Report by the working group on

euro risk-free rates

On the risk management implications of the transition
from EONIA to the €STR and the introduction of €STR-based fallbacks for EURIBOR

17 October 2019

Contents

1 Key recommendations

This report by the working group on euro risk-free rates focuses on the risk management implications of the transition from the current euro overnight index average (EONIA) to the ECB's euro short-term rate (€STR) and the inclusion of fallback rates for EURIBOR based on a €STR-based term structure methodology, i.e. the introduction of risk-free rates. The report focuses mainly on the risk management implications for banks, but also touches on additional challenges facing the asset management and insurance sectors. It should be read in conjunction with Recommendations of the working group on euro risk-free rates on the EONIA to €STR legal action plan and Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products.

The analysis conducted in this report consists of (i) general risk management considerations, (ii) risk management impact analysis of EONIA to €STR transition, (iii) risk management impact analysis of €STR-based fallback rates for EURIBOR, and (iv) additional risk management considerations for the asset management and insurance sectors. In line with this structure, the key recommendations resulting from the analysis are given below.

Recommendations regarding general risk management considerations:

1) In order to cope with the EONIA to €STR transition and the introduction of €STR-based fallback rates for EURIBOR, the working group recommends that market participants:

    a) set up a well-governed risk-free rates programme to identify exposures at risk and develop a transition strategy;

    b) identify all of the products that are likely to be affected and determine the most appropriate way to amend legacy EONIA contracts, design new business contracts and make adjustments throughout the transition;

    c) develop internal governance processes to ensure the proper oversight of changes to policies, systems, processes and controls and provide staff with training on the implications of the transition to enable adequate interaction with clients.

Recommendations regarding the risk management impact analysis of EONIA to €STR transition:

2) As a compensation mechanism when transitioning from EONIA to the €STR, the working group considered that exchanging the difference in present value in cash may have advantages in terms of operational simplicity when compared with a spread adjustment or an adjustment of the fixed leg. However, each market participant should decide on the compensation approach that is most

appropriate in its particular circumstances.[1] Market participants should also consider the risk of price and valuation changes throughout this transition and related effects on financial accounting.

3)   The working group recommends that market participants:

   a)   use historical time series for EONIA risk factors along the curve as feasible (and best available) proxies for the historical time series of €STR risk factors before 2 October 2019;

   b)   fix switch dates in transition planning in advance insofar as possible;

   c)   communicate with clients in advance in order to facilitate a smooth transition and include fallback provisions in contracts referencing EONIA, in particular for those maturing after the end of 2021, in accordance with the recommendations on the EONIA to €STR legal action plan.[2]

4)   The working group recommends that historical time series of the new curves be obtained using a two-step process, going from the present to the past. First, use the curves' past movements where available, i.e. from 2 October 2019 onwards, and, second, use the EONIA curve as proxy for earlier periods (before 2 October 2019).

5)   Regarding the calculation of internal model-based risk figures, it is recommended that market participants integrate new products referencing the €STR and €STR risk factors and scenarios into the calculations of value at risk (VaR), stressed VaR, sensitivities and stress testing. The profit and loss (P&L) calculation and the back-testing framework also need to be extended.[3]

6)   According to Article 365(2) of the Capital Requirements Regulation (CRR)[4], stressed VaR has to be calculated with model inputs calibrated on a 12-month period of significant financial stress relevant to the institution's portfolio. In the context of the EONIA to €STR transition, market participants should verify whether the current stress period is still appropriate.

7)   Regarding risk reporting and limit systems, the working group recommends market participants to ensure that market risks arising from new €STR-based products and €STR risk factors are limited. To meet this requirement, additional limits, for example for €STR sensitivities, might be necessary.

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[1]   Please see recommendation 5(b) in "Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products", ECB, August 2019.

[2]   See Recommendations of the working group on euro risk-free rates on the EONIA to €STR legal action plan.

[3]   The recommendation refers to internal model approaches for market risk and includes both pillar 1 and pillar 2. Please refer to the respective subsection in this report for further details.

[4]   Regulation (EU) No 575/2013 of the European Parliament and of the Council of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012 (OJ L 176, 27.6.2013, p. 1).

8) In order to assess the impact of the EONIA to €STR transition, each institution should conduct an appropriate quantitative impact assessment of key market risk figures, including:

   a) an impact test on VaR and sensitivity limits,

   b) an impact test on internal models for regulatory capital charges for market risk.

9) With respect to internal models for the calculation of regulatory own funds requirements for market risk, the working group recommends that banks and relevant European Supervisory Authorities and national competent authorities enter into a discussion with the goal of producing suitable standard interpretations regarding the required analysis and reporting of the model changes for internal models used under pillar 1 in the context of benchmark transition.

10) The working group recommends that market participants carefully assess potential impacts on their IT system landscape and processes related to risk management implications, including an analysis of the technical ability to switch from one valuation curve to another when required.

11) As the €STR will be published on a following business day (T+1) basis, with EONIA following suit from 2 October 2019 onwards, market participants should consider:

   a) potential effects on short-term liquidity risk/ratios,

   b) potential effects on settlement risks from changes in the publication schedule and its impact on fixing and payment processes and related systems.

Recommendations regarding the risk management impact analysis of €STR-based fallbacks for EURIBOR:

It should be noted that, at the time of writing, the working group is still undertaking evaluations and analyses with respect to fallback provisions and rates.

12) Through the analysis included in this report, the working group highlights possible risk management implications of (i) having timing inconsistencies in fallback provisions triggers and (ii) incorporating different fallback trigger language for different asset classes. In particular, side effects could arise from the lack of consistent language for the usual hedging product combinations. Market participants are recommended to consider these risks when developing fallback provision triggers.

13) From a risk management perspective, market participants should try to reduce the variability of fallback rates between different product classes (including derivatives) to a minimum, but it is ultimately a matter for parties to resolve taking account of their individual circumstances.

14) The working group recommends that market participants:

   a) gain an overview of the quantity of basis risk exposure from fallbacks in their current EURIBOR-indexed contracts by assessing the exposure amount and estimating the magnitude and volatility range of the spread;

   b) gain an overview of and develop a clear plan for current and future hedging instruments and strategies for the relevant basis risks, including associated costs;

   c) set up corresponding market observations and possible warning indicators for market liquidity in the relevant hedging instruments.

15) Current activities at institutions – in collaboration with system vendors – could include gap and activity planning for potential fallback rates regarded as particularly relevant. Fallback-relevant data should be collected. These could include relevant valuation and risk factors, and a high-quality history of these data could already be useful for risk management purposes. Market liquidity and observability will be key data and risk management aspects.

16) Market participants should consider establishing a governance framework involving front office and risk functions to monitor the benchmark and contractual fallback exposures at a sufficiently differentiated level on an ongoing basis (providing them with guidance, for example, on the reply to the letter of 3 July 2019 from the Chair of the Supervisory Board concerning banks' preparation with regard to interest rate benchmark reforms and the use of risk-free rates).

17) With respect to fallback data, it would be particularly useful to have a consistent source for the publication of fallback rate values, including the respective spread adjustments, i.e. a vendor could publish it ensuring compliance with the EU Benchmarks Regulation (BMR)[5] and with International Organization of Securities Commissions (IOSCO) principles.

Recommendations regarding additional risk management considerations for asset management and insurance market participants

18) In accordance with the general risk management implications outlined in Chapter 3, market participants should undertake a detailed impact assessment to identify the areas along the full value chain that are affected by the transition and that require the definition of mitigating actions.

19) The working group recommends with respect to Solvency II that insurance companies:

   a)   analyse all Solvency II dependencies in the light of the benchmark reform;

   b)   proactively engage with the European Insurance and Occupational Pensions Authority (EIOPA) and relevant national competent authorities for clarification regarding the long-term composition of the EIOPA liabilities discounting curve going forward.

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[5]   Regulation (EU) 2016/1011 of the European Parliament and of the Council of 8 June 2016 on indices used as benchmarks in financial instruments and financial contracts or to measure the performance of investment funds and amending Directives 2008/48/EC and 2014/17/EU and Regulation (EU) No 596/2014 (OJ L 171, 29.6.2016, p. 1).

2   Introduction

2.1   Background

EURIBOR and the euro overnight index average (EONIA) are the most widely used interest rate benchmarks for euro-denominated financial contracts. Both are administered by the European Money Markets Institute (EMMI). EURIBOR is the term reference rate for the euro, and is available for several tenors. EONIA is the overnight reference rate for the euro, computed on the basis of real transactions in the interbank market.

In 2018 the Benchmarks Regulation (BMR) came into effect. Due to their systemic importance, the two aforementioned benchmarks were added by the European Commission to the list of critical benchmarks pursuant to Article 20 of the BMR.[6]

2.2   The working group on euro risk-free rates

In September 2017 the European Central Bank (ECB), the Financial Services and Markets Authority (FSMA), the European Securities and Markets Authority (ESMA) and the European Commission announced the launch of the industry working group on euro risk-free rates. The working group was tasked with identifying and recommending risk-free rates that could serve as an alternative to the current benchmarks used in a variety of financial instruments and contracts in the euro area and with developing adoption plans.[7]

In September 2018 the working group recommended that the euro short-term rate (€STR) become the successor to EONIA.[8] In order to ensure smooth market adoption, there will be a two-year transition period. Key elements of the transition from EONIA to the €STR are:

- the existence of a transition period, which started on 2 October 2019 and ends on 31 December 2021, with the consequent cessation of publication of EONIA on 3 January 2022;

- the dependency of EONIA on the €STR during the transition period, as the EONIA methodology will be redefined as €STR plus a fixed spread of 8.5 basis points.

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[6]   See Commission Implementing Regulation (EU) 2017/1147 of 28 June 2017 amending Implementing Regulation (EU) 2016/1368 establishing a list of critical benchmarks used in financial markets pursuant to Regulation (EU) 2016/1011 of the European Parliament and of the Council (OJ L 166, 29.6.2017, p. 32).

[7]   See Terms of reference for the Working Group on Euro Risk-Free Rates and Composition of the Working Group on Euro Risk-Free Rates.

[8]   See ECB press release of 13 September 2018.

In contrast, EURIBOR has been reformed to become BMR-compliant under a new hybrid methodology which will be fully implemented by the end of 2019. Authorisation was granted by the FSMA, EMMI's supervisor, on 2 July 2019.

Because the overnight benchmark rate EONIA will cease to exist, the transition from EONIA to the €STR is currently the main focus of the work of the working group on euro risk-free rates. Although EURIBOR will continue to be provided under its reformed methodology, its use needs to comply with the requirements of the BMR. As a contingency measure to avoid future financial instability, the BMR requires EU supervised entities to produce and maintain robust written plans setting out the actions they will take in the event that a benchmark materially changes or ceases to be provided, including fallback provisions. This requires supervised entities to include a fallback for EURIBOR in their written plans and contracts where feasible and appropriate.

2.3 The sub-group on financial accounting and risk management

In order to ensure that its recommendations are adopted by all market participants, the working group has created a sub-group on financial accounting and risk management. The sub-group was tasked with analysing the impact on financial accounting and risk management of (1) the transition from EONIA to the €STR and (2) the inclusion of fallbacks for EURIBOR based on a €STR-based term structure methodology and the possible fallback triggers. The results of the analysis are published across three documents:

- a letter from the working group on euro risk-free rates to the International Accounting Standards Board (IASB),[9]

- a report analysing the impact on financial accounting,[10]

- this report analysing the impact on risk management.

The sub-group comprises representatives of European and international credit institutions, consulting and accounting firms, clearing houses, investment management firms and associations. The ECB, ESMA, the European Commission, and the FSMA act as observers in the sub-group.

2.4 Structure of the report

The present report focuses on the risk management implications of the transition from EONIA to the €STR and the inclusion of fallbacks for EURIBOR based on a €STR-based term structure methodology. Notably, the focus of the report is not on the effects of the transition on specific financial instruments but on the overall consequences for interest rate risk management, especially in the implementation phase during the transition period. While the present report primarily focuses on

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[9] See letter of 15 July 2019 from the working group on euro risk-free rates to the IASB.

[10] The report will be published on the ECB's website.

BMR/IOSCO risk implications for banks, it also touches on additional challenges facing the asset management and insurance sectors.

The report consists of four main parts. Following the executive summary and the introduction, Chapter 3 outlines the general risk management implications. Chapters 4 and 5 provide detailed analysis of implications arising from the EONIA to €STR transition and €STR-based fallback provisions and rates for EURIBOR, respectively. Finally, Chapter 6 provides an assessment of additional implications for the asset management and insurance sectors.

3   General risk management considerations for banks and asset management and insurance market participants

Notwithstanding that the purpose of the transition is to preserve the equivalence between the parties in order to provide contractual certainty, market participants need to carefully plan the transition from one benchmark reference rate to another in order to minimise disruption to markets and consumers. Besides banks, this is equally important for insurance companies, asset managers and any other market participant exposed to those interest rate benchmarks. A detailed transition plan should be based on an assessment of key risks and enable delivery before the relevant benchmark rates cease to exist. In assessing the risks of any transition, market participants should consider both quantitative and qualitative aspects.

A quantification of the outstanding notional amounts or carrying amounts and number of contracts at various levels, such as business line, product, region and legal entity, would help market participants to identify the exposures they have to the reference rates involved and align their business transition strategy accordingly. Risk measures, such as sensitivities (DV01) or other similar measures, should complement the analysis. At present, most market participants extract this information manually, which takes considerable time and effort. Market participants should consider automating the quantification of exposures and management information to increase reporting frequency while reducing the operational burden in order to support timely decision-making.

In analysing exposures to reference rates, market participants should include positions with direct or indirect dependency on the reference rates involved. Direct dependency means that the product specifications contain a direct link to a reference rate, e.g. an interest rate swap with floating leg paying three-month EURIBOR. On the other hand, indirect dependency occurs where product specifications are not explicitly linked to reference rates, but the reference rate is used for fair value measurement or any type of discounting.

Given the widespread use of benchmark rates in current business practices, market participants should also assess qualitative aspects of a transition to new benchmark rates. This should include a detailed impact assessment of the full value chain, including contracts, discounting, valuation and risk models. The objective of such an assessment is to identify the areas along the value chain that are impacted by the transition and that require the definition of mitigating actions. A potential measure could be the review/screening of the holdings of all portfolios in order to identify instruments that require amendment of their documentation or valuation and risk-calculation process.

Recommendation:

1. In order to cope with the EONIA to €STR transition and the introduction of €STR-based fallback rates for EURIBOR, the working group recommends that market participants:

    a) set up a well-governed risk-free rates programme to identify exposures at risk and develop a transition strategy;

    b) identify all of the products that are likely to be affected and determine the most appropriate way to amend legacy EONIA contracts, design new business contracts and make adjustments throughout the transition;

    c) develop internal governance processes to ensure the proper oversight of changes to policies, systems, processes and controls and provide staff with training on the implications of the transition to enable adequate interaction with clients.

4 Risk management impact analysis of EONIA to €STR transition

4.1 The EONIA to €STR transition period

Before discussing the risk management implications, this section provides a summary of the EONIA to €STR transition period. In September 2018 the working group recommended that the €STR should become the successor to EONIA.[11] Publication of the €STR started on 2 October 2019 based on transaction data from 1 October. For a smooth transition from EONIA to the €STR, there will be a two-year transition period which serves to avoid market disruptions and provide market participants with the opportunity to migrate legacy business from EONIA to the €STR. During this period, EONIA will be calculated as the €STR plus a fixed spread of 8.5 basis points.[12] Under this new methodology, EONIA will continue to be published by EMMI until 3 January 2022. The timeline for the transition period, as recommended by the working group,[13] is depicted in Figure 1 below.

Figure 1

Time of transition phase
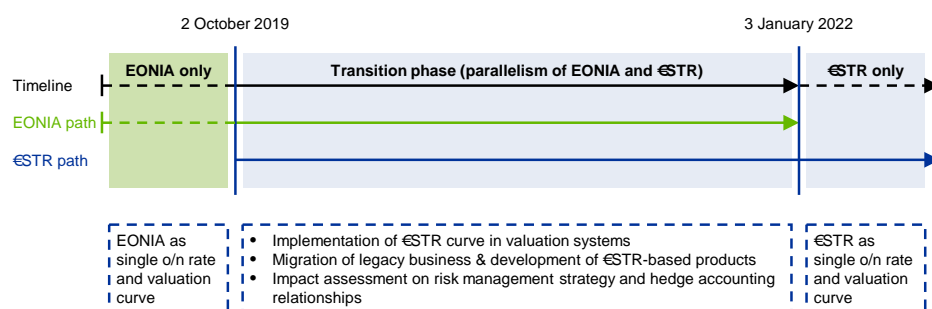
In order to ensure a smooth transition, market participants need to implement the €STR as the new reference rate in their risk management systems so that new business references the €STR instead of EONIA and legacy business referencing EONIA with maturities exceeding 3 January 2022 can be transitioned to the €STR.

The use of EONIA as a benchmark interest rate can be divided into two categories:

- EONIA used as a floating rate option (FRO), i.e. as a reference rate for the determination or projection of current and future cash flows;

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[11] See ECB press release of 13 September 2018.

[12] See ECB press release of 31 May 2019.

[13] See ECB press release of 14 March 2019.

- EONIA used as a discounting rate for valuation purposes.

While the interest rate swap market is presumably the most important market in terms of size, the change of discounting regime for the derivatives market is of particular interest when analysing risk management implications during the transition phase. The working group has already recommended a big bang approach for the change of discounting regime for cleared markets and a phased approach for bilateral credit support annexes (CSAs) to cater for individual discounting/compensations considerations[14]. In accordance with those recommendations, Figure 2 below depicts the key milestones during the transition period for the switch in the discounting regime at the discounting switch dates (DSDs).

Figure 2

Assumptions about key milestones during the transition phase
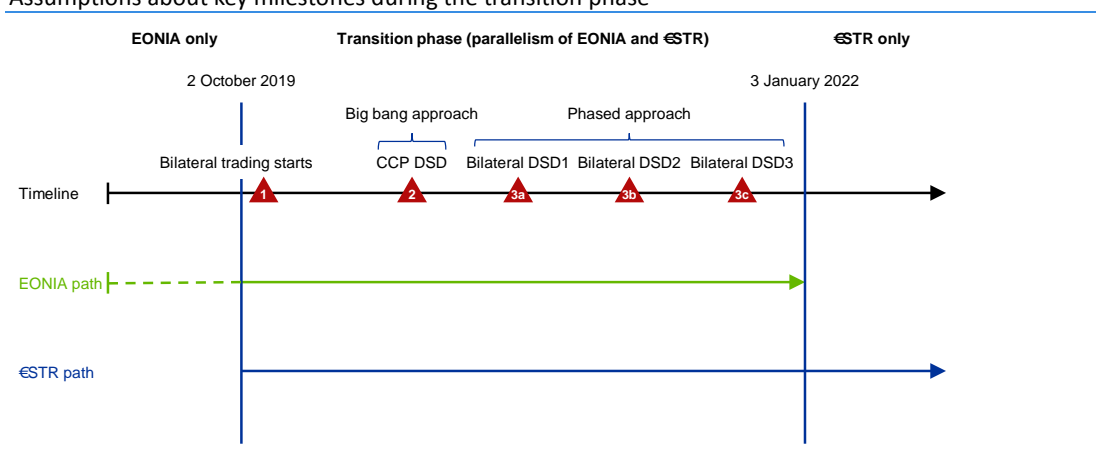
4.2   Overview of major risk types affected

The analysis below shows that the fixed link established between EONIA and the €STR substantially reduces the implications of EONIA to €STR transition for valuation risk, market risk and other risks and is thus expected to facilitate transition significantly. However, remaining practical and technical issues should be assessed and considered carefully by each institution.

Important for the purpose of risk management is the differentiation between the impact of the EONIA to €STR transition on risk itself and the impact of the transition on the practice of and systems for measuring and managing different risks. Financial institutions should carefully assess both impacts and improve or adopt the latter to mitigate and control the former. The working group reiterates that the present analysis concerns only the impact of the transition on risk and risk management practices. The transition also entails the necessity of introducing new products, such as

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[14]   See recommendation 6 included in "Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products", ECB, August 2019.

€STR-linked overnight index swaps (OISs). Although both aspects share various concerns, this analysis does not explicitly cover the introduction of specific new products or product features.

Figure 3 below depicts the major risk types that the working group has identified as affected by the introduction of risk-free rates resulting from the benchmark reform. Valuation and market risk are expected to be the most affected. While the risk types mentioned serve as first guidance on possible areas of focus for financial institutions and their assessment, the working group would like to highlight that the severity of individual impacts strongly depends on the individual business and technical circumstances. The following four subchapters on valuation risk, market risk, other financial risks and non-financial risks will detail the implications for the respective risk types.

Figure 3

Major risk types affected by the transitions resulting from the BMR
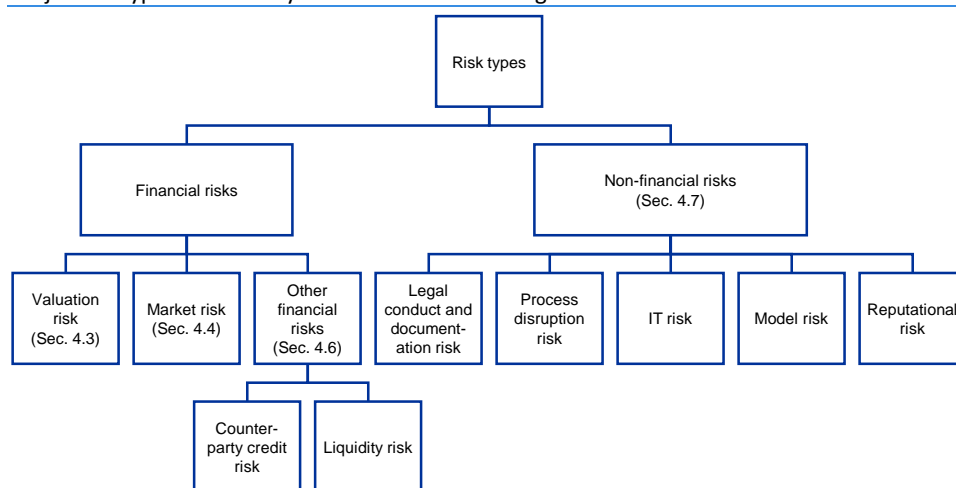
4.3 Practical implications for valuation risk

The valuation of various euro-denominated financial instruments currently depends on EONIA. It is used as a reference index in various financial products and as the collateral rate in both centrally cleared and bilaterally collateralised derivatives. Furthermore, derivatives referencing EONIA (e.g. euro OISs) are commonly used as the basis for deriving the discounting curve for valuation purposes. During the transition from EONIA to the €STR, the €STR will replace EONIA for these purposes. As EONIA and the €STR differ by the fixed spread of 8.5 basis points, transitioning from EONIA to the €STR (without a spread) will affect the valuation of financial products and trigger the need for compensation payments.

2) As a compensation mechanism when transitioning from EONIA to the €STR, the working group considered that exchanging the difference in present value in cash may have advantages in terms of operational simplicity when compared with a spread adjustment or an adjustment of the fixed leg. However, each market participant should decide on the compensation approach that is most appropriate in its particular circumstances.[15] Market participants should also consider the risk of price and valuation changes throughout this transition and related effects on financial accounting.

4.3.1 Valuation framework and the multi-curve environment

The above consideration will affect the valuation framework, models and systems of financial instrument valuation as well as related processes, including valuation adjustments (XVAs). As the existing multi-curve framework for interest rate curves is at the heart of the valuation framework, the following section outlines the necessary adjustments to the multi-curve framework in order to facilitate a smooth transition.

As will become clear below, the firm link between the €STR and EONIA during the transition phase is the key feature of this reform of overnight rates to substantially mitigate the impacts on valuation and market risk management.

The challenge for current multi-curve environments lies in the introduction of the €STR as an overnight rate, fulfilling in parallel the same functions as EONIA, namely as:

- a reference index for cash flows (most prominently in OISs), i.e. the floating rate option;

- the collateral rate in centrally cleared and bilateral derivatives business.

The working group has recommended avoiding the use of dual-strap curves where the projection and discount curves differ, as this should reduce the potential for price disputes[16]. However, the working group has also acknowledged that it may not be operationally feasible to change all FRO-linked contracts at exactly the same time. Therefore, during the transition phase, the rate combinations shown below in Table 1 could arise for derivatives. As not every combination is necessarily relevant for every market participant, the working group recommends each market participant to analyse each combination and decide on the specific relevance.

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[15] Please see recommendation 5(b) in "Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products", ECB, August 2019.

[16] See recommendation 7 in "Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €TSR on cash and derivatives products", ECB, August 2019.

Table 1

Possible combinations arising during the EONIA to €STR transition phase and interest rate curves needed

		PAI/CSA rate	
		EONIA	€STR
OIS index	**EONIA**	EONIA projection curve	EONIA projection curve
		EONIA discount curve	€STR discount curve
	€STR	€STR projection curve	€STR projection curve
		EONIA discount curve	€STR discount curve

Note: "PAI/CSA rate" is the price alignment interest (PAI) rate or credit support annex (CSA) rate.

Handling these possible combinations requires, above all, an adoption of the multi-curve framework of interest rate curves as the core of the valuation framework. Figure 4, left panel, shows a stylised pre-transition multi-curve framework. The key characteristic is the hierarchical dependency of all other interest rate curves on the EONIA (discounting) curve,[17] which has a pivotal role as the effective risk-free rate for the euro. The €STR and the €STR (discounting) curve will take over this role, starting with the transition period in which they will exist in parallel with EONIA.

The impact of this parallelism on the multi-curve framework will largely be driven by whether a sizeable, volatile and tradable basis between EONIA and the €STR is expected to develop along the term structure (i.e. between EONIA-linked and €STR-linked OISs) and how market liquidity is shared between the two markets.

Given that, from 2 October 2019, EONIA will be firmly linked to the €STR by a fixed spread of 8.5 basis points, the working group expects that (under mild assumptions resulting in negligible approximations)[18] this firm link will also be established along the term structure.[19] Thus, during the transition phase, the €STR curve will be able to be derived from the EONIA curve, and vice versa (see Figure 4, middle panel). Thus, €STR-linked and €STR-collateralised derivatives will be able to be valued using market information on EONIA derivatives, and vice versa, in all combinations shown in Table 1.

Furthermore, during the transition phase, the collateral rate of standard EURIBOR swaps will eventually change from EONIA to the €STR. Thus, when bootstrapping the corresponding EURIBOR projection curves, the appropriate discount curve has to be used. Note that the resulting projection

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[17]   Technically, the curve is commonly calibrated from EONIA-linked OISs, which are collateralised with EONIA as the collateral rate. OISs are compounding swaps paying the compounded EONIA index rate versus a fixed rate.

[18]   Please see the work already done by the working group, in particular "Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products", ECB, August 2019.

[19]   A good approximation of the €STR curve can be obtained by shifting the zeros of the EONIA curve by 8.5 basis points. See Annex 1 for further details.

curve can then (under mild assumptions resulting in negligible approximations) be use to project EURIBOR cash flows irrespective of the collateralisation.

In the post-transition phase, the €STR will have taken over the role performed by EONIA in the current pre-transition phase (see Figure 4, right panel).

Figure 4

Stylised evolution of multi-curve environment in transition from EONIA to the €STR

Pre-transition | Transition phase | Post-transition
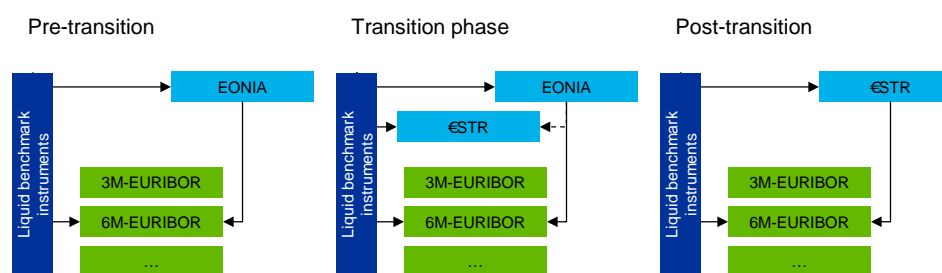
Note: EURIBOR is included for the sake of comprehensiveness.

As a technical side note, for both EONIA and €STR curves, during (and after) the transition phase, the common practice of using the fixing on day T when bootstrapping the end-of-day curves will no longer be feasible because €STR and EONIA fixings will be published on the following business day ("T+1").

4.3.2   Additional impacts on the valuation framework

Building on the multi-curve environment, the valuation framework entails the actual valuation function as well as the respective market data and control functions. The implications of the EONIA to €STR transition for these functions are listed in the table below. The relevance for specific institutions varies and has to be assessed individually. Given the analysis with regard to the multi-curve environment above and the firm link of EONIA to the €STR by a fixed spread, the implications can be assessed to be of minor relevance.

Please note that further discussion on EONIA to €STR-linked products, e.g. caps, floors and swaptions, can be found in Report by the working group on euro risk-free rates on the impact of the transition from EONIA to the €STR on cash and derivatives products.

The following table lists the functional areas of banks that will be most affected by the valuation aspects of the benchmark transition and the key considerations to be addressed and appropriately planned and executed.

Table 2

Implications of the EONIA to €STR transition for valuation and risk management functions

Function	Implication
Valuation	– Setting up capacity to value €STR-referencing and €STR-collateralised trades (including XVAs) – Setting up capacity to value under different collateralisation assumptions – Adapting multi-curve framework and valuation models (e.g. term structure models)
Market data management	– Setting up new €STR data feeds – Implementation of (possible) changes to EONIA data feeds, including consistent storage of fixings – Consideration of process/ methodology changes due to T+1 publication of the €STR (and EONIA)
Independent price verification (IPV)	– Setting up capacity to check €STR-linked and €STR-collateralised trades – Need to check compensation for value changes in the EONIA to €STR transition
Prudent valuation (PruVal) (core approach)	– Concerning, in particular, market price uncertainty and close-out cost additional valuation adjustment (AVA) – Setting up AVA calculation for €STR risk factors
Market conformity checks	– Setting up capacity to check €STR-linked and €STR-collateralised trades – Formal need to check compensation for value changes in the EONIA to €STR transition for market conformity
Pricing model validation	– (Possible) need for focused (re-)validations outside regular cycles

4.4   Practical implications for market risk

The introduction of new products referencing the €STR in parallel with products referencing EONIA, as well as the transition of products and the anticipated change in the discounting regime as outlined above, may lead to new basis risks and potential effects on market volatility and liquidity. These should be considered by banks from a practical market risk perspective.

As with to valuation risk, processes, models and systems related to market risk, including regulatory capital charges, will be affected. This section first outlines the major practical implications for market risk management resulting from the EONIA to €STR transition and then discusses implications in a regulatory context. The analysis concludes with a look at necessary modifications to IT systems and data.

The main practical implications of the EONIA to €STR transition for market risk management are depicted in the following table.

Table 3

Practical implications for market risk management of EONIA to €STR transition

1	Establishing the ability to value €STR-linked and €STR-collateralised products (cf. Section 4.3.1)
2	Introduction of the €STR (index and curve) as risk factors; adoption of pricing models to calculate corresponding €STR exposures; and establishment of a time series proxy
3	Assessment of the materiality of €STR-EONIA basis along the curve
4	Establishing the ability to transition from EONIA to €STR in EONIA-linked or EONIA-collateralised products, anticipating possible value shifts and related compensation payments
5	Catering for potential remaining EONIA exposure after 2021

Concerning points 1 to 3, the firm link between EONIA and the €STR and the high correlation between EONIA and pre-€STR in the past create the natural expectation of a negligible €STR-EONIA basis along the curve.[20] This leads to the conclusion that the historical time series of EONIA risk factors along the curve are feasible (and best available) proxies for the historical time series of €STR risk factors.

Concerning point 4, transition planning should fix switch dates in advance. Given the discussion above, possible value shifts and related compensation payments can then be quantified fairly accurately in advance, such that their effect can be isolated and tracked.

Concerning points 4 and 5, because of potential remaining exposure to EONIA which has not been transitioned before the end of 2021, contracts referencing EONIA should include fallback provisions (e.g. replace EONIA with €STR + 8.5 basis points) to enable institutions to price in the fallback rate (e.g. provide an €STR curve + 8.5 basis points as the discount curve).

Recommendation:

3) The working group recommends that market participants:

   a) use historical time series for EONIA risk factors along the curve as feasible (and best available) proxies for the historical time series of €STR risk factors before 2 October 2019;

   b) fix switch dates in transition planning in advance insofar as possible;

   c) communicate with clients in advance in order to facilitate a smooth transition and include fallback provisions in contracts referencing EONIA, in particular for those maturing after the end of 2021, in accordance with the recommendations on the EONIA to €STR legal action plan.[21]

4.4.1   Implications for market risk management in a regulatory context

This section expands the previous analysis of practical implications arising from the EONIA to €STR transition for market risk management by looking at the regulatory context of market risk management, in particular implications in the following six areas of interest:

- Internal capital adequacy assessment process (ICAAP)/ Supervisory Review and Evaluation Process (SREP)

- Standardised approaches for market risk

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[20]   Please note, however, that this assessment has to be conducted by each institution individually.

[21]   See Recommendations of the working group on euro risk-free rates on the EONIA to €STR legal action plan.

- Internal model approaches for market risk

- Formal model change criteria for internal models used under pillar 1

- Internal model approaches under the Fundamental Review of the Trading Book (FRTB)

- Implications for interest rate risk in the banking book (IRRBB)

4.4.2 Internal capital adequacy assessment process / Supervisory Review and Evaluation Process

The forward-looking internal capital adequacy assessment processes (ICAAP) is an institution's internal framework and consists of two pillars: the normative perspective and the economic perspective.

The normative perspective is a multi-year assessment of the institution's ability to fulfil all of its capital-related quantitative regulatory and supervisory requirements and demands under different scenarios. The economic perspective is a point-in-time comparison of (economically) measured risks, determined as VaR and/or by stress testing and measured over a one-year time horizon, and (economically) determined internal capital. In both the normative and the economic perspective, all material risks must be considered, and market risk resulting from changes in the overnight curve is expected to be material for almost all institutions.

For the normative perspective, new €STR-based products and a new €STR yield curve must be integrated into the capital planning processes and into scenarios in use, where applicable.

For the economic perspective, internal models are used to determine the amount of market risk. The implications for internal models are therefore also relevant for the ICAAP and are outlined in Section 4.4.4.

4.4.3 Standardised approaches for market risk

The current standardised approach for market risk is defined in Title IV of the CRR. It is generally exposure-based (e.g. based on notionals) and does not require the calculation of present values.

In May 2019 the CRR was amended by the CRR II[22] which introduced a standardised approach based on the Fundamental Review of the Trading Book (FRTB).[23] At the time of writing, it is generally

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[22]   Regulation (EU) 2019/876 of the European Parliament and of the Council of 20 May 2019 amending Regulation (EU) No 575/2013 as regards the leverage ratio, the net stable funding ratio, requirements for own funds and eligible liabilities, counterparty credit risk, market risk, exposures to central counterparties, exposures to collective investment undertakings, large exposures, reporting and disclosure requirements, and Regulation (EU) No 648/2012 (OJ L 150, 7.6.2019, p. 1).

expected that the FRTB standardised approach will have to be reported by specific institutions starting from 2021,[24] while the current standardised approach will continue to be used for the calculation of own funds requirements. In contrast to the current standardised approach, the FRTB standardised approach is based on sensitivities calculated using institutions' own pricing models.

If institutions want to trade products using the €STR as the forward rate, these positions have to be integrated into the standardised approach framework, as is the case for any other new product.

4.4.4 Internal model approaches for market risk

This subsection outlines practical implications for internal model-based approaches. No distinction is made between internal models used for calculating own funds requirements (pillar 1) and those used for calculating economic capital (pillar 2), as the implications apply to both.

For a generic internal model-based market risk management framework based on a calculation of VaR or expected shortfall, action is expected to be needed in the following areas (the motivations for such need for action are described below):

- Market data and pricing need to be adapted in the market risk systems. The corresponding main action points have already been outlined at the beginning of Section 4.4.

- For VaR models or expected shortfall market risk models, risk factor time series for the new curves need to be set up.

- For all new curves, including the €STR projection curve and the €STR discount curve, risk factors need to be set up in the market risk systems.

- For stochastic simulations, like Monte Carlo based VaR calculations, the stochastic distributions of the new risk factors need to be defined.

- Market data time series need to be made available for the new risk factors. These can then be used to calculate the statistical properties of the risk factors in a parametric or Monte Carlo type calculation, or for determining scenarios for historical simulations.

Regarding the risk factor definition, it is worth noting, that rates are often represented as a base rate plus a spread. For example, in a credit spread risk model the fair coupon of a bond might be represented as EONIA plus a certain percentage plus a credit spread. In cases where the spread is currently calculated relative to EONIA, it might be natural to calculate it relative to the €STR in

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[23]   See Basel Committee on Banking Supervision (BCBS), "Minimum capital requirements for market risk", Bank for International Settlements (BIS), January 2016, and BCBS, "Minimum capital requirements for market risk", BIS, January 2019 (rev. February 2019).

[24]   The reporting requirement will be effective no later than one year after the adoption of a delegated act with a deadline of 31 December 2019, according to the CRR, and it will apply only to institutions whose trading book business is above a threshold of €500 million or 10% of total assets. Institutions below this threshold are exempt from the reporting requirement.

future. If this is done without additional measures, jumps in the spreads might occur, possibly changing how market risks are allocated to market risk types, like interest rate risk, interest rate basis risk, and credit spread risk. As such changes require conscious model changes, institutions should be aware of this aspect.

As observed in the available pre-€STR data, historical time series of EONIA risk factors are the best available proxy for historical €STR risk factors. This also means that the stress period for the EONIA curve for the stressed VaR calculation can be seen as a good proxy for the stress period for the €STR curve. Even though this proxy is a natural choice, it should be combined with an increased focus on back-testing and validation as €STR markets develop: rigorous mark-to-market back-testing on appropriate sub-portfolios will be necessary to assess the quality of the proxies. For simulation methods that make assumptions about probability distributions, like Monte Carlo simulations, the statistical properties of the time series also need to be validated, once sufficiently long time series for the €STR and the benchmark derivative instruments used to construct the €STR curves are available.

> **Recommendation:**
>
> 4) The working group recommends that historical time series of the new curves be obtained using a two-step process, going from the present to the past. First, use the curves' past movements where available, i.e. from 2 October 2019 onwards, and, second, use the EONIA curve as proxy for earlier periods (before 2 October 2019).

For both stress testing and market risk models based on VaR or on expected shortfall, the calculation and aggregation of risk figures must be extended. The main action points are:

- Adoption of the risk management framework to cope with both the EONIA discounting curve and the €STR yield curve, as well as the corresponding projection curves as described in Section 4.3.1 covering the multi-curve environment.

- Preparation of the risk management system to switch from EONIA to €STR discounting on the discounting switch date.

- Preparation of the risk management system to switch from the EONIA projection curve to the successor curve.

- Integration of €STR risk factors and new €STR-based products into risk figure calculation, including P&L calculation and back-testing.

- Review of current stress period for calculating stressed VaR.

- New contracts (€STR-linked) and legacy contracts must be properly managed by the risk system with respect to possible different discounting methodologies as well as different projection curves.

5) Regarding the calculation of internal model-based risk figures, it is recommended that market participants integrate new products referencing the €STR and €STR risk factors and scenarios into the calculations of value at risk (VaR), stressed VaR, sensitivities and stress testing. The profit and loss (P&L) calculation and the back-testing framework also need to be extended.

6) According to Article 365(2) of the Capital Requirements Regulation (CRR), stressed VaR has to be calculated with model inputs calibrated on a 12-month period of significant financial stress relevant to the institution's portfolio. In the context of the EONIA to €STR transition, market participants should verify whether the current stress period is still appropriate.

7) Regarding risk reporting and limit systems, the working group recommends market participants to ensure that market risks arising from new €STR-based products and €STR risk factors are limited. To meet this requirement, additional limits, for example for €STR sensitivities, might be necessary.

For the determination of the impact on risk factors and for the validation of risk metrics, main considerations and issues are:

- The impact of the €STR introduction on risk figures is highly dependent on, for example, portfolio composition, open positions, and risk factors affected.

- One-off effects in P&L are possible on or shortly after the discounting switch date owing to the switch in discounting.

- Each institution should therefore conduct an impact analysis to quantify the individual changes in their risk figures.

- Risk management systems should be able to conduct various impact analyses (mirror or test environments may therefore be necessary).

- General expectations on how risk figures change as a result of the EONIA to €STR transition cannot be stated, as the actual change is strongly affected by portfolio composition and open positions.

Depending on the exposure of the portfolio of the respective financial institutions on the discounting switch date (or shortly after), a one-off jump in P&L is possible as a result of the change in the discounting of future cash flows at the lower €STR-level (8.5 basis points below the EONIA-level). On the other hand, this jump is not likely to be fully reflected in VaR figures, so institutions are advised to monitor back-testing outliers. If a back-testing outlier occurs, an assessment of whether or not it is expected should be made (i.e. can it be fully explained by the switch in discounting or not).

Recommendations:

8) In order to assess the impact of the EONIA to €STR transition, each institution should conduct an appropriate quantitative impact assessment of key market risk figures, including:

   a) an impact test on VaR and sensitivity limits,

   b) an impact test on internal models for regulatory capital charges for market risk.

For institutions using internal model approaches for the calculation of own funds requirements, the quantification of changes in market risk figures is mandatory (see the section below on formal model change criteria.

4.4.5 Formal model change criteria for internal models used under pillar 1

Banks with an approved internal model for the calculation of regulatory own funds requirements for market risk are required by a dedicated regulatory technical standard (RTS)[25] to assess the materiality of extensions and changes to the internal model.

Institutions should be aware of the requirements of the RTS and make their own assessment of changes related to the EONIA to €STR transition with regard to the model change criteria. When applying the model change governance requirements for internal models, it would be beneficial for banks and authorities to arrive at a common understanding under the given non-standard circumstances.

Recommendations:

9) With respect to internal models for the calculation of regulatory own funds requirements for market risk, the working group recommends that banks and relevant European Supervisory Authorities and national competent authorities enter into a discussion with the goal of producing suitable standard interpretations regarding the required analysis and reporting of the model changes for internal models used under pillar 1 in the context of benchmark transition.

4.4.6 Internal model approaches under the Fundamental Review of the Trading Book

In May 2019 the CRR was amended by the CRR II which introduced an alternative internal model approach based on the Fundamental Review of the Trading Book (FRTB)[26]. At the time of writing, it is generally expected that the alternative internal model approach will have to be reported by specific

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[25] Commission Delegated Regulation (EU) 2015/942 of 4 March 2015 amending Delegated Regulation (EU) No 529/2014 supplementing Regulation (EU) No 575/2013 of the European Parliament and of the Council as regards regulatory technical standards for assessing the materiality of extensions and changes of internal approaches when calculating own funds requirements for market risk (OJ L 154, 19.6.2015, p. 1).

[26] See Basel Committee on Banking Supervision (BCBS), "Minimum capital requirements for market risk", Bank for International Settlements (BIS), January 2016, and BCBS, "Minimum capital requirements for market risk", BIS, January 2019 (rev. February 2019).

institutions starting from second quarter of 2023,[27] while the current internal model approach will continue to be used for the calculation of own funds requirements.

The main issues for internal models under the FRTB regarding the EONIA to €STR transition are:

- The forthcoming FRTB regulation requires risk factors to be classified as modellable to pass the risk factor eligibility test.

- For expected shortfall calculated under stressed conditions, the observation period must reach back to and include the year 2007.

Under the forthcoming FRTB regulation, a bank must determine which risk factors within its trading desks are eligible to be included in the internal expected shortfall model for regulatory capital requirements. For a risk factor to be classified as modellable, a necessary condition is that it passes the risk factor eligibility test (RFET), which requires the identification of a sufficient number of observable real prices[28] that are representative for the risk factor.

In relation to the EONIA to €STR transition, the RFET, which has to be performed in 2021 before the FRTB applies, may have two outcomes that would imply a capital requirement add-on:

Table 4

Outcomes of risk factor eligibility test

Outcome	Assessment
The €STR fails the test and is assessed as non-modellable.	The postponement of the FRTB implementation to 2022 provides more time to develop a liquid market for the €STR and may allow a sufficient number of observations to avoid non-modellability.
	A liquid €STR market should be developed in the first half of 2020 to guarantee at least one year of price observations before the conduct of the first RFET in 2021.
EONIA fails the test and is assessed as non-modellable.	A liquidity reduction in the current EONIA market during the transition phase may lead to EONIA being assessed as non-modellable.

The FRTB also requires the expected shortfall to be calibrated to a period of stress. The calibration is based on a reduced set of modellable risk factors for which there is a sufficiently long period of

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[27] The reporting requirement will be effective from the end of a three-year period following the date of entry into force of a set of regulatory technical standards with a common deadline of 28 March 2020, according to the CRR, and it will apply only to institutions whose trading book business is above a threshold of €500 million or 10% of total assets. Institutions below this threshold are exempt from the reporting requirement.

[28] According to the FRTB, a real price is either a price at which the institution has conducted a transaction, a verifiable price for an actual transaction between other arms-length parties, a price obtained from a committed quote (which has to be collected and verified through a third-party vendor, a trading platform or an exchange), or a price that is obtained from a third-party vendor, which has to fulfil further conditions. For a risk factor to pass the RFET, an institution must identify on a quarterly basis either 24 real price observations per year (measured over the period used to calibrate the current expected shortfall model), or at least 100 real price observations over the previous 12 months.

observations (dating back to at least 2007), and which has to cover more than 75% of the expected shortfall.

Regarding the €STR, further practical implications may occur:

- If the €STR is a non-modellable risk factor, it cannot be used in the reduced set of risk factors.

- If the €STR is a modellable risk factor and is needed to explain at least 75% of variation, it also has to provide observations dating back to 2007. This requires a reconstruction of €STR observations back to 2007 using the proxy given above.

4.4.7 Implications for interest rate risk in the banking book

Institutions use internal methods for the measurement and management of interest rate risk in the banking book (IRRBB),[29] and all practical implications for internal model approaches already mentioned in Section 4.4.4 also apply to IRRBB. However, there are further IRRBB-specific implications, as outlined below, if an index is changed to a new benchmark rate.

- Scenario generation: the same practical implications apply as for internal models for the trading book and as already outlined in previous sections. This also applies to economic value of equity (EVE) stress tests (eight IRRBB scenarios, including the two outlier test scenarios).

- In addition, the €STR curves and €STR-based products must also be integrated into the earnings at risk calculation framework (net interest income, NII). The framework in general consists of time-resolved market scenarios (into which the €STR curves must be integrated) and scenarios modelling balance sheet evolution (into which €STR-based products must be integrated).

- Analysis of the impact on risk metrics and validation: the same practical implications apply as for internal models for the trading book as already outlined in Section 4.4. In addition, an impact analysis regarding earnings at risk and IRRBB stress testing should be performed.

As the €STR is economically similar to EONIA and EONIA will be equal to the €STR plus a fixed spread during the transition period and, if fallback agreements for EONIA exist, also beyond the end of 2021, the EONIA to €STR transition is not expected to affect market risk management of the banking book, i.e. banking book steering and hedging practices.

4.5 Technical implications for valuation and market risk management

As outlined in the previous sections, the transition from EONIA to the €STR and its practical implications for valuation and market risk management will have considerable technical implications,

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[29]   See, for example, European Banking Authority (EBA) Guidelines on the management of interest rate risk arising from non-trading book activities (EBA/GL/2018/02).

especially in relation to market data and IT system amendments. The following part therefore builds on the necessary adoptions outlined above and puts them in the context of IT systems and data.

4.5.1 Implications for IT systems

The transition from EONIA to the €STR will have an impact on the full front-to-back IT system landscape related to products, models, and processes affected by interest rate benchmarks. This is similar to a new product approval process where implications need to be assessed for each affected system. Such an assessment should generally consider all relevant IT systems. Precisely which systems are affected will depend on a financial institution's individual technical setup. However, Figure 5 gives a simplified and stylised overview.

Figure 5

Stylised overview of affected risk management IT systems
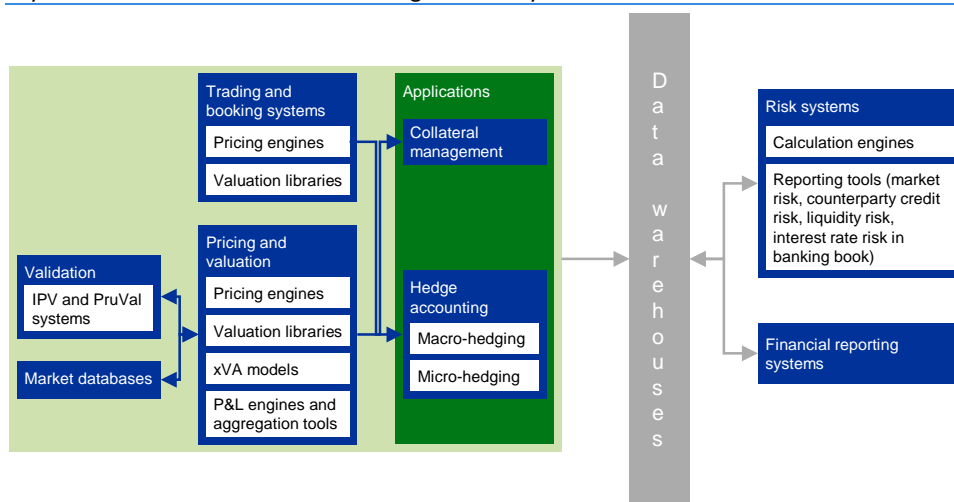
As outlined in the section covering practical implications for valuation risk, the valuation infrastructure will be particularly affected due to the introduction of €STR products and the future change of discounting curves. This includes pricing engines and valuation libraries, including VA models, interest rate (IR) curve bootstrapping tools, P&L engines, and IPV and PruVal systems. Market data systems and processes will also be affected due to new curves and products that need to be set up as outlined in Section 4.5.

Owing to the uncertainty in timelines for the individual switching of discounting regimes for both centrally cleared derivatives and bilaterally collateralised derivatives, several discounting curves for valuations need to be maintained in parallel. Market participants should analyse technical capabilities in order to be able to switch from one valuation curve to another when required.

Similarly, the risk infrastructures of institutions, in particular for market risk and counterparty credit risk, need to be amended in order to capture the above aspects. Moreover, the related calculation engines are likely to be affected and will need to be amended.

To be able to accurately analyse the impact on financial and risk figures, institutions should prepare their risk management systems accordingly. Depending on the institution's risk infrastructure, such

analyses could be conducted in the production system or in an isolated system environment (e.g. a production-like test environment). This would allow institutions to decompose changes to the model made in the context of €STR implementation into individual steps with the overall goal of reducing changes in risk figures to the contributions of each of the steps. Specific configurations might be needed for specific impact assessment purposes, especially for internal models, owing to the need to configure, segregate and maintain ad hoc sessions for regulatory purposes in parallel for an extended period of time (e.g. for model change assessment).

Recommendation:

10) The working group recommends that market participants carefully assess potential impacts on their IT system landscape and processes related to risk management implications, including an analysis of the technical ability to switch from one valuation curve to another when required.

4.5.2   Implications for data

Implications for data mainly stem from new market data required in relation to the introduction of the €STR, the development of €STR-based products and potentially new interest rate basis swap products. In terms of market data, the following points are worth consideration and assessment by institutions:

- Market data set-up: New interest rate curves need to be introduced as part of the market data framework (connectivity with external providers, trading systems, risk systems, financial reporting systems), including data quality processes and the calculation of new projection and yield curves, e.g. within the multi-curve bootstrapping procedures outlined in Section 4.3.1.

- Historical data: The calibration of internal models to measure market and counterparty credit risk (for the regulatory internal model approach (IMA), internal model method (IMM) or internal risk management) requires time series of historical market data, including historical stress periods, as outlined above. Such historical data time series need to be considered as part of market data warehouses and market data management processes.

In addition to implications for market data specifically, institutions are recommended to consider existing regulatory requirements on data and data management which may be impacted by the transition from EONIA to the €STR. On one hand, there are specific regulatory requirements related to market data, valuation and market risk, in particular in Article 105 of the CRR on prudent valuation and as part of requirements on model changes, model assessments and the ECB guide to internal models and the ECB Guide for the Targeted Review of Internal Models (TRIM) [30]. On the other hand, the new benchmark €STR needs to be integrated into the institution's guidelines and processes due to BMR requirements, such as benchmark inventories and reporting.

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[30]   See ECB guide to internal models, November 2018 and ECB Guide for the Targeted Review of Internal Models (TRIM), February 2017.

4.6 Implications for other financial risks

While the valuation and market risks already covered are the two risk types which are most affected by the EONIA to €STR transition, the analysis also extends to counterparty credit risk and liquidity risks as additional financial risk types.

With respect to **counterparty credit risk**, the anticipated change in the valuation of derivative instruments as outlined above will directly affect counterparty credit risk exposures. Assuming a perfectly working compensation mechanism, such risks should be mitigated for collateralised derivatives. Depending on individual valuation practices, exposures may also be impacted for uncollateralised derivatives, which should be analysed by financial institutions.

The processes, models and systems related to counterparty credit risk, including regulatory counterparty credit risk capital charges, may be affected as new €STR products, interest rate curves, and discounting mechanisms are needed for exposure calculation methodologies. In particular, banks using an internal model method for counterparty credit risk exposure calculation should assess required amendments, also taking into account regulatory guidelines on model assessment and model changes.

With respect to **liquidity risk**, when changing discounting curves for each counterparty, depending on agreed compensation mechanisms, exposure changes may trigger collateral margin calls and/or compensation payments. Financial institutions should analyse related risks due to potential liquidity effects on the respective switch dates.

The change in valuation of derivative instruments as outlined above will affect derivative exposures considered for the determination of regulatory liquidity ratios, e.g. the net stable funding ratio (NSFR) and the liquidity coverage ratio (LCR).

Recommendation:

11) As the €STR will be published on a following business day (T+1) basis, with EONIA following suit from 2 October 2019 onwards, market participants should consider:

a)   potential effects on short-term liquidity risk/ratios,

b)   potential effects on settlement risks from changes in the publication schedule and its impact on fixing and payment processes and related systems.

4.7 Implications for non-financial risks

Apart from financial risks, several non-financial risks and operational risks are affected by the transition from EONIA to the €STR as outlined in the following table:

Table 5

Implications for non-financial risk management

Risk type	Implications
Legal, conduct and documentation risk	End users and clients need to understand the interbank offered rate (IBOR) reforms before legal changes and new products are introduced and traded. For the execution of transactions using new indices, it is also necessary that clients have implemented a transition programme and understand the associated risks (hence the need for adequate disclosures).
	In addition to these general remarks, there are several aspects relating to legal and documentation risks in the context of the transition from EONIA to the €STR. Generally, such risks may arise due to required amendments to financial instrument contracts, current accounts and/or collateral agreements.
	Furthermore, institutions may be exposed to increased risk due to uncertainty about the interpretation of legacy contracts referencing EONIA concerning negotiated transition and fallbacks to €STR, including the failure to re-negotiate contracts in due time.
	Moreover, institutions may be exposed to increased risk due to insufficient disclosure of risks and insufficient documentation of discretionary actions taken, in particular in relationships with non-bank clients.
Process disruption and operational risk	There is an increased risk due to change and transformation activities related to the introduction of the €STR and the transition from EONIA to the €STR (e.g. booking failures, manual workarounds) which financial institutions should consider as part of their analysis and mitigation plans.
IT risk	In the context of the introduction of the €STR and the transition from EONIA to the €STR, there is an increased risk due to change and transformation activities in both in-house and vendor systems (e.g. breakdowns due to hard-coded references or missing fixings after amending the EONIA fixing from the same day to the following day with the introduction of the €STR).
Model risk	Model risk is likely to increase temporarily due to the possible need to amend or revise several models and conduct corresponding model validations and model risk assessments.
Reputational risk	In an environment of increased conduct, legal, IT and process disruption/operational risk, financial institutions may also be exposed to increased reputational risk as a result of increased public attention.

5 Risk management impact analysis of €STR-based fallback rates for EURIBOR

5.1 EURIBOR fallback provisions and rates

A crucial difference between EURIBOR and EONIA is that EURIBOR will continue to be provided under the new methodology. The analysis of EURIBOR will therefore primarily focus on the implementation of new fallback rates for EURIBOR based on a €STR-based term structure methodology and potential inconsistencies between different product classes which could use different fallback rates and/or triggers. The analysis of fallback rates will consider the previous analyses by the working group and also take into consideration recommendations from the International Swaps and Derivatives Association (ISDA).

Incorporating fallback provisions in contracts that make use of reference rate are not only required under the BMR for certain entities and contracts, but it should also be seen as a sound practice for every user. Therefore, contracts containing references to market indices should contain suitable fallback arrangements that will apply in case the original reference index materially changes or ceases to be provided. These fallback rates will become effective if a fallback trigger event occurs. Such an event typically consists of official notice from the administrator or the competent regulatory authority that the index cannot be provided. The index fixing process itself often contains contingency safeguards and alternative procedures that are intended to provide index values if there are temporarily disruptions in the ordinary delivery, but these are not the subject of this chapter.

Although EURIBOR was declared BMR-compliant by the FSMA on 2 July 2019 and will persist, a prudent approach to risk management should take the possibility of the non-availability of EURIBOR into account. This is also required by the BMR/IOSCO. In this case, the corresponding fallback rates will become effective.

A €STR-based term structure to be used as a fallback for EURIBOR could be produced by applying either a backward-looking methodology (based on calculations using realised rates) or a forward-looking methodology (which includes expectations). The working group is analysing how to produce such €STR-based term structures[31], analysing the possible co-existence of backward and forward-looking methodologies and which would be the most appropriate methodology for each financial product[32].

On 14 March 2019, the working group, taking account of the feedback received in response to the second public consultation on fallback rates for EURIBOR, recommended the OIS (tradable) quotes-based methodology as the €STR-based forward-looking term structure methodology that

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[31]   See Terms of reference of subgroup on term rates of the working group on euro risk-free rates.

[32]   See Terms of reference of subgroup 5 on cash and derivatives products of the working group on euro risk-free rates.

could be used as a fallback for EURIBOR-linked contracts within a reasonable time period following the launch of the daily €STR publication", requiring "(i) significant transfer of liquidity to €STR OIS markets, (ii) transparent and regulated underlying derivatives markets such as trading on multilateral trading facilities (MTFs), (iii) sufficient sources of data".[33] The working group also put emphasis on the reliability of the benchmark in times of stress. The working group is currently further analysing how to make the OIS (tradable) quotes-based methodology, as the recommended forward-looking methodology, a feasible alternative.

The working group is also working on providing a description of backward-looking methodologies and analysing the possible co-existence of backward and forward-looking methodologies and is planning to make recommendations on the most relevant EURIBOR fallback methodology for each financial product in liaison with ISDA and with similar initiatives in other jurisdictions. The present chapter first presents general scenarios that should be considered in the context of fallback rates, with particular application to EURIBOR, and with a view to risk management. The following sections then discuss the practical risk management implications and potential IT system and data implications.

5.2   Scenarios for fallback provisions and rates

Concrete fallback clauses contain a replacement rate together with an adjustment computation procedure and adjustment spread; the latter is in place in order to minimise the value transfer when shifting from the previous rate. When a fallback scenario is no longer seen as remote, the fallback arrangements will influence the affected instrument's valuation in proportion to the perceived likelihood of transition. For that reason the choice of fallback arrangement is important from a risk management point of view (see also the discussion in the following subsection).

Different classes of instruments are normally subject to different contractual agreements. Therefore it could well be that, when introducing fallback agreements for EURIBOR-linked contracts, these agreements differ across product classes.

In addition to that, there may be inconsistencies in the timing of fallback trigger events. If explicit wording in contracts differs from the standard definition of potential trigger events, fallback provisions can in principle be triggered at different times for different products.

Figure 6 shows the two types of inconsistencies, in (i) fallback rate definition and (ii) timing of fallback transition. It is evident that a timing inconsistency can add to the discrepancy between different fallback rate definitions, increasing potential risks to hedging, hedge accounting and asset and liability management (ALM).

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[33]   See "Recommendations of the working group on euro risk-free rates on the transition path from EONIA to the €STR and on a €STR-based forward-looking term structure methodology", ECB, 14 March 2019.

Figure 6

Potential main fallback inconsistencies between product classes
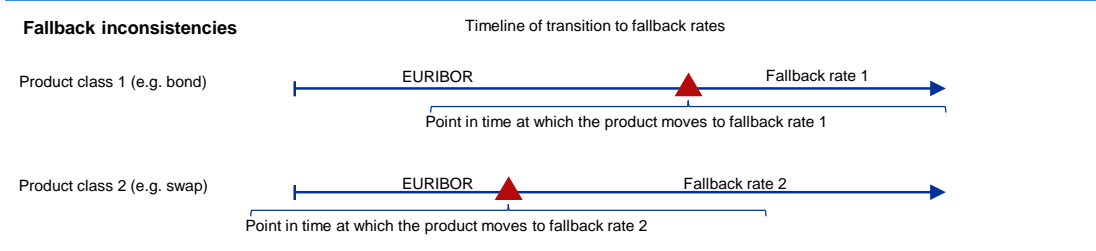
At present, working groups on risk-free rates in different jurisdictions are considering a multitude of possible fallback arrangements. In the United States, for instance, the Alternative Reference Rates Committee (ARRC) has published final recommendations for more robust LIBOR fallback language differentiating between different product classes (namely bilateral business loans, floating rate notes, securitisations and syndicated loans, while adjustable rate mortgages are still in the consultation phase as of July 2019).[34] These recommendations try to strike a balance between flexibility in unforeseeable circumstances, appropriateness for the financial instruments in question, standardisation and alignment between underlying cash products and hedging derivatives.

Furthemore, on 20 December 2018 the ISDA published an Anonymized Narrative Summary of Responses to the ISDA Consultation on Term Fixings and Spread Adjustment Methodologies. The feedback from this consultation, covering some of the major currencies, supports a fallback for ISDA derivative contracts based on a "compounded in arrears" methodology. The ISDA is planning to launch a similar consultation covering EURIBOR fallbacks for ISDA derivative contracts.

The working group is considering a range of possible fallback approaches and their pros and cons, taking the Financial Stability Board (FSB) user guide[35] as a starting point as well as the experience and proposals of other working groups and industry bodies.

In view of the different work streams across major markets, it cannot be ruled out that there may be different proposals for fallback arrangements applying across products and jurisdictions. This may lead to certain valuation difference and thus basis risks, which could affect hedging and ALM. Market participants should therefore be aware of such risks.

In view of these current developments, the working group recommends the following considerations for market participants holding contracts referencing EURIBOR (this includes EURIBOR as reformed following the hybrid methodology):

Establishing a common market practice is important in order to reduce operational costs and simplify the system implementation of the different fallback options.

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[34]   See "Fallback Contract Language", ARRC.

[35]   See "Overnight Risk-Free Rates: A User's Guide", FSB, June 2019.

12) Through the analysis included in this report, the working group highlights possible risk management implications of (i) having timing inconsistencies in fallback provisions triggers and (ii) incorporating different fallback trigger language for different asset classes. In particular, side effects could arise from the lack of consistent language for the usual hedging product combinations. Market participants are recommended to consider these risks when developing fallback provision triggers.

13) From a risk management perspective, market participants should try to reduce the variability of fallback rates between different product classes (including derivatives) to a minimum, but it is ultimately a matter for parties to resolve taking account of their individual circumstances.

Possible effects of implementing a certain fallback can be quantified by estimating the effect on valuations of a concrete fallback provision. A key aspect here is the determination of the spread adjustment which will occur during the fallback transition. Based on such quantitative assessments, the possible impact or risk/sensitivity of different fallback rates can be compared to guide the selection of different fallback choices.

5.3 Practical risk management implications of fallback provisions and rates

If fallback provisions are seen as only a very remote and irrelevant contractual provision, their effect on valuation will be correspondingly insignificant. However, fallback provisions will have an effect on valuation (and therefore also on hedging quality) when a trigger event appears more likely in the market, possibly long before the event actually occurs. For longer-maturity instruments the likelihood of a valuation effect from the fallback provisions increases. Differences in timing of the transition to fallback rates and the definition of those rates can potentially create P&L volatility related to the "basis risks" between EURIBOR and the corresponding fallback rates.

Basis risk depends not only on the size of the basis but primarily on the volatility of the basis. Current basis spread volatilities are of course only imperfect predictors of future volatility. In particular, contingent on a fallback event, which in the case of EURIBOR might well involve severe market turbulences, spread levels and volatilities are likely to change, possibly dramatically. This can only be quantified within scenario or stress testing type approaches, as basis risks might be much higher than foreseeable at present.

The basis risks may be hedged using appropriate instruments, such as basis swaps. However, in view of the uncertainty with respect to the applicable fallback rate, those instruments cannot yet be specified. Market liquidity of such hedging instruments is also a key consideration for the practicability and cost of such hedging activities, influencing in turn pricing and hedging of the products affected by basis risks. This is also an important consideration for liquidity transfer between different currency markets, using cross-currency swaps as hedges.

14) The working group recommends that market participants:

    a)   gain an overview of the quantity of basis risk exposure from fallbacks in their current EURIBOR-indexed contracts by assessing the exposure amount and estimating the magnitude and volatility range of the spread;

    b)   gain an overview of and develop a clear plan for current and future hedging instruments and strategies for the relevant basis risks, including associated costs;

    c)   set up corresponding market observations and possible warning indicators for market liquidity in the relevant hedging instruments.

5.4   IT system implications of fallback provisions and rates

The focus of this section is analysing the implications of the introduction of fallbacks for EURIBOR in systems and processes used for risk management. However, the general considerations included in Chapter 4, in particular the simplified and stylised representation of affected IT systems, as given in Figure 6, are also representative for the analysis of fallback provisions and rates, as the implications not only concern trading, valuation or risk systems, but the whole processing chain. For instance, loan accounting systems and processes must be confronted with topics such as differences in accrued interest calculation, back office / payments, inclusion of compounding, averaging for spread adjustments, etc. for relevant fallback rates.

Generally, the more diverse fallback rates across contracts are, the higher is the impact on systems in view of the implementation and maintenance costs for a multitude of scenarios. This is also valid if a waterfall type of fallback provision is implemented in a contract. Waterfalls are demanding, as they would require a great amount of system flexibility. Achieving such flexibility would require a long implementation cycle, and many institutions may be reluctant to cover such a cost in a scenario in which the disappearance of a benchmark may appear remote. Therefore, it is desirable to limit the different possibilities of fallback methodologies.

An additional process and data aspect is the observation of market liquidity, to guide pricing, hedging and accounting (e.g. leveling in IFRS accounting, or proxying/modellability of risk factors). This will involve data collection, the defining of key risk indicators and appropriate financial reporting.

15) Current activities at institutions – in collaboration with system vendors – could include gap and activity planning for potential fallback rates regarded as particularly relevant. Fallback-relevant data should be collected. These could include relevant valuation and risk factors, and a high-quality history of these data could already be useful for risk management purposes. Market liquidity and observability will be key data and risk management aspects.

16) Market participants should consider establishing a governance framework involving front office and risk functions to monitor the benchmark and contractual fallback exposures at a sufficiently differentiated level on an ongoing basis (providing them with guidance , for example, on the reply to the letter of 3 July 2019 from the Chair of the Supervisory Board concerning banks' preparation with regard to interest rate benchmark reforms and the use of risk-free rates).

5.5   Data implications of fallback provisions and rates

The requirements included in Section 4.2.3 for any new market data also apply to applicable fallbacks for EURIBOR.

Data for the observation of market liquidity are already widely available in front office activities. However, as discussed above, for EURIBOR fallback rates, some market instruments still need to be developed. A rapid start of €STR trading will be important for market participants.

The fallback trigger events themselves are, of course, subject to market developments and volume and diversification. Therefore, an appropriate view of the likelihood or remoteness of fallback triggers will be crucially influenced by market liquidity and the reliability/stability of observable quotes.

Finally, the analysis conducted in Chapter 4 reveals that the fixed spread between EONIA and the €STR facilitates the EONIA to €STR transition with respect to risk management implications significantly. These findings should be considered in the process of forming respective fallback rates for EURIBOR.

17) With respect to fallback data, it would be particularly useful to have a consistent source for the publication of fallback rate values, including the respective spread adjustments, i.e. a vendor could publish it ensuring compliance with the EU Benchmarks Regulation (BMR)[36] and with International Organization of Securities Commissions (IOSCO) principles.

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[36]   Regulation (EU) 2016/1011 of the European Parliament and of the Council of 8 June 2016 on indices used as benchmarks in financial instruments and financial contracts or to measure the performance of investment funds and amending Directives 2008/48/EC and 2014/17/EU and Regulation (EU) No 596/2014 (OJ L 171, 29.6.2016, p. 1).

6 Additional risk management implications for the asset management and insurance market participants

Building on the analysis conducted above, the following section provides guidance on the components of a risk assessment and a discussion of additional risk management aspects that are of particular relevance for the asset management and insurance sectors. The working group would like to highlight once more the necessity of a detailed transition plan, which should be based on an assessment of key risks as outlined in Section 4.2 and enable delivery by the end of 2021 (for the EONIA to €STR transition). The present section covers both implications for risk management from the EONIA to €STR transition and implications arising from €STR-based fallback rates for EURIBOR.

Recommendation:

18) In accordance with the general risk management implications outlined in Chapter 3, market participants should undertake a detailed impact assessment to identify the areas along the full value chain that are affected by the transition and that require the definition of mitigating actions.

6.1 Key considerations

The following non-exhaustive list provides an overview of potential implications for asset management and insurance companies along the value chain. The working group has identified implications for valuation, risk management and outreach functions in the following fields.

- **NAV and risk calculations:**

  For net asset value (NAV) and risk calculations the new interest rates need to be mapped to the respective instruments and a suitable way needs to be found to move from the old regime to the new (e.g. IT applications) without creating any disruptions or inconsistencies during the transfer, for example regarding the effectiveness of hedges.

- **Internal and external reporting in the context of the T+1 publication of the €STR:**

  Reflecting the publication of EONIA and the €STR at T+1 in internal processes could have a substantial impact on internal and external reporting. This is especially relevant where reports are produced over night. This in turn could lead to important changes regarding existing reporting times, related batch jobs and data flows into downstream systems.

- **Changes in the IT landscape due to the publication of EONIA and the €STR in parallel:**

  Parallel processing of EONIA and the €STR and publication at T+1 may have an impact on systems, applications, interfaces and batch jobs (e.g. NAV calculations). This could result in a large IT effort for

implementation and testing, including front-to-back regression testing. Please also refer to Section 4.5.

- **Outsourcing of services to third parties:**

  Market participants may be affected by services that are outsourced to third parties. A transition from existing to new reference rates would require that external service providers are able to ensure operational readiness, that existing contracts with those providers (e.g. custody agreements) which refer to benchmark rates are updated and that there is alignment with the third parties on the timing of the transition.

- **Adjustments of existing investment guidelines:**

  The transition to new risk-free rates could affect existing investment guidelines referring to current IBORs. Changes in investment guidelines could require approval from both fund boards and clients. The adjusted investment guidelines/prospects/investment contracts must be distributed to the clients. In addition, the investment guidelines must be coded and tested.

- **Communication to clients:**

  Market participants will need to pay due regard to the interests of their clients and treat them fairly and to pay due regard to the information needs of their clients and communicate with them in order to educate and inform them and, where necessary, renegotiate contracts. These principles will apply in relation to contracts that they are entering into and products they are selling and will be relevant in the context of introducing new fallback provisions and ensuring the provision of adequate disclosure and communication of pay-out profiles.

6.2 Insurance industry related topics with respect to Solvency II

The insurance industry uses reference rates as actively as other sell or buy-side participants. For insurance companies there are multiple areas to consider when assessing the impact of the benchmark reform and developing transition plans. A significant part of such an assessment overlaps with the previous sections.

In addition, the working group would like to highlight that the introduction of €STR-based fallback rates for EURIBOR creates an extra layer of challenges for insurers, stemming from the regulatory framework for liabilities valuation (Solvency II framework). Market participants are required to use a set of predefined "risk-free" curves derived from benchmark rates to derive best estimate liability (BEL) figures. Any change in this area could potentially have a large impact on the reported capital position, since insurers possess significant risks at longer tenors.

The Solvency II basic risk-free curve is intended to be as near risk-free as possible, but is also based on deep, liquid and transparent markets. With the market for OIS derivatives being, other than at very short dates, historically relatively illiquid, Solvency II as currently drafted uses:

- IBOR swap curves (e.g. the six-month EURIBOR curve for EUR)

- Less a credit risk adjustment (CRA)

- The CRA is derived from 50% of the 12-month moving average between observed fixings of the IBOR (three-month for EUR) and the corresponding OIS rate (EONIA for EUR)

If the market in the €STR becomes sufficiently liquid compared to EURIBOR, then the logic of Solvency II would suggest that the regulatory risk-free curve might shift to the €STR, with no need for a CRA. However, this will require a decision from EIOPA and a change in the regulations. Furthermore, as insurers are major users of long-dated derivatives, any shift in liquidity from EURIBOR to the €STR may depend on changes in the regulatory curve, and changes in the curve may depend on a shift in liquidity, resulting in a circular process.

In the sterling (GBP) market, where the BoE is suggesting LIBOR may not survive as a benchmark beyond the end of 2021, the equivalent BoE working group has written to EIOPA suggesting that the use of LIBOR in the Solvency II curve may not be appropriate post 2021, and is also hindering adoption of derivatives based on SONIA, the new near-risk-free rate.[37]

Recommendation:

19) The working group recommends with respect to Solvency II that insurance companies:

  a) analyse all Solvency II dependencies in the light of the benchmark reform;

  b) proactively engage with the European Insurance and Occupational Pensions Authority (EIOPA) and relevant national competent authorities for clarification regarding the long-term composition of the EIOPA liabilities discounting curve going forward.

The working group would also like to clarify that as long as EIOPA uses EONIA there is no impact on any CRA. An impact will only arise only if the CRA is based on the €STR. Overall, companies should have a complete understanding of the impact of EONIA to €STR transition on BEL calculations.

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[37] See the letter of 9 July 2019 from the BoE Working Group on Sterling Risk-Free Reference Rates to EIOPA on "Removal of Regulatory Barriers to IBOR transition and establishment of a pan-European Taskforce".

7 Annex

7.1 Annex 1 – Deriving €STR curves from EONIA curves (and vice versa)

7.1.1 Calculating €STR projection rates from a given EONIA yield curve

Let $P(t, T)$ denote the EONIA-linked discount factor for observation time t and maturity time T. The simply compounded EONIA index rate L_i for an overnight period T_{i-1} to T_i with day count fraction τ_i is related to these discount factors via

$$L_i = \left[\frac{1}{P(T_{i-1}, T_i)} - 1\right]\frac{1}{\tau_i}.$$

The corresponding forward EONIA rate $L_i(t)$ for $t \leq T_{i-1}$ is defined as the expectation in the EONIA-centric T_i-forward measure[38] $\mathbb{Q}^{T_i}$ using $P(t, T_i)$ as numeraire. We get the familiar formula

$$L_i(t) = \mathbb{E}_t^{T_i}\left\{\left[\frac{1}{P(T_{i-1}, T_i)} - 1\right]\frac{1}{\tau_i}\right\} = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - 1\right]\frac{1}{\tau_i},$$

with $\mathbb{E}_t^{T_i}[\cdot]$ the expectation with respect to $\mathbb{Q}^{T_i}$ given the information available at t; this can be calculated using the EONIA yield curve bootstrapped at time t.

Let the simply compounded €STR rate for an overnight period T_{i-1} to T_i be denoted by R_i. Since simply compounded overnight rates for EONIA and the €STR are linked by the deterministic additive spread s, we have

$$R_i = L_i - s.$$

As a consequence, the forward €STR rate $R_i(t)$ (using the EONIA-based $P(t, T_i)$ as a numeraire) is also linked to the forward EONIA rate via that same fixed spread; that is

$$R_i(t) = \mathbb{E}_t^{T_i}\left\{\left[\frac{1}{P(T_{i-1}, T_i)} - 1\right]\frac{1}{\tau_i} - s\right\} = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - 1\right]\frac{1}{\tau_i} - s = L_i(t) - s.$$

This relationship allows us to price EONIA-collateralised €STR-linked swaps without any further modelling assumptions on the €STR forward rate.

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[38] In this section, we define the (EONIA-centric) risk-neutral T-forward measure $\mathbb{Q}^T$ for a time horizon T using the EONIA-collateralised zero bond maturing at T as a numeraire. An €STR-centric T-forward measure $\overline{\mathbb{Q}}^T$ can be defined analogously, using the €STR-collateralised T-bond as a numeraire. We argue that the difference between these two measures is non-zero but negligible for all practical purposes.

The €STR forward rates $R_i(t)$ could also be derived from an EONIA-centric €STR projection curve $P^R(t, T)$ calculated from the EONIA yield curve on the overnight time grid $[t = T_0, T_1, \dots, T_{i-1}, T_i, \dots]$ via the relationship

$$R_i(t) = \left[\frac{P^R(t, T_{i-1})}{P^R(t, T_i)} - 1\right]\frac{1}{\tau_i} = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - 1\right]\frac{1}{\tau_i} - s$$

which yields the recursion $P^R(t, T_0) = 1$ and

$$P^R(t, T_i) = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - \tau_i s\right]^{-1} P^R(t, T_{i-1}).$$

7.1.2 Calculating €STR discount curves from a given EONIA yield curve

Using the notation and the results from the previous section, we argue that the EONIA-centric €STR projection curve $P^R(t, T)$ is a good proxy for the €STR discounting curve, which is to be used for discounting €STR-collateralised flows and for projecting €STR-collateralised €STR flows.

To do so, we now let $\overline{P}(t, T)$ denote the €STR-linked discount factor with maturity T and observation date t. It is related to the €STR index rate via

$$R_i = \left[\frac{1}{\overline{P}(T_{i-1}, T_i)} - 1\right]\frac{1}{\tau_i}.$$

The forward €STR rate using €STR-linked discount factor $\overline{P}(t, T_i)$ as numeraire is defined as

$$\overline{R}_i(t) = \overline{\mathbb{E}}_t^{T_i}\left\{\left[\frac{1}{\overline{P}(T_{i-1}, T_i)} - 1\right]\frac{1}{\tau_i}\right\} = \left[\frac{\overline{P}(t, T_{i-1})}{\overline{P}(t, T_i)} - 1\right]\frac{1}{\tau_i},$$

where $\overline{\mathbb{E}}_t^{T_i}[\cdot]$ is the t-conditional expectation in the €STR-centric T_i-forward measure $\overline{\mathbb{Q}}^{T_i}$ that is defined in terms of the €STR-collateralised T_i-bond. We argue that for all practical purposes, the differences between the measures $\overline{\mathbb{Q}}^{T_i}$ and $\mathbb{Q}^{T_i}$ are negligible; that is $\overline{\mathbb{Q}}^{T_i} \approx \mathbb{Q}^{T_i}$.[39] This gives

$$\overline{R}_i(t) = \overline{\mathbb{E}}_t^{T_i}\{R_i\} \approx \mathbb{E}_t^{T_i}\{R_i\} = R_i(t)$$

and, hence,

$$\left[\frac{\overline{P}(t, T_{i-1})}{\overline{P}(t, T_i)} - 1\right]\frac{1}{\tau_i} \approx \left[\frac{P^R(t, T_{i-1})}{P^R(t, T_i)} - 1\right]\frac{1}{\tau_i} = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - 1\right]\frac{1}{\tau_i} - s.$$

The €STR discount curve $\overline{P}(t, T_i)$ is thus approximated by the €STR projection curve $P^R(t, T_i)$ and the latter can be derived from the EONIA yield curve, as shown in the previous section.

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[39] Actually, both measures would coincide if the deterministic spread were applied at the level of continuously compounded rates instead of simply compounded rates. Moreover, both measures would trivially coincide if interest rates were deterministic.

7.1.3 Transformation of continuously compounded zero rates and par rates

Sections 1 and 2 showed that under mild approximations, the €STR projection curve and €STR discount curve can be derived directly from the EONIA yield curve. In this section, we derive a complementary formula to directly convert zero rates from the EONIA yield curve into zeros from a corresponding €STR yield curve.

First, we neglect the distinction between $\overline{\mathbb{Q}}^{T_i}$ and $\mathbb{Q}^{T_i}$, thus assuming an equality

$$\left[\frac{\overline{P}(t, T_{i-1})}{\overline{P}(t, T_i)} - 1\right]\frac{1}{\tau_i} = \left[\frac{P(t, T_{i-1})}{P(t, T_i)} - 1\right]\frac{1}{\tau_i} - s.$$

Writing discount factors in terms of continuously compounded forward rates, we have

$$P(t, T) = \exp\left\{-\int_t^T f(t, x)dx\right\} \text{ and}(t, T) = \exp\left\{-\int_t^T \overline{f}(t, x)dx\right\},$$

obtaining over each overnight interval $[T_{i-1}, T_i]$ the following

$$\exp\left\{\int_{T_{i-1}}^{T_i} \overline{f}(t, x)dx\right\} = \exp\left\{\int_{T_{i-1}}^{T_i} f(t, x)dx\right\} - \tau_i s.$$

Now, defining the EONIA zero rates $z(t, T)$ and €STR zero rates $\overline{z}(t, T)$ in terms of these forward rates as

$$z(t, T) = \frac{1}{T-t}\int_t^T f(t, x)dx \text{ and}(t, T) = \frac{1}{T-t}\int_t^T \overline{f}(t, x)dx,$$

we obtain, using the identity above with $T_0 = t$ and $T_n = T$

$$\overline{z}(t, T) = \frac{1}{T-t}\int_t^T \overline{f}(t, x)dx = \frac{1}{T-t}\sum_{i=1}^n \ln\left[\exp\left(\int_{T_{i-1}}^{T_i} f(t, x)dx\right) - \tau_i s\right]$$

$$= \frac{1}{T-t}\ln\left[\prod_{i=1}^n \left(\exp\left(\int_{T_{i-1}}^{T_i} f(t, x)dx\right) - \tau_i s\right)\right].$$

This formula allows to directly calculate zeros of the €STR yield curve from overnight forwards derived from the EONIA yield curve.

This formula can be made more accessible by using first order Taylor expansion to obtain

$$\int_{T_{i-1}}^{T_i} \overline{f}(t, x)dx = \int_{T_{i-1}}^{T_i}\left(f(t, x) - \frac{\tau_i s}{T_i - T_{i-1}}\right)dx + \mathcal{O}\left(\left[\int_{T_{i-1}}^{T_i}\overline{f}(t, x)dx\right]^2\right) + \mathcal{O}\left(\left[\int_{T_{i-1}}^{T_i} f(t, x)dx\right]^2\right)$$

and by revisiting

$$\overline{z}(t, T) = \frac{1}{T-t}\int_t^T \overline{f}(t, x)dx = \frac{1}{T-t}\sum_{i=1}^n\int_{T_{i-1}}^{T_i}\overline{f}(t, x)dx \approx \frac{1}{T-t}\sum_{i=1}^n\int_{T_{i-1}}^{T_i}\left(f(t, x) - \frac{\tau_i s}{T_i - T_{i-1}}\right)dx,$$

in order to arrive at the simple approximation formula[40]

$$\bar{z}(t, T) \approx z(t, T) - \frac{\tau}{T - t} s.$$

Given the EONIA zero curve (bootstrapped) and €STR zero curve (derived), any par rate for each of the three constellations involving €STR shown in Table 1 can easily be calculated, if needed.

7.1.4   Approximate equality of T_i-forward measures

In Section 7.1.2 we claimed that for a given time horizon T, the difference between the EONIA-centric forward measure $\mathbb{Q}^T$ and the €STR-centric forward measure $\overline{\mathbb{Q}}^T$ can be neglected for all practical purposes. In this section, we justify this claim.

First, we show that the two measures would coincide if a deterministic spread were applied not to simply daily compounded rates but to continuously compounded rates. To do so, let us recall that the present value of a fully collateralised future payoff $V(T)$ with continuously compounded collateral rate $r(t)$ is given by[41]

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

where $\mathbb{E}_t[\cdot]$ is the t-conditional expectation with respect to the risk neutral measure $\mathbb{Q}$.[42] If another continuously compounded collateral rate $\bar{r}(t)$ applies, one obtains a different present value

$$\overline{V}(t) = \mathbb{E}_t\left[e^{-\int_t^T \bar{r}(s)ds} V(T)\right].$$

Defining the collateral-specific zero coupon bonds (or discount factors)

$$P(t, T) = \mathbb{E}_t\left[e^{-\int_t^T r(s)ds}\right] \text{and}(t, T) = \mathbb{E}_t\left[e^{-\int_t^T \bar{r}(s)ds}\right],$$

we may change measures and write

$$V(t) = P(t, T) \cdot \mathbb{E}_t^T[V(T)], \overline{V}(t) = \overline{P}(t, T) \cdot \overline{\mathbb{E}}_t^T[V(T)].$$

The relationship between the forward $\mathbb{E}_t^T[V(T)]$ and the forward $\overline{\mathbb{E}}_t^T[V(T)]$ is discussed in Piterbarg in the section on "Forward Contract".[43] If we assume that the continuously compounded

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[40]   The difference between this and the exact formula is commonly less than 1/100 of a basis point. The pre-factor $\frac{\tau}{T-t}$ depends on the day count convention used for the spread s and the zero rates.

[41]   Piterbarg, V., "Funding beyond discounting: collateral agreements and derivatives pricing", *Risk-magazine.net*, March 2010, pp. 97-102.

[42]   In a complete and arbitrage free market, there exists a unique risk neutral measure which does not depend on any collateralisation assumption.

collateral rates $r(t)$ and $\bar{r}(t)$ are linked via a deterministic spread, the calculations simplify considerably: if

$$r(t) = \bar{r}(t) + \bar{s}(t)$$

for a deterministic spread function $\bar{s}(t)$, then

$$\bar{V}(t) = \mathbb{E}_t\left[e^{-\int_t^T \bar{r}(s)ds} \cdot V(T)\right] = e^{-\int_t^T \bar{s}(u)du} \cdot \mathbb{E}_t\left[e^{-\int_t^T r(s)ds} \cdot V(T)\right] = e^{-\int_t^T \bar{s}(u)du} \cdot V(t)$$

and hence, in particular,

$$\bar{P}(t,T) = e^{-\int_t^T \bar{s}(u)du} \cdot P(t,T).$$

We thus obtain

$$\frac{\bar{V}(t)}{\bar{P}(t,T)} = \frac{e^{-\int_t^T \bar{s}(u)du} \cdot V(t)}{e^{-\int_t^T \bar{s}(u)du} \cdot P(t,T)} = \frac{V(t)}{P(t,T)},$$

which yields the result that

$$\mathbb{E}_t^T[V(T)] = \bar{\mathbb{E}}_t^T[V(T)].$$

Equality of the measures $\mathbb{Q}^T$ and $\bar{\mathbb{Q}}^T$ can directly be obtained by observing that the Radon-Nikodym derivative

$$\left.\frac{d\mathbb{Q}^T}{d\mathbb{Q}}\right|_t = \frac{e^{-\int_0^t r(u)\,du} \cdot P(t,T)}{P(0,T)}$$

does not depend on $\bar{s}$.

Let us now consider the situation where deterministic basis spreads are applied to daily simply compounded rates, which is relevant for EONIA and the €STR. This situation is inconsistent with an assumption of deterministic basis spreads at the level of continuously compounded rates, unless rates are all assumed to be deterministic.[44] It follows that, in this case, the measures $\mathbb{Q}^T$ and $\bar{\mathbb{Q}}^T$ are indeed different from one another. However, this difference is negligible for all practical purposes:

- The calculations in Section 7.1.3 show that applying the constant 8.5 basis points spread to continuously compounded zeros on the one hand and to daily compounded zeros on the other hand amounts to a difference in continuously compounded zeros of around 1/100 of a basis point. It follows that the Radon-Nikodym derivative $(*)$ above, which, as we have seen, is invariant under continuously compounded deterministic spreads, does not change under application of the given 8.5 basis points daily compounded spread, up to a high level of accuracy.

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[43]   Piterbarg, V., op. cit.

[44]   Schlenkrich, S. and Miemiec, A., "Choosing the Right Spread", *Wilmott*, Issue 77, May 2015, pp. 60-67.

- If a simply compounded spread is applied over a time interval Δ, then the measures $\mathbb{Q}^T$ and $\overline{\mathbb{Q}}^T$ converge to one another as $\Delta \rightarrow 0$ (continuous compounding limit). They also converge to one another as Δ is fixed and as the interest rate volatility goes to zero.

- The assumption of forward rates being independent of the discounting method (and the collateral rate) is commonly applied in multi-curve discounted cash flow pricing methods.

All differences may be expected to be far lower than any bid/ask-spread observed in the market.