New Interest Rate Benchmarks Valuations and Risk Management

Cass Business School, London, 19 June 2019

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Disclaimer and Acknowledgments

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Acknowledgments

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   - Risk management issues

4. Bye-Bye multi-curves?

5. Focus on XVAs

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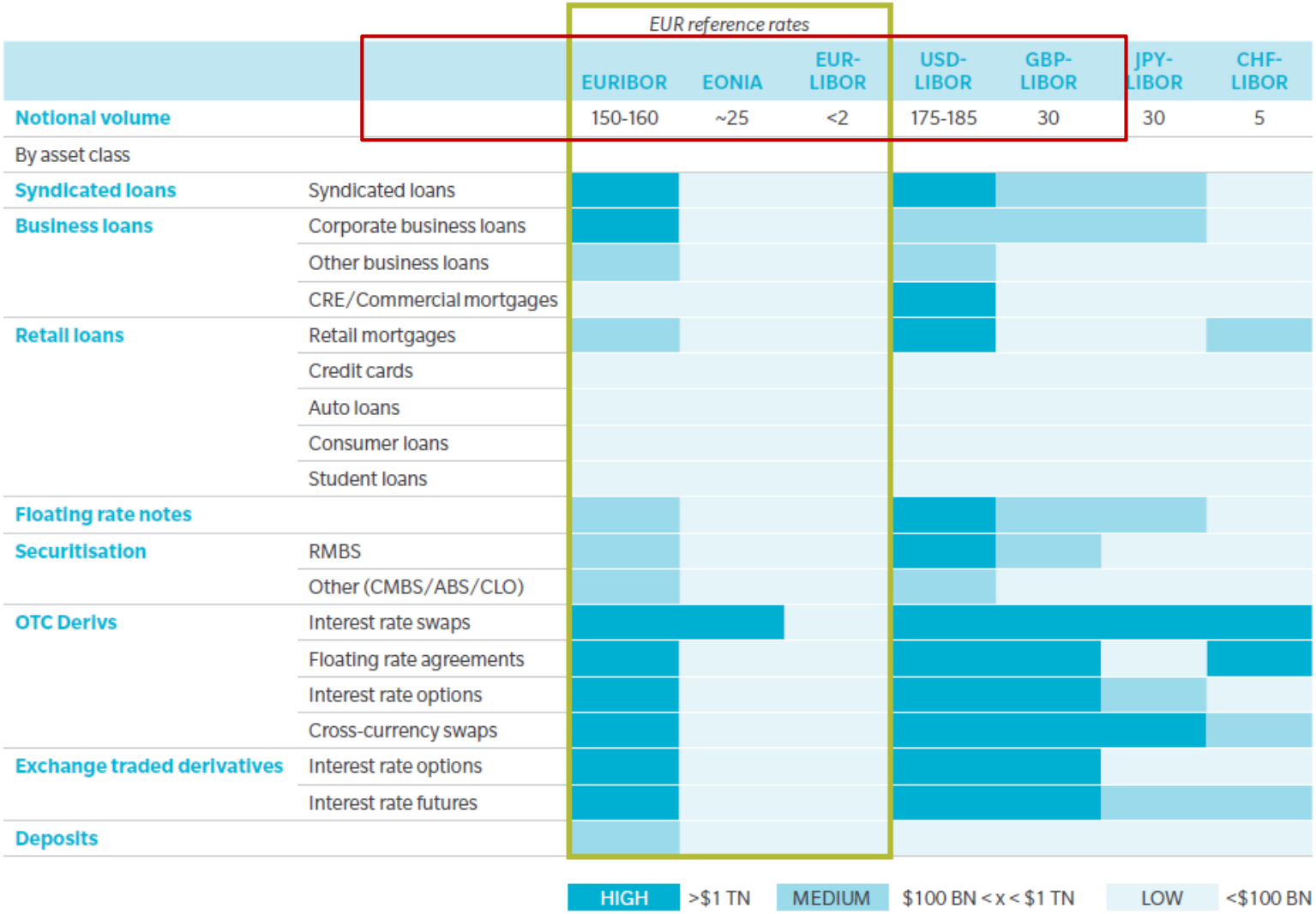
7. Appendix: funding spread

8. References

1: Introduction
Interest rates are everywhere



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

INTEREST RATE BENCHMARKS: EURO

Rate	EONIA	EONIA+	€STR	EURIBOR	EURIBOR H
Long name	Euro OverNight Index Average	Euro OverNight Index Average (reformed)	Euro Short Term Rate	Euro Interbank Offered Rate	Hybrid Euro Interbank Offered Rate
Administrator	EMMI	EMMI	ECB	EMMI	EMMI
Calculation Agent	ECB	ECB	ECB	EBASS	EBASS
Life	Born 4 Jan. 1999 Dead 30 Sep. 2019	Born 2 Oct. 2019 Dead 3 Jan. 2022	Premature 15 Mar. 17 Born 2 Oct. 2019	Born 30 Dec. 1998 Dead summer 2019	Born summer 2019
Panel	28 EU banks	--	MMSR (52 participants)	19 EU Banks	19 EU Banks
Definition	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	€STR + spread	EUR unsecured borrowings in the wholesale sector by MMSR participants	The rate at which euro interbank term deposits are being offered within the EU and EFTA countries by one prime bank to another	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
Data sources and conditions	Panel banks data at T<18:00 CET	€STR, spread fixed on 2 Oct. 2019	MMSR data at T, size > 1 mln€	Panel banks data at T (expert judgment)	Panel banks data at T (transaction + expert judgment)
Formula	Volume-weighted average	€STR + spread	Volume-weighted trimmed average (25%)	Trimmed average (15%)	Trimmed average (15%)
Publication time	T (19:00 CET)	T+1 (9:00 CET)	T+1 (9:00 CET)	T (11:00 CET)	T+1 (11:00 CET)
Compliance	BMR: NO	BMR: NO	BMR: exp. 2019 (ECB)	BMR: NO	BMR: exp. 2019 (FSMA)
Calendar	TARGET2	TARGET2	TARGET2	TARGET2	TARGET2
Tenor	O/N	O/N	O/N	1W, 1M, 3M, 6M, 12M	1W, 1M, 3M, 6M, 12M
Secured	NO	NO	NO	NO	NO
Day count convention	Act/360	Act/360	Act/360	Act/360	Act/360
Business Days Convention	Following	Following	Following	Following (1W), mod. following (1M-12M)	Following (1W), mod. following (1M-12M)
Decimals	3	3	3	3	3
Reuters/BBG	EONIA=/EONIA index	EONIA=/EONIA index	--	EURIBOR=/EUR003M:IND	EURIBOR=/EUR003M:IND

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

INTEREST RATE BENCHMARKS: USD, GBP

Rate	USD EFFR	USD SOFR	GBP SONIA	GBP SONIA+
Long name	Effective Federal Funding Rate	Secured Overnight Financing Rate	Sterling OverNight Index Average	Sterling OverNight Index Average (reformed)
Administrator	NY FED	NY FED	Bank of England	Bank of England
Calculation Agent	NY FED	NY FED	Bank of England	Bank of England
Life	Born 1954	Born 3 April 2018	Born March 1997 Dead 22 Apr. 2018	Born 23 Apr. 2018
Panel	Institutions holding reserves at the NY FED	--	WMBA members	--
Definition	USD unsecured borrowings of reserve balances between depository institutions at NY Fed	USD borrowings collateralized by Treasury Securities	GBP borrowings brokered by WMBA members between London counterparties	GBP borrowing wholesale bilateral or broker transactions
Data sources and conditions	Domestic Trading Desk of the NY Fed	BNYM and DTCC	WMBA members data between 00:00 and 15.15 GMT at day T, deal size > 25 mln£	Sterling Money Market data between 00:00 and 15.15 GMT at day T, deal size > 25 mln£
Formula	Volume-weighted median	Volume-weighted median (cut lowest 25th percentile)	Volume-weighted average	Volume-weighted trimmed average (25%)
Publication time	T+1 (9:00 ET)	T+1 (8:30 ET)	T (18:00 GMT)	T+1 (9:00 GMT)
Compliance	IOSCO: YES (NY FED)	IOSCO: YES (NY FED)	IOSCO: NO	IOSCO: YES (BoE)
Calendar	NY FED	NY FED + market	London business days	London business days
Tenor	ON	ON	ON	ON
Secured	NO	YES	NO	NO
Day count convention	Act/360	Act/360	Act/365	Act/365
Business Days Convention	Following	Following	Following	Following
Decimals	2	2	4	4
Reuters/BBG	USONFFE=/FEDL01 Index	USDSOFR=/SOFRRATE Index	SONIA1/WMBA	SONIAOSR=/SONIO/N Index

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

OTHER INTEREST RATE BENCHMARKS: CHF, JPY,…

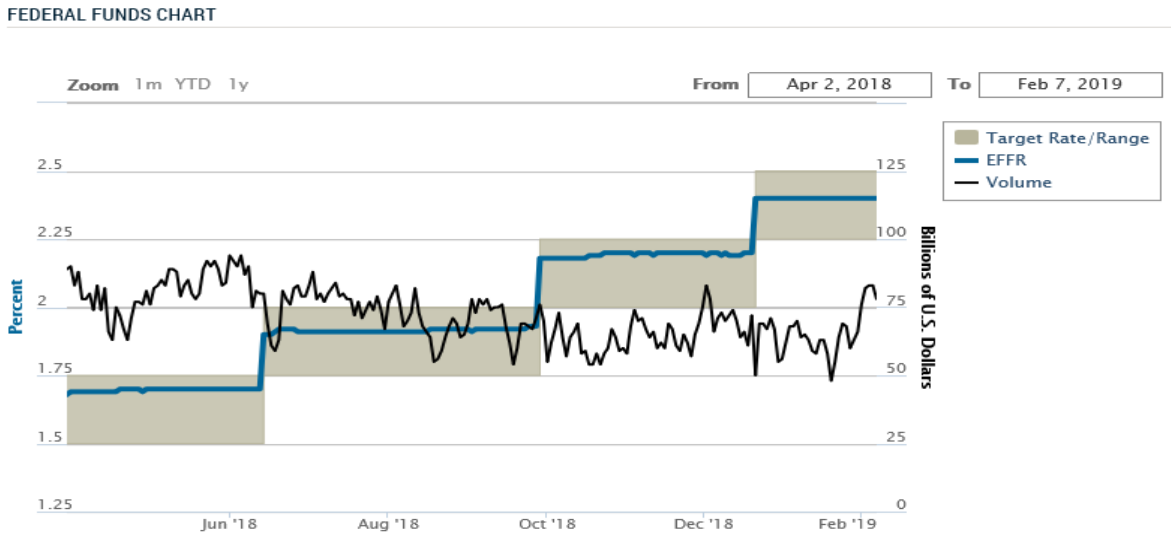
Rate	CHF SARON	JPY TONAR			
Long name	Swiss Average Rate OverNight (SARON)	Tokyo OverNight Average Rate			
Administrator	SIX Swiss Exchange	Bank of Japan			
Calculation Agent	SIX Swiss Exchange	Bank of Japan			
Life	Born 25 August 2009	Born 11 April 1996			
Panel	--	--			
Definition	CHF interbank repo transactions	JPY uncollateralized overnight call rate market			
Data sources and conditions	Order book of SIX Repo Ltd electronic trading platform	Main money market brokers			
Formula	Volume-weighted average	Volume-weighted average			
Publication time	T (12:00, 16:00, 18:00 CET)	T (17:15 JST)			
Compliance	IOSCO: YES (SIX)	IOSCO: YES (BoJ)			
Calendar	Trading days of CHF repo market	Trading days of JPY money market			
Tenor	ON	ON			
Secured	YES	NO			
Day count convention	Act/360	Act/365			
Business Days Convention	Following	Following			
Decimals	6	3			
Reuters/BBG	SARON.S/SSARON	JPONMU=RR/MUTSCALM			

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

Summary

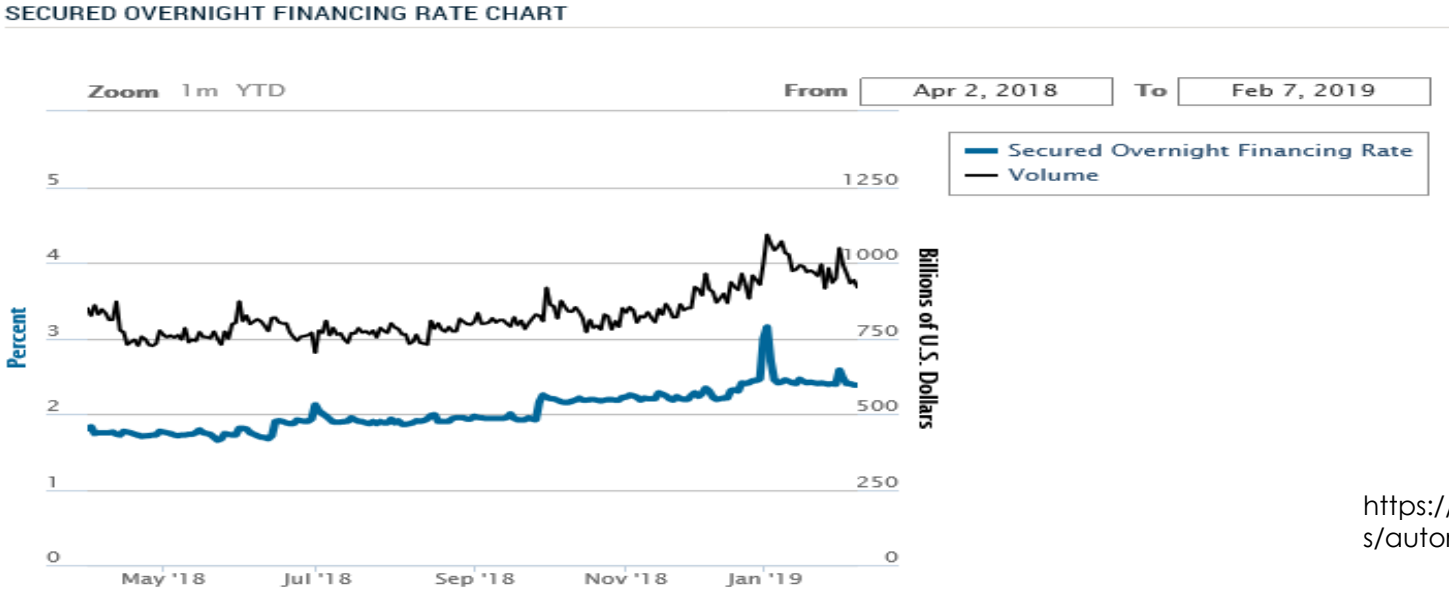
2: Classic vs Modern Benchmark Rates

SOFR so far: fixing data



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

DATE	SOFR (%)	EFFR (%)	Basis
2019-02-08	2.37	2.40	-0.03
2019-02-07	2.38	2.40	-0.02
2019-02-06	2.38	2.40	-0.02
2019-02-05	2.40	2.40	-
2019-02-04	2.40	2.40	-
2019-02-01	2.47	2.40	0.07



https://apps.newyorkfed.org/markets/autorates/sofr

2: Classic vs Modern Benchmark Rates
SOFR so far: market instruments

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.

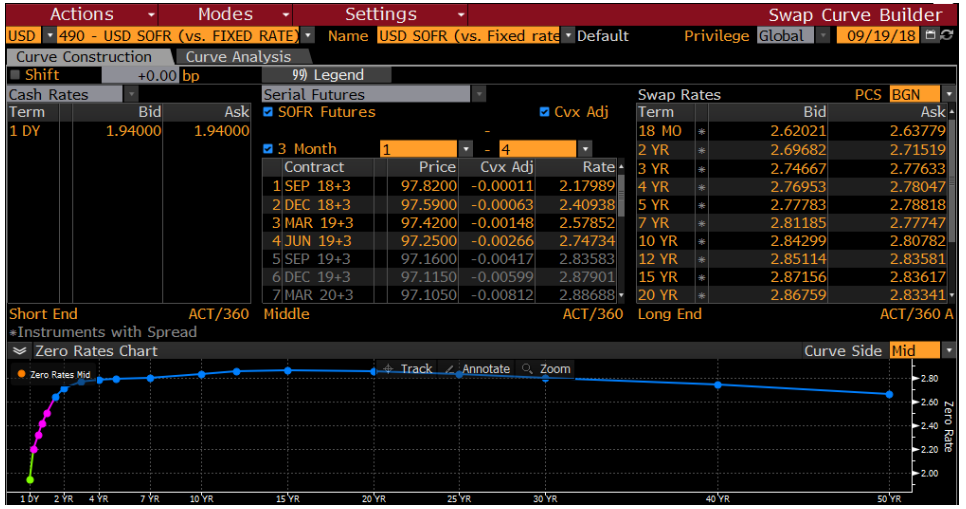
2. **SOFR OTC Swaps**

   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

Risk.net 4 Feb. 2019

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.

Risk.net 12 Feb. 2019

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

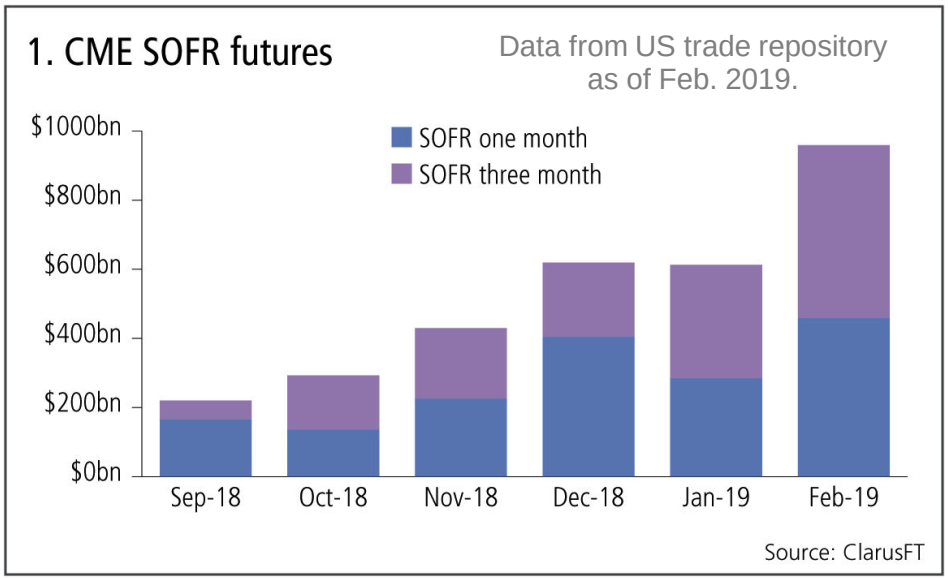
Risk.net 21 May 2019

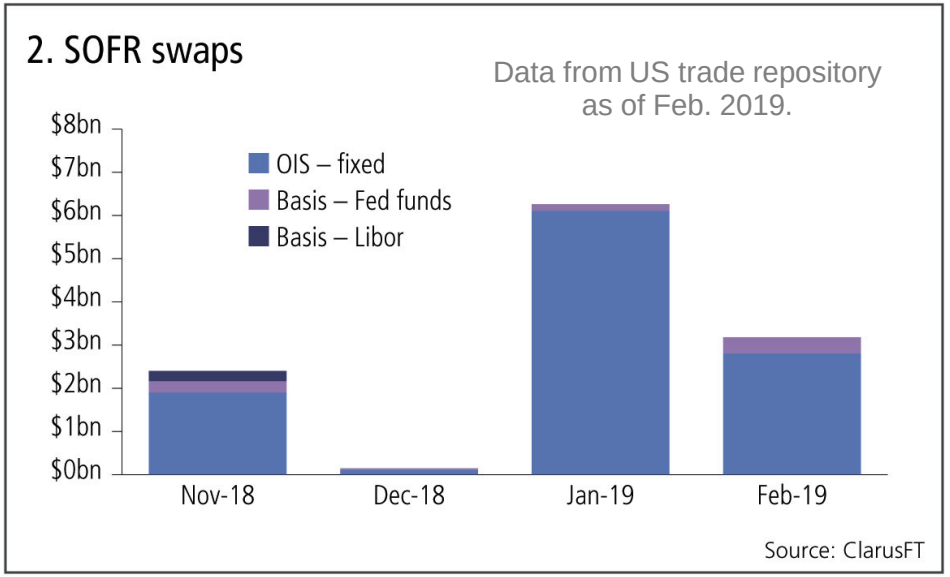
Swaps users mull 'big bang' for SOFR discounting

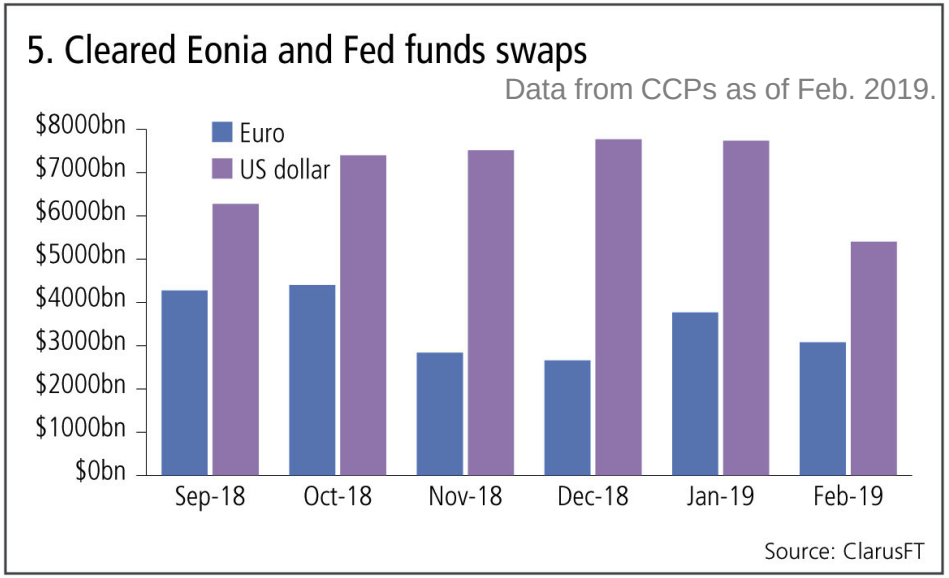
Cleared and bilateral US dollar swaps could move to SOFR discounting on the same day in 2020

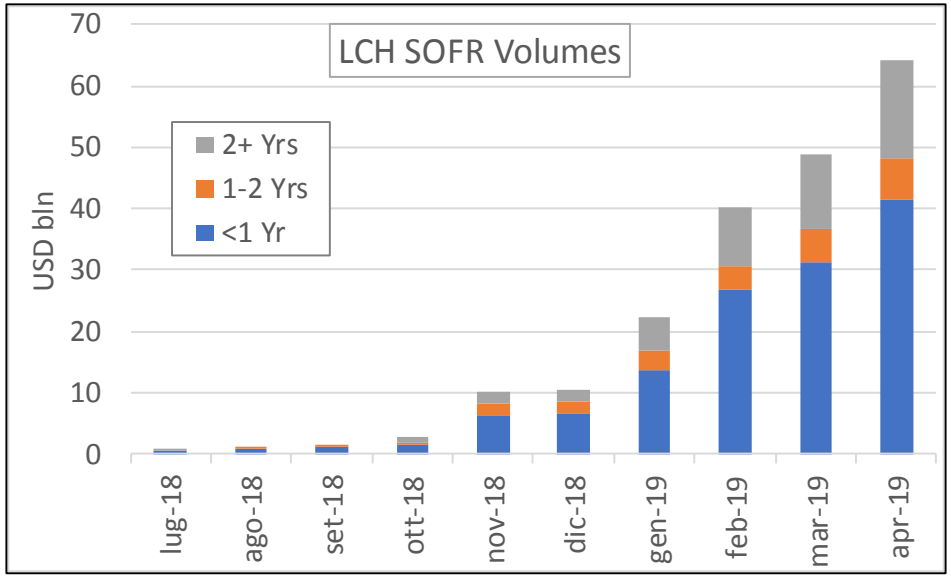
2: Classic vs Modern Benchmark Rates

SOFR so far: market (il)liquidity



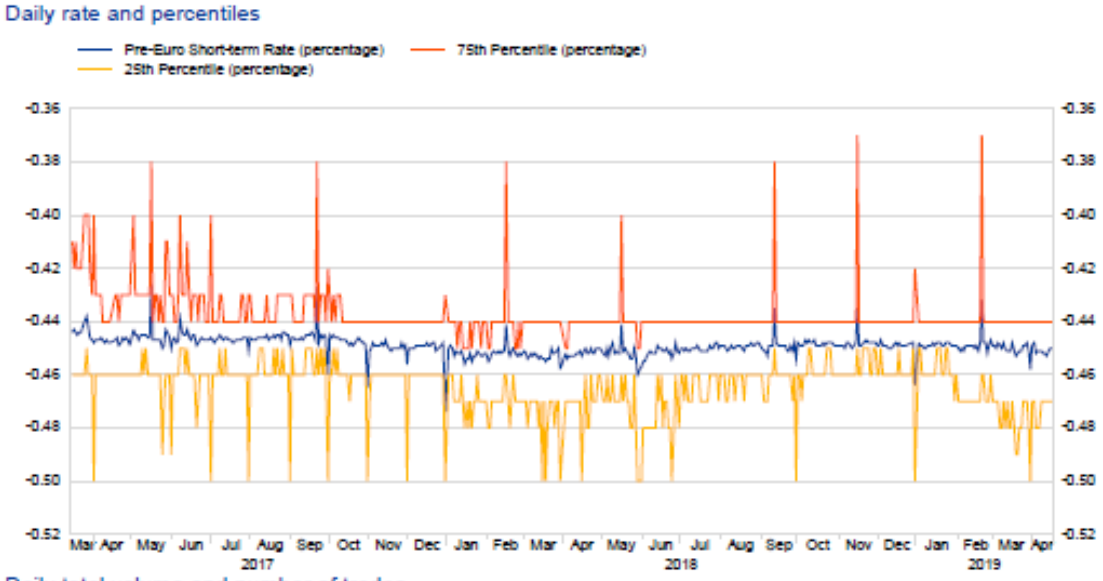


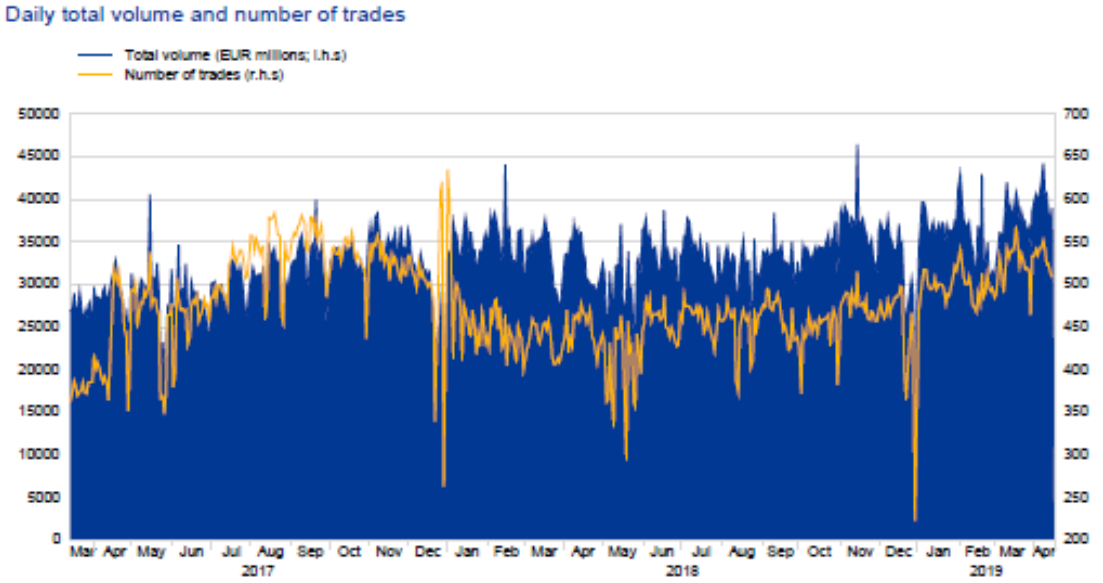




2: Classic vs Modern Benchmark Rates

€STR so far: pre-€STR fixings & basis





Pre-€STR data

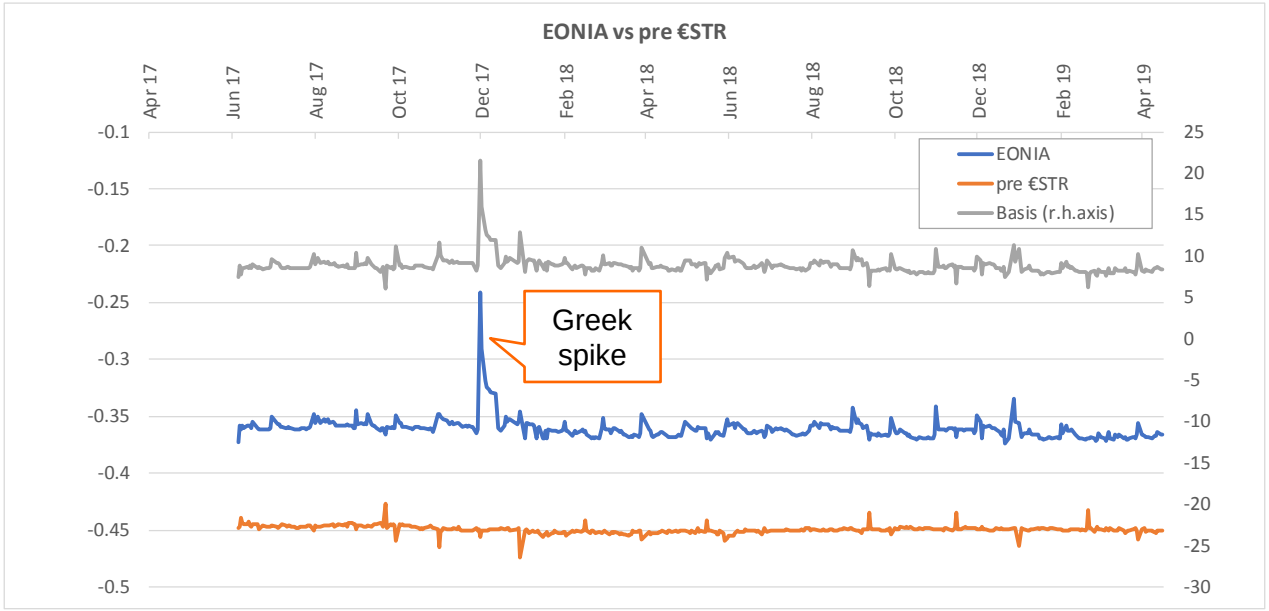
The pre-€STR is calculated using the same methods as defined for the €STR.

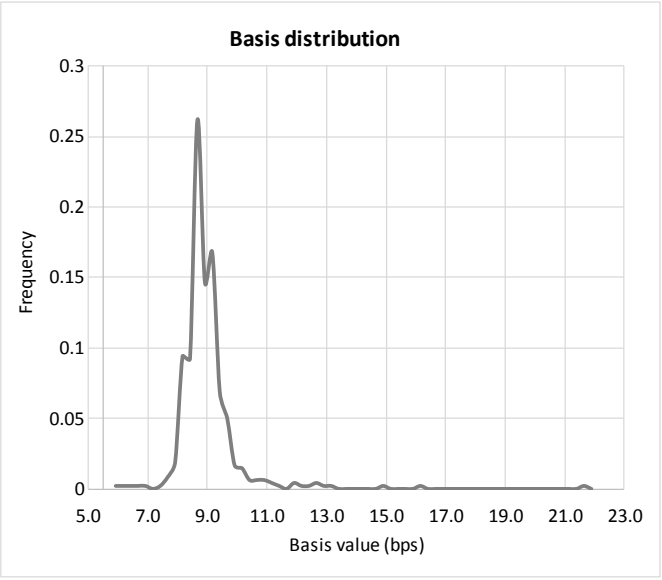
The pre-€STR differs in that it is based on final data and includes all revisions in terms of cancellations, corrections and amendments submitted by reporting agents at the time of calculating the rate, while the €STR will be published every morning and take into account only the data received by the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

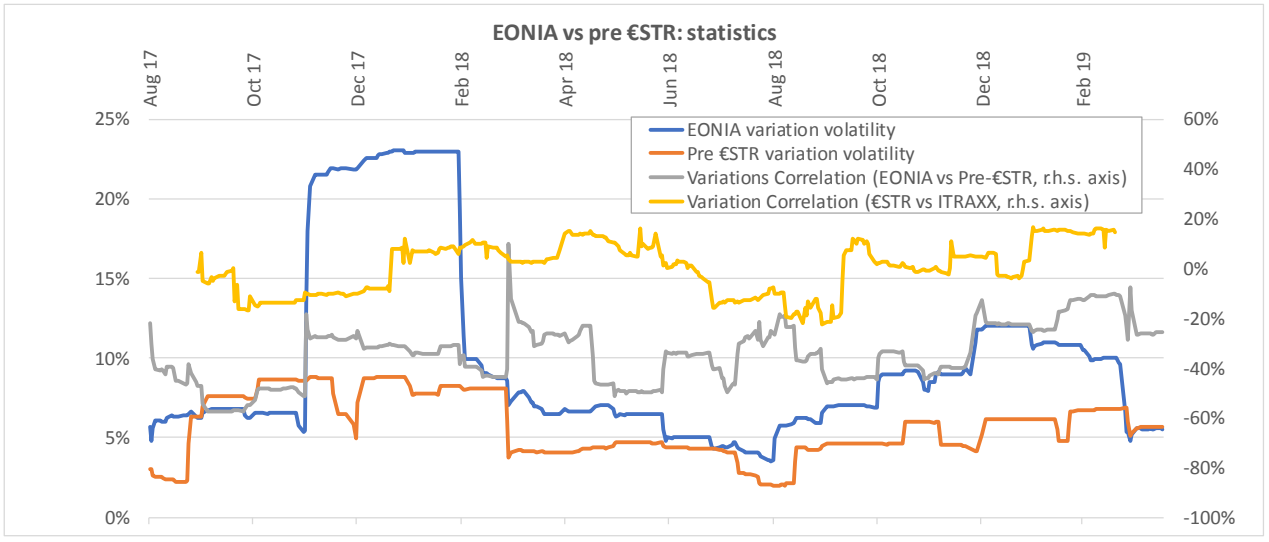
Source: ECB

2: Classic vs Modern Benchmark Rates

€STR so far: pre-€STR fixings & basis







Basis Distribution Stats		
Min	6.1	bps
Max	21.5	bps
Mean	8.8	bps
Std dev	1.0	bps
Observations	478	

2: Classic vs Modern Benchmark Rates

€STR so far: *habemus basis*

PRESS RELEASE

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

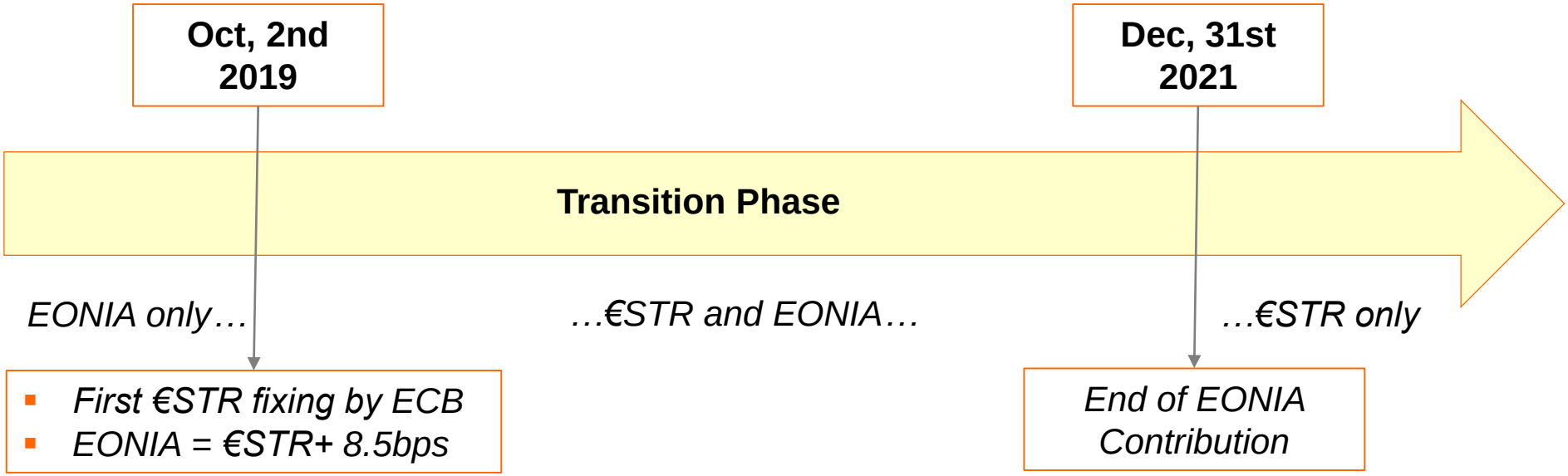
31 May 2019

- 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.

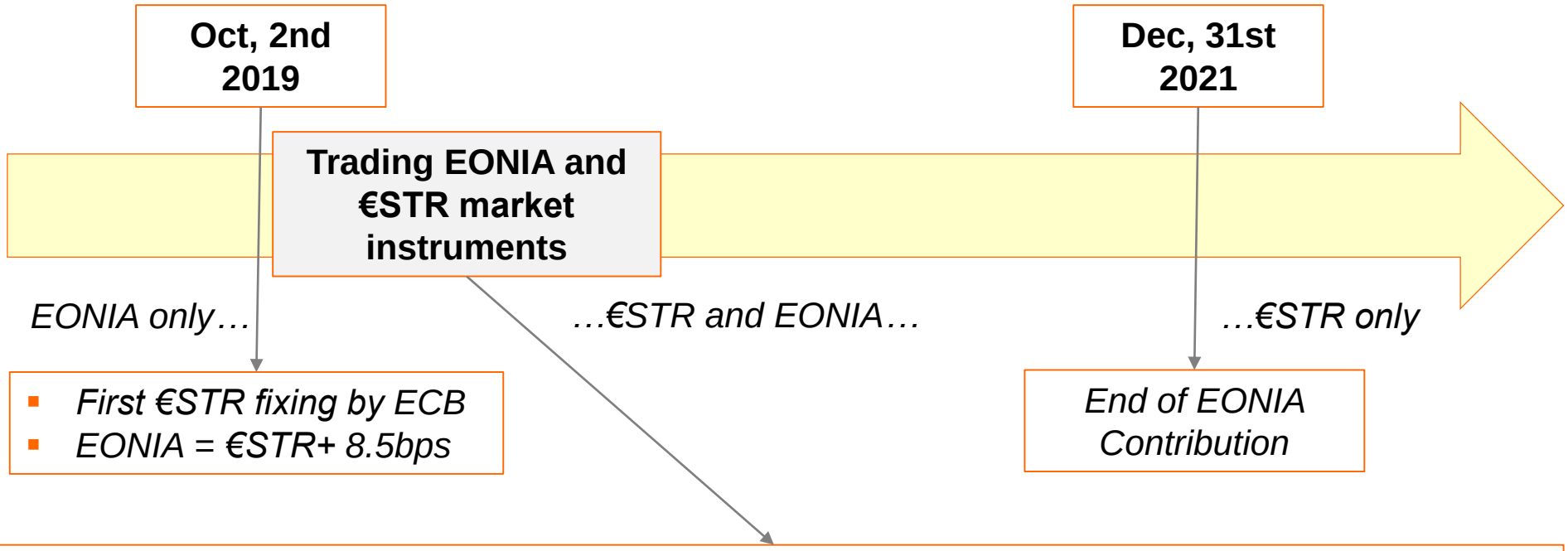
2: Classic vs Modern Benchmark Rates

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



2: Classic vs Modern Benchmark Rates

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

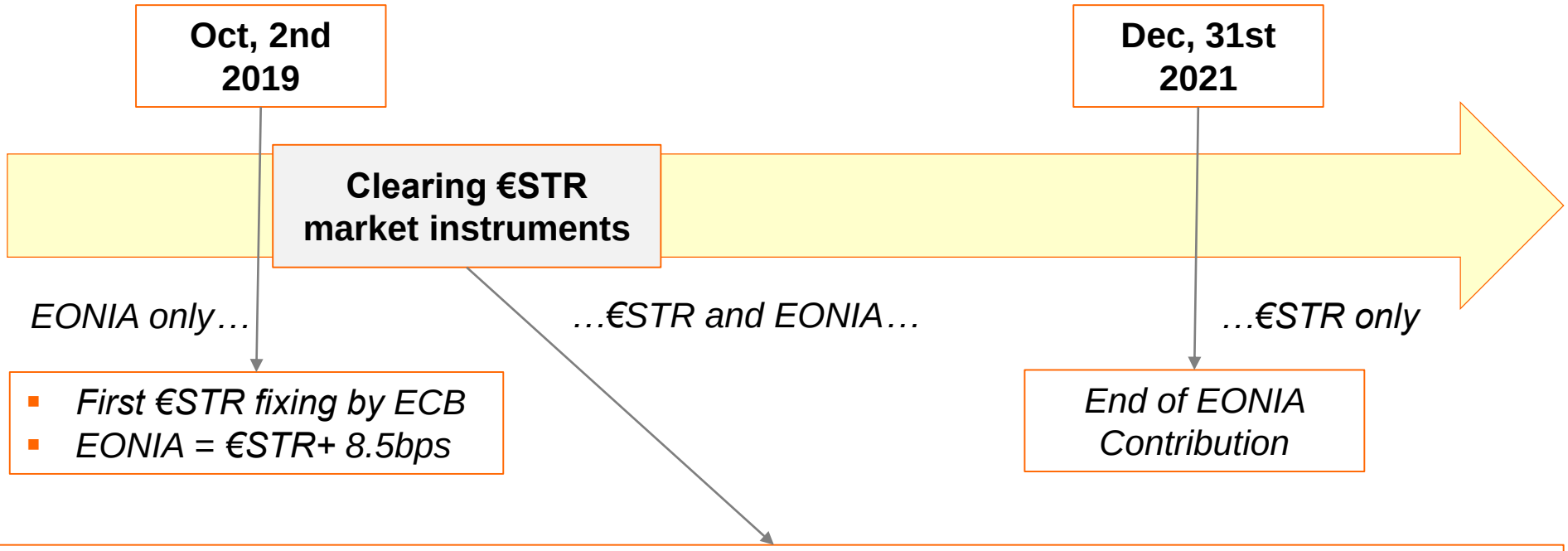


On 2 Oct. 2019 (or shortly after)

- 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]

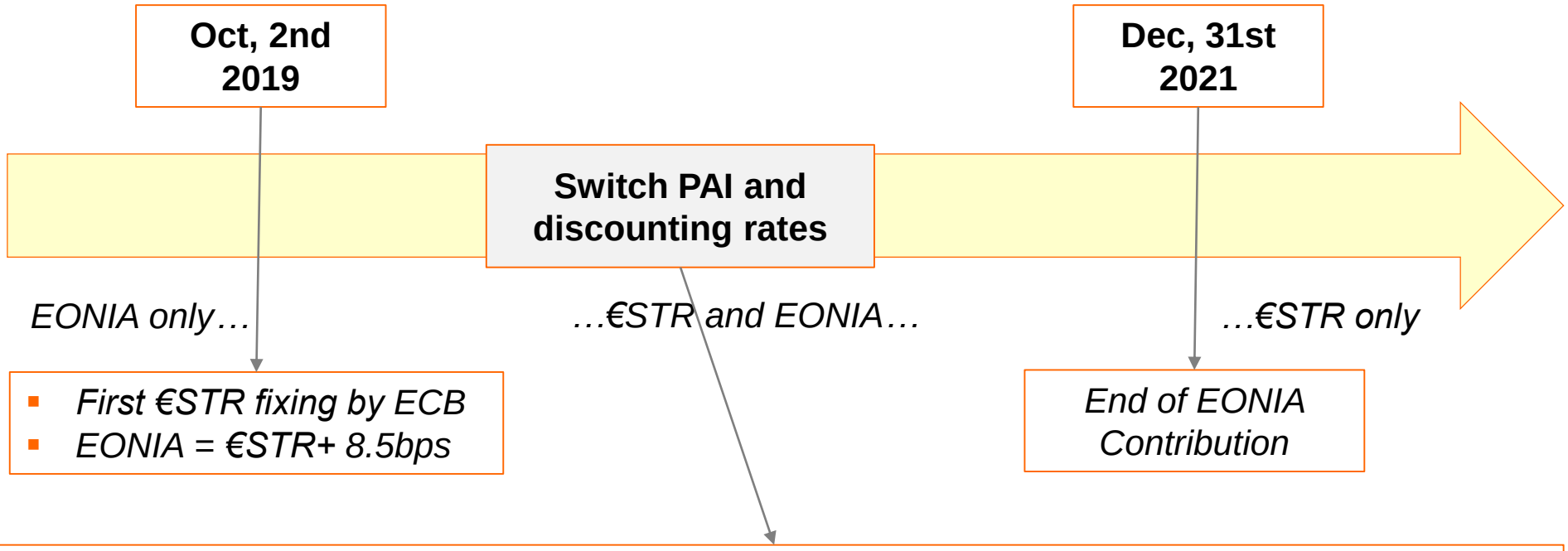


On 2 Oct. 2019 (or shortly after)

- 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]



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]

	2019 Q3	2019 Q4	2020 H1	2020 H2	2021 H1	2021 H2	2022
1. EONIA fixing	Available up to 31 Dec. 2021						No longer available
2. €STR fixing	NA	Available since 2 Oct. 2019					
3. EONIA mkt instruments	Liquid		Available but less and less liquid and relevant				No longer available
4. €STR mkt Instruments	NA	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?)					Available
5. EONIA term structure	Available both as EONIA = €STR + spread or directly from EONIA mkt instruments						No longer available
6. €STR term structure	NA	Available both as €STR = EONIA - spread and directly from €STR mkt instruments					Available directly from €STR mkt instruments
7. CCPs clearing for EONIA trades	Available, using either directly EONIA or €STR + spread term structures						No longer available
8. CCPs clearing for €STR trades	NA	Available, using either EONIA – spread or directly €STR term structures					Available

Legenda: **black** = sure events; **red** = events needing some assumption (see previous slide); orange background = transition phase; blue background = transition finished, situation at regime.

2: Classic vs Modern Benchmark Rates

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

	2019 Q3	2019 Q4	2020 H1	2020 H2	2021 H1	2021 H2	2022
9. CCPs PAI rate for EONIA trades	EONIA until CCPs switch, needs compensation scheme				€STR		No longer available
10. CCPs PAI rate for €STR trades	NA	EONIA until CCPs switch, needs compensation scheme			€STR		€STR
11. Bilateral CSAs PAI rate for EONIA trades	EONIA until CCPs switch, needs multilateral protocols with compensation schemes				€STR ongoing transition on bilateral basis, possible litigations		No longer available
12. Bilateral CSAs PAI rate for €STR trades	NA	EONIA until CCPs switch, needs multilateral protocols with compensation schemes			€STR ongoing transition on bilateral basis, possible litigations		Done
13. Discount rate for uncollateralised trades	EONIA until CCPs switch				€STR ongoing transition on unilateral basis, needs clients communication, XVAs impacts [1]		€STR
14. EONIA legacy trades versus CCPs, Exchanges, and all other counterparties	To be defined						To be defined
15. Other issues	To be defined						

Legenda: **black** = sure events; **red** = events needing some assumption (see previous slide); orange background = transition phase; blue background = transition finished, situation at regime.

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**."*

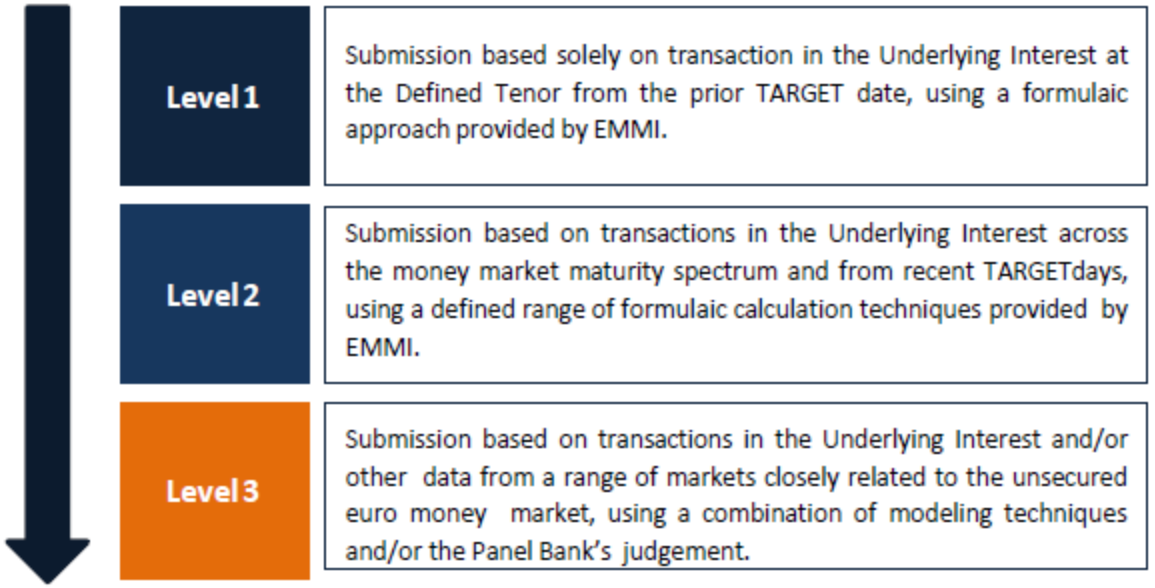
interbank	being offered	Prime Bank	at 11 AM
...the use of interbank transactions in the original Euribor specification reflects the structure of the money markets in the 1980s and 1990s when bank-to-bank activity was a predominant source of bank wholesale funding...	...the family of IBOR indices are 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" 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.	
wholesale	**borrowing**	**own cost of funds**	

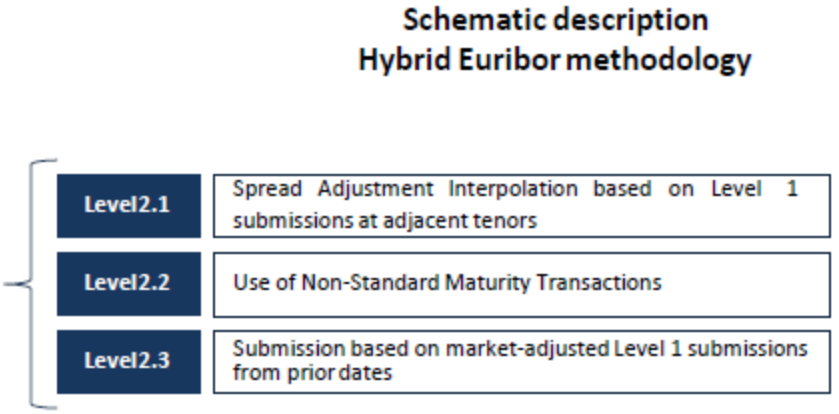
*"Euribor is a measure of the rate at which **wholesale funds** in euro could be **borrowed** by **credit institutions** in the EU and EFTA countries in the unsecured money market"*

Source: EMMI

2: Classic vs Modern Benchmark Rates
EURIBOR so far: methodology

- **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:



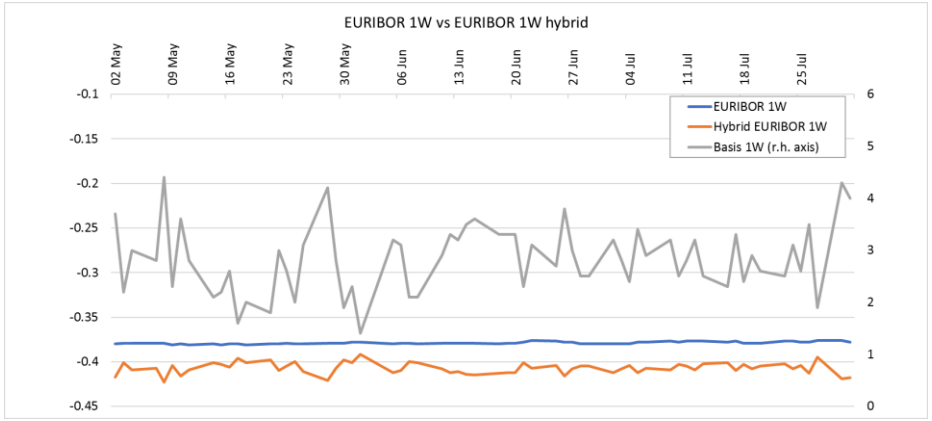


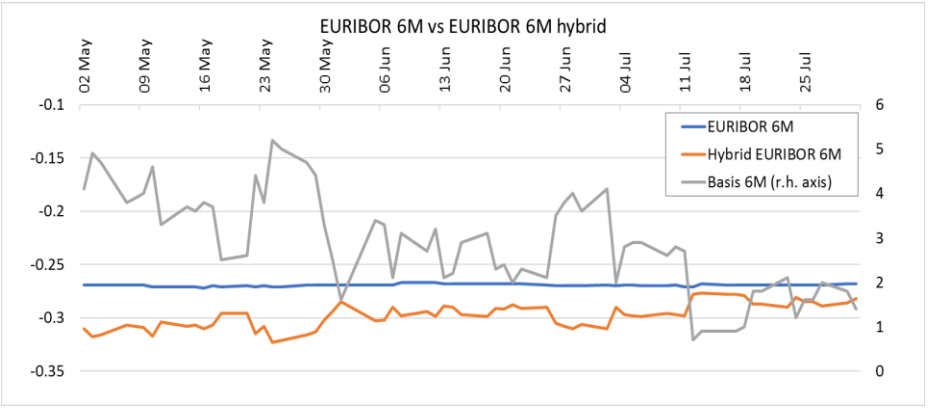
(source: EMMI)

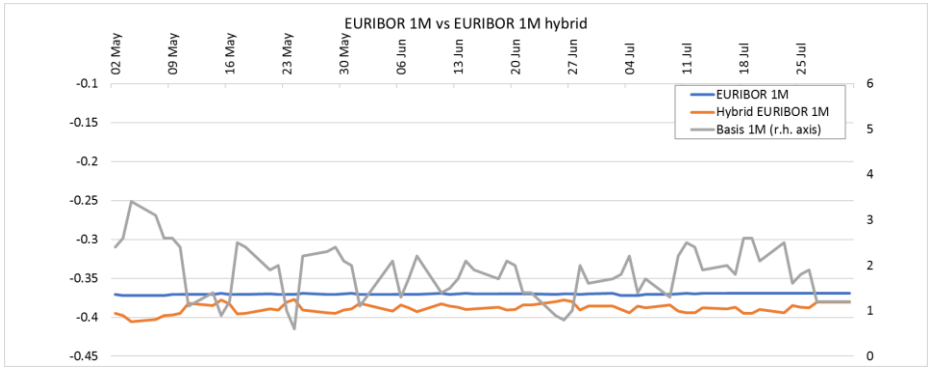
- EMMI conducted a test under live conditions from May to July 2018, finding **Hybrid Euribor lower than Euribor by 1-5 bps depending on the tenor 1M, 3M, 6M, 12M.**

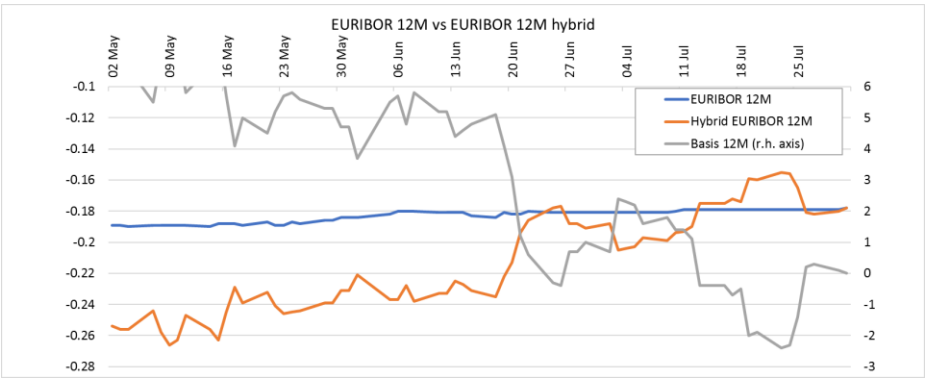
2: Classic vs Modern Benchmark Rates

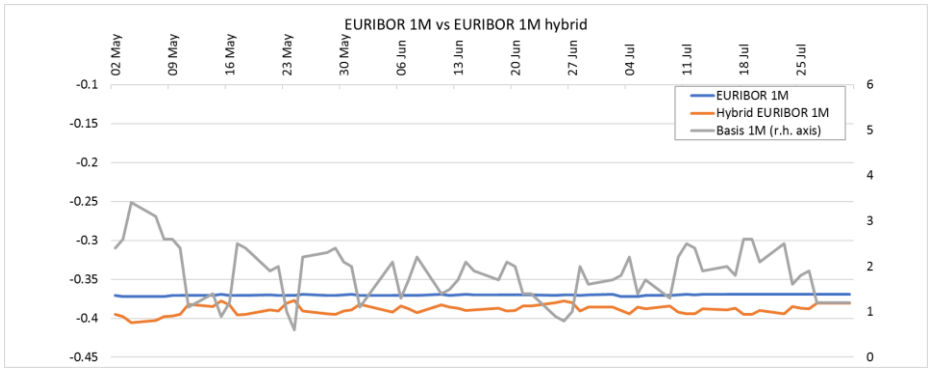
EURIBOR so far: basis







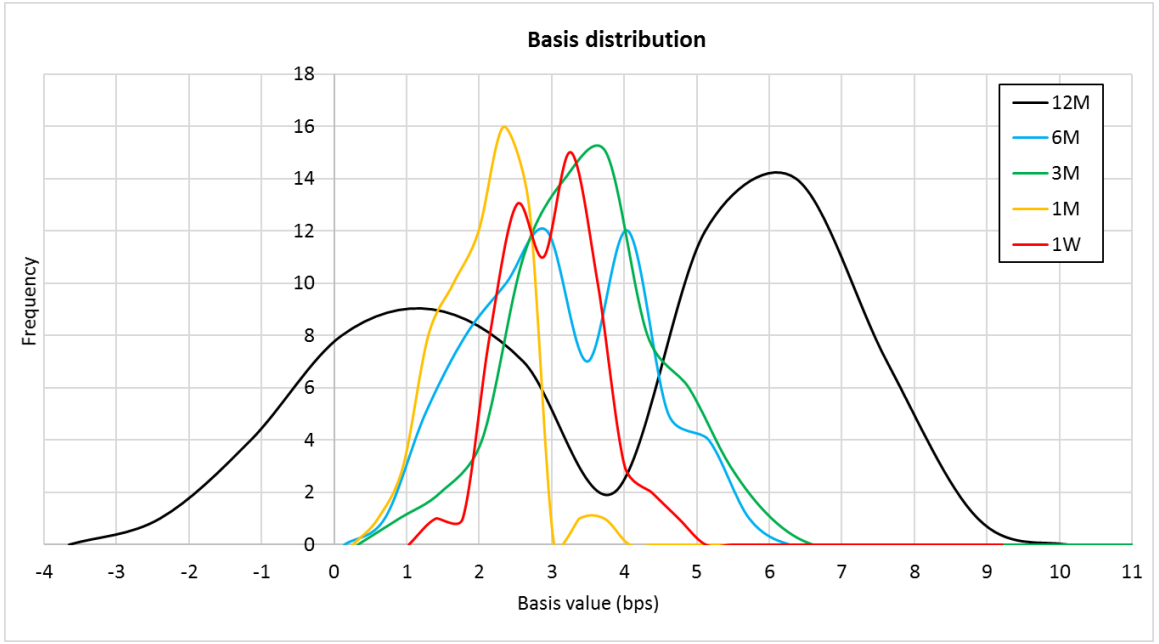




Data source: EMMI

2: Classic vs Modern Benchmark Rates

EURIBOR so far: basis



Basis Distribution Stats	Tenor 1W	1M	3M	6M	12M
Observations	65	65	65	65	65
EURIBOR					
Min	-0.381	-0.372	-0.329	-0.272	-0.190
Max	-0.376	-0.369	-0.319	-0.267	-0.178
Mean	-0.379	-0.370	-0.323	-0.269	-0.183
Std dev	0.001	0.001	0.002	0.001	0.004
Volatility of returns	1.6%	1.5%	1.1%	1.3%	1.5%
Hybrid EURIBOR					
Min	-0.423	-0.406	-0.378	-0.323	-0.266
Max	-0.392	-0.377	-0.330	-0.277	-0.155
Mean	-0.407	-0.389	-0.355	-0.298	-0.214
Std dev	0.006	0.006	0.011	0.012	0.032
Volatility of returns	13.2%	8.9%	10.4%	12.0%	12.9%
Correlation (w.r.t. EURIBOR)	-8.0%	13.8%	-4.2%	7.6%	20.3%
Basis					
Min	1.4	0.6	0.9	0.7	-2.4
Max	4.4	3.4	5.5	5.2	7.7
Mean	2.8	1.9	3.2	2.9	3.1
95° Percentile	4.1	2.6	5.0	4.8	7.3
Std dev	0.6	0.6	1.0	1.1	2.8
Volatility	13.4%	8.9%	10.5%	11.9%	12.7%

- 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

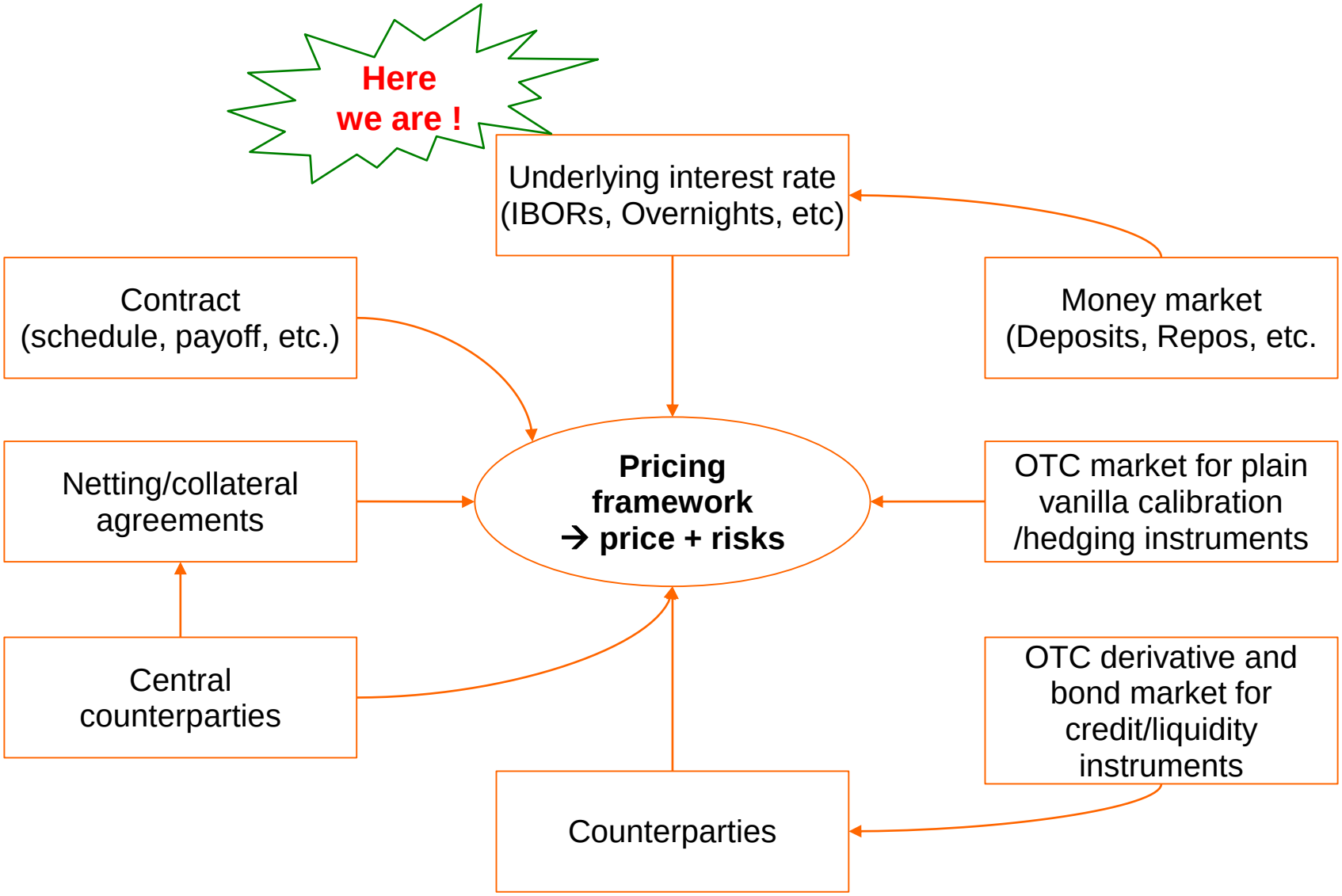
6. Conclusions

7. Appendix: funding spread

8. References

3: Pricing and Risk Management

Pricing financial instruments is a complex task



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),

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

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

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

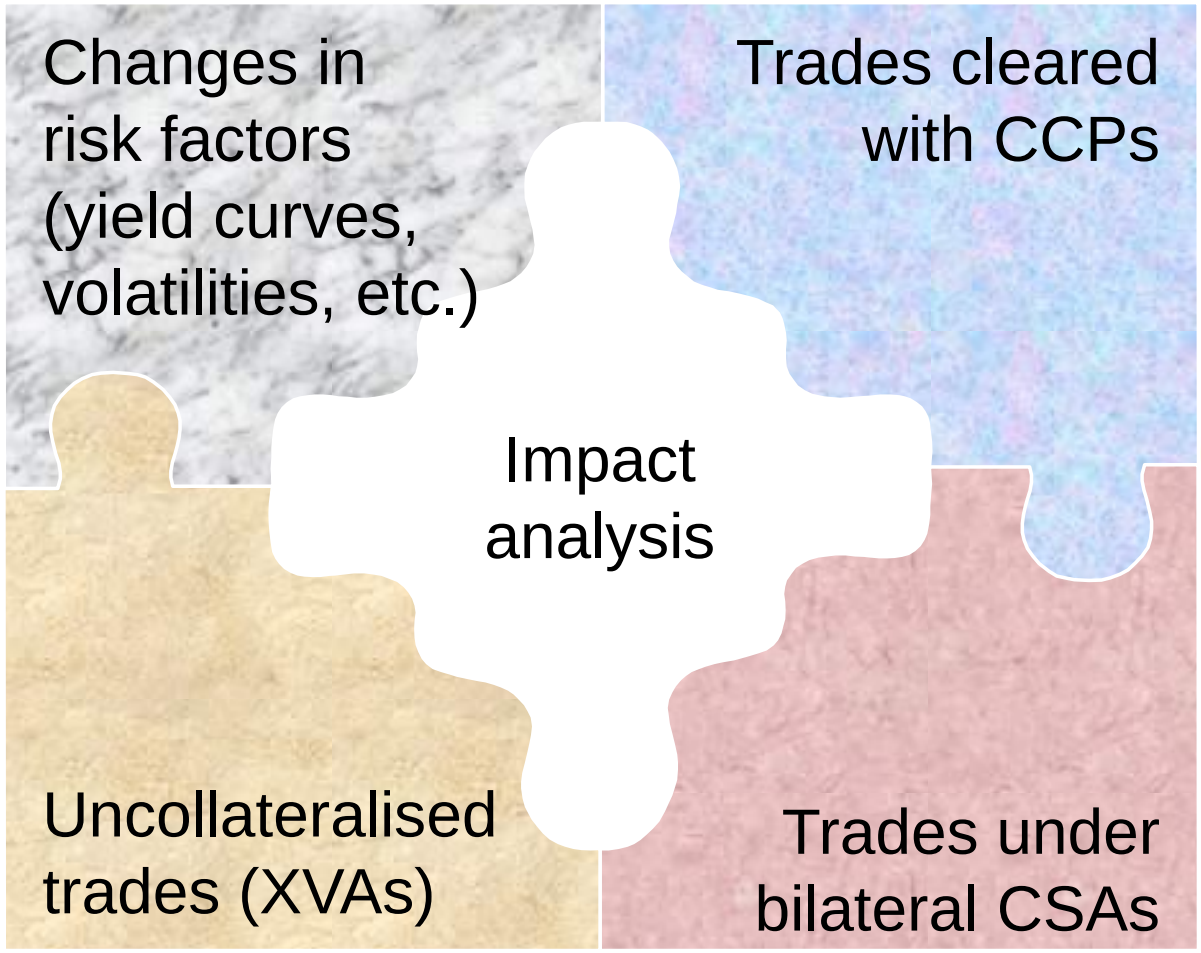
Possibly affected by
EONIA→ €STR transition

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

Possibly affected by
EONIA→ €STR transition
EURIBOR → Hybrid EURIBOR transition

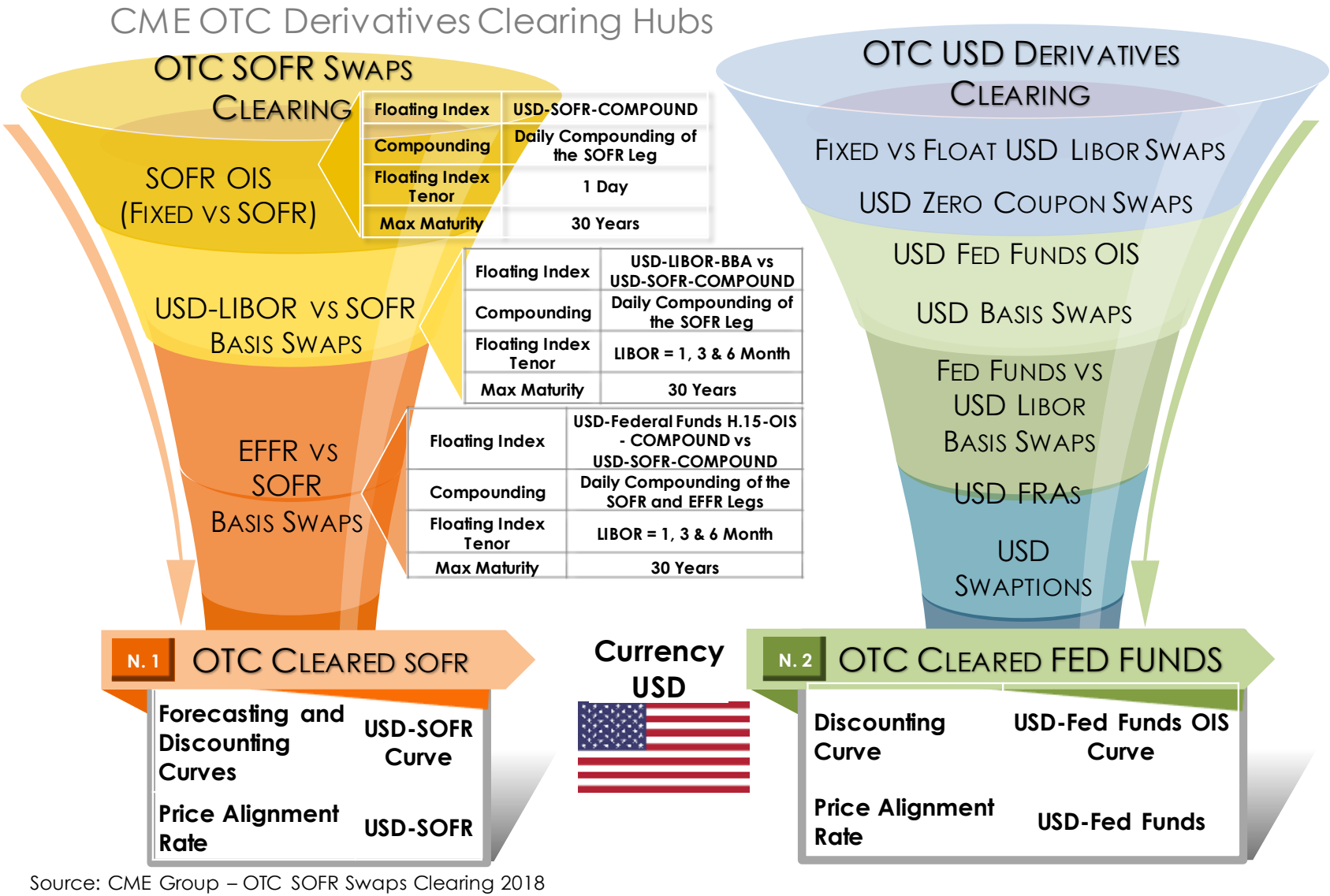
3: Pricing and Risk Management
Pricing impact analysis: overview [2/2]

Finding the pieces of the puzzle



3: Pricing and Risk Management

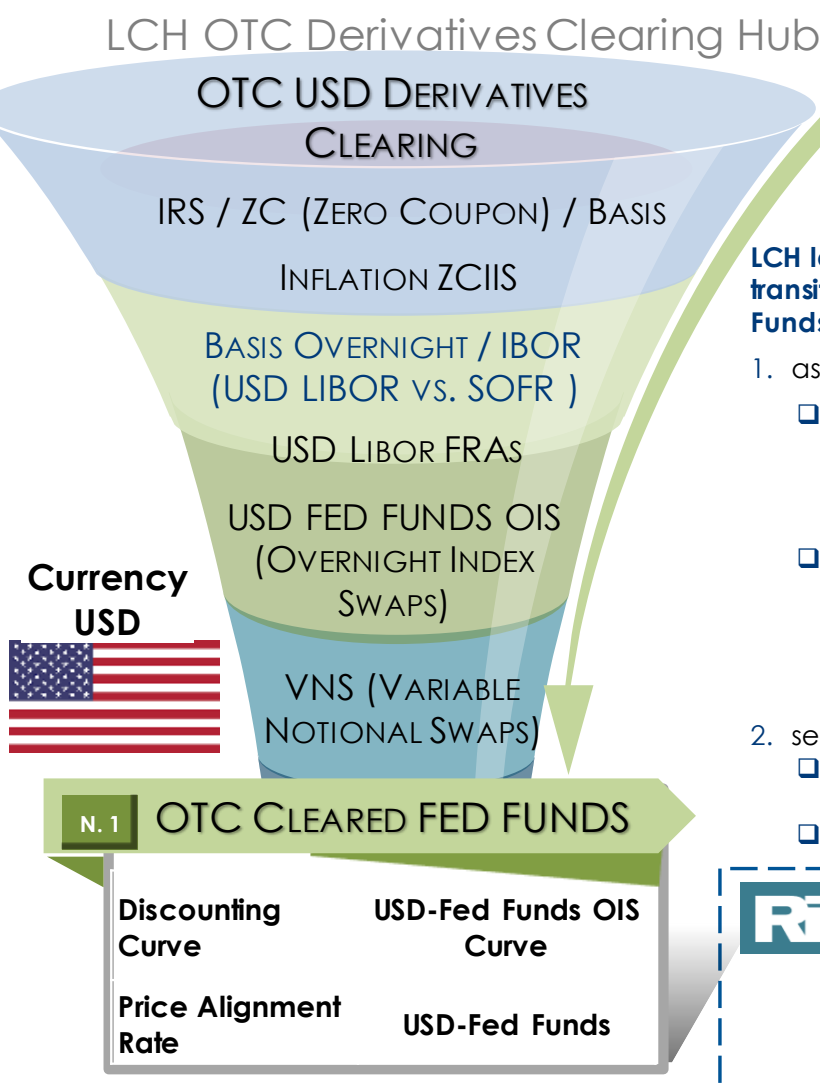
Pricing impact analysis: the fundamental role of CCPs [1/2]



Source: CME Group – OTC SOFR Swaps Clearing 2018

3: Pricing and Risk Management

Pricing impact analysis: the fundamental role of CCPs [2/2]



Source: LCH

LCH The Markets' Partner

Home / Membership / LTD Membership / LTD Member Updates / Consultation on transition to SOFR discounting

Consultation on transition to SOFR discounting

Tue, 06/11/2018

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.

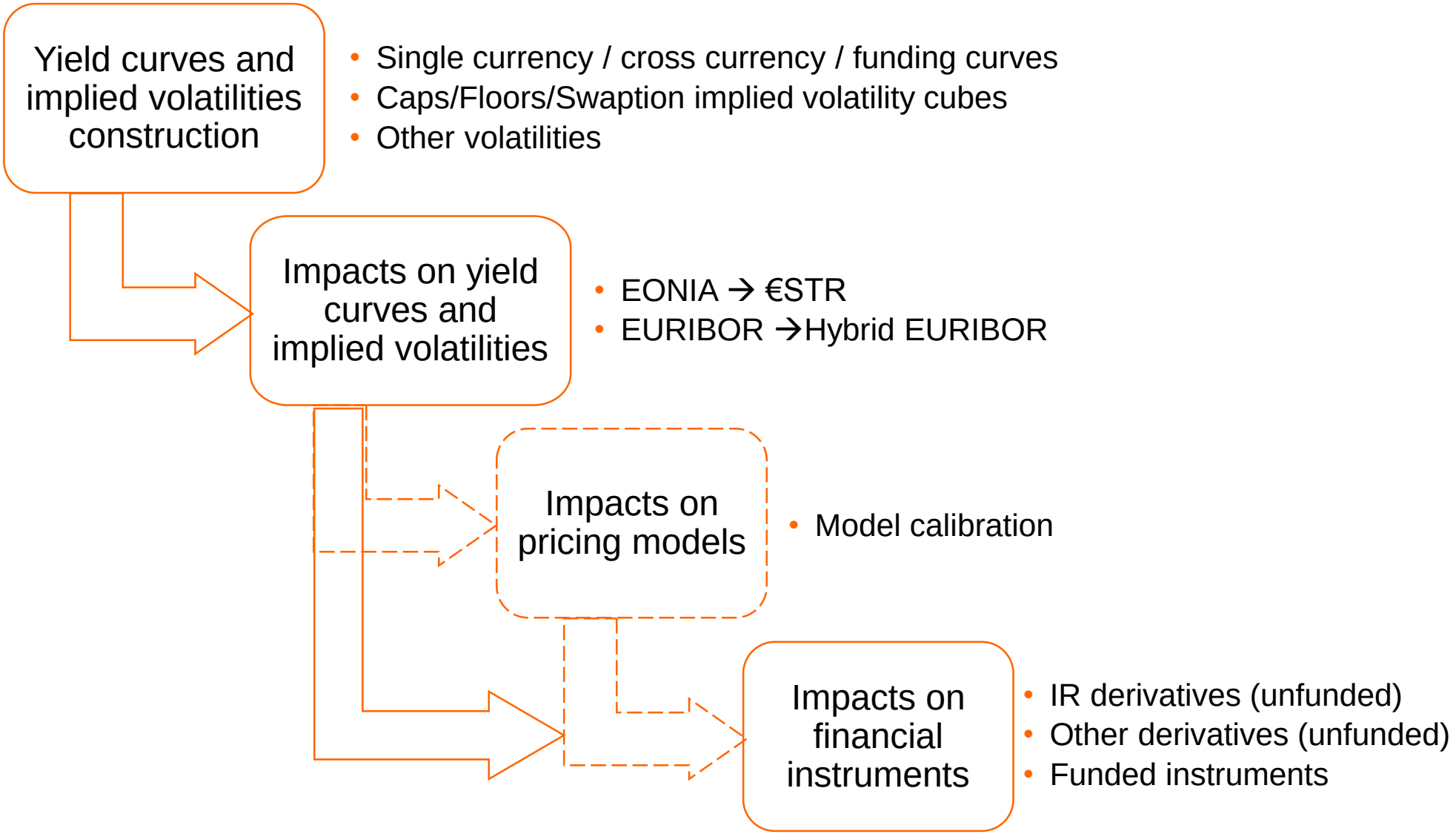
Risk.net

12 Feb 2019

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



3: Pricing and Risk Management
Pricing impact analysis: interest rate [1/5]

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

Yield curve	Comments
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]

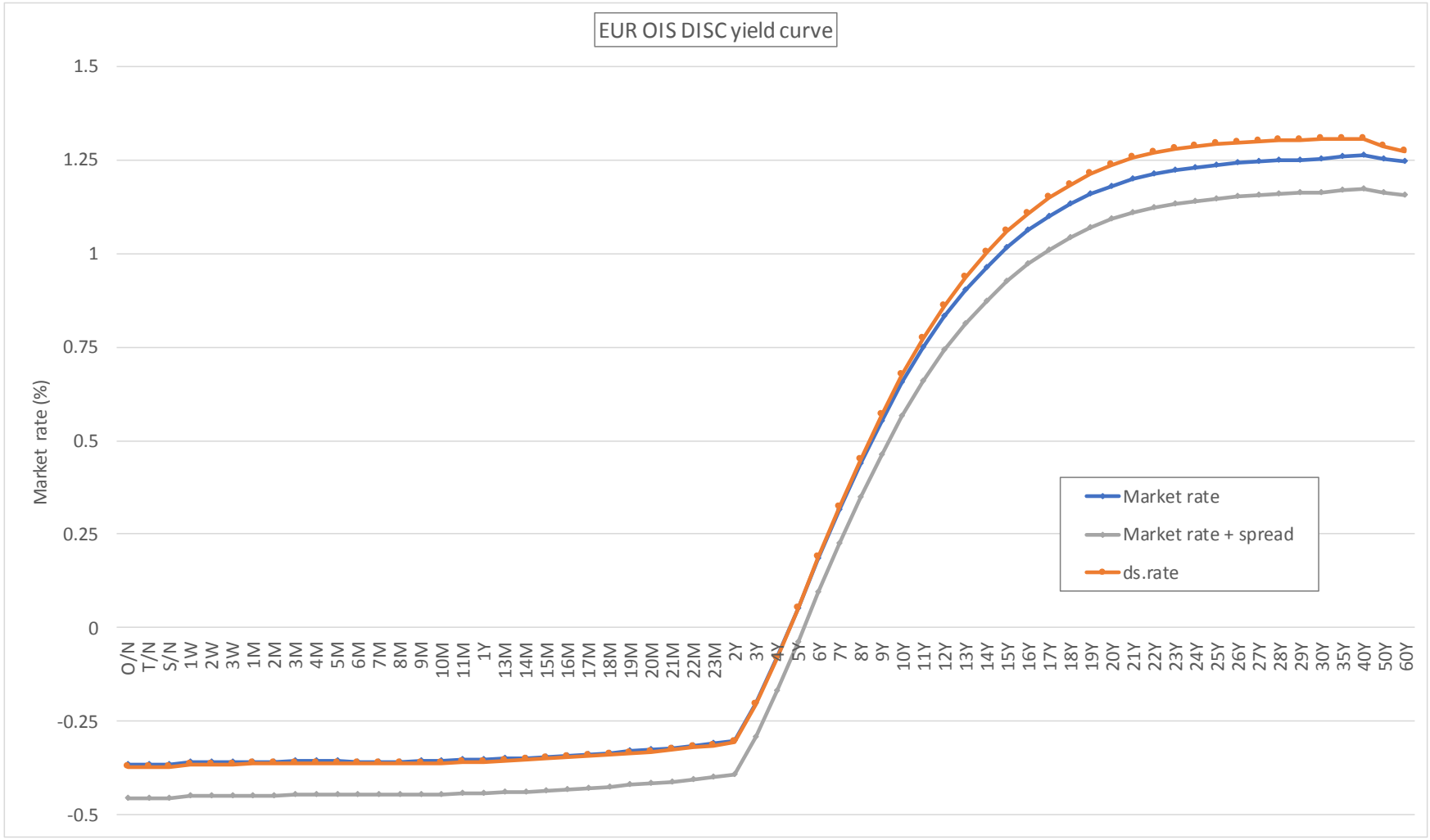
Accordingly, we may expect the following **impacts on yield curves** from EONIA→€STR and EURIBOR → Hybrid EURIBOR transitions.

Expected impacts on yield curves		As is	EONIA → ESTER transition	EURIBOR → Hybrid EURIBOR transition
EONIA OIS curve	Forwards	EONIA OIS	ESTER OIS	EONIA OIS
	Discounts	EONIA OIS	ESTER OIS	EONIA OIS
EURIBOR curves	Forwards	EURIBOR	EURIBOR (small)	Hyibrid EURIBOR
	Discounts	EURIBOR Std	EURIBOR Std (small)	Hybrid EURIBOR Std
EUR CCS basis curves (e.g. EURUSD)	Forwards	EURIBOR USDLIBOR	EURIBOR (small) USDLIBOR	Hybrid EURIBOR USDLIBOR CCS EURUSD basis
	Discounts	EONIA OIS EONIA CCS basis	ESTER OIS ESTER CCS Basis	EONIA OIS ESTER CCS Basis
Funding curves	Discounts	Benchmark bonds	Benchmark bonds	Benchmark bonds

Red = impacted quantities.

The impact of EONIA → €STR transition on forward rates is negligible.

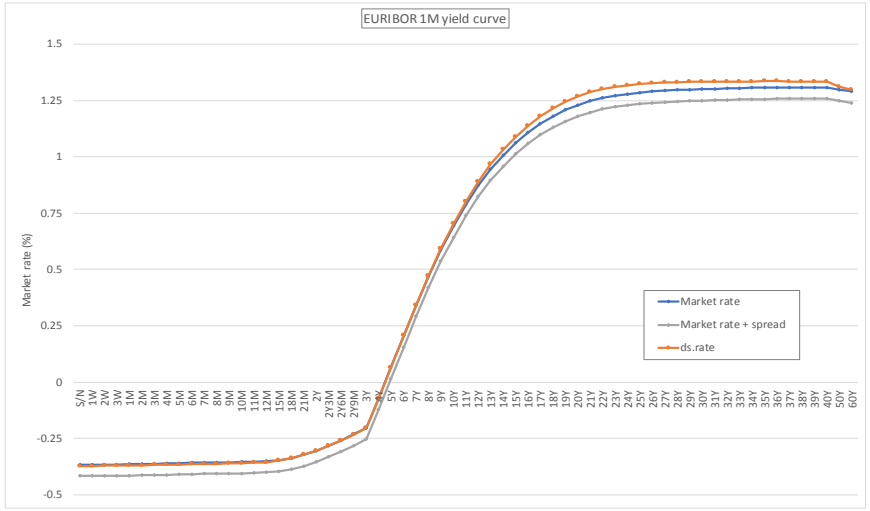
3: Pricing and Risk Management
Pricing impact analysis: interest rate [3/5]

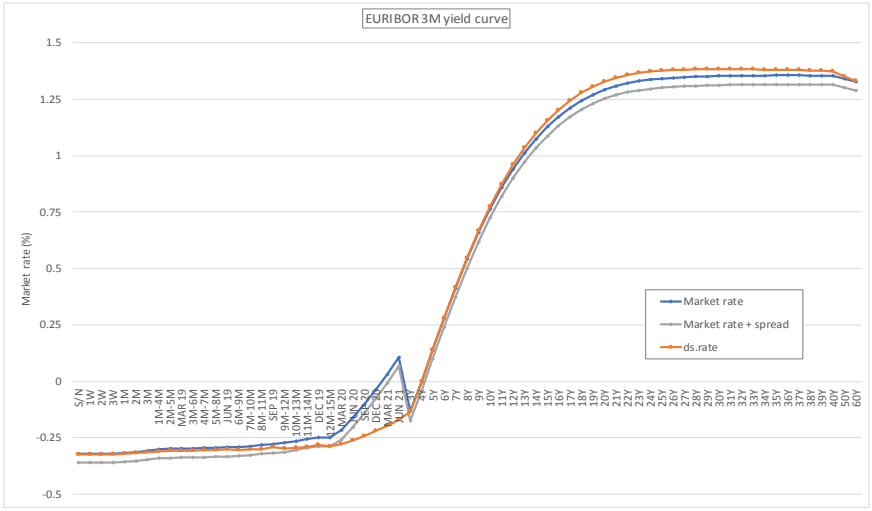


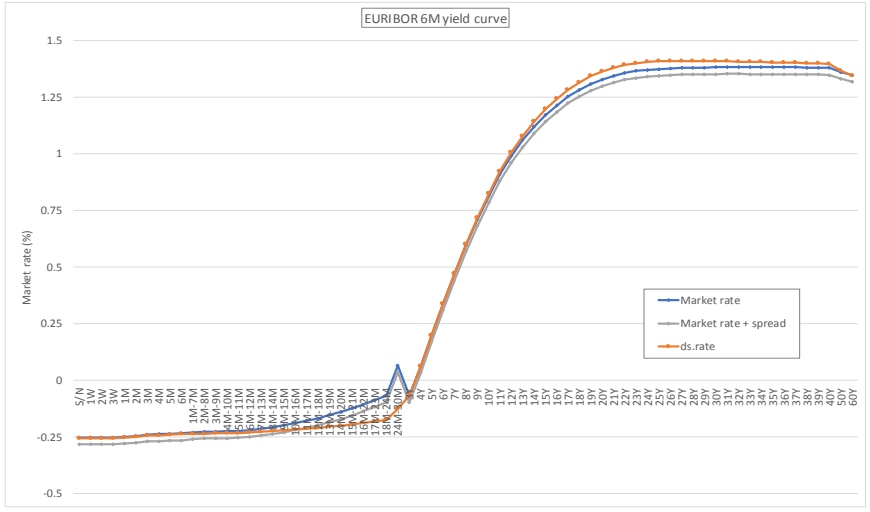
EONIA OIS yield curve as of EoY 2018 (blue), and expected EONIA → €STR transition impact of -9 bps on market rates (grey) (horizontal scale is non-linear).

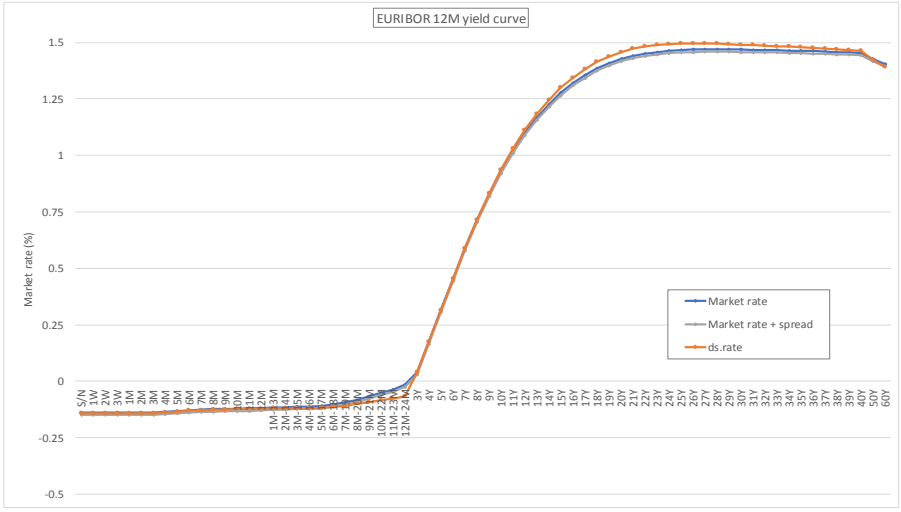
3: Pricing and Risk Management

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).

3: Pricing and Risk Management
Pricing impact analysis: interest rate [5/5]

Accordingly, we may expect the following **impacts on IR financial instruments** from EONIA→€STR and EURIBOR → Hybrid EURIBOR transitions.

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

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.

12:12 12APR19 ICAP UK69580 VCAP3A

EUR Caps/Floors - Shifted Black Volatilities

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STK	ATM	-0.75	-0.5	-0.25	-0.13	0.00	0.25	0.50	1.00	1.50	2.00	3.00	5.00	10.0
1Y	-0.3	4.48	5.6	3.1	5.6	7.3	8.8	11.1	13.1	16.3	18.9	21.0	24.6	30.0	42.1
18M	-0.3	5.30	5.3	4.3	6.0	7.4	8.7	10.6	12.2	14.8	16.9	18.6	21.4	25.5	32.3
2Y	-0.2	6.45	6.3	5.6	6.8	8.0	9.0	10.6	11.8	13.8	15.4	16.8	19.0	22.1	26.9
3Y	-0.1	8.87	8.9	8.0	7.9	8.7	9.6	10.7	11.5	12.8	13.7	14.6	15.9	18.1	21.6
4Y	-0.0	10.38	10.7	9.6	9.2	9.8	10.5	11.4	12.0	12.9	13.7	14.4	15.5	17.2	19.9
5Y	0.08	11.47	11.9	10.7	10.2	10.7	11.2	11.9	12.5	13.3	13.9	14.5	15.6	17.2	19.8
6Y	0.17	12.24	12.7	11.6	11.0	11.4	11.8	12.4	12.8	13.5	14.0	14.6	15.5	16.9	19.2
7Y	0.28	12.71	13.3	12.2	11.6	11.9	12.2	12.7	13.0	13.5	13.9	14.3	15.0	16.2	18.1
8Y	0.38	13.02	13.7	12.7	12.1	12.3	12.5	12.9	13.1	13.5	13.7	14.0	14.5	15.4	17.0
9Y	0.48	13.14	14.1	13.0	12.4	12.5	12.7	13.0	13.2	13.4	13.5	13.7	14.0	14.7	16.1
10Y	0.57	13.22	14.3	13.3	12.7	12.8	12.9	13.1	13.2	13.3	13.4	13.4	13.6	14.1	15.4
12Y	0.73	13.26	14.7	13.8	13.1	13.2	13.2	13.3	13.3	13.2	13.2	13.1	13.1	13.3	14.1
15Y	0.91	13.08	14.9	14.0	13.4	13.4	13.4	13.3	13.2	13.0	12.9	12.7	12.5	12.5	12.9
20Y	1.07	12.75	14.9	14.2	13.6	13.5	13.4	13.3	13.1	12.8	12.5	12.3	12.0	11.8	11.9
25Y	1.13	12.56	14.9	14.2	13.7	13.5	13.4	13.2	13.0	12.7	12.4	12.1	11.8	11.5	11.6
30Y	1.14	12.42	14.9	14.2	13.7	13.5	13.4	13.1	12.9	12.5	12.2	12.0	11.6	11.3	11.3

Shift = 3.00% 1y,18m and 2y vs 3m, 3y and above vs 6m

3: Pricing and Risk Management
Pricing impact analysis: interest rate Cap/Floor volatility [2/4]

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.

Expected impacts of EONIA → €STR transition	As is	Scenario 1: Constant Term Volatility	Scenario 2: Constant Premium
Term volatility (normal)	Market quotes	Market quotes	Market quotes
Cap/Floor premium	Black formula (EONIA OIS discounting)	Black formula (€STR OIS discounting)	Black formula (EONIA OIS discounting)
Forward volatility	Inverted Black formula (EONIA OIS discounting)	Inverted Black formula (€STR OIS discounting)	Inverted Black formula (€STR OIS discounting)

3: Pricing and Risk Management
Pricing impact analysis: interest rate Cap/Floor volatility [3/4]

Accordingly, we may expect the following impacts on market data and financial instruments.

Expected impacts of EONIA → €STR transition	Scenario 1: Constant Term Volatility	Scenario 2: Constant Premium
Impacted market data	▪ ESTER discounting ▪ EURIBOR forwards (small) ▪ Term volatilities ▪ Cap/Floor premia (small) ▪ Forward volatilities (small)	▪ ESTER discounting ▪ EURIBOR forwards (small) ▪ Term volatilities ▪ Cap/Floor premia ▪ Forward volatilities (small)
Impacted financial instruments	▪ Caps/Floors plain vanilla/digital ▪ 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). ▪ 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.

3: Pricing and Risk Management
Pricing impact analysis: interest rate Cap/Floor volatility [4/4]

Regarding the EURIBOR → Hybrid EURIBOR transition, there are two possible scenarios, depending on the behavior of the volatility.

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

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.

12:13 12APR19 ICAP VCAP2P

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

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	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	15Y	20Y	25Y	30Y
1M Opt	2.0	6.5	13.5	20.5	28.5	36.0	44.0	53.5	62.5	71.0	109	149	182	211
2M Opt	3.5	10.0	20.0	31.5	44.0	56.5	69.0	82.0	95.0	107	166	224	275	318
3M Opt	4.5	12.5	25.0	39.0	53.5	69.5	85.5	102	117	135	206	275	337	396
6M Opt	6.5	19.0	37.0	58.0	81.0	105	128	151	175	200	302	400	489	568
9M Opt	10.0	26.5	49.5	76.0	104	131	160	188	217	249	369	486	596	701
1Y Opt	14.5	35.0	63.0	94.0	126	158	193	225	257	294	434	574	702	820
18M Opt	22.5	52.5	90.0	130	171	213	255	294	333	375	548	714	869	1017
2Y Opt	32.0	70.0	117	164	212	262	309	356	402	446	649	843	1021	1187
3Y Opt	49.0	104	165	228	290	353	411	468	525	581	823	1059	1274	1482
4Y Opt	66.5	136	210	284	361	432	502	575	644	708	985	1252	1498	1739
5Y Opt	83.0	165	251	336	424	507	588	669	747	821	1127	1428	1704	1979
7Y Opt	108.5	216	323	429	533	634	731	826	921	1013	1376	1741	2076	2411
10Y Opt	138.5	272	402	531	657	778	897	1012	1123	1240	1688	2135	2538	2953
15Y Opt	168.0	329	487	639	785	934	1074	1211	1351	1492	2045	2581	3079	3555
20Y Opt	186.5	365	543	712	881	1052	1212	1373	1531	1680	2324	2883	3425	3939
25Y Opt	199.0	394	584	765	945	1122	1292	1458	1627	1788	2482	3058	3633	4179
30Y Opt	207.5	411	609	802	991	1173	1346	1508	1672	1837	2561	3154	3748	4322

3: Pricing and Risk Management

Pricing impact analysis: interest rate Swaption volatility

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.

Expected impacts	As is	EONIA → ESTER transition	EURIBOR → Hybrid EURIBOR transition
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	

3: Pricing and Risk Management
Pricing impact analysis: other financial instruments

The impacts on other finacial instrumenst 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 – ΔEVE.
- 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 Effectivness Test.

Liquidity Risk

- Analysis of the expected changes in the shift sensitivities – ΔEVE.
- 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 Effectivness 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.

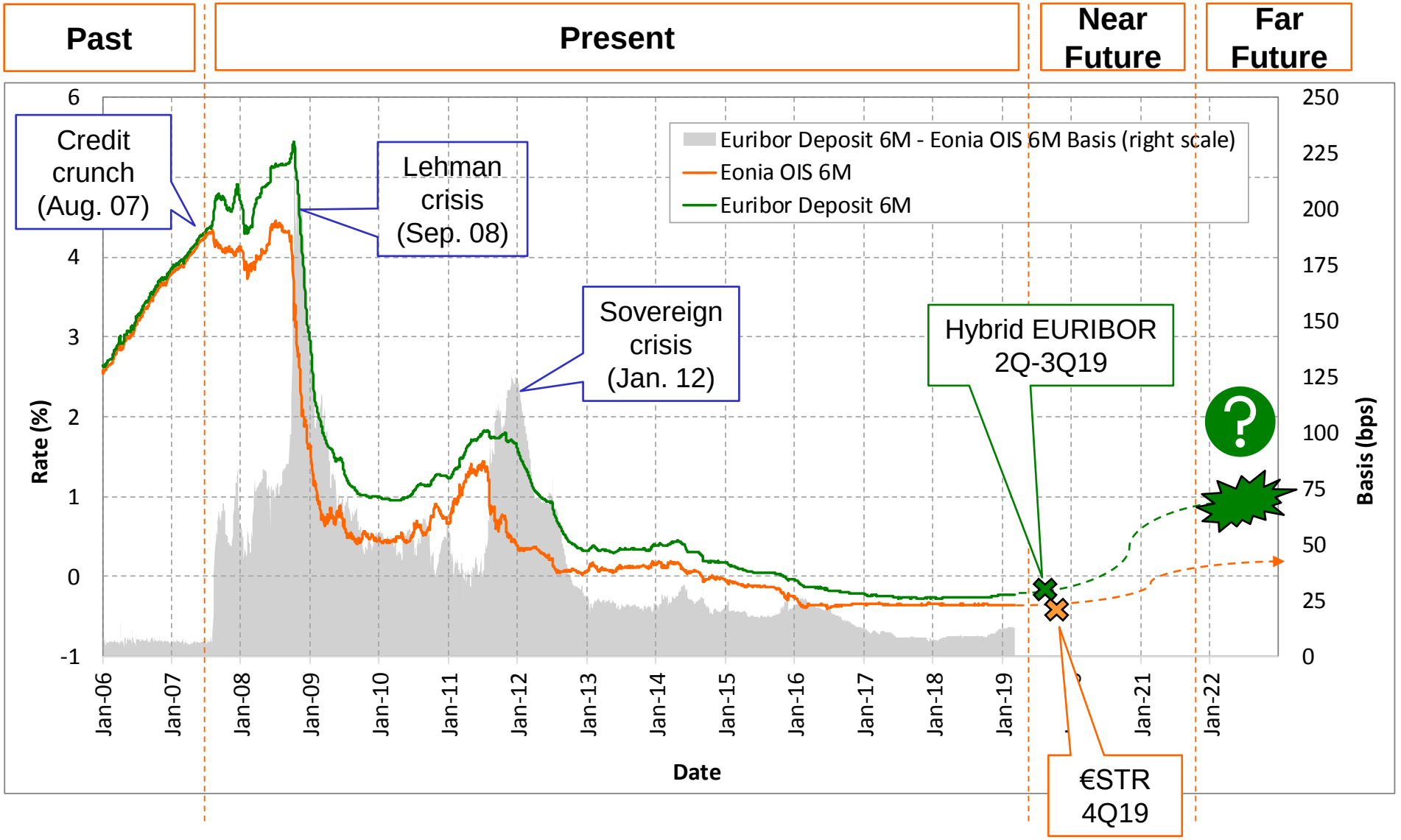
Counterparty Credit Risk

- 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 absorbtion and internal limits on Credit Portfolio and CVA VaR

Summary

4: Bye Bye Multi-Curves ?

Past, present, and possible futures [1/3]



4: Bye Bye Multi-Curves ?
Past, present, and possible futures [2/3]

	Past	Present	Near Future (nearly certain)	Far Future (uncertain)
Yield curves (single currency	▪ EURIBOR ▪ Funding	▪ OIS ▪ EURIBOR 1M ▪ EURIBOR 3M ▪ EURIBOR 6M ▪ EURIBOR 12M ▪ Bases ▪ Funding	▪ €STR ▪ OIS ▪ EURIBOR 1M ▪ EURIBOR 3M ▪ EURIBOR 6M ▪ EURIBOR 12M ▪ More bases ▪ Funding	
CCS basis yield curves	▪ Many CCS	▪ Many CCS	▪ Many CCS	
Cap/Floor Volatilities	▪ EURIBOR	▪ EURIBOR 1M ▪ EURIBOR 3M ▪ EURIBOR 6M ▪ EURIBOR 12M	▪ EURIBOR 1M ▪ EURIBOR 3M ▪ EURIBOR 6M ▪ EURIBOR 12M	
Swaption volatilities	▪ EURIBOR	▪ EURIBOR 3M ▪ EURIBOR 6M	▪ EURIBOR 3M ▪ EURIBOR 6M	

4: Bye Bye Multi-Curves ?
Past, present, and possible futures [2/3]

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

(per currency)

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

Once upon a time, there was an ancient financial world,
with many many interest rates and volatilities…

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?

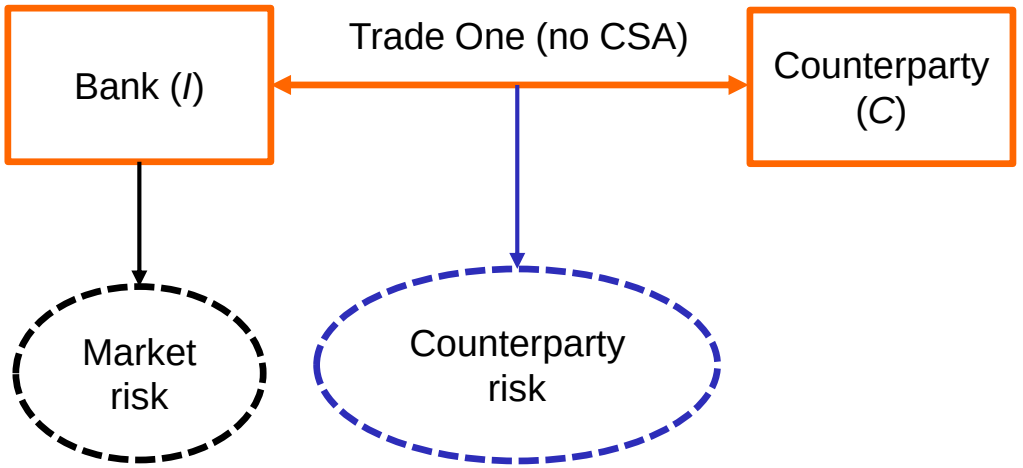
5. Focus on XVAs

6. Conclusions

7. Appendix: funding spread

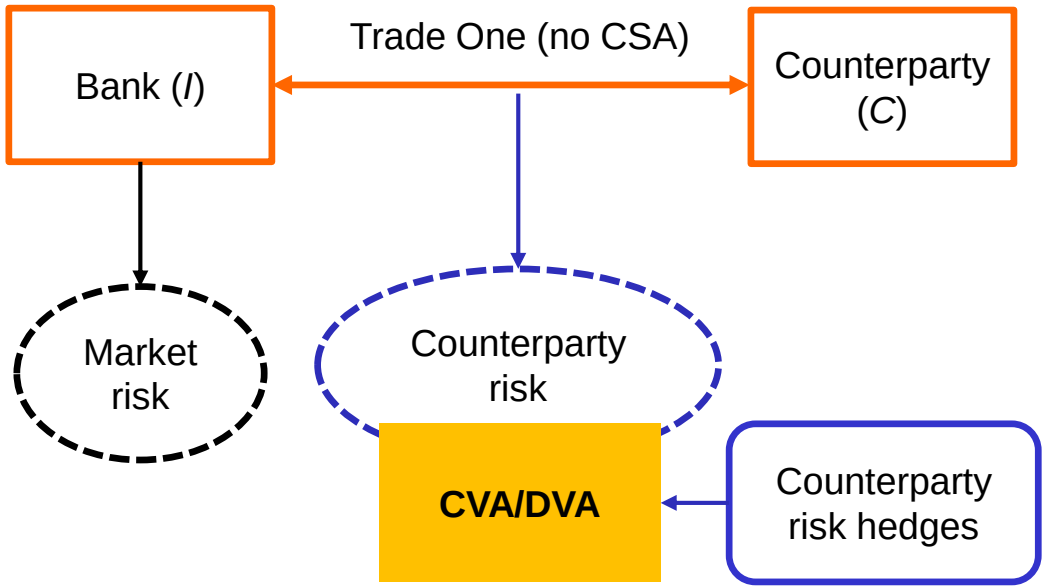
8. References

5: Focus on XVAs
Overview [1/4]

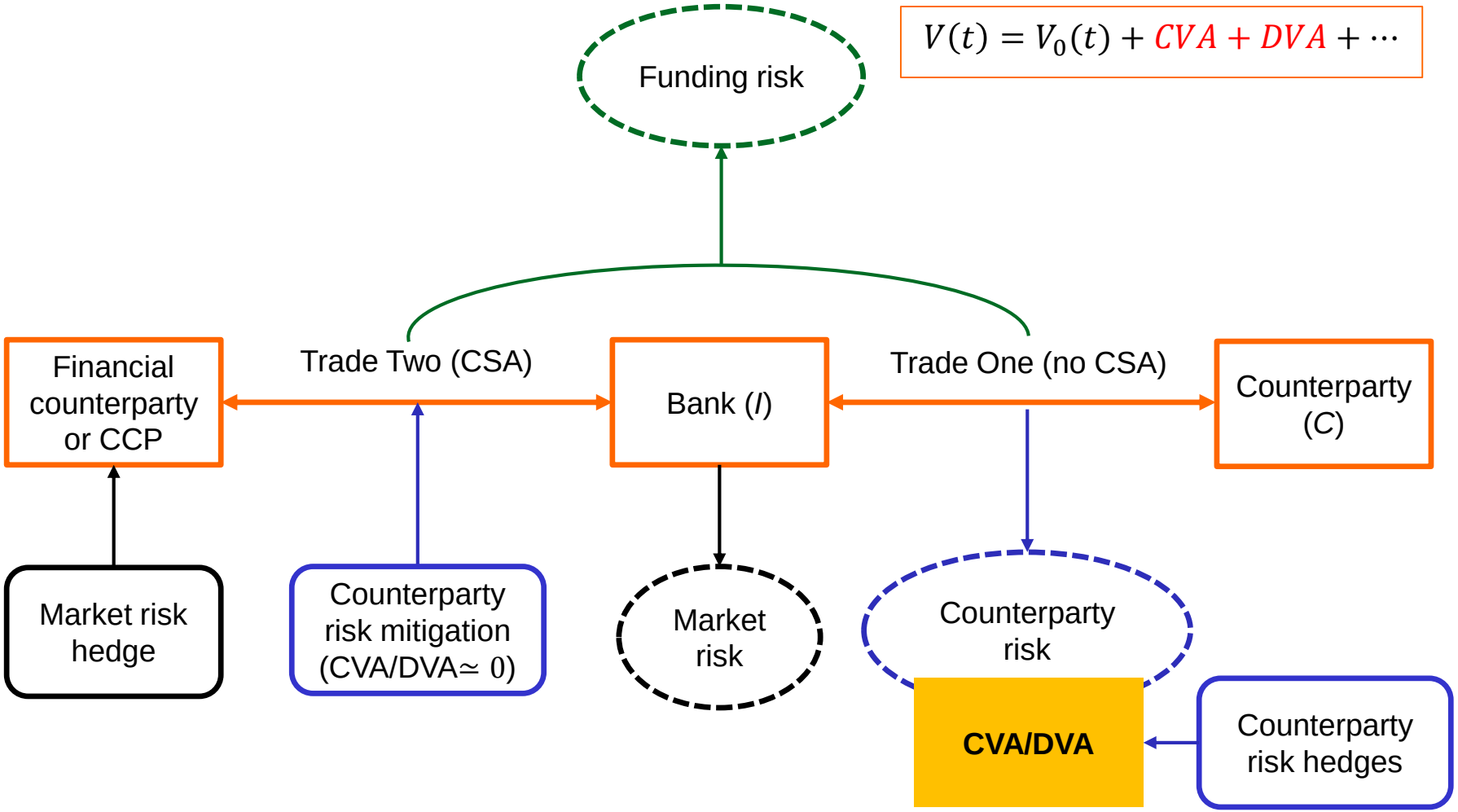


5: Focus on XVAs
Overview [2/4]

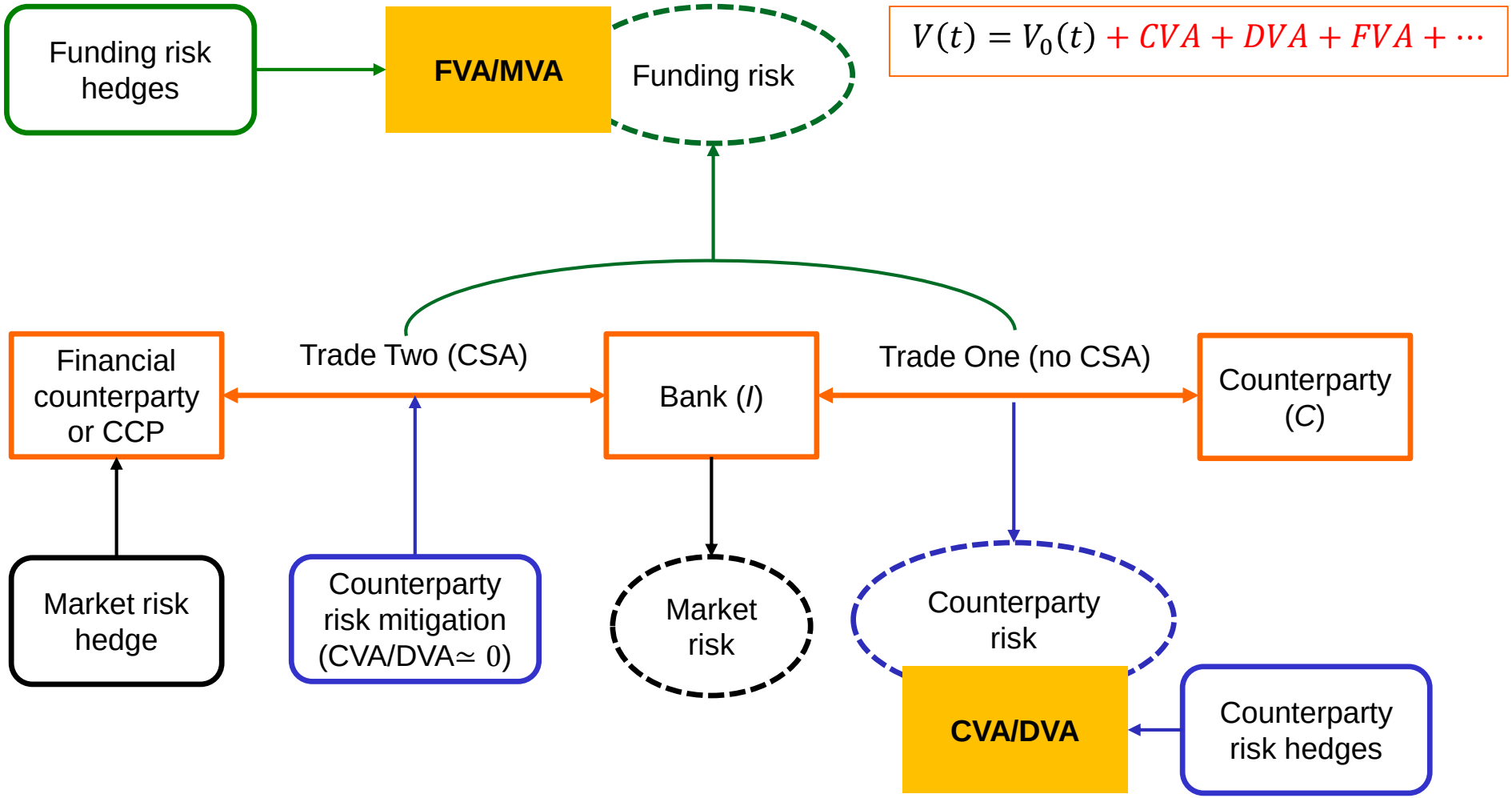
$$V(t) = V_0(t) + CVA + DVA + \cdots$$



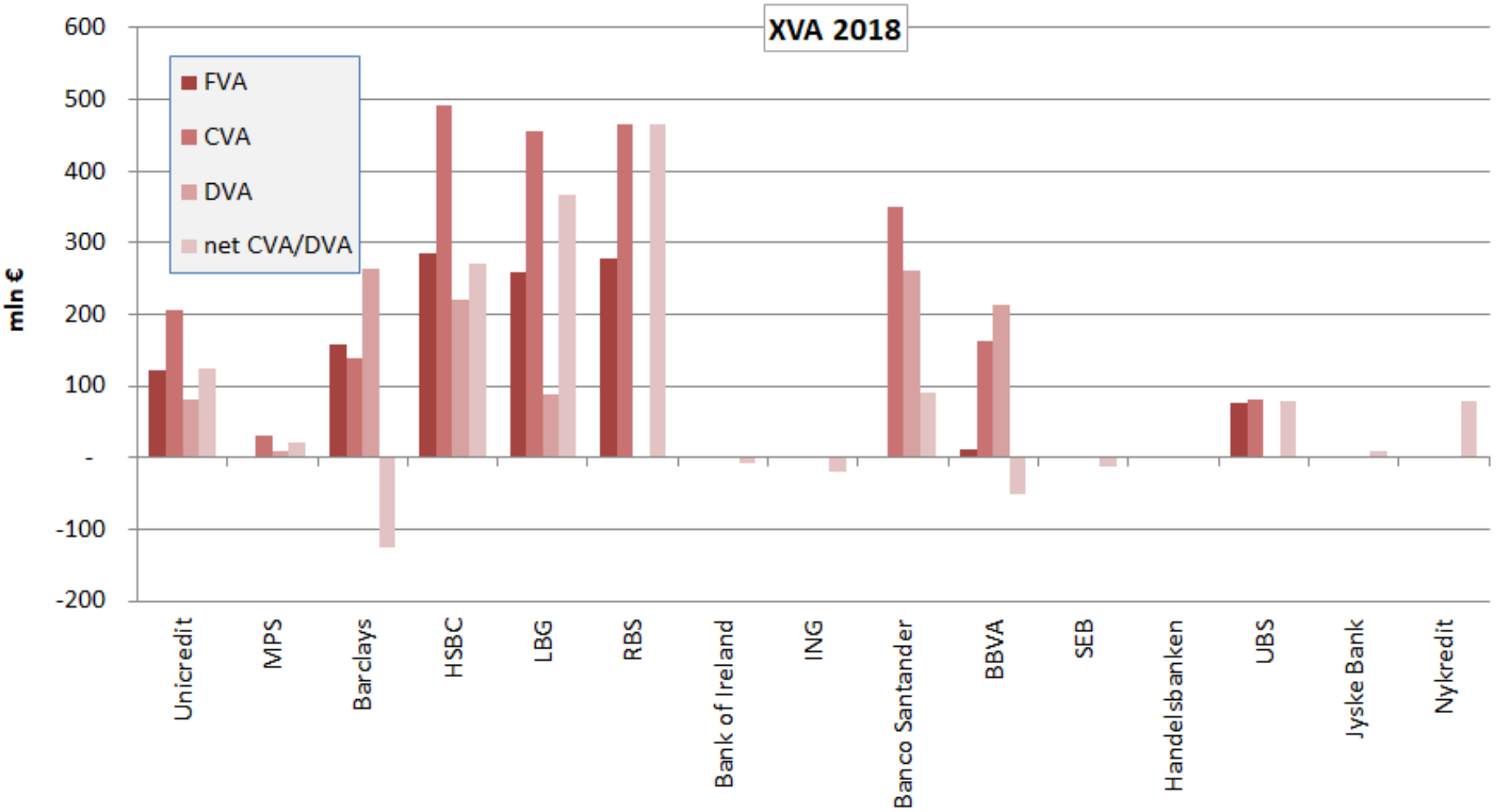
5: Focus on XVAs
Overview [3/4]



5: Focus on XVAs
Overview [4/4]

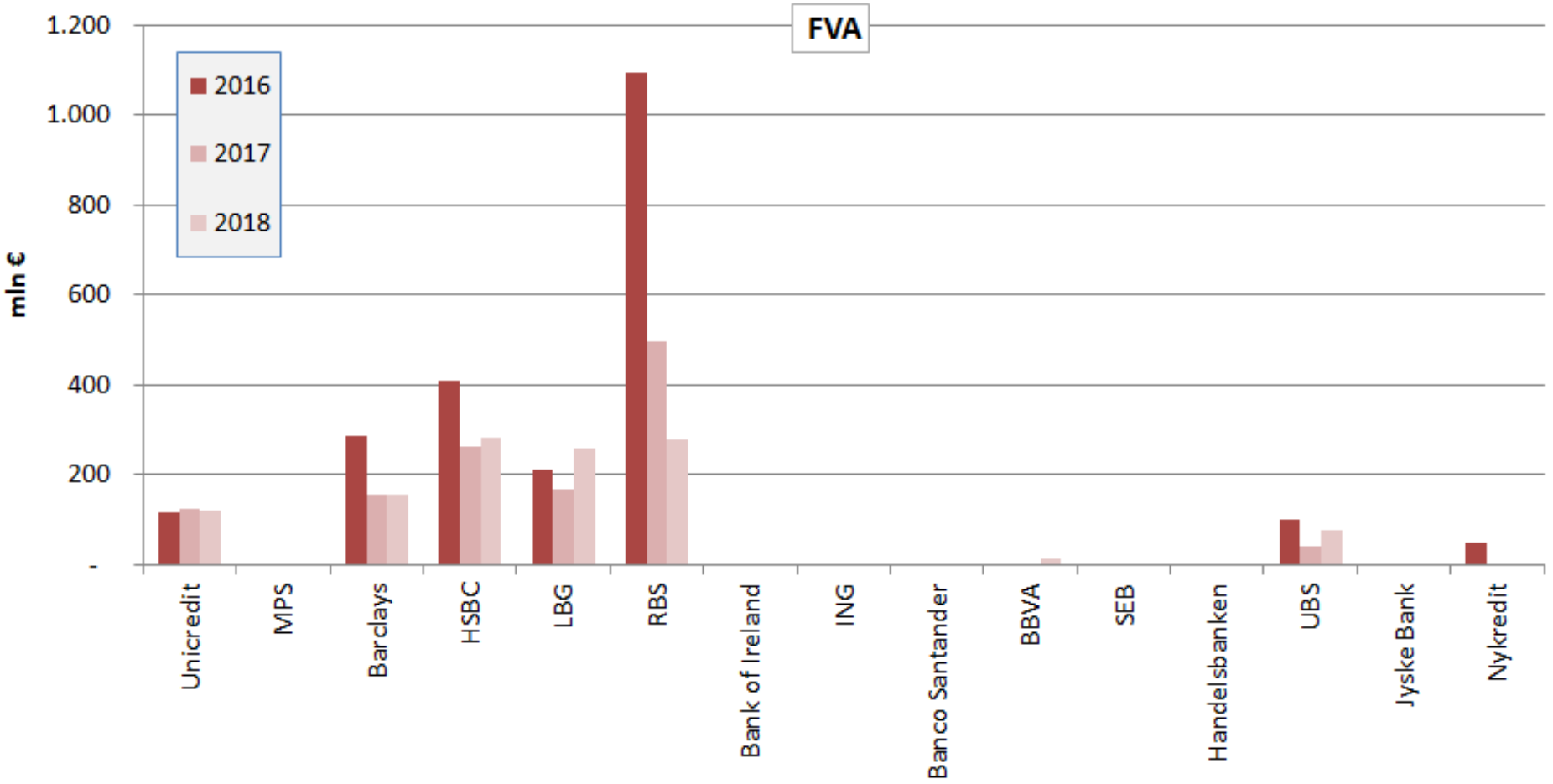


5: Focus on XVAs
Overview: international benchmarking [1/2]



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

XVA formulas	
CVA	$CVA_C(t) = -LGD_C(t)\int_t^T \mathbb{E}_t^{\mathbb{Q}}[D(t,u)[V(u) - \mathcal{C}_C(u)]^+]S_I(t,u)dQ_C(t,u) \leq 0$
DVA	$DVA_C(t) = -LGD_I(t)\int_t^T \mathbb{E}_t^{\mathbb{Q}}[D(t,u)[V(u) - \mathcal{C}_C(u)]^-]S_C(t,u)dQ_I(t,u) \geq 0$
FVA	$FVA(t) = -\int_t^T \mathbb{E}_t^{\mathbb{Q}}\left[D(t,u)\left(\sum_{C=1}^{N_C}[V(u) - \mathcal{C}_C(u)]S_C(t,u)\right)^+ fs_I(u)\right]S_I(t,u)du \leq 0$
MVA	$MVA_C(t) = -\int_t^T \mathbb{E}_t^{Q}[D(t,u)IM_C(u)fs_I(u)]S_I(t,u)du \leq 0$

€STR / Hybrid EURIBOR Forwarding Curves

€STR Discounting Curve

Exposure $V(u)$

Volatilities

Discount factor $D(t,u)$

Survival probabilities $S_x(t,u)$
Marginal default probabilities $dQ_x(t,u)$

Funding spread $fs_I(u)$

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 Valutation Adjustment (DVA) for I is zero.
- We suppose that the counterparty is default-free → also the Credit Valutation Adjustment (CVA) for I is zero.
- → The fair value of the trade is given by

$$V(t) = \mathrm{V}_0(t) + FVA(t) = P_d(t,T)\, C + FVA(t)$$

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,

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

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

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

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

- 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 $\tau_I > t$)

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

5: Focus on XVAs
Defaultable Zero Coupon Bond [2]

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

$$\mathcal{R}(t) = RP_d(t,T) \qquad 0 \leq R \leq 1$$

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

$$P_I(t,T) = P_d(t,T)\left(1-(1-R)(1-S_I(t,T))\right)$$

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

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

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

where $H_c(u)$ is the total exposure relative to the counterparty c in the funding set $\{1,\dots,N\}$ 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

$$
\begin{aligned}
\mathrm{FVA}(t) &= -\mathbb{E}_t^{\mathbb{Q}} \left\{ \int_t^T D(t,u) \left[\mathbb{E}_u^{\mathbb{Q}} \left[D(u,T) \mathcal{C} \right] \right]^+ s_I(u) \mathbb{1}_{\{\tau_I > u\}} du \right\} \\
&= -\mathcal{C}\, \mathbb{E}_t^{\mathbb{Q}} \left\{ \int_t^T D(t,u) \left[P_d(u,T) \right]^+ s_I(u) \mathbb{1}_{\{\tau_I > u\}} du \right\} \\
&= -\mathcal{C} \int_t^T \mathbb{E}_t^{\mathbb{Q}} \left\{ D(t,u) P_d(u,T) s_I(u) \mathbb{1}_{\{\tau_I > u\}} \right\} du \\
&= -\mathcal{C} \int_t^T \mathbb{E}_t^{\mathbb{Q}} \left\{ D(t,u) P_d(u,T) \right\} \mathbb{E}_t^{\mathbb{Q}} \left\{ s_I(u) \mathbb{1}_{\{\tau_I > u\}} \right\} du \\
&= -\mathcal{C} \int_t^T s_I(u) \mathbb{E}_t^{\mathbb{Q}} \left\{ e^{-\int_t^u r(s) ds} \mathbb{E}_u^{\mathbb{Q}} \left\{ e^{-\int_u^T r(s) ds} \right\} \right\} \mathbb{E}_t^{\mathbb{Q}} \left\{ \mathbb{1}_{\{\tau_I > u\}} \right\} du \\
&= -\mathcal{C} \int_t^T s_I(u) \mathbb{E}_t^{\mathbb{Q}} \left\{ \mathbb{E}_u^{\mathbb{Q}} \left\{ e^{-\int_t^T r(s) ds} \right\} \right\} S_I(t,u)\, du
\end{aligned}
$$

5: Focus on XVAs
XVA impact [2]

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

$$\mathrm{FVA}(t) = -\mathcal{C}P_d(t,T)\int_t^T s_I(u)S_I(t,u)du$$

- 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

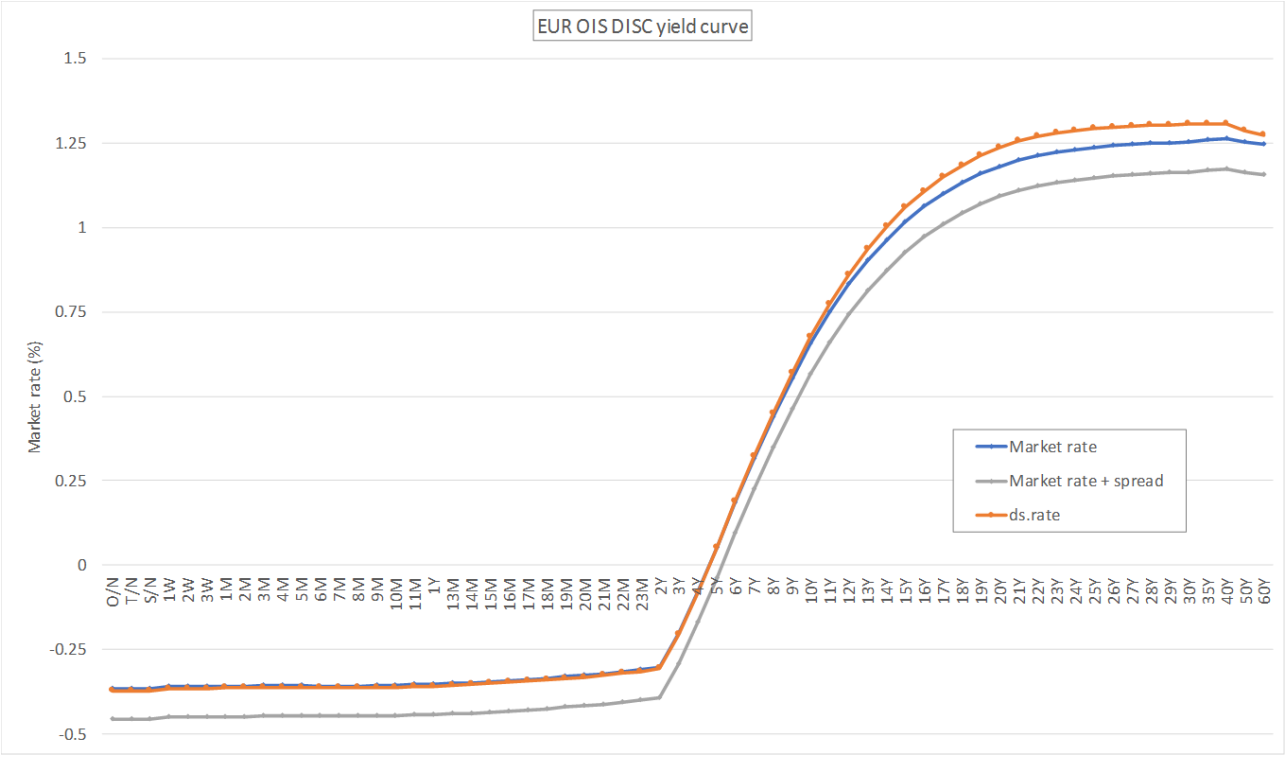
$$\begin{aligned}
\mathrm{FVA}(t) &= -(1-R)\mathcal{C}P_d(t,T)\int_t^T \left[-\frac{\partial_u S_I(t,u)}{S_I(t,u)}\right] S_I(t,u)du \\
&= (1-R)\mathcal{C}P_d(t,T)\int_t^T \partial_u S_I(t,u)du \\
&= (1-R)\mathcal{C}P_d(t,T)[S_I(t,T)-1] \\
&= \mathcal{C}P_d(t,T)[R+S_I(t,T)-1-RS_I(t,T)] \\
&= \mathcal{C}P_d(t,T)[R+S_I(t,T)(1-R)-1] \\
&= \mathcal{C}[R+P_d(t,T)S_I(t,T)(1-R)-P_d(t,T)] \\
&= -\mathcal{C}[P_d(t,T)-P_I(t,T)]
\end{aligned}$$

5: Focus on XVAs
XVA impact [3]

- We now assume that the €STR OIS curve is given by the EONIA OIS curve minus a constant spread (-9 bps at the moment),

$$R_d^{EST}(t,T) = R_d^{EON}(t,T) - \Delta \quad \forall T > t \qquad \Delta > 0$$

$$R_x(t,T) := -\frac{1}{\tau(t,T)} \log P_x(t,T)$$



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

$$R_I(t,T) := R_d^{EON}(t,T) + \mathcal{S}_I(t,T) \Rightarrow R_d^{EST}(t,T) + \mathcal{S}'_I(t,T) := R'_I(t,T)$$

$$\mathcal{S}_I(t,T) = \frac{1}{\tau(T-t)} \log \frac{P_d(t,T)}{P_I(t,T)},$$

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

$$\begin{aligned} P'_I(t,T) &= P_I(t,T) \\ \Rightarrow R'_I(t,T) &= R_I(t,T) \\ \Rightarrow \mathcal{S}'_I(t,T) &= \mathcal{S}_I(t,T) + \Delta \end{aligned}$$

5: Focus on XVAs
XVA impact [5]

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

$$V(t) = V^0(t) + \mathrm{FVA}(t) = P_d(t,T)\,\mathcal{C} + \mathrm{FVA}(t)$$

$$\begin{aligned} V'(t) &= \mathcal{C}\,P'_d(t,T) - \mathcal{C}\,\left[P'_d(t,T) - P'_I(t,T)\right] \\ &= \mathcal{C}\,P'_I(t,T) \\ &= \mathcal{C}\,P_I(t,T) \\ &= V(t). \end{aligned}$$

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

$$\mathcal{R}(t) = RP_d(t,T) \qquad 0 \leq R \leq 1$$

becomes

$$\begin{aligned}
P_I(t,T) &= R\ \mathbb{E}_t^{\mathbb{Q}}\left[\int_t^T P_d(u,T)\gamma(u)e^{\int_t^u (r(s)+\gamma(s))ds}\right]du + P_I(t,T) \\
&= R\ \mathbb{E}_t^{\mathbb{Q}}\left[e^{\int_t^T r(s)ds}\int_t^T \gamma(s)e^{\int_t^u \gamma(s)ds}du\right] + P_I(t,T) \\
&= R\ \mathbb{E}_t^{\mathbb{Q}}\left[e^{\int_t^T r(s)ds}\left(1-e^{\int_t^T \gamma(s)ds}\right)\right] + P_I(t,T) \\
&= R\left(P_d(t,T) - P_I(t,T)\right) + P_I(t,T) \\
&= R\ P_d(t,T) + (1-R) + P_I(t,T) \\
&= R\ P_d(t,T) + (1-R)P_d(t,T)S_I(t,T) \\
&= P_d(t,T)(R + (1-R)S_I(t,T))
\end{aligned}$$

7: Appendix
Funding spread [2]

- We rewrite the ZCB value in such a way

$$\begin{aligned} P_I(t,T) &= P_d(t,T)\left[R + S_I(t,T) - RS_I(t,T) + 1 - 1\right] \\ &= P_d(t,T)\left[1 - (1-R) + S_I(t,T)(1-R)\right] \\ &= P_d(t,T)\left[1 - (1-R)(1-S_I(t,T))\right]. \end{aligned}$$

- Since the zero funding spread is defined as

$$\mathcal{S}(t,T) = \frac{1}{T-t}\log\frac{P_d(t,T)}{P_I(t,T)}$$

then

$$\begin{aligned} \mathcal{S}(t,T) &= \frac{1}{T-t}\log\frac{1}{1-(1-R)(1-S_I(t,T))} \\ &= -\frac{1}{T-t}\log\left[1-(1-R)(1-S_I(t,T))\right] \\ &= -\frac{1}{T-t}\log\left[1-1+S_I(t,T)+R-RS_I(t,T)\right] \\ &= -\frac{1}{T-t}\log\left\{S_I(t,T)\left[1+R\left(-1+\frac{1}{S_I(t,T)}\right)\right]\right\}. \end{aligned}$$

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 survivial probability inside the spread rate formula, we arrive to

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

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

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

8: References

General

1. D. Duffie (2018) " Bloomberg Quantitative (BBQ) Seminar: How to build a strategy for converting LIBOR contracts", Bloomberg Professional Services, March 05, 2018
2. European Commission (2019) " Sustainable finance: Commission welcomes agreement on a new generation of low-carbon benchmarks", Press release, Brussels, 25 February 2019
3. ISDA (2018) "Benchmarks", November 2018.
4. N. Sherif, "Libor-in-arrears swaps face unwinds on benchmark death", Risk, 18 Apr. 2019

€STR & EONIA

14. Working Group on Euro Risk Free Rates Subgroup n. 2 (2018) " Update by Subgroup 2 on the identification and recommendation of a term structure on RFRs", 4th meeting, Frankfurt am Main, 11 July 2018.
15. Working Group on Euro Risk Free Rates Subgroup n. 2 (2018) " Update by Subgroup 2 on the identification and recommendation of a term structure on RFRs", 5th meeting, Frankfurt am Main, 13 September 2018.
16. Working Group on Euro Risk Free Rates Subgroup n. 2 (2018) " Update by Subgroup 2 on the identification and recommendation of a term structure on RFRs", 6th meeting, Frankfurt am Main, 18 October 2018.
17. Working Group on Euro Risk Free Rates Subgroup n. 4 (2018) "EONIA-RFR Transition", Presentation at the Roundtable on Euro Risk-Free Rates at the ECB, Frankfurt am Main, 9 November 2018.
18. Working Group on Euro Risk Free Rates Q&A Session (2018) "Discussion on term rates initiatives", Presentation at the Roundtable on Euro Risk-Free Rates at the ECB, Frankfurt am Main, 9 November 2018.
1. P. Nicoloso (2018) "ESTER as an alternative euro risk-free rate", Presentation to ECB representative office, Brussels, 16 October 2018.
2. J. Kes, (2018) "High level implementation plan", Working Group Euro Risk Free Rates, 18 October 2018.
3. European Central Bank (2018) "Report by the working group on euro risk-free rates on the transition from EONIA to ESTER", Frankfurt, 20 December 2018.
4. European Central Bank (2019) "Feedback on the report on the transition from EONIA to ESTER by the working group on euro risk-free rates", Frankfurt, February 2019.
5. European Central Bank (2019) " Second public consultation by the working group on euro risk-free rates on determining an ESTER-based term structure methodology as a fallback in EURIBOR-linked contracts Summary of responses", Frankfurt, February 2019.

8: References

SOFR & EFFR

1. Federal Reserve Bank of New York, https://apps.newyorkfed.org/markets/autorates/fed%20funds
2. LCH, (2018), "Consultation on transition to SOFR discounting", 6 November 2018, https://www.lch.com/membership/ltd-membership/ltd-member-updates/consultation-transition-sofr-discounting.
3. CME Group (2018) "OTC SOFR Swaps Clearing", Q4 2018, https://www.cmegroup.com/trading/interest-rates/cleared-otc-sofr-swaps.html.
4. R. Mackenzie Smith (2019) " SOFR, so bad: liquidity lags transition ambitions", Risk.net, 4 February 2019.
5. H. Bartholomew (2019) "LCH plans 2020 switch to SOFR discounting", Risk.net, 12 February 2019.

EURIBOR

14. J. L. Schirmann (2018) "Update on the hybrid Euribor methodology", European Money Market Institute, Presentation to Working Group Euro Risk Free Rates, Frankfurt am Main, 18 October 2018.

XVAs

21. Gregory, Jon, The XVA Challenge: Counterparty Credit Risk, Funding, Collateral, and Capital, John Wiley & Sons, September 2015
22. Green, Andrew, XVA: Credit, Funding and Capital Valuation Adjustment, John Wiley & Sons, November 2016
23. C. Albanese, S. Caenazzo, S. Iabichino (2015) "Capital and Funding", Working Paper.
24. L. Andersen, D. Duffie, Y. Song (2019) " Funding Value Adjustments", The Journal of Finance, Volume 74, Issue 1, February 2019.