CME Group

CME Term €STR Methodology

CME Group Benchmark Administration Limited

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1. Overview of the CME Term €STR

1.1. Introduction

The euro short-term rate (€STR) reflects the wholesale euro unsecured overnight borrowing costs of banks located in the euro area. The €STR is published on each TARGET2 business day based on transactions conducted and settled on the previous TARGET2 business day (the reporting date “T”) with a maturity date of T+1.

The €STR fixings are published by the ECB at 08:00 CET on each TARGET2 business day.

CME Term €STR Reference Rates provide the forward-looking measurement of overnight €STR based on market expectations implied from derivatives markets.

1.2. CME Term €STR reference rates

The CME Term €STR Reference Rates is a daily set of forward-looking interest rate estimates, calculated and published for 1-month, 3-month, 6-month and 12-month tenors.

The calculation method builds on the work developed by Federal Reserve economists, Erik Heitfield and Yang-Ho Park, and published in the Finance and Economic Discussion Series (FEDS) 2019-014.[1]

The work of Heitfield and Park lays out a method to determine a possible path of overnight rates that is consistent with the observable averages implied by €STR based derivative contracts. Upon determining a path of overnight rates one can directly create averages over standard tenors. These will be published as CME Term €STR Reference Rates.

The publication of CME Term €STR Reference Rates will occur on the next Business Day following the Business Day during which futures data sampling takes place. CME Term €STR Reference Rates are computed based on a reference period that begins two Business Days (T+2) after the Publication Date.

CME Term €STR Reference Rates will be calculated for each Business Day, in accordance with the ECB Target 2 Calendar.[2]

CME Group Benchmark Administration Limited (CBA), a UK regulated benchmark administrator, is the Benchmark Administrator of CME Term €STR Reference Rates with CME Inc. (CME) providing calculation agent and distribution services. This document describes the methodology used by CBA to calculate the CME Term €STR Reference Rates.

[1] *Inferring Term Rates from SOFR Futures Prices,” Finance and Economics Discussion Series 2019-014*

[2] *https://www.ecb.europa.eu/ecb/contacts/working-hours/html/index.en.html*

2. Data Inputs

CME Term €STR Reference Rates Methodology uses a combination of three month €STR Futures, Spot Starting €STR swaps and €STR ECB-dated swaps to ensure that the term structure is appropriately calculated, providing as many data points as possible.

2.1. €STR futures contracts

Three-Month €STR futures (ESR) is a quarterly contract that follows the IMM schedule.

For a contract for a given delivery month, the Final Settlement Price shall be 100 minus compounded daily €STR during the contract Reference Quarter.

The calculation of Term €STR will utilize the first five quarterly (March, June, September, December) €STR futures contracts in the calculation. The prices used in the projection model will be the 4:00pm London Marker prices (XYR).

2.2. €STR OIS transactions data

An €STR Overnight Index Swap (OIS) is an instrument that involves an exchange of cash flows between two parties. One leg is calculated using the floating rate Compounded €STR Index and the other leg using a fixed rate. The trades included in the calculation will have to meet the below criteria:

- Day count convention on both fixed and floating leg must be ACT/360
- Trades including fees or variable notional must be excluded
- Trades must be submitted between 09:00 CET and 19:00 CET

2.2.1. Spot starting swaps

CME Group utilizes spot starting OIS with 3M, 6M and 1Y tenors. A spot starting swap is a swap starting two business days after the trade date. The below table specifies the permitted spot starting swap durations for each of the three tenors.

Tenor	3M	6M	1Y
Duration in number of calendar days	[80, 100]	[165, 195]	[340, 380]

2.2.2. ECB-dated swaps

An ECB-dated swap is defined as a swap starting on an ECB Maintenance Start Date and ending on the next ECB Maintenance Start Date. CME Group utilizes the ECB-dated swaps for the next two maintenance periods in the calculation of Term €STR.

Maintenance period 1 refers to the period between the closest maintenance start date and the following one, the period will roll on the Monday preceding the upcoming maintenance start date (see below for an example).

Example

Maintenance Start Dates List = [24-Jul, 18-Sep, 23-Oct, 18-Dec]

- Current Date = 15-July

ECB-dated swap 1 = Swap starting on 24-Jul and ending on 18-Sep
ECB-dated swap 2 = Swap starting on 18-Sep and ending on 23-Oct

- Current Date = 22-July

ECB-dated swap 1 = Swap starting on 18-Sep and ending on 23-Oct
ECB-dated swap 2 = Swap starting on 23-Oct and ending on 18-Dec

2.3. €STR OIS quotes data

For both spot starting and ECB-dated swaps, CME Group will receive daily a dataset of quotes from different dealers. This data is provided by Tradeweb.

For each tenor, the administrator will compute an afternoon median and a full-day median.

2.3.1. Afternoon median

The afternoon median will be calculated using the quotes from the intervals [14:20 - 14:30], [14:50 - 15:00], [15:20 - 15:30], [15:50 - 16:00], [16:20 - 16:30], [16:50 - 17:00], [17:20 - 17:30], [17:50 - 18:00], [18:20 - 18:30], [18:50 - 19:00] (CET).

For each interval, the calculation will follow the below steps:

- Calculate the mid quotes defined as **(Ask Quote + Bid Quote) / 2**
- For each dealer i, calculate the median of the mid quotes noted **Median_dealer_i**
- Calculate the overall median for the interval using the **Median_dealer_i** as inputs

An arithmetic average of the available medians is then calculated. This number is called the afternoon median.

2.3.2. Full-day median

The full-day median follows the same calculation approach as the afternoon median with the following intervals [9:50 - 10:00], [10:50 - 11:00], [11:50 - 12:00], [12:50 - 1300], [13:50 - 14:00], [14:50 - 15:00], [15:50 - 16:00], [16:50 - 17:00], [17:50 - 18:00], [18:50 - 19:00] (CET).

2.4. O/N €STR

The O/N €STR is required as an input to determine the predicted €STR from the futures contracts during the accrual period. This rate is published at 8:00am CET by the ECB on T+1

2.5. Holiday calendar

CME Term €STR Reference Rates will be calculated for each Business Day, in accordance with the ECB Target 2 Calendar.[3]

2.6. ECB maintenance period dates

Changes to the ECB central bank rates are determined by the ECB governing council every 6 weeks[4]. If a rate change is determined at an ECB meeting, it is enacted at the start of the next maintenance period. The ECB date inputs for the projection model will therefore be the maintenance period dates.

2.7. Use of expert judgement

The Methodology does not foresee the use of expert judgement to be applied in the determination of the CME Term €STR Reference Rates.

However, CBA reserves the right to apply discretion or expert judgement when making decisions in unusual cases or in circumstances not addressed by the rules and methodologies applicable to the rates. Where such circumstances arise a notice will be published on the CBA Notice Page.

[3] *https://www.ecb.europa.eu/ecb/contacts/working-hours/html/index.en.html*

[4] *ECB calendar of reserve maintenance periods*

3. Calculation of the Term €STR [reference rates]

3.1. OIS waterfall methodology

The CME Term €STR reference rates are calculated using a waterfall calculation to ensure sufficient data is available for each OIS input, prior to being combined with the €STR futures data into the projection model. Listed below are four levels in order for the OIS data aggregation under the waterfall methodology.

1. VWAP of the OIS transactions from 2:15pm to 7:00pm CET. The VWAP is calculated for each tenor by MarkitServ Ltd. The aggregation of the OIS transactions is using a band around median based on Mean Absolute Deviation (MAD) to remove the outliers.
2. VWAP of the OIS transactions from 9:00am to 7:00pm CET. The VWAP is calculated for each tenor by MarkitServ Ltd. The aggregation of the OIS transactions is using a band around median based on Mean Absolute Deviation (MAD) to remove the outliers.
3. The afternoon quotes marker for the given tenor as described in section 2.3.
4. The full-day quotes marker calculated as described in section 2.3.

After the waterfall calculation, the €STR OIS inputs are combined with the €STR futures inputs within the projection model as described in section 3.2.

3.2. Modeling forward rates

3.2.1. Overview

CME Group determines the path of overnight €STR by assuming the overnight €STR follows a piecewise constant step function and can only jump up or down on ECB Policy Maintenance Start Dates and remain constant within the ECB Policy Maintenance Period. Though the overnight rates are not directly observable, CME Group utilizes €STR futures contracts traded on the CME Inc. DCM and the €STR swaps to obtain estimates of overnight €STR on average over the specific contract reference periods. With these references as inputs, the optimal path for the overnight €STR is determined such that the errors between the model-implied prices and the observed market prices are minimized.

Finally, term rates will be constructed by compounding overnight €STR following specific conventions. Details of the algorithm are highlighted in the sections below.

3.2.2. Piecewise-constant €STR forecasting model

Denote the calculation date for CME Term €STR Reference Rate is t_0. Define $Horizon$ as the length of the period covered by the overnight rate forecast model. By default, we use 18 months. Let t represents a date covered in the overnight rate forecast model, then we have $t_0 \leq t \leq t_0 + Horizon$, where t is a business day in accordance with the *TARGET2* holiday schedule.

Next, we define the following notations used for the projected overnight €STR model:

- S_k: the date of the k^{th} maintenance start date that occurs after t_0, where $k = 1, 2,..., K$ and K is the index of the last maintenance start date within the horizon.
- M_k: the announcement date of policy decision associated with S_k. In other words, the rate policy decision announced on M_k starts on S_k.
- θ_0: the initial overnight €STR as of date t_0.
- θ_k: the jump size in overnight €STR that occurs on the S_k. A positive θ_k means a rate hike on M_k, while a negative θ_k means a rate cut. Note that $\theta_0, \theta_1,..., \theta_k$ are represented in percentage terms. For example, when interest rate of the first step is 1.23%, $\theta_0 = 1.23$. When the forecasted rate change is 25 bps, $\theta_1 = 0.25$.
- $f_{t;\Theta}$: the overnight €STR as of the date t, where $t > t_0$. $\Theta = \left(\theta_0, \theta_1,..., \theta_K\right)$ and K is the index of the last relevant Maintenance start date within the horizon.
- $1\{\cdot\}$; indicator function returning 1 if the statement is true and 0 otherwise.

The overnight forward €STR starting from S_k (inclusive) and ending at S_{k+1} (exclusive) can be computed as:

$$f(t; \Theta) = \theta_0 + \sum_{k=1}^{K} \theta_k \cdot 1\left\{t \geq S_k\right\}.$$

We solve for the unknown parameter set Θ such that the projected path of the overnight €STR results in the smallest mismatches for the futures and OIS and markers.

3.2.3. Reference θ_0 value (Initial €STR projected value)

CME Group incorporates the current market rate environment to obtain a reference value for θ_0, the starting value of the forecast term structure. However, given the methodology for €STR fixings calculation, €STR fixings could experience fluctuations at end of month, end of year, etc. We will aggregate information available in €STR fixings from a short historical period for a reference θ_0. Let's define $\hat{\theta}_0$ as the reference θ_0 value calculated from information about recent fixings and rate policies.

To calculate $\hat{\theta}_0$, we use the following methodology to get an estimate of the average of the current rate level, while being able to rule out the disturbance from €STR's month-end fluctuations.

Let r_t be the series of available fixings, where $t < t_0$. Next, let $S_0, S_{-1},..., S_{-R}$ be the list of maintenance period start dates **on or before** t_0, where $t_0 \geq S_0 > S_{-1} > ... > S_{-R}$. Let the announced rate changes corresponding to each maintenance period start date be $h_0, h_{-1},..., h_{-R}$. Then, for each fixings, we define the adjusted fixing r_t' for a given date t as:

$$r_t' = r_t + \sum_{r=0}^{R} h_{-r} \cdot 1\{t < S_{-r}\}.$$

Finally, let the set of the latest N_{fix} fixings date be T_{fix}, then the reference level of θ_0 will be:

$$\hat{\theta}_0 = \sum_{t \in T_{fix}} r_t' / N_{fix}.$$

We will use the value $N_{fix} = 20$ to represent the last one month of information.

3.2.4. Reference θ_1 value

ECB decides on changes to monetary policy during their ECB governing council. The announcement for any rate change is announced on ECB governing council meeting date, but is only enacted starting from ECB policy maintenance period start date. In order to reflect rate change information during the period between announcement date and corresponding maintenance period start date, CME Group will use the value of rate change as reference θ_1 value during the optimization. Note that when the calculation date is not between an announcement and the corresponding maintenance period start date, there is no need for having a reference θ_1 since no future rate changes are known.

3.2.5. Optimization

In order to determine the optimal path for the overnight €STR, CME Group implemented the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm that solves for the unknown parameter set Θ and utilizes the first 5 ESR quarterly contracts, spot starting swaps with 3-month, 6-month, 12-month tenors (denoted as 3M, 6M and 12M), and the first 2 ECB-dated swaps (denoted as MP1 and MP2).

The optimization function is designed to solve the following minimization problem:

$$\min_{\Theta} \left\{ \sum_c \omega_c^{fut} \left(P_c^{fut}(\Theta) - \hat{P}_c^{fut}\right)^2 + \sum_n \omega_n^{OIS} \left(R_n^{OIS}(\Theta) - \hat{R}_n^{OIS}\right)^2 + \lambda_0 (\theta_0 - \hat{\theta}_0)^2 + \lambda_1 (\theta_1 - \hat{\theta}_1)^2 + \lambda_{reg} \left[\frac{\sum_{k=1}^{K} (\theta_k)^2}{K} \right] \right\},$$

where:

- $\hat{P}_c^{fut}$: the 4pm €STR futures markers for a given contract c.
- P_c^{fut}: the model-implied €STR futures price for a given contract c.
- $\hat{R}_n^{OIS}$: the input par rate (in %) of the OIS for a given tenor n.
- R_n^{OIS}: the model-implied par rate (in %) of the OIS for a given tenor n.
- $\hat{\theta}_1$: the reference θ_1 value (size of rate jump) from the most recent ECB announcement.
- ω_c^{fut} and ω_t^{OIS}: weights for errors of the €STR futures price and OIS par-rate.
- λ_{reg}: weight for regularization penalty term.
- λ_1 : weight for θ_1 error term. When calculation date t_0 is **not** between announcement date (inclusive) and the corresponding maintenance period start date (exclusive), λ_1 is set to 0.
- λ_0: weight for θ_0 error term.

The framework of the optimization method is guided by the following principles:

- Reflect market expectations: The first and second term of the optimization function is the weighted average squared error between implied values and observed prices of 5 ESR contracts, and 5 OTC swaps. The optimization algorithm tries to minimize the mean squared errors of the deviations from market expectations.
- Equivalent importance of inputs: We assign each input price the same level of importance with respect to the contribution to the error function in the optimization. Currently with ten reference instruments, the weight for each futures and swap contract (ω_c^{fut} and ω_n^{OIS}) is 0.1.
- Incorporation of ECB rate change announcement information: We use reference $\hat{\theta}_1$ value to align to the announced rate change information between ECB announcement date and maintenance period start date. The optimization algorithm minimizes any difference between model $\theta_1$and reference $\hat{\theta}_1$.
- Eighteen month jump window: We assume that no jumps will occur more than eighteen months after the as of date.
- Policy gradualism: The last term of the optimization function is a penalty function which will impose punishment on large jump sizes. This regularization term in the optimization function ensures that the optimization prefers “gradual jump patterns” of the overnight €STR rather than “extreme jump patterns” if the two patterns lead to the same contract prices.

3.2.6. Pricing reference instruments

For ESR futures contracts, whose reference contract is not the front contract ($c > 0$), the implied value only depends on projected overnight €STR:

$$P_c^{fut}(\Theta) = 100 \times \left\{1 - \frac{360}{N_c^{fut}}\left[\prod_{t \in T_c^{fut}}\left(1 + \frac{f(t;\theta)d_t}{360}\right) - 1\right]\right\}.$$

where:

- T_c^{fut}: set of Business Days in the reference period of the c-th contract.
- N_c^{fut} : total number of calendar days in the reference period of c-th contract.
- d_t: the number of calendar days from date t to its next Business Day following the *TARGET2* calendar, if the next Business Day is no later than the end date of the c-th contract; otherwise, d_t equals to the number of days from date t to the end date of the c-th contract.

For the first ESR futures contract, in some cases, part of the fixings in the reference period are known as of the calculation date. For those, the model-implied price can be calculated using published €STR fixings and projected overnight €STR:

$$P_c^{fut}(\Theta) = 100 \times \left\{1 - \frac{360}{N_c^{fut}}\left[\prod_{t \in T_c^{fut-}}\left(1 + \frac{r_t d_t}{360}\right) \cdot \prod_{t \in T_c^{fut+}}\left(1 + \frac{f(t;\theta)d_t}{360}\right) - 1\right]\right\},$$

where:

- r_t: published €STR fixing for date t.
- $T_c^{fut+} = \left\{t \in T_c^{fut} \mid t \geq t_0\right\}$. This is because when $t = t_0$, r_t is unknown.
- $T_c^{fut-} = \left\{t \in T_c^{fut} \mid t < t_0\right\}$.

The pricing of OIS par rate follows a similar calculation:

$$R_n^{OIS}(\Theta) = 100 \times \frac{360}{N_n^{OIS}}\left[\prod_{t \in T_n^{OIS}}\left(1 + \frac{f(t;\theta)d_t}{360}\right) - 1\right].$$

- T_n^{OIS}: set of business days in the reference period of the swap corresponding to tenor n.
- N_n^{OIS} : total number of calendar days in the reference period of the swap corresponding to tenor n.

- d_t: the number of calendar days from date t to its next Business Day following the *TARGET2* calendar.

3.2.7. Computing term rates from projected overnight rates

Term Rates are derived by compounding the overnight €STR over one, three, six and twelve months.
The compounding follows conventions listed as below:

$$h(T) = \frac{360}{N_m} \times \left[\prod_{t \in T_m} \left(1 + \frac{f(t;\Theta) \times d_t}{360}\right) - 1 \right].$$

- m: the tenor of term rate (e.g. 1-month, 3-month, 6-month, 12-month)
- T_m: the set of business days in the compounding period of tenor m. Each term tenor will start two business days after the publication date (i.e. three business days after the calculation date). The term rate spans the corresponding tenor and end date is adjusted in accordance with Modified Following Conventions.
- N_m: the number of calendar days in set T_m.
- t : a business day in T_m.
- d_t: the number of calendar days from date t to its next business day following the *TARGET2* holiday schedule.
- $f(t; \Theta)$: the projected overnight €STR as of date t.

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Appendix I – Key Terms & Definitions

TERM	DESCRIPTION
Administrator	CME Group Benchmark Administration Limited
BMR	Benchmark Regulation
Business Day	Business Day in accordance with the CME Globex Trading Schedule
CBA	CME Group Benchmark Administration Limited
DCM	Designated Contract Market
€STR	Euro Short-Term Rate
FCA UK	Financial Conduct Authority (UK)
IMM	International Money Market day-count convention
IOSCO	International Organization of Securities Commissions