New Interest Rate Benchmarks
Valuations and Risk Management


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Disclaimer and Acknowledgments

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Acknowledgments
We acknowledge fruitful discussions with L. Cefis, N. Moreni, and many other colleagues in Intesa Sanpaolo and Banca IMI.
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   ▪ €STR so far
   ▪ EURIBOR so far
   ▪ Transition impacts

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   ▪ The fundamental role of CCPs
   ▪ Pricing impact analysis
   ▪ Risk management issues

4. Bye-Bye multi-curves?

5. Focus on XVAs

6. Conclusions

7. Appendix: funding spread

8. References
1: Introduction

Interest rates are everywhere

<table>
<thead>
<tr>
<th>Notional volume</th>
<th>EURIBOR</th>
<th>EONIA</th>
<th>EUR-LIBOR</th>
<th>USD-LIBOR</th>
<th>GBP-LIBOR</th>
<th>JPY-LIBOR</th>
<th>CHF-LIBOR</th>
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<tr>
<td>150-160</td>
<td>~25</td>
<td>&lt;2</td>
<td>175-185</td>
<td>30</td>
<td>30</td>
<td>5</td>
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<table>
<thead>
<tr>
<th>By asset class</th>
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<tr>
<td>Syndicated loans</td>
</tr>
<tr>
<td>Business loans</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Retail loans</td>
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</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Floating rate notes</td>
</tr>
<tr>
<td>Securitisation</td>
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<td>OTC Derivs</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Exchange traded derivatives</td>
</tr>
<tr>
<td>Deposits</td>
</tr>
</tbody>
</table>

Source: Oliver Wyman analysis, data as available as of December 2017 and updated to reflect estimates from the 2nd and 3rd meetings of the working group on euro risk-free rates.
<table>
<thead>
<tr>
<th>Rate</th>
<th>EONIA</th>
<th>EONIA+</th>
<th>€STR</th>
<th>EURIBOR</th>
<th>EURIBOR H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long name</td>
<td>Euro OverNight Index Average</td>
<td>Euro OverNight Index Average (reformed)</td>
<td>Euro Short Term Rate</td>
<td>Euro Interbank Offered Rate</td>
<td>Hybrid Euro Interbank Offered Rate</td>
</tr>
<tr>
<td>Administrator</td>
<td>EMMI</td>
<td>EMMI</td>
<td>ECB</td>
<td>EMMI</td>
<td>EMMI</td>
</tr>
<tr>
<td>Calculation Agent</td>
<td>ECB</td>
<td>ECB</td>
<td>ECB</td>
<td>EBASS</td>
<td>EBASS</td>
</tr>
<tr>
<td>Panel</td>
<td>28 EU banks</td>
<td>--</td>
<td>MMSR (52 participants)</td>
<td>19 EU Banks</td>
<td>19 EU Banks</td>
</tr>
<tr>
<td>Definition</td>
<td>The rate at which banks of sound financial standing in the EU and EFTA countries lend funds in the overnight interbank money markets in euro</td>
<td>€STR + spread</td>
<td>EUR unsecured borrowings in the wholesale sector by MMSR participants</td>
<td>The rate at which euro interbank term deposits are being offered within the EU and EFTA countries by one prime bank to another</td>
<td>The rate at which wholesale funds in euro could be obtained by credit institutions in the EU and EFTA countries in the unsecured money market</td>
</tr>
<tr>
<td>Data sources and conditions</td>
<td>Panel banks data at T&lt;18:00 CET</td>
<td>€STR, spread fixed on 2 Oct. 2019</td>
<td>MMSR data at T, size &gt; 1 mln€</td>
<td>Panel banks data at T (expert judgment)</td>
<td>Panel banks data at T (transaction + expert judgment)</td>
</tr>
<tr>
<td>Formula</td>
<td>Volume-weighted average</td>
<td>€STR + spread</td>
<td>Volume-weighted trimmed average (25%)</td>
<td>Trimmed average (15%)</td>
<td>Trimmed average (15%)</td>
</tr>
<tr>
<td>Publication time</td>
<td>T (19:00 CET)</td>
<td>T+1 (9:00 CET)</td>
<td>T+1 (9:00 CET)</td>
<td>T (11:00 CET)</td>
<td>T+1 (11:00 CET)</td>
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<td>BMR: NO</td>
<td>BMR: exp. 2019 (ECB)</td>
<td>BMR: NO</td>
<td>BMR: exp. 2019 (FSMA)</td>
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<tr>
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<td>TARGET2</td>
<td>TARGET2</td>
<td>TARGET2</td>
<td>TARGET2</td>
</tr>
<tr>
<td>Tenor</td>
<td>O/N</td>
<td>O/N</td>
<td>O/N</td>
<td>1W, 1M, 3M, 6M, 12M</td>
<td>1W, 1M, 3M, 6M, 12M</td>
</tr>
<tr>
<td>Secured</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Business Days Convention</td>
<td>Following</td>
<td>Following</td>
<td>Following</td>
<td>Following (1W), mod. following (1M-12M)</td>
<td>Following (1W), mod. following (1M-12M)</td>
</tr>
<tr>
<td>Decimals</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reuters/BBG</td>
<td>EONIA=EONIA index</td>
<td>EONIA=EONIA index</td>
<td>--</td>
<td>EURIBOR=EUR003M:IND</td>
<td>EURIBOR=EUR003M:IND</td>
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</table>

**Important notes:** author Marco Bianchetti, information recovered on a best effort basis as of May 2019. Send any comment to marco.bianchetti(AT)intesasanpaolo.com
<table>
<thead>
<tr>
<th>Rate</th>
<th>USD EFFR</th>
<th>USD SOFR</th>
<th>GBP SONIA</th>
<th>GBP SONIA+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long name</td>
<td>Effective Federal Funding Rate</td>
<td>Secured Overnight Financing Rate</td>
<td>Sterling OverNight Index Average</td>
<td>Sterling OverNight Index Average (reformed)</td>
</tr>
<tr>
<td>Administrator</td>
<td>NY FED</td>
<td>NY FED</td>
<td>Bank of England</td>
<td>Bank of England</td>
</tr>
<tr>
<td>Panel</td>
<td>Institutions holding reserves at the NY FED</td>
<td>--</td>
<td>WMBA members</td>
<td>--</td>
</tr>
<tr>
<td>Definition</td>
<td>USD unsecured borrowings of reserve balances between depository institutions at NY Fed</td>
<td>USD borrowings collateralized by Treasury Securities</td>
<td>GBP borrowings brokered by WMBA members between London counterparties</td>
<td>GBP borrowing wholesale bilateral or broker transactions</td>
</tr>
<tr>
<td>Data sources and conditions</td>
<td>Domestic Trading Desk of the NY Fed</td>
<td>BNYM and DTCC</td>
<td>WMBA members data between 00:00 and 15.15 GMT at day T, deal size &gt; 25 mln £</td>
<td>Sterling Money Market data between 00:00 and 15.15 GMT at day T, deal size &gt; 25 mln £</td>
</tr>
<tr>
<td>Formula</td>
<td>Volume-weighted median</td>
<td>Volume-weighted median (cut lowest 25th percentile)</td>
<td>Volume-weighted average</td>
<td>Volume-weighted trimmed average (25%)</td>
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<td>T+1 (9:00 GMT)</td>
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<td>IOSCO: YES (NY FED)</td>
<td>IOSCO: NO</td>
<td>IOSCO: YES (BoE)</td>
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<td>Calendar</td>
<td>NY FED</td>
<td>NY FED + market</td>
<td>London business days</td>
<td>London business days</td>
</tr>
<tr>
<td>Tenor</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Secured</td>
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<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Business Days Convention</td>
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<td>Following</td>
<td>Following</td>
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<td>Decimals</td>
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<td>2</td>
<td>4</td>
<td>4</td>
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<td>Reuters/BBG</td>
<td>USONFFE=/FEDL01 Index</td>
<td>USDSOFR=/SOFRRATE Index</td>
<td>SONIA1/WMBA</td>
<td>SONIAOSR=/SONIO/N Index</td>
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<table>
<thead>
<tr>
<th>Rate</th>
<th>CHF SARON</th>
<th>JPY TONAR</th>
</tr>
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<tbody>
<tr>
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<td>Swiss Average Rate OverNight (SARON)</td>
<td>Tokyo OverNight Average Rate</td>
</tr>
<tr>
<td>Administrator</td>
<td>SIX Swiss Exchange</td>
<td>Bank of Japan</td>
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<tr>
<td>Calculation Agent</td>
<td>SIX Swiss Exchange</td>
<td>Bank of Japan</td>
</tr>
<tr>
<td>Life</td>
<td>Born 25 August 2009</td>
<td>Born 11 April 1996</td>
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<td>Panel</td>
<td>--</td>
<td>--</td>
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<td>Definition</td>
<td>CHF interbank repo transactions</td>
<td>JPY uncollateralized overnight call rate market</td>
</tr>
<tr>
<td>Data sources and conditions</td>
<td>Order book of SIX Repo Ltd electronic trading platform</td>
<td>Main money market brokers</td>
</tr>
<tr>
<td>Formula</td>
<td>Volume-weighted average</td>
<td>Volume-weighted average</td>
</tr>
<tr>
<td>Publication time</td>
<td>T (12:00, 16:00, 18:00 CET)</td>
<td>T (17:15 JST)</td>
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<td>IOSCO: YES (BoJ)</td>
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<td>Calendar</td>
<td>Trading days of CHF repo market</td>
<td>Trading days of JPY money market</td>
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<td>Tenor</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
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<td>NO</td>
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<td>Day count convention</td>
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<td>Act/365</td>
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<td>Business Days Convention</td>
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<td>Following</td>
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<td>Decimals</td>
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<td>Reuters/BBG</td>
<td>SARON.S/SSARON</td>
<td>JPONMU=RR/MUTSCALM</td>
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7. Appendix: funding spread

8. References
# Classic vs Modern Benchmark Rates

SOFR so far: fixing data

<table>
<thead>
<tr>
<th>DATE</th>
<th>SOFR (%)</th>
<th>EFFR (%)</th>
<th>Basis</th>
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<tbody>
<tr>
<td>2019-02-08</td>
<td>2.37</td>
<td>2.40</td>
<td>-0.03</td>
</tr>
<tr>
<td>2019-02-07</td>
<td>2.38</td>
<td>2.40</td>
<td>-0.02</td>
</tr>
<tr>
<td>2019-02-06</td>
<td>2.38</td>
<td>2.40</td>
<td>-0.02</td>
</tr>
<tr>
<td>2019-02-05</td>
<td>2.40</td>
<td>2.40</td>
<td>-</td>
</tr>
<tr>
<td>2019-02-04</td>
<td>2.40</td>
<td>2.40</td>
<td>-</td>
</tr>
<tr>
<td>2019-02-01</td>
<td>2.47</td>
<td>2.40</td>
<td>0.07</td>
</tr>
</tbody>
</table>

https://apps.newyorkfed.org/markets/autorates/fed%20funds

https://apps.newyorkfed.org/markets/autorates/sofr
The market for financial instruments indexed to SOFR is already under development.

1. **SOFR Futures (CME)**
   - 1-month Futures: strip of 7 Futures indexed to arithmetic average of daily SOFR values during the contract delivery month.
   - 3-month Futures: strip of 20 Futures indexed to compounded daily SOFR values during the contract reference quarter.

2. **SOFR OTC Swaps**
   Indexed to compounded daily SOFR values during the coupon period (as other OISs), OTC quotes available from brokers
   - **SOFR OISs**: brokers’ quotes available (e.g. Tullet, USDSROIS=TPSR).
   - **SOFR vs EFFR Basis Swaps**: brokers’ quotes available (e.g. Tullet, USDSRFF=TPSR).
   - Only a limited number of transactions observed and/or cleared so far, increasing liquidity.

3. **SOFR Bonds**
   Bonds indexed to SOFR have been issued by Banks and Insurances (19 bonds for 19 mld USD as of Oct. 2018).

Bloomberg SOFR yield curve →
2: Classic vs Modern Benchmark Rates

SOFR so far: market (il)liquidity

SOFR, so bad: liquidity lags transition ambitions
Thin current trading may lead to poor fallback choices, and dim SOFR’s appeal ahead of Libor’s death

---

NEED TO KNOW

- Trading of SOFR-linked derivatives has been limited since the new rate was launched in April as the US Libor replacement.
- A total of 52 swaps referencing the new rate were traded last year. Open interest in SOFR futures had been growing prior to the end of last year, but stands at less than 1% of the notional for Libor-referencing eurodollar contracts.
- Dealers worry illiquidity could curb the adoption of the new benchmark as the fallback rate in legacy swaps contracts.
- Firms may also be reluctant to transfer Libor positions to SOFR before Libor disappears, which will increase the need for the imperfect solution of fallbacks.
- The present sluggish state of the SOFR market may result in short-sighted responses to Isda’s upcoming consultation on the adjustments the new rate will need to act as a fallback.
- Trading in SOFR derivatives should take off once SOFR discounting becomes mandatory; the industry creates a SOFR term rate, kick-starting the cash market; and firms make the required operational changes.

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LCH plans 2020 switch to SOFR discounting
Users opt for one-step switch to new US dollar regime, as long as CCP cooks up compensation scheme

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Swaps users mull ‘big bang’ for SOFR discounting
Cleared and bilateral US dollar swaps could move to SOFR discounting on the same day in 2020
2: Classic vs Modern Benchmark Rates

SOFR so far: market (il)iquidity

1. CME SOFR futures
   - Data from US trade repository as of Feb. 2019.
   - SOFR one month
   - SOFR three month

2. SOFR swaps
   - Data from US trade repository as of Feb. 2019.
   - OIS – fixed
   - Basis – Fed funds
   - Basis – Libor

5. Cleared Eonia and Fed funds swaps
   - Data from CCPs as of Feb. 2019.
   - Euro
   - US dollar

LCH SOFR Volumes

M. Bianchetti, Cass Business School, 19 June 2019
2: Classic vs Modern Benchmark Rates

€STR so far: pre-€STR fixings & basis

Pre-€STR data

The pre-€STR is calculated using the same methods as defined for the €STR.

The pre-€STR differs in that it is based on final data and includes all revisions in terms of cancellations, corrections and amendments submitted by reporting agents at the time of calculating the rate, while the €STR will be published every morning and take into account only the data received by the submission deadline of 07:00 CET that morning.

Source: ECB
2: Classic vs Modern Benchmark Rates

€STR so far: pre-€STR fixings & basis

**Basis Distribution Stats**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>6.1 bps</td>
</tr>
<tr>
<td>Max</td>
<td>21.5 bps</td>
</tr>
<tr>
<td>Mean</td>
<td>8.8 bps</td>
</tr>
<tr>
<td>Std dev</td>
<td>1.0 bps</td>
</tr>
<tr>
<td>Observations</td>
<td>478</td>
</tr>
</tbody>
</table>

**EONIA vs pre €STR**

- Greek spike

**EONIA vs pre €STR: statistics**

- EONIA variation volatility
- Pre €STR variation volatility
- Variations Correlation (EONIA vs Pre-€STR, ch.s. axis)
- Variation Correlation (€STR vs ITRAXX, ch.s. axis)
2: Classic vs Modern Benchmark Rates

€STR so far: *habemus basis*

PRESS RELEASE

**ECB provides a one-off spread between €STR and EONIA**

31 May 2019

- Spread between €STR and EONIA is calculated at 0.085% (8.5 basis points)
- Spread is based on methodology recommended by Working Group on euro risk-free rates
- Spread is to be used by EMMI in new EONIA methodology as of 2 October 2019
- ISIN assigned to €STR is EU000A2X2A25 (FISN: ECB/EUR EURO SHORT-TERM RATE IR)

The European Central Bank has calculated the spread between €STR and EONIA based on the methodology as recommended by the Working Group on euro risk-free rates and adopted by the European Money Market Institute (EMMI) for the recalibration of the EONIA methodology as of 2 October 2019 and until its discontinuation by EMMI. The ECB has calculated this spread at 0.085% (8.5 basis points) on the basis of daily EONIA and pre-€STR data from 17 April 2018 to 16 April 2019. The International Securities Identification Number assigned to €STR is EU000A2X2A25. The Financial Instrument Short Name (FISN) is ECB/EUR EURO SHORT-TERM RATE IR.
2: Classic vs Modern Benchmark Rates

€STR so far: transition timeline [1/4]

Oct, 2nd 2019

Transition Phase

Dec, 31st 2021

- First €STR fixing by ECB
- EONIA = €STR + 8.5bps

End of EONIA Contribution

…€STR and EONIA…

…€STR only
2: Classic vs Modern Benchmark Rates

€STR so far: transition timeline [2/4]

Oct, 2nd 2019

Trading EONIA and €STR market instruments

- First €STR fixing by ECB
- EONIA = €STR + 8.5bps

Dec, 31st 2021

End of EONIA Contribution

EONIA only…

…€STR and EONIA…

…€STR only

On 2 Oct. 2019 (or shortly after)

- Both EONIA and €STR term structures are known (i.e. the EONIA-€STR spread is propagated to any term with no distortions → proof from the OIS pricing formula).
- Nothing prevents market participants to quote and trade €STR market instruments, because data are available for valuations (€STR term structure for underlying forwards and EONIA term structure for discounting).
2: Classic vs Modern Benchmark Rates

€STR so far: transition timeline [3/4]

<table>
<thead>
<tr>
<th>Oct, 2nd 2019</th>
<th>Dec, 31st 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing €STR market instruments</td>
<td>End of EONIA Contribution</td>
</tr>
</tbody>
</table>

EONIA only… …€STR and EONIA… …€STR only

- First €STR fixing by ECB
- EONIA = €STR + 8.5bps

On 2 Oct. 2019 (or shortly after)

- The new €STR market instruments will be subject to the same clearing obligations of the old EONIA market instruments. This assumption is not strictly necessary, but mandatory clearing would help the development of the previous steps.
- CCPs will be able to clear €STR instruments as soon as possible, using the available €STR and EONIA term structures.
**2: Classic vs Modern Benchmark Rates**

**€STR so far: transition timeline [4/4]**

- **Oct, 2nd 2019**
  - First €STR fixing by ECB
  - EONIA = €STR + 8.5bps

- **Dec, 31st 2021**
  - End of EONIA Contribution
  - ...€STR only

**Switch PAI and discounting rates**

- EONIA only…
- ...€STR and EONIA…
- ...€STR only

Sometime after 2 Oct. 2019 (2020 ?)

- CCPs will switch to €STR PAI and discounting rates. Compensation schemes are expected to soften the transition.
- Bilateral CSAs will switch to €STR PAI rate. Compensation schemes are expected to soften the transition similar to those used by CCPs with their clearing members
- Big bang or step by step transition?
### 2: Classic vs Modern Benchmark Rates

#### €STR so far: transition timeline [3/4]

<table>
<thead>
<tr>
<th></th>
<th>2019 Q3</th>
<th>2019 Q4</th>
<th>2020 H1</th>
<th>2020 H2</th>
<th>2021 H1</th>
<th>2021 H2</th>
<th>2022</th>
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<tbody>
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<td>1. EONIA fixing</td>
<td></td>
<td></td>
<td>Available up to 31 Dec. 2021</td>
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<td></td>
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<td>2. €STR fixing</td>
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<td></td>
<td>Available since 2 Oct. 2019</td>
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<td></td>
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<tr>
<td>3. EONIA mkt instruments</td>
<td>Liquid</td>
<td></td>
<td>Available but less and less liquid and relevant</td>
<td></td>
<td></td>
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<td>No longer available</td>
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<tr>
<td>4. €STR mkt Instruments</td>
<td>NA</td>
<td></td>
<td>Available and more and more liquid and relevant. Expected OISs (fixed vs €STR), Basis Swaps (€STR vs EURIBOR), Cross Currencies (€STR vs SOFR/etc. ?), others (for compensation schemes?)</td>
<td></td>
<td></td>
<td></td>
<td>Available</td>
</tr>
<tr>
<td>5. EONIA term structure</td>
<td></td>
<td></td>
<td>Available both as EONIA = €STR + spread or directly from EONIA mkt instruments</td>
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<td></td>
<td></td>
<td>No longer available</td>
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<tr>
<td>6. €STR term structure</td>
<td>NA</td>
<td></td>
<td>Available both as €STR = EONIA - spread and directly from €STR mkt instruments</td>
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<td>Available from €STR mkt instruments</td>
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<td>7. CCPs clearing for EONIA trades</td>
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<td>Available, using either directly EONIA or €STR + spread term structures</td>
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<td>8. CCPs clearing for €STR trades</td>
<td>NA</td>
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<td>Available, using either EONIA – spread or directly €STR term structures</td>
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Legenda: **black** = sure events; **red** = events needing some assumption (see previous slide); orange background = transition phase; blue background = transition finished, situation at regime.
<table>
<thead>
<tr>
<th>9. CCPs PAI rate for EONIA trades</th>
<th>2019 Q3</th>
<th>2019 Q4</th>
<th>2020 H1</th>
<th>2020 H2</th>
<th>2021 H1</th>
<th>2021 H2</th>
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<td>10. CCPs PAI rate for €STR trades</td>
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<td>11. Bilateral CSAs PAI rate for EONIA trades</td>
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<td>12. Bilateral CSAs PAI rate for €STR trades</td>
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<td>13. Discount rate for uncollateralised trades</td>
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<td>14. EONIA legacy trades versus CCPs, Exchanges, and all other counterparties</td>
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<td>15. Other issues</td>
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</table>
2: Classic vs Modern Benchmark Rates

EURIBOR so far: methodology

“the rate at which euro interbank deposits are being offered within the EU and EFTA countries by one Prime Bank to another at 11AM Brussels time.”

- **interbank**: ...the use of interbank transactions in the original Euribor specification reflects the structure of the money markets in the 1980s and 1990s when bank-to-bank activity was a predominant source of bank wholesale funding...

- **being offered**: ...the family of IBOR indices are based upon and aimed at representing funding markets. This is supported by the fact that LIBOR, originally evolved as a standardized benchmark for the pricing of floating-rate corporate loans.

- **Prime Bank**: “Prime Bank” has never been precisely defined. The Prime Bank historically represented both a concept of the financial standing of the party borrowing funds and of a substantial party supplying funds.

- **at 11 AM**: own cost of funds

“Euribor is a measure of the rate at which wholesale funds in euro could be borrowed by credit institutions in the EU and EFTA countries in the unsecured money market”

Source: EMMI
Hybrid methodology, supported by transactions whenever available, but relies on other techniques or data sources according to input criteria established by EMMI.

Data hierarchy: for each day in which the index is calculated, contributing banks will have to base their submissions, for each tenor, on:

- Level 1: Submission based solely on transaction in the Underlying Interest at the Defined Tenor from the prior TARGET date, using a formulaic approach provided by EMMI.
- Level 2: Submission based on transactions in the Underlying Interest across the money market maturity spectrum and from recent TARGETdays, using a defined range of formulaic calculation techniques provided by EMMI.
- Level 3: Submission based on transactions in the Underlying Interest and/or other data from a range of markets closely related to the unsecured euro money market, using a combination of modeling techniques and/or the Panel Bank’s judgement.

EMMI conducted a test under live conditions from May to July 2018, finding Hybrid Euribor lower than Euribor by 1-5 bps depending on the tenor 1M, 3M, 6M, 12M.
2: Classic vs Modern Benchmark Rates

EURIBOR so far: basis

Data source: EMMI
Data ranges from **02 May and 31 July 2018** resulting from the contribution of **37 institutions** including banks, trade associations, infrastructure providers, consultancy firms, and others.

Hybrid Euribor is **more volatile** with respect to Euribor for all tenors. This is due to the different type of contributions underlying Hybrid Euribor, based also on **real transactions** which are more affected by market movements, from a **larger panel** trading in a **wider market**.

Hybrid Euribor is a **lending rate** and thus generally higher than Euribor, which is a borrowing rate.

The Hybrid Euribor **12M rate** is the most volatile and the **basis** respect to the Euribor rate became **negative** in July 2018.
Summary

1. Introduction

2. Classic vs Modern Benchmark Rates
   - SOFR so far
   - €STR so far
   - EURIBOR so far
   - Transition impacts

3. Pricing and Risk Management
   - The fundamental role of CCPs
   - Pricing impact analysis
   - Risk management issues

4. Bye-Bye multi-curves?

5. Focus on XVAs

6. Conclusions

7. Appendix: funding spread

8. References
Pricing and Risk Management

Pricing financial instruments is a complex task

Here we are!

Pricing framework → price + risks

- Underlying interest rate (IBORs, Overnights, etc.)
- Money market (Deposits, Repos, etc.)
- OTC market for plain vanilla calibration /hedging instruments
- OTC derivative and bond market for credit/liquidity instruments

- Netting/collateral agreements
- Central counterparties
- Contract (schedule, payoff, etc.)
- Counterparties
3: Pricing and Risk Management

Pricing impact analysis: overview [1/2]

General formula for the fair value $V(t)$ at time $t$ of a future cash flow at time $T > t$

$$V(t) = V_0(t) + XVA(t).$$

XVAs focus later

The Risk Free Net Present Value $V_0(t)$ (sometimes also called mark to market) is the base component of the fair value without credit and funding components, i.e. the price under perfect collateralization (an ideal CSA ensuring a perfect match between variation margin and base value at any time $t$),

$$V_0(t) = P_d(t, T) \mathbb{E}_t^Q[V(T)].$$

Possibly affected by EONIA $\rightarrow$ €STR transition

By no arbitrage, the discount rate $r_d$ must be equal to the Price Alignment Interest (PAI) rate used for variation margin,

$$P_d(t, T) = \exp \left[ - \int_t^T r_d(u) \, du \right]$$

The expected value of future cash flow $\mathbb{E}_t^Q[V(T)]$ depends on market risk factors, e.g. EONIA/EURIBOR forwards, volatilities, etc.

Possibly affected by EURIBOR $\rightarrow$ Hybrid EURIBOR transition

Possibly affected by EONIA $\rightarrow$ €STR transition
Pricing impact analysis: overview [2/2]

Finding the pieces of the puzzle

Changes in risk factors (yield curves, volatilities, etc.)

Uncollateralised trades (XVAs)

Trades cleared with CCPs

Trades under bilateral CSAs

Impact analysis
3: Pricing and Risk Management
Pricing impact analysis: the fundamental role of CCPs [1/2]
LCH launched in November 2018 a consultation on the transition of discounting in the USD swaps market from Fed Funds to SOFR.

1. asking SwapClear users to express an opinion on
   - whether LCH should support a transitional phase in which SOFR-discounted USD trades co-exist with existing FF-discounted trades ('Dual Discounting as Proposed in the Paced Transition Plan'), or
   - whether LCH should preserve the single discounting environment for USD swaps and, at the appropriate time, run a process to convert all existing FF-discounted trades to SOFR ('Single-step Approach including Conversion of Legacy Book').

2. seeking feedback on
   - whether compensation payments are necessary or desirable in a conversion process
   - the best timing of the agreed next steps.

LCH plans 2020 switch to SOFR discounting

Users opt for one-step switch to new US dollar regime, as long as CCP cooks up compensation scheme.
3: Pricing and Risk Management

Pricing impact analysis: overview

Yield curves and implied volatilities construction
- Single currency / cross currency / funding curves
- Caps/Floors/Swaption implied volatility cubes
- Other volatilities

Impacts on yield curves and implied volatilities
- EONIA → €STR
- EURIBOR → Hybrid EURIBOR

Impacts on pricing models
- Model calibration

Impacts on financial instruments
- IR derivatives (unfunded)
- Other derivatives (unfunded)
- Funded instruments
### 3: Pricing and Risk Management

**Pricing impact analysis: interest rate [1/5]**

The interest rate curves are presently built from market quotes as follows.

<table>
<thead>
<tr>
<th>Yield curve</th>
<th>Comments</th>
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</table>
| **Single currency**  | ▪ **Yield curves** (e.g. EONIA OIS; EURIBOR6M, etc.): bootstrapping algorithm which obtains the curve pillars recursively from quoted IRS, using the pricing formulas of collateralized instruments (collateral OIS discounting).  
                         ▪ **Basis yield curves** (e.g. Eonia OIS vs EURIBOR6M, EUREX vs LCH): same methodology above, using quoted Basis Swaps |
| **Cross currency**   | ▪ **Cross currency basis yield curves** (e.g. EURIBOR3M vs USDLIBOR3M collateralized in USD): bootstrapping algorithm using quoted both single and Cross Currency Swaps and their corresponding pricing formulas in the base collateral currency.  
                         ▪ **Collateral currency yield curves** (e.g. USD IRS on USDLIBOR3M collateralised in EUR): same methodology above. |
| **Funding curves**   | ▪ **Derivatives**: funding curves construction based on market CDS + funding spread fitted on market benchmarks.  
                         ▪ **Bonds** and other funded instruments: funding curves construction based on a fitting algorithm of quoted benchmarks using e.g. Nelson-Siegel or Svensson model.  
                         ▪ In both cases funding yield curves are built conventionally as EONIA or EURIBOR + funding spread. |

Because of the consistent usage of OIS discounting, **the yield curve construction algorithm is intrinsically multi-curve**. → Changing OIS discount rates also affects IBOR forward rates.
3: Pricing and Risk Management
Pricing impact analysis: interest rate [2/5]

Accordingly, we may expect the following impacts on yield curves from EONIA→€STR and EURIBOR → Hybrid EURIBOR transitions.

<table>
<thead>
<tr>
<th>Expected impacts on yield curves</th>
<th>As is</th>
<th>EONIA → ESTER transition</th>
<th>EURIBOR → Hybrid EURIBOR transition</th>
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</thead>
<tbody>
<tr>
<td>EONIA OIS curve</td>
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<tr>
<td>Forwards</td>
<td>EONIA OIS</td>
<td>ESTER OIS</td>
<td>EONIA OIS</td>
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<tr>
<td>Discounts</td>
<td>EONIA OIS</td>
<td>ESTER OIS</td>
<td>EONIA OIS</td>
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<tr>
<td>EURIBOR curves</td>
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<tr>
<td>Forwards</td>
<td>EURIBOR</td>
<td>EURIBOR (small)</td>
<td>Hybrid EURIBOR</td>
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<tr>
<td>Discounts</td>
<td>EURIBOR Std</td>
<td>EURIBOR Std (small)</td>
<td>Hybrid EURIBOR Std</td>
</tr>
<tr>
<td>EUR CCS basis curves (e.g. EURUSD)</td>
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<tr>
<td>Forwards</td>
<td>EURIBOR USDLIBOR</td>
<td>EURIBOR (small) USDLIBOR</td>
<td>Hybrid EURIBOR USDLIBOR CCS EURUSD basis</td>
</tr>
<tr>
<td>Discounts</td>
<td>EONIA OIS EONIA CCS basis</td>
<td>ESTER OIS ESTER CCS Basis</td>
<td>EONIA OIS ESTER CCS Basis</td>
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<tr>
<td>Funding curves</td>
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<tr>
<td>Discounts</td>
<td>Benchmark bonds</td>
<td>Benchmark bonds</td>
<td>Benchmark bonds</td>
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Red = impacted quantities.

The impact of EONIA → €STR transition on forward rates is negligible.
EONIA OIS yield curve as of EoY 2018 (blue), and expected EONIA → €STR transition impact of -9 bps on market rates (grey) (horizontal scale is non-linear).
3: Pricing and Risk Management
Pricing impact analysis: interest rate [4/5]

EURIBOR 1M, 3M, 6M, 12M yield curves as of EoY 2018 (blue), and possible EURIBOR → Hybrid EURIBOR transition impacts on market rates (grey) (horizontal scale is non-linear).
Accordingly, we may expect the following impacts on IR financial instruments from EONIA→€STR and EURIBOR → Hybrid EURIBOR transitions.

<table>
<thead>
<tr>
<th>Expected impacts on linear IR instruments</th>
<th>EONIA → ESTER transition</th>
<th>EURIBOR → Hybrid EURIBOR transition</th>
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<tbody>
<tr>
<td>IR Derivatives (unfunded)</td>
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<tr>
<td>▪ Forward Rate Agreements (FRA)</td>
<td>YES</td>
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<td>▪ Overnight Indexed Swaps (OIS)</td>
<td>YES</td>
<td>NO</td>
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<tr>
<td>▪ Swaps (IRS) and Basis Swaps (BIRS)</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>▪ Cross Currency Swaps (CCS)</td>
<td>YES</td>
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</tr>
<tr>
<td>IR Funded instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Deposits</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>▪ Repos</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>▪ Loans, mortgages</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>▪ Bonds (floating rate)</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>▪ Bonds (fixed rate)</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

Bonds and other IR funded instruments suffer no impacts under both transitions according to the assumption that the funding rate will remain unchanged. A change of EONIA or EURIBOR must be balanced by a corresponding increase of the bond credit spread.
3: Pricing and Risk Management

Pricing impact analysis: interest rate Cap/Floor volatility [1/4]

The Cap/Floor volatility surfaces (expiry x strike) are obtained from market quotes as follows:

- **EURIBOR tenors 3M, 6M**: are obtained from market quotes (either in terms of term volatilities or premia) and mapped in terms of implied forward shifted-lognormal (or normal) volatility surfaces (i.e. Caplet/Floorlet volatilities) using OIS discounting;

- **EURIBOR tenors 1M, 12M**: are obtained from the surfaces above via Kienitz model using OIS discounting.

- In both cases a **SABR model** is calibrated and used to obtain non-quoted expiries/strikes.
Accordingly, there are two possible alternative scenarios for the EONIA/€STR transition:

- **Scenario 1 (Constant Term Volatility):** keep constant the market term volatility surface → use €STR OIS discounting to obtain premia and forward volatilities;
- **Scenario 2 (Constant Premium):** keep constant the market term volatility surface and the premia (obtained using EONIA OIS discounting) → use €STR OIS discounting to obtain forward volatilities.

### Table: Expected Impacts of EONIA → €STR Transition

<table>
<thead>
<tr>
<th>Expected impacts of EONIA → €STR transition</th>
<th>As is</th>
<th>Scenario 1: Constant Term Volatility</th>
<th>Scenario 2: Constant Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term volatility (normal)</td>
<td>Market quotes</td>
<td>Market quotes</td>
<td>Market quotes</td>
</tr>
<tr>
<td>Cap/Floor premium</td>
<td>Black formula (EONIA OIS discounting)</td>
<td>Black formula (€STR OIS discounting)</td>
<td>Black formula (EONIA OIS discounting)</td>
</tr>
<tr>
<td>Forward volatility</td>
<td>Inverted Black formula (EONIA OIS discounting)</td>
<td>Inverted Black formula (€STR OIS discounting)</td>
<td>Inverted Black formula (€STR OIS discounting)</td>
</tr>
</tbody>
</table>
Accordingly, we may expect the following impacts on market data and financial instruments.

<table>
<thead>
<tr>
<th>Expected impacts of EONIA → €STR transition</th>
<th>Scenario 1: Constant Term Volatility</th>
<th>Scenario 2: Constant Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacted market data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESTER discounting</td>
<td>▪ ESTER discounting</td>
<td>▪ ESTER discounting</td>
</tr>
<tr>
<td>EURIBOR forwards (small)</td>
<td>▪ EURIBOR forwards (small)</td>
<td>▪ EURIBOR forwards (small)</td>
</tr>
<tr>
<td>Term volatilities</td>
<td>▪ Term volatilities</td>
<td>▪ Term volatilities</td>
</tr>
<tr>
<td>Cap/Floor premia (small)</td>
<td>▪ Cap/Floor premia (small)</td>
<td>▪ Cap/Floor premia</td>
</tr>
<tr>
<td>Forward volatilities (small)</td>
<td>▪ Forward volatilities (small)</td>
<td>▪ Forward volatilities (small)</td>
</tr>
</tbody>
</table>

| Impacted financial instruments              |                                    |                                 |
| Caps/Floors plain vanilla/digital           | ▪ Caps/Floors plain vanilla/digital |                                 |
| Any structured product using Cap/Floor volatilities, e.g. Ratchet/Sticky Caps/Floors | ▪ Any structured product using Cap/Floor volatilities, e.g. Ratchet/Sticky Caps/Floors | |
| Any product involving an EURIBOR convexity adjustment (e.g. in arrear IRSs). | ▪ Any product involving an EURIBOR convexity adjustment (e.g. in arrear IRSs). | |
| Debt securities involving Caps/Floors (e.g. floating rate Bonds) | ▪ Debt securities involving Caps/Floors (e.g. floating rate Bonds) | |

Overall, the impacts on Cap/Floor premia and forward volatilities are expected to be small.
Regarding the EURIBOR → Hybrid EURIBOR transition, there are two possible scenarios, depending on the behavior of the volatility.

<table>
<thead>
<tr>
<th>Expected impacts of EURIBOR → Hybrid EURIBOR transition</th>
<th>Scenario 1: Constant Forward Volatility</th>
<th>Scenario 2: Variable Forward Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacted market data</td>
<td>▪ EURIBOR forwards</td>
<td>▪ EURIBOR forwards</td>
</tr>
<tr>
<td></td>
<td>▪ Term volatilities</td>
<td>▪ Term volatilities</td>
</tr>
<tr>
<td></td>
<td>▪ Cap/Floor premia</td>
<td>▪ Cap/Floor premia</td>
</tr>
<tr>
<td></td>
<td>▪ Forward volatilities</td>
<td>▪ Forward volatilities</td>
</tr>
<tr>
<td>Impacted financial instruments</td>
<td>▪ All (small)</td>
<td>▪ All</td>
</tr>
</tbody>
</table>

The analysis of historical series of market Cap/Floor term volatilities does not show changes related to the EURIBOR → Hybrid EURIBOR transition.
3: Pricing and Risk Management

Pricing impact analysis: interest rate Swaption volatility

The swaption volatility cube (option expiry x swap tenor x option strike) are obtained from market quotes as follows:

- **Swaption volatility cube for EURIBOR tenor 6M**: is obtained from market forward premia (physical and cash delivery) for ATM swaption, from shifted-lognormal implied volatility spread for OTM swaptions, and mapped in terms of implied forward shifted-lognormal volatility cubes.

- **Swaption volatility cube for other EURIBOR tenors** (i.e. 3M): is obtained from the cube above using par basis point volatility (i.e. equating forward swap rate variances) and €STR OIS discounting.

- In both cases a SABR model is calibrated and used to obtain non-quoted expiries/tenors/strikes.

<table>
<thead>
<tr>
<th>1Y</th>
<th>2Y</th>
<th>3Y</th>
<th>4Y</th>
<th>5Y</th>
<th>6Y</th>
<th>7Y</th>
<th>8Y</th>
<th>10Y</th>
<th>15Y</th>
<th>20Y</th>
<th>25Y</th>
<th>30Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>2.5</td>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
<td>6.5</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
</tr>
<tr>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
<td>6.5</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
</tr>
<tr>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
<td>6.5</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
<td>10.0</td>
<td>10.5</td>
</tr>
<tr>
<td>6.0</td>
<td>6.5</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
<td>10.0</td>
<td>10.5</td>
<td>11.0</td>
<td>11.5</td>
<td>12.0</td>
</tr>
</tbody>
</table>

**EUR ATM Swaption Straddles (PHYSICAL LCH) - Fwd Premium Mids (Eonia disc)**

Please call +44 (0)20 7532 3050 for further details.
Since the impacts of EONIA→ESTER transition on EURIBOR par swap rates are negligible, and the market quotes forward Swaptions premia, we expect that the impact on Swaption implied forward shifted-lognormal volatility cubes is negligible. Hence we expect the impact table below.

<table>
<thead>
<tr>
<th>Expected impacts</th>
<th>As is</th>
<th>EONIA → ESTER transition</th>
<th>EURIBOR → Hybrid EURIBOR transition</th>
</tr>
</thead>
</table>
| **Impacted market data** | ▪ EONIA OIS (discounts)  
▪ EURIBOR (forward swaps)  
▪ Swaption forward Premia  
▪ Swaption forward volatility | ▪ ESTER OIS discounts  
▪ EURIBOR forward swaps  
▪ Swaption forward Premia  
▪ Swaption forward volatility | ▪ EONIA OIS discounts  
▪ Hybrid EURIBOR (forwards)  
▪ Swaption forward Premia  
▪ Swaption forward volatility |
| **Impacted financial instruments** | | Pure discount effect | |
The impacts on other financial instruments are expected as follows.

- **Interest rates derivatives:**
  - IR exotics: priced using IR models (i.e. Short Rate Models, Libor Market model)

- **Other derivatives** (equity/FX/credit/commodity):
  - Impacts due to discounting effects (both in case of OIS and Standard discounting)
  - Impacts due to implied volatilities, similarly to IR Caps/Floors

- **Certificates:**
  - Expected impacts on Certificates (huge amounts issued by banks…) are negligible compared to the market bid ask spreads, and due to compensations between the input credit curve and the discounting curve.

- **XVAs:** see next slides
3: Pricing and Risk Management

Risk Management Issues

**Banking Book Interest Rate Risk**
- Analysis of the expected changes in the shift sensitivities – ∆EVE.
- Analysis of expected changes in the Net Interest Income.
- Impact Analysis on hedges in the IAS/IFRS framework (Hedge Accounting), both for assets (Credits and Bond Portfolios) and liabilities (Issued Bonds) especially with respect to the Effectiveness Test.

**Liquidity Risk**
- Analysis of the expected changes in the shift sensitivities – ∆EVE.
- Analysis of expected changes in the Net Interest Income.
- Impact Analysis on hedges in the IAS/IFRS framework (Hedge Accounting), both for assets (Credits and Bond Portfolios) and liabilities (Issued Bonds) especially with respect to the Effectiveness Test.

**Operational Risk**
- Impact analysis on the revision of internal processes and procedures
- Early involvement of technical and control functions via a project organization may provide an oversight on operative decisions and address potential issues since their discovery, in order to minimize ICT, model and legal risks.

**Market Risk**
- Analysis of the changes in sensitivities and VaR limits.
- Impact analysis with respect to Internal Model Market Risk Capital Requirements.
- Analysis of new risk factors, construction of new time series.
- Analysis of a potential Risk Not In Model capital requirement under the current framework, and a Non-Modellable Risk Factor capital add-on under the FRTB.

**Counterparty Credit Risk**
- Impact analysis with respect to Internal Model Counterparty Risk Capital Requirements.
- Analysis of time simulation of new risk factors and their impact on counterparty future exposures.
- Impact assessment on credit line absorption and internal limits on Credit Portfolio and CVA VaR.
Summary

1. Introduction

2. Classic vs Modern Benchmark Rates
   - SOFR so far
   - €STR so far
   - EURIBOR so far
   - Transition impacts

3. Pricing and Risk Management
   - The fundamental role of CCPs
   - Pricing impact analysis
   - Risk management issues

4. Bye-Bye multi-curves?

5. Focus on XVAs

6. Conclusions

7. Appendix: funding spread

8. References
4: Bye Bye Multi-Curves?
Past, present, and possible futures [1/3]

- **Past**
  - Credit crunch (Aug. 07)
  - Lehman crisis (Sep. 08)

- **Present**
  - Sovereign crisis (Jan. 12)

- **Near Future**
  - Hybrid EURIBOR 2Q-3Q19

- **Far Future**
  - €STR 4Q19

---

**Graph Details**
- **Euribor Deposit 6M - Eonia OIS 6M Basis (right scale)**
- **Eonia OIS 6M**
- **Euribor Deposit 6M**

**Dates**
- Jan-06 to Jan-22
# 4: Bye Bye Multi-Curves?
Past, present, and possible futures [2/3]

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Present</th>
<th>Near Future (nearly certain)</th>
<th>Far Future (uncertain)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield curves</strong> (single currency)</td>
<td>EURIBOR, Funding</td>
<td>OIS, EURIBOR 1M, EURIBOR 3M, EURIBOR 6M, EURIBOR 12M, Bases, Funding</td>
<td>€STR, OIS, EURIBOR 1M, EURIBOR 3M, EURIBOR 6M, EURIBOR 12M, More bases, Funding</td>
<td></td>
</tr>
<tr>
<td><strong>CCS basis yield curves</strong></td>
<td>Many CCS</td>
<td>Many CCS</td>
<td>Many CCS</td>
<td></td>
</tr>
<tr>
<td><strong>Cap/Floor Volatilities</strong></td>
<td>EURIBOR</td>
<td>EURIBOR 1M, EURIBOR 3M, EURIBOR 6M, EURIBOR 12M</td>
<td>EURIBOR 1M, EURIBOR 3M, EURIBOR 6M, EURIBOR 12M</td>
<td></td>
</tr>
<tr>
<td><strong>Swaption volatilities</strong></td>
<td>EURIBOR</td>
<td>EURIBOR 3M, EURIBOR 6M</td>
<td>EURIBOR 3M, EURIBOR 6M</td>
<td></td>
</tr>
</tbody>
</table>
## 4: Bye Bye Multi-Curves? Past, present, and possible futures [2/3]

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Present</th>
<th>Near Future (nearly certain)</th>
<th>Far Future (uncertain)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield curves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(single currency)</td>
<td>EURIBOR</td>
<td>OIS EURIBOR 1M EURIBOR 3M EURIBOR 6M EURIBOR 12M Bases Funding</td>
<td>€STR OIS EURIBOR 1M EURIBOR 3M EURIBOR 6M EURIBOR 12M More bases Funding</td>
<td>€STR only? Funding One (funding) basis?</td>
</tr>
<tr>
<td><strong>CCS basis yield curves</strong></td>
<td>Many CCS</td>
<td>Many CCS</td>
<td>Many CCS</td>
<td>Many CCS</td>
</tr>
<tr>
<td><strong>Cap/Floor Volatilities</strong></td>
<td>EURIBOR</td>
<td>EURIBOR 1M EURIBOR 3M EURIBOR 6M EURIBOR 12M</td>
<td>EURIBOR 1M EURIBOR 3M EURIBOR 6M EURIBOR 12M</td>
<td>€STR ?</td>
</tr>
<tr>
<td><strong>Swaption volatilities</strong></td>
<td>EURIBOR</td>
<td>EURIBOR 3M EURIBOR 6M</td>
<td>EURIBOR 3M EURIBOR 6M</td>
<td>€STR ?</td>
</tr>
</tbody>
</table>

(per currency)
Once upon a time, there was an ancient financial world, with many many interest rates and volatilities…
Summary

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2. Classic vs Modern Benchmark Rates
   - SOFR so far
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   - Risk management issues

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5. Focus on XVAs

6. Conclusions

7. Appendix: funding spread

8. References
5: Focus on XVAs
Overview [1/4]
5: Focus on XVAs
Overview [2/4]

\[ V(t) = V_0(t) + CVA + DVA + \cdots \]
5: Focus on XVAs
Overview [3/4]

\[ V(t) = V_0(t) + CVA + DVA + \cdots \]

- Financial counterparty or CCP
- Trade Two (CSA)
- Bank (l)
- Trade One (no CSA)
- Counterparty (C)

Market risk hedge

Counterparty risk mitigation (CVA/DVA ≈ 0)

Market risk

Counterparty risk

CVA/DVA

Counterparty risk hedges
Focus on XVAs
Overview [4/4]

\[ V(t) = V_0(t) + CVA + DVA + FVA + \ldots \]
As of Q4-2018, 16 EU Banks disclosed CVA/DVA figures and 7 banks also disclosed FVA figures, related to fair valuations.
5: Focus on XVAs
Overview: international benchmarking [2/2]

FVA figures (at fair value) disclosed by 7 banks in the last three years. FVA figures have been disclosed by banks since 2013 (see e.g. M. Cameron, “JP Morgan takes $1.5 billion FVA loss”, Risk, 14 Jan. 2014).
## 5: Focus on XVAs

### XVA formulas

<table>
<thead>
<tr>
<th>XVA</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CVA</strong></td>
<td>$CVA_C(t) = -LGD_C(t) \int_t^T \mathbb{E}_t^Q \left[ D(t,u) [V(u) - C_C(u)]^+ \right] S_1(t,u) dQ_C(t,u) \leq 0$</td>
</tr>
<tr>
<td><strong>DVA</strong></td>
<td>$DVA_C(t) = -LGD_I(t) \int_t^T \mathbb{E}_t^Q \left[ D(t,u) [V(u) - C_C(u)]^- \right] S_C(t,u) dQ_I(t,u) \geq 0$</td>
</tr>
<tr>
<td><strong>FVA</strong></td>
<td>$FVA(t) = -\int_t^T \mathbb{E}<em>t^Q \left[ D(t,u) \left( \sum</em>{C=1}^{N_C} [V(u) - C_C(u)] S_C(t,u) \right)^+ \right] f_{s_1}(u) S_1(t,u) du \leq 0$</td>
</tr>
<tr>
<td><strong>MVA</strong></td>
<td>$MVA_C(t) = -\int_t^T \mathbb{E}<em>t^Q \left[ D(t,u) IM_C(u) f</em>{s_1}(u) \right] S_1(t,u) du \leq 0$</td>
</tr>
</tbody>
</table>

### Parameters

- **€STR / Hybrid EURIBOR Forwarding Curves**
- **Discount factor** $D(t,u)$
- **Exposure** $V(u)$
- **Survival probabilities** $S_x(t,u)$
- **Marginal default probabilities** $dQ_x(t,u)$
- **Funding spread** $f_{s_1}(u)$
- **Volatilities**
5: Focus on XVAs
An important feature of FVA

Proposition: under the EONIA-€STR transition, assuming constant funding rates, the fair value of an uncollateralised trade is constant, since the impacts on risk free value and FVA cancel each other.

Proof We will proof the proposition above in a simplified situation, as follows.

- We consider a single uncollateralized trade with a single future cashflow $C > 0$ received by the investor $I$ from the counterparty $C$.
- Bonds and other IR funded instruments suffer no impacts under both transitions.
- → The Debt Valuation Adjustment (DVA) for $I$ is zero.
- We suppose that the counterparty is default-free → also the Credit Valuation Adjustment (CVA) for $I$ is zero.
- → The fair value of the trade is given by

$$V(t) = V_0(t) + FVA(t) = P_d(t, T) C + FVA(t)$$
5: Focus on XVAs

Defaultable Zero Coupon Bond [1]

- We define the risky zero coupon bond with no recovery rate as the bond paying one unit of currency at maturity if the issuer $I$ is not defaulted before,

$$P_I(t,T) = \mathbb{E}_t^Q[D(t,T)1_{[\tau_I > T]}],$$

$$D(t,T) = e^{-\int_t^T r(s)ds},$$

where $\tau_I > t$ is the (stochastic) default time of the issuer.

- Supposing that interest rates and default time are independent, we obtain

$$P_I(t,T) = \mathbb{E}_t^Q[e^{-\int_t^T [r(s)+s_I(s)]ds}].$$

- Let’s now consider the more realistic case where recovery rate is not zero. We identify it with the process $\mathcal{R}(t)_{t \geq 0}$. It can be shown that the expression of the price of a risky zero coupon bond becomes (for simplicity $\tau_I > t$)

$$P_I(t,T) = \mathbb{E}_t^Q \left[ e^{-\int_t^{\tau_I} r(s)ds} \mathcal{R}(\tau_I)1_{\{\tau_I \leq T\}} + e^{-\int_t^T r(s)ds}1_{\{\tau_I > T\}} \right]$$

$$= \mathbb{E}_t^Q \left[ \int_t^T \mathcal{R}(u)\gamma(u)e^{\int_u^T [r(s)+\gamma(s)]ds}du \right] + \mathbb{E}_t^Q \left[ e^{-\int_t^T [r(s)+\gamma(s)]ds} \right]$$
5: Focus on XVAs
Defaultable Zero Coupon Bond [2]

- For the recovery rate we adopt the «recovery of treasury» model, such that

\[ \mathcal{R}(t) = RP_d(t, T) \quad 0 \leq R \leq 1 \]

- Under such model the price of the risky zero coupon bond simplifies as

\[ P_I(t, T) = P_d(t, T) (1 - (1 - R)(1 - S_I(t, T))) \]

where \( S_I(t, T) = \mathbb{E}_t^Q [\mathbb{1}_{\{\tau_I > T\}}] = \mathbb{Q}(\tau_I > T) \) is the survival probability of \( I \) until time \( T \), evaluated in \( t \).

- We define the Funding Valuation Adjustment (FVA) intended as a Funding Cost

\[ FVA(t) = -\mathbb{E}_t^Q \left\{ \int_t^T D(t, u) \left[ \sum_{c=1}^N H_c(u) \mathbb{1}_{\{\tau_c > u\}} \right]^{+} s_I(u) \mathbb{1}_{\{\tau_I > u\}} du \right\} \]

where \( H_c(u) \) is the total exposure relative to the counterparty \( c \) in the funding set \( \{1, \ldots, N\} \) and \( s_I(t) \) is the instantaneous funding spread for \( I \).
5: Focus on XVAs

XVA impact [1]

- For a single positive cashflow and no counterparty risk, the FVA reduces to

\[
FVA(t) = -\mathbb{E}_t^Q \left\{ \int_t^T D(t, u) \left[ \mathbb{E}_u^Q [D(u, T)C] \right]^+ s_I(u) 1_{\{\tau_1 > u\}} du \right\}
\]

\[
= -C \mathbb{E}_t^Q \left\{ \int_t^T D(t, u) [P_d(u, T)]^+ s_I(u) 1_{\{\tau_1 > u\}} du \right\}
\]

\[
= -C \int_t^T \mathbb{E}_t^Q \left\{ D(t, u) P_d(u, T) s_I(u) 1_{\{\tau_1 > u\}} \right\} du
\]

\[
= -C \int_t^T \mathbb{E}_t^Q \left\{ D(t, u) P_d(u, T) \right\} \mathbb{E}_t^Q \left\{ s_I(u) 1_{\{\tau_1 > u\}} \right\} du
\]

\[
= -C \int_t^T s_I(u) \mathbb{E}_t^Q \left\{ e^{-\int_t^u r(s) ds} \mathbb{E}_u^Q \left\{ e^{-\int_u^T r(s) ds} \right\} \right\} \mathbb{E}_t^Q \left\{ 1_{\{\tau_1 > u\}} \right\} du
\]

\[
= -C \int_t^T s_I(u) \mathbb{E}_t^Q \left\{ \mathbb{E}_u^Q \left\{ e^{-\int_t^T r(s) ds} \right\} \right\} S_I(t, u) du
\]
5: Focus on XVAs

XVA impact [2]

- If we use the tower rule property for nested conditional expectations, we get

\[ FVA(t) = -CP_d(t, T) \int_t^T s_I(u)S_I(t, u)du \]

- Using the following relationship (see appendix)

\[ s_I(u) = \gamma_I(t)(1 - R) = -\frac{\partial_u S_I(t, u)}{S_I(t, u)}(1 - R) \]

where \( \gamma_I(t) \) is the hazard rate, we obtain

\[ FVA(t) = - (1 - R)CP_d(t, T) \int_t^T \left[ -\frac{\partial_u S_I(t, u)}{S_I(t, u)} \right] S_I(t, u)du \]

\[ = (1 - R)CP_d(t, T) \int_t^T \partial_u S_I(t, u)du \]

\[ = (1 - R)CP_d(t, T)[S_I(t, T) - 1] \]

\[ = CP_d(t, T)[R + S_I(t, T) - 1 - RS_I(t, T)] \]

\[ = CP_d(t, T)[R + S_I(t, T)(1 - R) - 1] \]

\[ = C[R + P_d(t, T)S_I(t, T)(1 - R) - P_d(t, T)] \]

\[ = -C[P_d(t, T) - P_I(t, T)] \]
We now assume that the \( \text{\euro STR OIS} \) curve is given by the EONIA OIS curve minus a constant spread (-9 bps at the moment),

\[
R^E_{d}^{ST}(t,T) = R^E_{d}^{ON}(t,T) - \Delta \quad \forall T > t \quad \Delta > 0
\]

\[
R_x(t,T) := -\frac{1}{\tau(t,T)} \log P_x(t,T)
\]
5: Focus on XVAs

XVA impact [4]

- Under the EONIA→€STR transition the following quantities are impacted (the new value is denoted by «’»)

  ✓ Discount factors

  \[ P_d(t, T) \rightarrow P'_d(t, T) \]

  ✓ Funding (Zero) Rate of the risky ZCB

  \[ R_I(t, T) := R_d^{EON}(t, T) + S_I(t, T) \rightarrow R_d^{EST}(t, T) + S'_I(t, T) := R'_I(t, T) \]

  \[ S_I(t, T) = \frac{1}{\tau(T - t)} \log \frac{P_d(t, T)}{P_I(t, T)} \]

- Assuming that the transition does not affect the overall ZCB value, then

  \[ P'_I(t, T) = P_I(t, T) \]

  \[ \Rightarrow R'_I(t, T) = R_I(t, T) \]

  \[ \Rightarrow S'_I(t, T) = S_I(t, T) + \Delta \]
5: Focus on XVAs

XVA impact [5]

- Putting all the pieces into the equation of fair value of the trade, we obtain finally

\[
V(t) = V^0(t) + \text{FVA}(t) = P_d(t, T) C + \text{FVA}(t)
\]

\[
V'(t) = C \ P'_d(t, T) - C \ [P'_d(t, T) - P'_I(t, T)]
\]

\[
= C \ P'_I(t, T)
\]

\[
= C \ P_I(t, T)
\]

\[
= V(t).
\]

c.v.d.

We have proved that, under appropriate hypotheses, the impact of EONIA → €STR transition on a trade is neutralised by the corresponding variation of the funding spread, which restores the indifference on the price of the defaultable ZCB issued by I to the transition.

The proof can be generalized to multiple stochastic cash flows.
6: Conclusions and Q&A

Take aways

- **Volumes**: EURIBOR and USDLIBOR ~ 150-200 $tn, EONIA, GBPLIBOR and JPYLIBOR ~ 30 $tn

- **EONIA→€STR transition** could be smooth and fast because EONIA/€STR fixed spread.

- **Cleared trades**: CCPs decisions about PAI and discounting rates key trigger, compensation schemes are needed to avoid huge value transfers.

- **Trades under bilateral CSAs**: expected to follow CCPs trigger, standard rules are needed to drive repapering bilateral CSAs and avoid litigations.

- **Uncollateralised trades**: need consistency w.r.t. The corresponding cleared/collateralised hedgings, pricing impacts possibly smoothed by FVA cancellation under reasonable assumptions.
7: Appendix
Funding spread [1]

The value of the risky zero coupon under Recovery of Treasury model, where

\[ R(t) = RP_d(t, T) \quad 0 \leq R \leq 1 \]

becomes

\[ P_I(t, T) = R \mathbb{E}^Q_t \left[ \int_t^T P_d(u, T) \gamma(u) e^{\int_t^u (r(s) + \gamma(s)) \, ds} \right] \, du + P_I(t, T) \]

\[ = R \mathbb{E}^Q_t \left[ e^{\int_t^T r(s) \, ds} \int_t^T \gamma(s) e^{\int_t^u \gamma(s) \, ds} \, du \right] + P_I(t, T) \]

\[ = R \mathbb{E}^Q_t \left[ e^{\int_t^T r(s) \, ds} \left( 1 - e^{\int_t^T \gamma(s) \, ds} \right) \right] + P_I(t, T) \]

\[ = R (P_d(t, T) - P_I(t, T)) + P_I(t, T) \]

\[ = R P_d(t, T) + (1 - R) + P_I(t, T) \]

\[ = R P_d(t, T) + (1 - R) P_d(t, T) S_I(t, T) \]

\[ = P_d(t, T) (R + (1 - R) S_I(t, T)) \]
7: Appendix

Funding spread [2]

- We rewrite the ZCB value in such a way

\[ P_I(t, T) = P_d(t, T) \left[ R + S_I(t, T) - R S_I(t, T) + 1 - 1 \right] \]
\[ = P_d(t, T) \left[ 1 - (1 - R) + S_I(t, T)(1 - R) \right] \]
\[ = P_d(t, T) \left[ 1 - (1 - R)(1 - S_I(t, T)) \right]. \]

- Since the zero funding spread is defined as

\[ S(t, T) = \frac{1}{T - t} \log \left( \frac{P_d(t, T)}{P_I(t, T)} \right) \]

then

\[ S(t, T) = \frac{1}{T - t} \log \left( \frac{1}{1 - (1 - R)(1 - S_I(t, T))} \right) \]
\[ = - \frac{1}{T - t} \log \left[ 1 - (1 - R)(1 - S_I(t, T)) \right] \]
\[ = - \frac{1}{T - t} \log \left[ 1 + S_I(t, T) + R - R S_I(t, T) \right] \]
\[ = - \frac{1}{T - t} \log \left\{ S_I(t, T) \left[ 1 + R \left( -1 + \frac{1}{S_I(t, T)} \right) \right] \right\}. \]
7: Appendix
Funding spread [3]

- We recall that the survival probability may be defined through the hazard rate $\gamma_I(t)$

$$S_I(t, T) = e^{-\int_t^T \gamma(s) ds}$$

- Inserting the survival probability inside the spread rate formula, we arrive to

$$S(t, T) = \frac{\int_t^T \gamma(s) ds}{T - t} - \frac{1}{T - t} \log \left[ 1 + R \left( e^{\int_t^T \gamma(s) ds} - 1 \right) \right].$$

- In order to obtain the instantaneous spread rate, we apply the limit

$$s_I(t) = \lim_{T \to t^+} S(t, T) = \gamma(t)(1 - R)$$
8: References

General

€STR & EONIA
8: References

**SOFR & EFFR**

**EURIBOR**

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