wednesday, 19 December. Its minimum price increment is ½ bp through close of trading on Friday, 10 August. When trading resumes on Sunday, 12 August, for trade date Monday, 13 August, its minimum price increment is ¼ bp.

Contract Listings = Whites through Golds

SFR listings comprise four March Quarterly (March, June, September, and December) contracts in the nearby "White" year and in each of the deferred "Red", "Green", "Blue", and "Gold" years. Thus, a newly listed SFR contract will be tradable for approximately five years before it comes to final settlement.

CME One-Month SOFR Futures

The structure of the One-Month SOFR ("SER") futures contract, summarized in Exhibit 5, resembles the exchange's 30-Day Federal Funds ("FF") futures in nearly all respects.

Exhibit 5 -- CME One-Month SOFR Futures Contract Specifications

Trading Unit	Average daily SOFR interest during futures contract Delivery Month, such that each basis point per annum of interest is worth $41.67 per futures contract.
Price Basis	Contract-grade IMM Index: *100 minus R.* *R* = average daily SOFR interest during contract Delivery Month. *Example*: Contract price of 97.295 IMM Index points signifies *R* = 2.705 percent per annum.
Contract Size	$41.67 per basis point per annum (or $4,167 per contract-grade IMM Index point)
Minimum Price Increment (MPI)	0.005 IMM Index points (½ basis point per annum) equal to $20.835 per contract, *provided that*: • If first day of contract Delivery Month is Sat, Sun, or Mon, then MPI is 0.0025 Index points, equal to $10.4175 per contract, as of first trading day of contract Delivery Month. • If first day of contract Delivery Month is Tue, Wed, Thurs, or Fri, then MPI is 0.0025 Index points, equal to $10.4175 per contract, as of last Sunday of month preceding contract Delivery Month.
Termination of Trading	*Last Day of Trading*: Last Exchange Business Day of contract Delivery Month. *Termination of Trading*: Close of CME Globex trading on Last Day of Trading.
Delivery	By cash settlement, by reference to Final Settlement Price, on first US government securities market business day following Last Day of Trading. Final Settlement Price: Contract-grade IMM Index evaluated at *R* = arithmetic average of daily SOFR during Delivery Month.
Delivery Months	Nearest 7 calendar months.

Trading Venues and Hours	*CME Globex and CME ClearPort*: 5pm to 4pm, Sun-Fri.
CME Globex Algorithm	Split FIFO and Pro-Rata (K Algorithm, with Top Order Allocation = 100% and Pro Rata Allocation = 100%)
Block Trade Minimum Size	Asian Trading Hours (4pm–12am, Mon-Fri on regular business days and at all weekend times) 125 contracts European Trading Hours (12am– 7am, Mon-Fri on regular business days) 250 contracts Regular Trading Hours (7am–4pm, Mon-Fri on regular business days) 500 contracts
Product Codes	CME: SR1 Bloomberg: SER Cmdty <GO>

Last Trading Day

…is the last business day of the contract delivery month. *Example*: For October 2018 SER futures, the scheduled last day of trading is Wednesday, 31 October.

Final Settlement Price

…is 100 contract price points minus average daily SOFR interest during the contract delivery month, with the average value rounded to the nearest 1/10th of one bp per annum. Normally, the exchange will compute an expiring contract's final settlement price on the morning of the first business day following the end of the expiring contract's delivery month. *Example*: For October 2018 SER futures, the delivery month ends on (and includes) Wednesday, 31 October, and determination of the final settlement price is scheduled to occur on Thursday, 1 November, after FRBNY has published the SOFR value based on trade activity for Wednesday, 31 October.

Similar to SFR futures, determination of the final settlement price for an expiring SER future will incorporate any revised values that FRBNY publishes for all but the last business day in the contract delivery month. For the delivery month's last business day, the SOFR value that enters calculation of the final settlement price shall be the value first published by the FRBNY. To be clear, any revised SOFR value such as FRBNY might publish at 2:30pm that day would not enter into the final settlement price.[9]

Price = 100 Minus Rate

Like FF futures, the SER futures contract price is quoted in IMM Index form, equal to 100 price points minus the expected value of average daily SOFR interest during the contract delivery month.

Example: If market participants generally expect the average level of daily SOFR to be 2.718 percent during the month of October, then the price of October SER futures should trade in the neighborhood of 97.280 or 97.285 (*ie*, around 97.282, equal to 100.000 minus 2.718). If the October SER futures contract is eligible to trade in ¼ bp minimum price increments, then the price more likely would trade at or around 97.2800 or 97.2825 (as before, either side of 97.282).

1 Basis Point = $41.67

Gains or losses on a contract position are calculated simply by determining the number of bps by which the contract price has moved, then multiplying by the value of one bp. As with FF futures, *each bp of contract interest is worth $41.67. Thus, contract size = $4,167 x the contract IMM Index.*

Price Increments = Either ¼ Bp or ½ Bp

The SER contract price trades in increments of either ¼ bp or ½ bp, depending on the proximity of the contract final settlement date. As with FF futures, the minimum price increment is ½ bp, worth $20.835 per contract, up to the start of the first day of the Delivery Month. From the first day of the Delivery Month until termination of trading, the contract minimum price increment is ¼ bp, worth $10.4175 per contract.

Additionally, in cases where the first day of the Delivery Month is a Tuesday, Wednesday, Thursday, or Friday, the contract minimum price increment reduces to ¼ bp at the start of CME Globex trading on the Sunday preceding the first day of the Delivery Month.

Examples: For October 2018 SER futures, the first day of the Delivery Month is Monday, 1 October. Thus, the minimum price increment is ½ bp until the start of CME Globex trading on Sunday, 30 September (*ie*, for trade date Monday, 1 October). From then until termination of trading in the contract, the minimum price increment is ¼ bp.

For August 2018 SER futures, by contrast, the first day of the Delivery Month is Wednesday, 1 August. In this case, the minimum price increment is ½ bp until the start of CME Globex trading on Sunday, 29 July. From that point – the start of the Monday, 30 July, trade date -- until trading terminates in the contract on Friday, 31 August, the minimum price increment is ¼ bp.

Contract Listings = Nearest 7 Serial Calendar Months

At any given time, the Exchange lists seven contracts for trading, one for each of the seven nearest calendar months. By implication, a newly-listed SER futures contract trades for seven months until it goes to final settlement.

Complementarity Between SER and SFR

Prior to the start of the contract's Reference Quarter, the SFR futures contract rate -- the "Rate" portion of the "100 minus Rate" contract price – gauges market expectation of business-day-compounded SOFR during the Reference Quarter, expressed as an interest rate per annum. After the nearby contract enters its Reference Quarter, the contract rate becomes a mix of (i) known SOFR values, *ie*, published values for all days from start of the Reference Quarter to the present, and (ii) market expectations of SOFR values for all remaining days in the Reference Quarter that lie ahead.

As the expiring contract progresses through its Reference Quarter, the forward-looking expectational component of its price plays a diminishing role in fair valuation. In general, progressively decreasing uncertainty about the contract's final settlement price means steadily less contract price volatility.

Market practitioners familiar with 30-Day Federal Funds futures will recognize this quandary immediately. As an expiring FF contract makes its way through its delivery month, contract users know increasingly more of the daily EFFR values that will determine the contract's final settlement price. Room for price volatility in the contract shrinks accordingly.

Seen in this light, ***the SER futures strip makes a useful complement to SFR futures for market participants who seek finer granularity in framing expectations of SOFR values, or who seek finer resolution of SOFR volatility, within horizons out to six months or so***.

Spread Trading with SOFR Futures

For SFR futures, CME Globex enables trading of standardized intramarket calendar spreads and combinations, largely matching those available for ED futures. Likewise for SER futures, CME Globex intramarket calendar spreads are enabled so as to match those for FF futures.

A diverse array of CME Globex intermarket spreads are available among SFR and SER futures and the incumbent ED and FF futures. These are summarized graphically below and tabularly in Exhibit 6, and are discussed at greater length in the following paragraphs.

Exhibit 6 – Futures Intermarket Spreads: SOFR, 30-Day Federal Funds, and Three-Month Eurodollars

	Globex Symbol	Front	Back	Leg Ratio (#	Minimum Price	Implied	# Spread

	Example	Leg	Leg	contracts)	Increment (fraction of 1 bp)	Pricing (Y/N)	Months Listed
SER:FF	July 2018: SR1N8:ZQN8*	SER	FF	1:1	0.25	N	1**
					0.50	Y	6
SFR:ED	September 2018 SR3U8:GEU8*	SFR	ED	1:1	0.25	N	1**
					0.50	Y	19
SER:SFR	(Oct+Nov) vs Sep 2018 SR1V8X8:SR3U8	SER	SFR	(3+3) : 10	0.25	N	3
FF:SFR	(Oct+Nov) vs Sep 2018 ZQV8X8:SR3U8	FF	SFR	(3+3) : 10	0.25	N	4

* For convenience of reference, GE is the CME Globex symbol for ED, ZQ is the CME Globex symbol for FF, SR1 is the CME Globex symbol for SER, and SR3 is the CME Globex symbol for SFR.

** Implied pricing is disabled when the minimum price increments in the nearby futures contract and in the spread are reduced from 0.5 basis points to 0.25 basis points.

Intercommodity Spread Basics

All CME Globex intermarket spreads described here are subject to pro rata trade matching. (For more information, see *Appendix -- Technical Details of SOFR Inter-Commodity Spreads on CME Globex*.)

The SER:FF spread comprises purchase (sale) of one One-Month SOFR futures contract and sale (purchase) of one 30-Day Federal Funds futures contract. Each leg is weighted at $41.67 per bp in the corresponding underlying interest rate.

Similarly, the SFR:ED spread consists of the purchase (sale) of one Three-Month SOFR future and the sale (purchase) of one Three-Month Eurodollar future, with each leg weighted at $25 per bp in the respective underlying interest rate.

As Exhibit 6 indicates, implied pricing functionality links the liquidity between the CME Globex order book for either of these spreads – SER:FF or SFR:ED -- and the order books for outright trades in the component contracts. Worth note is that implied pricing applies in these spreads only when the component contracts are trading in minimum price increments of 0.5 bps. Specifically –

- For the seven delivery months for which CME Globex SER:FF intermarket spreads are listed, implied pricing applies to all but the nearby month, for which both the nearby SER contract and the nearby FF contract trade in minimum price increments of ¼ bp.
- For the 20 March Quarterly contract months for which CME Globex SFR:ED intermarket spreads are listed, implied pricing applies to all but the nearby contract month, when the SFR contract trades in minimum price increment of ¼ bp.

For each of the three spreads involving futures with different basis point values, the corresponding CME Globex intermarket spread is standardized so that each leg is weighted at $250 per basis point. For instance, the SER:SFR spread comprises purchase (sale) of six SER futures (six contracts x $41.67 per bp per contract) and sale (purchase) of 10 SFR futures (10 contracts x $25 per bp per contract).

Additionally, the one-month contract leg (either FF futures or SER futures) is split between two different futures delivery months so as to approximate coverage of the period of interest rate exposure embodied in the three-month contract leg.

> *Example*: Consider a September 2018 SER:SFR spread (SR1V8X8:SR3U8 in CME Globex symbology). On the front leg, the SER position consists of purchase (sale) of three each of October and November futures. The back leg is a sale (purchase) of 10 September 2018 SFR contracts, for which the Reference Quarter spans from 19 September through 18 December (*ie*, from IMM Wednesday in September through the Tuesday before IMM Wednesday in December). In effect, the SER contracts in the front leg are distributed so as to encompass the inner two months of the three-month interest rate exposure period in the SFR position.

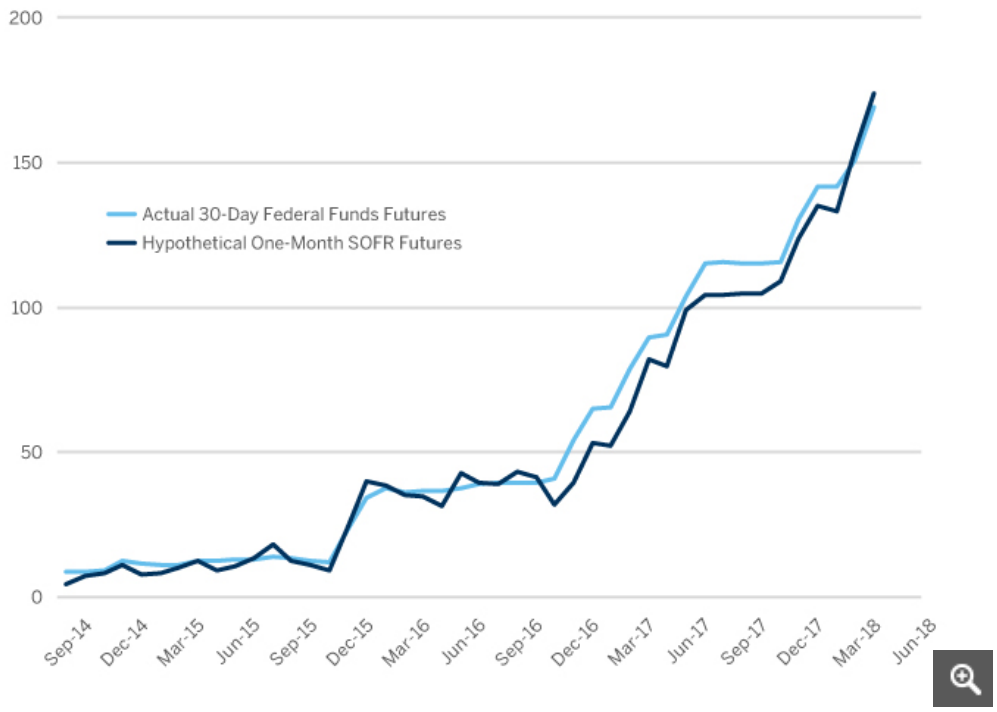
The same construction and proportions apply to the CME Globex standardized FF:SFR spread and FF:ED spread (the latter of which was introduced in March 2018).

One-Month SOFR Futures and 30-Day Federal Funds Futures

For the CME Globex SER:FF spread, the price display convention is “SER price minus FF price”. To the extent that the SOFR values underlying the SER contract are typically lower than the EFFR values underlying the FF contract, SER:FF spread values typically will be positive. *Example*: The hypothetical SER contract final settlement price and the actual FF final settlement price for the September 2017 contract month imply a price spread of 9.9 basis points: SERU7 minus FFU7 = 98.946 minus 98.847 = 0.099 price points = 9.9 bps.

The gray line in Exhibit 7 traces the contract rates at futures final settlement for FF for each of the 44 months between September 2014 and April 2018, inclusive. The blue line in Exhibit 7 is the outcome, if the same calculation is applied to obtain the arithmetic average of estimated historical daily SOFR values for each those same months.[10]

Exhibit 7 -- Contract Interest Rates at Futures Final Settlement (Basis Points per Year): Actual FF and Hypothetical SER, Sep 2014 through Apr 2018



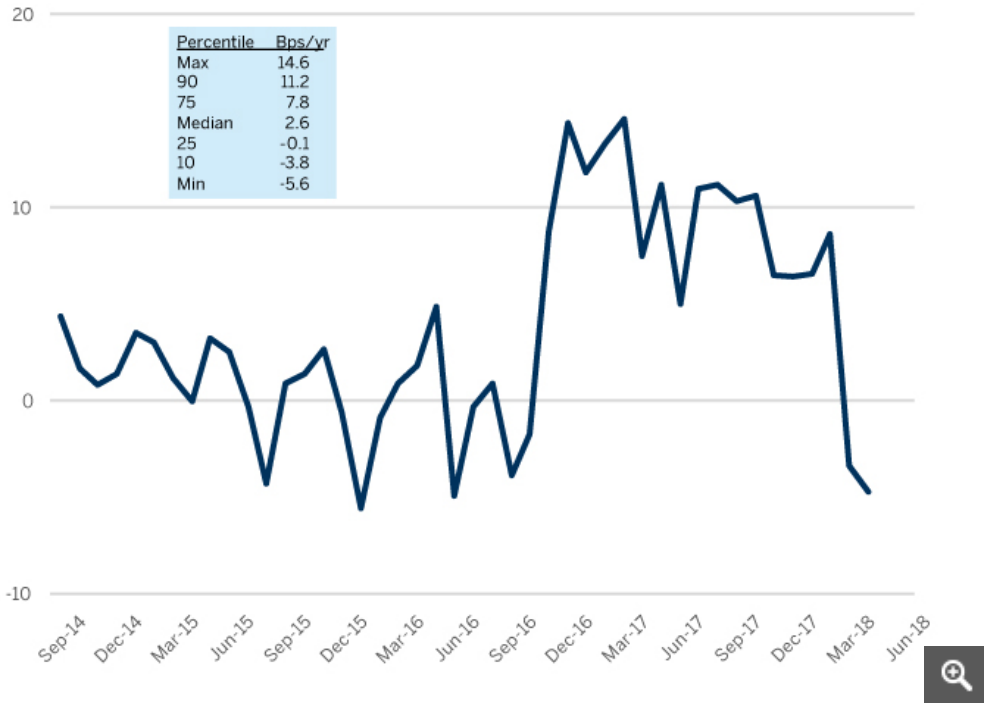
Source: FRBNY, CMEG calculations

Although month-averaging smooths much of SOFR's comparatively lively day-to-day volatility, at least some residual effect persists. In Exhibit 7, the median absolute change from one month-average level to the next is 0.8 bps for EFFR. By contrast, it is 3.1 bps for SOFR, nearly four times more volatile.

Exhibit 8 highlights two other comparative features that warrant mention --

- Over the entire 44-month span, monthly SOFR levels normally run 2.6 bps below monthly EFFR.
- Occasionally, anomalies in daily SOFR volatility are large enough to exert impact on month-average SOFR. During the final weeks of June and September 2016, for example, Treasury GC repo rates spiked, causing the usually positive SOFR-EFFR interest rate spread to flip temporarily, with month-average SOFR exceeding the corresponding month-average EFFR by 4.9 bps in June and 3.9 bps in September.

Exhibit 8 -- Contract Interest Rate Spreads at Futures Final Settlement (Basis Points per Annum): Actual FF minus Hypothetical SER, Sep 2014 through Apr 2018



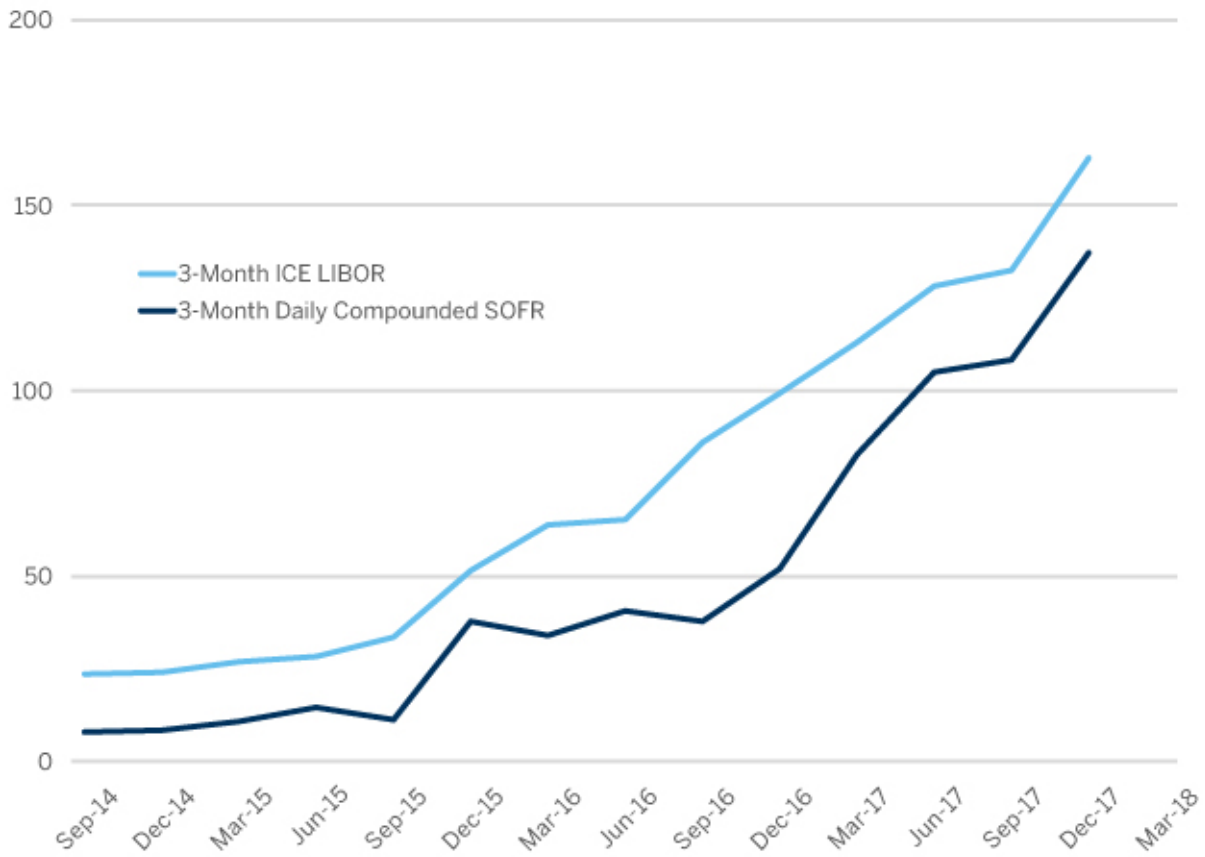
Source: FRBNY, CMEG calculations

Three-Month SOFR Futures and Three-Month Eurodollar Futures

CME Globex SFR:ED intermarket spreads are enabled for each of the 20 contract months for which SFR is listed for trading. *Eg*, at SFR launch on 7 May, contract months for SFR:ED spreads span from June 2018 through March 2023, inclusive. Here too, the price display convention is “SFR price minus ED price."

These should furnish a clear view of the market assessment of the term structure of basis spreads between forward-starting 3-month SOFR OIS fixed rates and the corresponding forward-starting 3-month Eurodollar deposit rates. Exhibit 9 depicts the corresponding futures contract final settlement rates, and Exhibit 10 shows the corresponding interest rate spreads, for each of the 14 March Quarterly contract months between September 2014 and December 2017, inclusive.

Exhibit 9 -- Futures Contract Final Settlement Rates (Basis Points per Year): Actual ED and Hypothetical SFR, Sep 2014 through Dec 2017



Data Sources: ICE Benchmark Administration Limited, FRBNY, CMEG calculations