EIOPA-BoS-15/035

31 January 2018

Technical documentation of the methodology to derive EIOPA's risk-free interest rate term structures

EIOPA has changed the methodology to calculate the risk-free interest rate term structures as follows:

The ticker for Swiss franc OIS rates was replaced. The change is implemented on page 33.

Furthermore the description of the derivation of the UFR was updated in accordance with earlier announcements[1] and clarifications were included with regard to the treatment of Icelandic government bonds (page 24) and the calculation of the long-term average spread (page 68).

[1] https://eiopa.europa.eu/Publications/Reports/Specification%20of%20the%20methodology%20to%20derive%20the%20UFR.pdf

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Letter of the Executive Director

Solvency II aims at implementing an economic and risk-based supervisory framework in the field of insurance and reinsurance. The framework is built upon three pillars, all equally relevant, that provide for quantitative requirements (Pillar 1), qualitative requirements (Pillar 2) and enhanced transparency and disclosure (Pillar 3).

The starting point in Solvency II is the economic valuation of the whole balance sheet, where all assets and liabilities are valued according to market consistent principles.

The risk-free interest rate term structure (hereafter in this letter, risk-free interest rate) underpins the calculation of liabilities by insurance and reinsurance undertakings. EIOPA is required to publish the risk-free interest rate.

This technical document sets out the basis on which it will do so. It is the result of collaboration between EIOPA's members and its staff.

As a default approach, the risk-free interest rate is primarily derived from the rates at which two parties are prepared to swap fixed and floating interest rate obligations. In the absence of financial swap markets, or where information of such transactions is not sufficiently reliable, the risk-free interest rate is based on the government bond rates of the country. The risk-free interest rates are:

- Calculated for different time periods, reflecting that the liabilities of insurance and reinsurance undertakings stretch years and decades into the future.
- Calculated in respect of the most important currencies for the EU insurance market.
- Adjusted to reflect that a portion of the interest rate in a swap transaction (or a government bond) will reflect the risk of default of the counterparty and hence without adjustment would not be risk-free.
- Based on data available from financial markets. For those periods in the more distant future for which data are not available, the rate is extrapolated from the point at which data are available to a macroeconomic long-term equilibrium rate.

An adjustment (the volatility adjustment) is made to the liquid part of the risk-free interest rate in order to reduce the impact of short term market volatility on the balance sheet of undertakings. EIOPA is required to provide, both on a currency and country basis, the size of this adjustment for volatility.

A different adjustment (the matching adjustment) is made in respect of predictable portfolios of liabilities. An undertaking can assign to eligible portfolios assets with fixed cash flows that it intends to hold to maturity. EIOPA is required to provide an estimate of what portion of the spread of such assets above the risk-free interest rate reflects risks not faced by those who hold assets to maturity.

Many of the parameters of the risk-free rates are already determined in legislation. Some choices remain however, and in many cases more than one option is possible. The rationale for the key choices made by EIOPA is set out in section 1 (Basis for decision) of this technical documentation. The choices made by EIOPA, always within the limits set by EU legislation, are designed to secure the following objectives.

Replicability

EIOPA intends the risk-free rate interest rate to be capable of replication by undertakings and other interested parties, through this technical documentation. This will benefit undertakings for their own risk management and other purposes. One consequence of replicability is that the use of so-called "expert judgement" i.e. the exercise of discretion in the regular construction of the risk-free interest rate, has been kept to a minimum.

Market consistency

Whenever possible, data from deep, liquid and transparent financial markets are used to construct the risk-free interest rate. Adopting such a market consistent approach helps foster transparency in insurance markets with a positive impact on understanding and trust, as well as helping create a level playing field by enabling the comparison between undertakings.

Solvency II reporting

The intended frequency of publication of the risk-free interest rate is monthly. Such a frequency will enable undertakings to have a common basis for calculating the value of the financial information they are required to report to their supervisor on a quarterly and annual basis.

Stability for insurance undertakings

EIOPA does not want to exacerbate volatility in the value of liabilities through unwarranted changes to the risk-free interest rate. Changes would naturally have to be justifiable on an EU-wide basis. The experience of those EIOPA members who have already produced risk-free interest rates is however that from time to time the case for change is made. Regardless of any earlier changes, there will also be a more formal stocktake, for example at the point at which the calibration of capital requirements under Solvency II is reviewed.

The risk-free rate interest rate is intended to be published from February 2015, to give undertakings time to prepare. EIOPA does not seek a timescale between publication of the risk-free interest rate and the requirement on undertakings to report that could trigger rapid sale or purchase of assets.

Policyholders

These objectives will benefit policyholders. Replicability, market consistency, Solvency II reporting, and stability for undertakings will make easier the valuation of undertakings and the work of supervisors.

The key components of the risk-free rate are summarised in the table below. They are explained in much greater detail, alongside other components, in the technical documentation.

Component	Approach adopted by EIOPA
Assessment of deep, liquid, transparent financial market information	• Assessments by each EIOPA member or (for non-EEA currencies) analysis of market interest rates
Last liquid point (LLP)	• Euro: residual volume criterion • Other EEA currencies: assessment by each EEA member state • Non-EEA currencies: EIOPA assessment
Extrapolation	• Smith-Wilson method as applied in the Long-term Guarantees Assessment
Convergence maturity	• Euro: 60 years • Non-euro currencies: in general max(LLP+40Y; 60Y)
Volatility adjustment: calculation of risk correction	• Calculated in the same manner as the fundamental spread • For government bonds, based on the long-term average spreads over the basic risk-free interest rates term structure • For assets other than government bonds, based on the maximum of: the long-term average spreads a probability of default and cost of downgrade based on the projection of an average 1-year transition matrix
Matching adjustment: calculation of fundamental spread	• Separate calculation of a probability of default and cost of downgrade based on the projection of an average 1-year transition matrix

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Legal basis

4. The Union legislator entrusted EIOPA to lay down and publish technical information on risk-free interest rates with the purpose to allow for the consistent calculation of technical provisions by insurance and reinsurance undertakings under Article 77e(1) of the Solvency II Directive.

5. To further reinforce the importance of that technical information towards achieving consistency in the calculation of technical provisions, the Union legislator provided for binding effects of this technical information on insurance and reinsurance undertakings, subject to the inclusion of this information into an implementing act of the European Commission (Article 77e(2) of the Solvency II Directive).

6. In accordance with recital 23 of the Commission Delegated Regulation (EU) 2015/35[2] (hereinafter "Delegated Regulation"), the present EIOPA technical documentation is published by EIOPA as part of the technical information published pursuant to Article 77e(1) of the Solvency II Directive. The technical documentation explains in a transparent manner how the relevant risk-free interest rate term structures are derived. It is published to achieve a consistent calculation of technical provisions.

[2] Commission Delegated Regulation (EU) No 2015/35 of 10 October 2014 supplementing Directive 2009/138/EC of the European Parliament and of the Council on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II) (OJ L 12, 17.01.2015, p. 1)

1. Basis for decision

7. The development of the methodology to calculate the relevant risk-free interest rates term structures has required a number of decisions on the methods, assumptions and inputs to use in that calculation.

8. EIOPA has based those decisions on the following principles:

    a) respect to the essential elements underpinning the political agreement of Directive 2014/51/EU (Omnibus II Directive),

    b) transparency of all the elements of the process of calculation,

    c) replicability of the calculations, which has as a direct consequence the restriction of expert judgement to the minimum extent possible, if any,

    d) market consistency, prudent assessment of the technical provisions and optimal use of market information.

9. The following items describe the main decisions adopted, following the order of the topics contained in this technical documentation.

1.A. General issues

Financial market data used as inputs

10. This technical documentation identifies the financial market data used as inputs of the calculations.

11. EIOPA keeps unambiguous neutrality regarding the market data providers competing in the market. The reason for selecting market data providers relies only on the high priority given to:

    a) the legal imperative of publishing the concrete figures of the technical information set out in Article 77e of the Solvency II Directive,

    b) the full traceability of the calculations, as part of EIOPA's commitment to the principle of transparency,

    c) the 'replicability' of the process of calculation by those stakeholders wishing to reproduce the technical information,

    d) the ability to put into place an appropriate process of validation.

12. In order to ensure the appropriateness of the data, two market data sources are used, one for inputs ('direct input provider'), and the other for validation.

13. EIOPA has decided to use the same direct input provider for swaps and government bonds curves. EIOPA has selected different providers for yields

of corporate bonds and for default statistics to reduce the operational risk and the dependence on the data providers.

14. The selection of these providers should not be understood as EIOPA's preference for them. The selection does not constitute advice to undertakings when deciding which provider better fits to their needs.

Use of market data with maturities of less than one year

15. EIOPA has decided to publish the relevant risk-free interest rates term structure from 1 year maturity onwards. Instruments with a maturity below 1 year are not always swaps and the adjustment of their credit risk, among other features, may add unnecessary complexity to the calculations. Furthermore, below 1-year rates have a negligible impact on the rates extrapolated with the Smith-Wilson method, and hence a negligible impact on the amount of long-term technical provisions.

Methods for the assessment of deep, liquid and transparent financial markets (DLT assessment)

16. Based on academic literature and the methods applied by practitioners EIOPA has analysed the metrics and criteria commonly used for assessments of market liquidity and assessed their applicability for the purposes of setting a conceptual framework for the DLT assessment.

17. Having in mind that the National Competent Authorities have better knowledge of the financial markets of each currency, the DLT assessment of EEA currencies has been made by each National Competent Authority. All National Authorities applied the same methodology and reported their findings in a common template. Three main findings may be extracted from the set of lessons learnt:

    a) The application of the common conceptual framework should not rely on hard thresholds and should not disregard qualitative information. In particular, a number of criteria are inter-linked and the markets for the same financial instruments for different currencies may present different features.

    b) The DLT assessment is a demanding exercise and therefore the frequency of updating the assessment should be carefully considered.

    c) Furthermore, with the exception of crisis situations, frequent violent changes in the outputs of the DLT assessment do not seem plausible. Rather, a plausible future trend will be the development of financial markets and the extension of the market interest rates meeting DLT requirements (i.e. the use of market consistent information).

1.B. Basic risk-free interest rates term structure

Credit risk adjustment (CRA)

18. The Delegated Regulation only covers the calculation of the CRA for those currencies with DLT swap markets and overnight swaps markets.
19. For currencies where either swaps or overnight swaps markets do not meet DLT requirements or currencies whose risk-free interest rates term structure is based on government bonds rates, EIOPA has applied the objective criteria described below in section 5, avoiding any margin for expert judgement.
20. Furthermore EIOPA is aware of the initiatives in the Union for the development of more transparent financial markets for risk-free financial instruments.

Extrapolation method

21. The interpolation, where necessary, and extrapolation of interest rates have been developed applying the Smith-Wilson method.
22. This method is of course not the only one possible method for the extrapolation of interest rates. All methods have their pros and cons.
23. The Smith-Wilson method has been applied during the last years of the development of the Solvency II framework, and in particular in the fifth Quantitative Impact Study (QIS5) and in the Long-term Guarantees Assessment (LTGA) that has underpinned the political agreement of the Omnibus II Directive.
24. EIOPA will however carefully monitor market developments, and their influence on the implementation of the Smith-Wilson method.

Last Liquid Point (LLP)

25. The Delegated Regulation includes a specific recital for the determination of the LLP and the application of DLT requirements for the euro. Its sets out a criterion regarding the residual volume of bonds meeting DLT requirements (residual volume criterion). The criterion is precise except for the very specific market data to be used as input.
26. For currencies other than the euro, according to recital 30 of the Omnibus II Directive, the choice of the LLP should allow undertakings to match with bonds the cash flows which are discounted with non-extrapolated interest rates in the calculation of the best estimate. The application of this principle is currently challenging due to the limitation of the information available on cash flows from insurance and reinsurance obligations. Therefore, for currencies other than the euro, EIOPA is basing the LLP on the results of the DLT assessment, rather than developing that matching criterion at this stage.

Convergence point

27. The Omnibus II Directive explicitly reflects for the euro a convergence period of 40 years and a LLP of 20 years, which is equivalent to assuming that the forward rate will be close to its ultimate level from 20+40=60 years maturity onwards.
28. For currencies other than the euro, the convergence point is the maximum of (LLP+40 years) and 60 years. This method is considered as the most stable, least influenced by expert judgement and also the one with lowest impact on the level playing field between market participants.
29. In accordance with recital 30 of the Omnibus II Directive, the selected option keeps the allowance of different outcome for specific cases conditional on their adequate justification.

1.C. Volatility adjustment (VA) and Matching adjustment (MA)

Financial market inputs for VA and MA

30. The Delegated Regulation states that the manner in which the risk correction for the VA and the fundamental spread for the MA are calculated should be the same. EIOPA understands that the intention of the phrase '*in the same manner*' in Article 51 is to cover all the elements of the calculation, including the data underlying it. This means that the same approach should be applied for both the risk correction and the fundamental spread. In particular EIOPA has not used different market default and transition inputs for these calculations.
31. EIOPA has gathered inputs on bonds, using the following granularity: currency, credit quality, duration and economic sector of the issuer. This segmentation is based on Article 77c of the Solvency II Directive.

Financial market inputs for bond yields

32. EIOPA has elaborated a conceptual framework in order to apply to the maximum extent the use of market indices in the calculation of the VA as required in Article 49(3)(b) of the Delegated Regulation.
33. For this purpose EIOPA maps the representative portfolios of assets to yields that are derived from yield curves and yield indices.
34. In the case of the euro currency VA, EIOPA has opted for a simplification in the use of indices for central government bonds: the replacement of the calculation based on all the government curves of the members of the euro area, by a single curve: the ECB yield curve, annual spot rates, with reference to all members of the euro area.

35. For non-euro currencies and for the purpose of the country-specific increase of the VA, the use of yield curves for each issuer of government bonds is necessary given the materially different degrees of home-bias.

36. Finally, in the case of other bonds (e.g. corporate bonds and collaterised bonds, etc.), a major challenge has been the availability of the information with the necessary granularity (maturities, ratings, economic sectors) for all relevant currencies.

Inputs for the calculation of the long-term average spread

37. Article 54(3) of the Delegated Regulation sets out:

    The long-term average referred to in Article 77c(2)(b) and (c) of Directive 2009/138/EC shall be based on data relating to the last 30 years. Where a part of that data is not available, it shall be replaced by constructed data. The constructed data shall be based on the available and reliable data relating to the last 30 years. Data that is not reliable shall be replaced by constructed data using that methodology. The constructed data shall be based on prudent assumptions.

38. There is currently a lack of full 30 years of historical data for swaps and government bonds, for almost all currencies. Furthermore, overnight swap markets (whose short term rates are necessary for the calculation of the credit risk adjustment), were active only since the end of the last century.

39. EIOPA has decided to construct the missing spread data for each currency and maturity using the average of the spread data that is available from 1 January 1985 or, failing that, whenever reliable spread data is first available. In practice, the lack of overnight swap rates has led to consider market data only from January 1999.

40. The same considerations apply to the floor for bonds other than central government and central banks bonds, with two further features that increase the practical difficulties:

    a) For most EEA currencies there are no reliable yield term structures for corporate bonds.

    b) For the euro, the curves currently provided by financial market data providers have a limited history.

41. For the selection of market providers, EIOPA has considered a decision process for central governments and central banks bonds and for other bonds (e.g. corporates), taking into account in particular the following:

    a) the availability of historical data,

    b) the market information and methodology behind the construction of the market indices (e.g. government and corporate bonds),

c) the granularity (e.g. buckets regarding the maturities, ratings, economic sectors, for bonds other than central governments and central banks).

Central governments and central banks bonds - Calculation of the long-term average spread

42. Depending on the period of observation, EIOPA has considered whether market data should be weighted for the calculation of the average referred to in Article 77c(2) of the Solvency II Directive.

43. Both in the LTGA and the EIOPA Stress Test 2014 a simple average was applied.

44. The allowance of adjustments to the simple average means to disregard market observations and embeds the use of material expert judgement. This option lacks legal basement and has been rejected due to the subjective assumptions required.

45. Furthermore, EIOPA believes that assuming a flat curve as reconstructed history (e.g. for the euro before 1 January 1999) is the most neutral choice as well as being in line with the Solvency II Directive and in particular the political agreement on the Omnibus II Directive. The level should be equal to the simple and unadjusted average of the available market spreads.

Methodology of calculation of the spread before risk correction, for currencies where yield term structures are not available

46. For most of the EEA currencies either there are no available interest rate term structures for the assets relevant to determine S_{corp}[3] or the number of potential underlying assets to build such curves is rather low. Market data providers only produce corporate yield curves for a few EAA currencies (just the most developed financial markets).

47. In absence of empirical data, EIOPA has decided to apply the following formulas which are based on the approach already applied in the LTGA:

$$S_{corp}^{X} = S_{corp}^{€} + \kappa \cdot \left(Y_{rfr}^{X} - Y_{rfr}^{€}\right)$$

$$Y_{corp}^{X} = Y_{corp}^{€} + (1+\kappa) \cdot \left(Y_{rfr}^{X} - Y_{rfr}^{€}\right)$$

where € denotes the euro, *X* refers to a currency without yield term structures for the assets relevant for the spread S_{corp}, Y_{corp} denotes the

[3] According to Article 50 of the Delegated Regulation, S_{corp} denotes the average currency spread on bonds other than governments bonds, loans and securitizations included in the reference portfolio of assets for that currency or country.

yield of the respective corporate bonds of the same credit quality, Y_{rfr} denotes the basic risk-free interest rate and κ is equal to 0.5. The inputs of this formula are maturity dependent according to the information available.

48. This approach is based on the following rationale: spreads might be better reflected by spreads derived from the basic risk-free rates than using no data. In addition, this method is simple and, where necessary, immediately applicable to all published currencies in a consistent manner.

49. Further than its simplicity and traceability, this formula guarantees that for each currency their 'notional' yield curves for corporates will behave - compared to the basic risk-free interest rates term structure - similarly to the main currency where corporate yield term structures for the euro are available for a number of years.

50. Setting $\kappa = 0.5$ seems the best proxy for a formula to be applied to all relevant currencies. This proxy provides a central estimate and ensures that differences with the more accurate and complex calculation are reduced to the maximum extent possible using a simple and implementable approach.

Granularity of yield information for bonds other than central government and central bank bonds

51. An appropriate granularity according to maturities, ratings and economic sectors has been adopted in order to adequately capture the different behaviour of spreads (e.g. of financial and non-financial bonds).

2. Governance and controls of the process of calculation and publication

52. EIOPA has established internal governance arrangements in order to define the essential elements of the operational framework such as:

    i) The period of time after which the technical information shall be published

    ii) Definition of the functions involved

    iii) The resources necessary for running the process and the registers and logs for recording

    iv) Internal controls to safeguard the process used built on 'four eyes' principle

    vi) The frequency of activities, in particular audits, reviews and internal controls

    viii) Definition in a limitative manner of the areas where expert judgement in the process is allowed (e.g. some areas of the DLT assessment). In that case, the documentation of the expert judgement includes its content, link to the authorized scope, validation, internal control and log of escalation, in order to ascertain that, in accordance with the EIOPA regulation, such expert judgement is independently exercised, it acts in the interest of the Union, enhances the protection of policyholders and fosters a level playing field of the EU insurance market.

    ix) Definition of the specific process to follow new information might advise the review of the technical information already published. EIOPA rules on public consultation will apply to the review of this technical documentation,

    x) Contingency plans for continuing the publication of the technical information in case of unexpected events

    xi) Rules in order to record, store and report exceptional events in the development of any of the steps of the process (process events, IT events, financial market data events, etc.)

    xii) Establishment of an oversight function and of a control function ensuring that the technical information is provided and published or made available in accordance with the methodology, assumptions and inputs approved by EIOPA.

53. EIOPA's framework regarding code of conduct and conflict of interests applies to all the persons involved in the process in any function. All these persons have to declare and sign the relevant documentation at least every year, and as soon as any factual or potential, current or foreseeable, conflict of interest appears or may appear.

54. EIOPA has not approved and does not envisage approving, the outsourcing of any function or activity of the process for the calculation and publication of the technical information, other than the collection of data of financial markets from generally used financial providers, and the outsourcing applied to some parts of the IT systems of EIOPA.

3. Data sources for the inputs from financial markets

3.A. Financial market data providers

55. In order to mitigate the operational risks of a market provider failure, the calculation of the technical information should not over-rely on a single market source.

56. A first way to ensure this would be to derive each input using data obtained from a range of providers. A second alternative would be to calculate a given input based on data from a single market provider, but to use different providers for different inputs or functions, under the condition that all sources are sufficiently consistent.

57. As a general rule EIOPA has opted for the second of these options, on the basis that an application of the first option to all inputs would introduce additional complexity and increase the operational risks, without providing material benefits compared to the second alternative.

58. EIOPA has no evidence of the superiority of a concrete market data provider. The choice of market data providers included in this technical documentation are disclosed only for the purposes of transparency (recital 23 of the Delegated Regulation).

59. In accordance with recital 23 of the Delegated Regulation, EIOPA's technical documentation will accompany the technical information set out in Article 77e(2) of the Solvency II Directive in order to ensure transparency.

60. The following providers are used (see subsections below for detail):

    a. Swaps and overnight indexed swaps: Bloomberg

    b. Government bonds: Bloomberg

    c. Bonds other than government bonds: Markit – iBoxx indices and, for Danish covered bonds, Bloomberg

    d. Default statistics: Standard & Poors

61. The market data inputs will be analysed under the relevant review process according to section 2.

3.B. Selection of the relevant currencies

62. EIOPA applies the following criteria to select the currencies (and countries for the country specific increase of the volatility adjustment) for which technical information is published:

    - all currencies and countries of the EEA,
    - all non-EEA currencies, where EIOPA has evidence on their materiality for the EU insurance sector, and where reliable and adequate financial

market data are publicly available to perform the necessary calculations.

63. The list of relevant currencies and, where applicable, countries can be found in Annex 14.A.

64. EIOPA will review the list of relevant currencies on an annual basis. Any changes will be announced three month before their implementation. In exceptional circumstances EIOPA may deviate from this process to change the list of relevant currencies.

3.C. Selection of market rates

65. The construction of the basic risk-free interest rate term structures is based on swaps and/or government bonds as set out in Article 44 of the Delegated Regulation. EIOPA is aware of the initiatives in the Union to develop in the future risk-free instruments traded on deep, liquid and transparent markets.

66. EIOPA applies the financial references in the table below from the market data provider selected.

67. The last column of the table specifies whether the financial instruments applied are either swaps or government bonds. For a clear identification of swaps, the floating is also included.

68. In the process of calculation of the basic risk-free interest rates term structures, the tickers for government bonds are used only for the currencies with 'GVT' in the last column. The inputs to the process of calculation of the volatility and matching adjustments regarding government bonds are also based on the information referred to in the table below.

Table 1. Swaps and government bonds used for the derivation of the technical information

Country	ISO 3166	ISO 4217	Swap Ticker	Swap freq	Swap Float Ticker	Government Bond Ticker Id	Govts/ Swaps
Euro	-	EUR	EUSA CMPL Curncy	1	EUR006M Index	ECB curve all governments-spot	SWP
Austria	AT	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0063Z BLC2 Curncy	SWP
Belgium	BE	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0006Z BLC2 Curncy	SWP
Bulgaria (*)	BG	BGN	EUSA CMPL Curncy	1	EUR006M Index	BI0662Z BVLI Curncy	SWP
Croatia	HR	HRK				G0369Z BLC2 Curncy	GVT
Cyprus	CY	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP
Czech Rep.	CZ	CZK	CKSW CMPL Curncy	1	PRIB06M Index	G0112Z BLC2 Curncy	SWP
Denmark (*)	DK	DKK	EUSA CMPL Curncy	1	EUR006M Index	G0011Z BLC2 Curncy	SWP
Estonia	EE	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP

Finland	FI	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0081Z BLC2 Curncy	SWP
France	FR	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0014Z BLC2 Curncy	SWP
Germany	DE	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0016Z BLC2 Curncy	SWP
Greece	GR	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0156Z BLC2 Curncy	SWP
Hungary	HU	HUF	HFSW CMPL Curncy	1	BUBOR06M Index	G0165Z BLC2 Curncy	GVT
Iceland	IS	ISK				I328 CMPL Index	GVT
Ireland	IE	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0062Z BLC2 Curncy	SWP
Italy	IT	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0040Z BLC2 Curncy	SWP
Latvia	LV	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP
Liechtenstein	LI	CHF	SFSW CMPL Curncy	1	SF0006M Index		SWP
Lithuania	LT	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP
Luxembourg	LU	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP
Malta	MT	EUR	EUSA CMPL Curncy	1	EUR006M Index		SWP
Netherlands	NL	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0020Z BLC2 Curncy	SWP
Norway (*)	NO	NOK	NKSW CMPL Curncy	1	NIBOR6M Index	G0078Z BLC2 Curncy	SWP
Poland	PL	PLN				G0177Z BLC2 Curncy	GVT
Portugal	PT	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0084Z BLC2 Curncy	SWP
Romania	RO	RON	RNSW CMPL Curncy	1	BUBR3M Index	BI0631Z BVLI Curncy	GVT
Russia	RU	RUB	RRSWM CMPL Curncy	1	MOSKP3 Index	G0326Z BLC2 Curncy	SWP
Slovakia	SK	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0256Z BLC2 Curncy	SWP
Slovenia	SI	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0259Z BLC2 Curncy	SWP
Spain	ES	EUR	EUSA CMPL Curncy	1	EUR006M Index	G0061Z BLC2 Curncy	SWP
Sweden	SE	SEK	SKSW CMPL Curncy	1	STIB3M Index	G0021Z BLC2 Curncy	SWP
Switzerland	CH	CHF	SFSW CMPL Curncy	1	SF0006M Index	G0082Z BLC2 Curncy	SWP
United Kingdom	GB	GBP	BPSW CMPL Curncy	2	BP0006M Index	G0022Z BLC2 Curncy	SWP
Australia	AU	AUD	ADSW CMPT Curncy	2	BBSW6M Index	G0001Z BLC2 Curncy	SWP
Brazil	BR	BRL				G0393Z BLC2 Curncy	GVT
Canada	CA	CAD	CDSW CMPN Curncy	2	CDOR03 Index	G0007Z BLC2 Curncy	SWP
Chile	CL	CLP	CHSWP CMPN Curncy	2	CLICP Index	G0351Z BLC2 Curncy	SWP
China	CN	CNY	CCSWO CMPT Curncy	4	CNRR007 Index	G0299Z BLC2 Curncy	SWP
Colombia	CO	COP	CLSWD CMPN Curncy	4	DTF RATE Index	G0217Z BLC2 Curncy	GVT
Hong Kong	HK	HKD	HDSW CMPT Curncy	4	HIHD03M Index	G0095Z BLC2 Curncy	SWP
India	IN	INR				BI0571Z BVLI Curncy	GVT
Japan	JP	JPY	JYSW CMPT Curncy	2	JY0006M Index	G0018Z BLC2 Curncy	SWP
Malaysia	MY	MYR	MRSWQO CMPT Curncy	4	KLIB3M Index	G0196Z BLC2 Curncy	SWP
Mexico (*)	MX	MXN	MPSW CMPN Curncy	13	MXIBTIIE Index	G0251Z BLC2 Curncy	SWP
New Zealand	NZ	NZD	NDSW CMPT Curncy	2	NFIX3FRA Index	G0049Z BLC2 Curncy	SWP
Singapore	SG	SGD	SDSW CMPT Curncy	2	SORF6M Index	G0107Z BLC2 Curncy	SWP
South Africa	ZA	ZAR	SASW CMPL Curncy	4	JIBA3M Index	G0090Z BLC2 Curncy	SWP
South Korea	KR	KRW	KWSWO CMPT Curncy	4	KWCDC Index	G0173Z BLC2 Curncy	SWP

Taiwan	TW	TWD				BI0594Z BVLI Curncy	GVT
Thailand	TH	THB	TBSWO CMPT Curncy	2	THFX6M Index	BI0570Z BVLI Curncy	SWP
Turkey	TR	TRY	TYSW CMPL Curncy	1	TRLIB3M Index		SWP
United States	US	USD	USSW CMPN Curncy	2	US0003M Index	G0111Z BLC2 Curncy	SWP

Notes:

- Bloombergs identifiers. Prices PX_LAST.
- For reference dates after 31 May 2015, the swap rates for European and African currencies are based on London fixing (CMPL), for American currencies are based on New York fixing (CMPN) and for the currencies of Asia and Australia are based on Tokyo fixing (CMPT). For earlier reference dates, all swap rates are based on New York fixing, irrespective of their currency.
- For reference dates after 30 November 2017 the Bloomberg government bond tickers with the exception of Iceland are converted from continuous to annual compounded rates before application, where relevant, of the credit risk adjustment.

69. Specific cases are:

(a) The Norwegian currency, whose 1 year interest rate is based on swaps with floating NIBOR 03 months, while the rest of interest rates are based on NIBOR 06 months.

(b) For those non-euro countries with contracts where the benefits guaranteed to the policy holders are valued in euro while the payments (including the evolutions of the exchange rate) are in the local currency, the term structure is derived on the basis on the interest rates denominated in the local currency.

(c) The rates for Icelandic government bonds are the rates of Bloomberg’s Iceland Sovereign Curve with pricing source EXCH. These rates are usually not zero coupon rates but are treated as such.

(d) For the Bulgarian lev and the Danish krone the basic-risk-free interest rate term structures are based on the financial instruments used for the euro because these two currencies meet the legal conditions to be considered as pegged to the euro.

(e) For the Mexican peso the relevant tickers are MPSW1A, MPSW2B, MPSW3C, MPSW4D, MPSW5E, MPSW7G, MPSW10K, MPSW16C and MPSW21H (all CMPN Curncy). The tickers MPSW16C and MPSW21H are used for the maturities 15 and 20 years respectively.

Basic risk-free interest rate term structure

4. Identification of relevant financial instruments and assessment of depth, liquidity and transparency

4.A. Introduction

70. According to Article 77a of the Solvency II Directive the relevant risk-free interest rate term structure should be based on relevant financial instruments traded in deep, liquid and transparent (DLT) markets. This provision is further specified in recital 21, Article 1(32), (33) and (34), and Articles 43, 44 and 46 of the Delegated Regulation. The identification of the relevant financial instruments is based on a DLT assessment.

71. The inputs for the DLT assessment are market data on interest rate swap rates, government bond rates and corporate bond rates. These are obtained from market data providers whose services are also available to insurance and reinsurance undertakings.

72. The output of the DLT assessment is a list, for each currency, of the maturities for which the market of the relevant financial instrument is considered DLT including the identification of the last maturity for which rates can be observed in DLT markets (section 7.B refers to the determination of the last liquid point (LLP)).

4.B. Conceptual framework for EEA currencies

73. In a first step, an initial DLT assessment for EEA currencies is carried out by the relevant National Competent Authorities.

74. In a second step, EIOPA has a process in place aimed at ensuring homogeneity across national assessments and preserving a level playing field.

75. The relevant financial instruments for EEA currencies that are currently used to derive the term structures were identified on the basis of a DLT assessment carried out in 2015.

76. The table below sets out the results of the DLT assessment. The entries identify the instrument used: S=Interest rate swap, B=government bond, «*empty*»=no DLT markets for this maturity available. The last non-empty entry defines the LLP. No market data beyond the LLP is used. Hence, no further entries are shown in the table, even if single maturities beyond the LLP might be considered as meeting DLT criteria.

77. For the Bulgarian lev and the Danish krone no DLT assessments are made. Since these currencies are pegged to the euro, their basic risk-free interest rates are based on the DLT assessment for the euro.

78. The relevant risk-free interest rates are based on market data for integer maturities from one year onwards.

Table 2. EEA currencies: Financial instruments used for the derivation of the basic risk-free interest rate term structures

	EUR	CHF	NOK	PLN	ISK	HRK	RON	SEK	CZK	HUF	GBP
1Y	S	S	S	B		B	B	S	S	B	S
2Y	S	S	S	B	B		B	S	S	B	S
3Y	S	S	S	B	B	B	B	S	S	B	S
4Y	S	S	S	B		B	B	S	S	B	S
5Y	S	S	S	B			B	S	S	B	S
6Y	S	S	S	B	B			S	S	B	S
7Y	S	S	S	B			B	S	S	B	S
8Y	S	S	S	B	B	B	B	S	S	B	S
9Y	S	S	S	B		B	B	S	S	B	S
10Y	S	S	S	B			B	S	S	B	S
11Y		S									S
12Y	S	S							S		S
13Y		S									S
14Y		S									S
15Y	S	S							S	B	S
16Y to 19Y											S
20Y	S	S									S
25Y		S									S
30Y											S
35, 40, 45, 50Y											S

The table sets out the financial instruments currently used to derive the risk-free interest rates. Past changes to the selection of financial instruments are set out in the Annex to section 4.

Table 3. DLT assessment for swaps of EEA currencies whose term structures are based on swap rates (1 = DLT , 0 = non-DLT)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40	45	50
EUR	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0
CHF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0
CZK	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
GBP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NOK	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEK	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. DLT assessment for government bonds in EEA currencies whose term structures are based on government bonds (1 = DLT , 0 = non-DLT)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40	45	50
HRK	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HUF	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ISK	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLN	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RON	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

For the euro the last liquid point is 20 years, determined in accordance with recital 21 of the Delegated Regulation.

4.C. Conceptual framework for non-EEA currencies

79. The DLT assessment for non-EEA currencies is carried out using a specific approach based on the empirical evidence provided by market information on the behaviour of the relevant rates. The empirical evidence is assessed using a twofold approach (see the Annex to this subsection for a more detailed explanation):

    a. volatility analysis;

    b. analysis of the bid-ask spread.

    The analysis of bid-ask spread is carried out for all currencies using both the observed bid-ask spread and also the approximation of the Roll measure, as applied in EBA's report on high quality liquid assets (HQLA)[4].

80. The two aforementioned approaches are supported by three toolkits:

    a. Chart analysis, consisting of analysis of volatility and analysis of bid-ask spread with the Roll measure;

    b. Quantitative analysis;

    c. Qualitative analysis.

81. Where these approaches do not provide conclusive results, the market is not deemed to be DLT. Consequently, the interest rate for the affected maturity and currency is disregarded as input.

82. The swap markets for four non-EEA currencies do not meet the DLT requirements. For the time being, according to the Delegated Regulations, the risk-free interest rate term structures of those currencies are based on government bond rates.

Table 5. DLT assessment for non-EEA currencies whose risk-free interest rate term structures are based on government bonds (1 = DLT , 0 = non-DLT)

Country	Currency	1	2	3	4	5	6	7	8	9	10
Brazil	BRL	1	1	1	1	1	1	1	1	1	1
Colombia	COP	1	1	1	1	1	1	1	1	1	1
India	INR	1	1	1	1	1	1	1	1	1	1
Taiwan	TWD	1	1	1	1	1	1	1	1	1	1

[4] Report on appropriate uniform definitions of extremely high quality liquid assets (extremely HQLA) and high quality liquid assets (HQLA) and on operational requirements for liquid assets under Article 509(3) and (5) CRR, http://www.eba.europa.eu/documents/10180/16145/EBA+BS+2013+413+Report+on+definition+of+HQLA.pdf

Table 6. DLT assessment for swaps for non-EEA currencies whose term structures are based on swaps (1 = DLT , 0 = non-DLT)

Country	Currency	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40	45	50
Russia	RUB	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia	AUD	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0
Canada	CAD	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	0	1	0	0	0	0
Chile	CLP	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
China	CNY	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hong Kong	HKD	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Japan	JPY	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0
Malaysia	MYR	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Mexico	MXN	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
New Zealand	NZD	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Singapore	SGD	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
South Africa	ZAR	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
South Korea	KRW	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Thailand	THB	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Turkey	TYR	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
United States	USD	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	0	1	0	1

From 20 years onwards, only the rates for the maturities shown in the table are applied.

The table sets out the financial instruments currently used to derive the risk-free interest rates. Past changes to the selection of financial instruments are set out in the Annex to section 4.

4.D. Update of the DLT assessment

83. EIOPA will update the DLT assessment for the relevant currencies on an annual basis. In case of indications that the depth, liquidity or transparency of financial markets has significantly changed, EIOPA may update the DLT assessment for the affected currencies outside the annual update.

84. The changes resulting from the DLT assessment will be implemented after a warning period of up to three months. The duration of the warning period will depend on the urgency of the changes and the materiality of their impact. Where appropriate, EIOPA will avoid the implementation of changes at the end of a quarter.

85. The update will be based on the methodology for the DLT assessment set out in this technical documentation.

4.E. Currencies without DLT financial instruments

86. For those currencies where EIOPA does not publish the technical information set out in Article 77e of the Solvency II Directive, the methodology described in this document should be applied.

87. In case of lack of reliable financial market data to apply the methodology, it is expected that insurance and reinsurance undertakings, the relevant EEA supervisor and the supervisor of the corresponding country will have a dialogue in order to derive appropriate technical information.

88. For that purpose the use of the basic risk-free interest rate term structures of economies sufficiently similar or inter-linked, may be an option, provided that any adjustment to the term structure used as reference is made under a prudent and objective process, and it is compatible with the methodology described in this document.

5. Credit risk adjustment

5.A. Legal framework

89. The calculation of the credit risk adjustment has been developed in accordance with recital 20 and Article 45 of the Delegated Regulation.

5.B. Application of the adjustment

90. The credit risk adjustment (CRA) is applied as a parallel downward shift of the market rates observed for maturities up to the last liquid point.
91. With regard to swaps, the CRA is applied to the observed par swap rates before deriving zero coupon rates. In the case of risk-free interest rate term structures based on government bond rates, the input rates are already zero coupon rates. The credit risk adjustment is applied to those government bonds rates.
92. The credit risk adjustment may lead to negative interest rates (i.e. there is no floor for the adjusted rates).

5.C. Calculation of the credit risk adjustment

93. The calculation of the CRA considers three possible situations, which are successively described below.

First situation

94. In the first situation, the risk-free interest rate term structure is based on swap rates and the relevant overnight indexed swap (OIS) rate meets the DLT requirements.
95. In this case the approach prescribed in Article 45 of the Delegated Regulation for the credit risk adjustment applies, with the following methodological conventions:
    a. The maturity of the OIS rate used to derive the CRA is consistent with the tenor of the floating legs of the swap instruments used to derive the term structure.

       For example, the risk-free interest rate term structure for the Swiss franc is based on swaps with floating legs that refer to the six month IBOR. Consistently with this, the OIS rate used in the CRA calculation is the 6 month Swiss franc OIS rate.

       In the case of the Swedish currency, the risk-free interest rate term structure is based on swaps with floating legs that refer to the three month IBOR, and consequently the OIS rate used in the CRA calculation is the 3 month Swedish krona OIS rate.

b. For the euro, the OIS rate to be used is the 3-month rate, as specified in recital 20 of the Delegated Regulation.

c. The calculation of the one-year average referred to in Article 45 of the Delegated Regulation is based on daily data for the last twelve months. The average is a simple average calculated giving equal weight to all of the observations.

96. In cases where market data is missing for either the interbank offered rate or for the relevant OIS rate, the missing data are completed by linear interpolation and flat extrapolation. If for more than 20% of the business days during the preceding year the swap rate or the OIS rate or both are missing, it is considered that DLT requirements are not met. In that case the third method described in this subsection applies.

Second situation

97. The second situation considered for the calculation of the CRA concerns EEA currencies that are not in the first situation. For these currencies, the same CRA as for the euro applies.

98. A specific case is the Norwegian krone. For that currency the CRA for the Swedish krona applies.

Third situation

99. In the third situation, for the remainder of currencies the following method applies:

a. A ratio is calculated of the sum of the current interest rates for the currency for maturities from 1 to 10 years (numerator) and the sum of the current interest rates for the US dollar and the same maturities (denominator). Only maturities meeting DLT requirements for both currencies are considered.

b. The ratio is applied to the CRA for the US dollar before the application of the corridor (i.e. after applying the 50% factor).

c. The credit risk adjustment for the currency is derived by applying a corridor of 10 to 35 bps to the output of step (b).

d. Where the sum of the current interest rates for the US dollar referred to in point (a) is zero or negative the CRA is 35 bps.

e. The rates referred to in point (a) are chosen in line with paragraph 115.

100. For all currencies, irrespective of their situation,, the corridor for the CRA to swap rates of 10 to 35 bps set out in Article 45 of the Delegated Regulation applies. The CRA is rounded to the nearest integer basis points. The rounding is applied in the final step of the calculation.

5.D. Data sources for the credit risk adjustment

101. The following table lists the currencies for which on a monthly basis the criterion set out in paragraph 96 is checked. In case there are sufficient swap data and overnight indexed swap data, the first situation described above applies and the CRA is calculated with interbank offered rates and OIS rates specified in the table.

Table 7. Currencies with DLT overnight indexed swap markets

Currency	ISO 4217	Bloomberg ticker (PX_LAST)	
Euro	EUR	EUR003M Index	EUSWEC CMPL Curncy
Krona	SEK	STIB3M Index	SKSWTNC CMPL Curncy
Swiss franc	CHF	SF0006M Index	SFSNTF CMPL Curncy
Pound sterling	GBP	BP0006M Index	BPSWSF CMPL Curncy
Canadian dollar	CAD	CDOR03 Index	CDSOC CMPN Curncy
Yen	JPY	JY0006M Index	JYSOF CMPT Curncy
US dollar	USD	US0003M Index	USSOC CMPN Curncy
Australian dollar	AUD	BBSW6M Index	ADSOF CMPT Curncy
Hong Kong dollar	HKD	HIHD03M Index	HDSOC CMPT Curncy
Ringgit	MYR	KLIB3M Index	MRSOC CMPT Curncy
New Zealand dollar	NZD	NFIX3FRA Index	NDSOF CMPT Curncy

Notes:

- For reference dates after 31 May 2015, the overnight swap rates for European currencies are based on London fixing (CMPL), for American currencies are based on New York fixing (CMPN) and for the currencies of Asia and Australia are based on Tokyo fixing (CMPT). For earlier reference dates, all overnight swap rates are based on New York fixing, irrespective of their currency.

- For the Swiss franc, the Bloomberg ticker SFSWTF is used for reference dates until 31 December 2017.

6. Currency risk adjustment for currencies pegged to the euro

6.A. Legal framework

102. According to Article 48 of the Delegated Regulation, the basic risk-free interest rate term structure for a currency pegged to the euro should be the term structure for the euro, adjusted for currency risk. The Danish krone and the Bulgarian lev have been identified as relevant currencies that meet the requirements set out in that Article.

6.B. Application of the adjustment

103. The currency risk adjustment is applied in addition to, and in the same way as the credit risk adjustment (see section 5).
104. The currency risk adjustment may lead to negative interest rates (i.e. there is no floor for the adjusted rates).
105. The currency risk adjustments for the Danish krone and the Bulgarian lev are currently as follows:
    - 1 bp for the Danish krone;
    - 5 bps for the Bulgarian lev.

6.C. Calculation of the adjustment

106. According to Article 48(2) of the Delegated Regulation, the currency risk adjustment should correspond to the cost of hedging against the risk that the value in the pegged currency of an investment denominated in euro decreases as a result of changes in the level of the exchange rate between the euro and the pegged currency.
107. In line with that provision, the currency risk adjustment for the relevant currency is based on the following formula:

$$CurrencyRA = -f \cdot \frac{BE}{SCR(0)} \cdot \frac{LAC}{Duration} \cdot \frac{RM}{TP}$$

where:

- $CurrencyRA$ denotes the currency risk adjustment;
- f denotes the adjusted currency risk factor for the exchange rate of the relevant currency to the euro as set out in the implementing technical standard with regard to the adjusted factors to calculate the capital requirement for currency risk for currencies pegged to the euro;
- BE denotes the best estimate;

- $SCR(0)$ denotes the current Solvency Capital Requirement applied to calculate the risk margin;

- LAC denotes the ratio of the adjustment for the loss-absorbing capacity of technical provisions and $SCR(0)$;

- $Duration$ denotes the modified duration of the technical provisions;

- RM denotes the risk margin;

- TP denotes the technical provisions.

The currency risk adjustment is calculated with regard to insurance and reinsurance obligations denominated in the relevant currency. As the adjustment should be the same for all insurance and reinsurance undertakings, an average adjustment for all undertakings is estimated.

108. The rationale of the formula is as follows:

- The cost of hedging against currency risk referred to in Article 48(2) of the Delegated Regulation corresponds to the cost of providing eligible own funds to cover the SCR for currency risk.

- The SCR for currency risk is calculated as $f \cdot BE \cdot LAC$, based on the assumption that all the liabilities gives rise to currency risk (i.e. it is not hedged) and that the loss-absorbing capacity of technical provisions mitigates the risk.

- The cost of capital for covering the SCR for currency risk is derived by multiplying the ratio of the SCR for currency risk and the total SCR by the risk margin, resulting in $\frac{factor \cdot BE \cdot LAC}{SCR(0)} \cdot RM$.

- The cost of capital is translated into a change of the discount rate by dividing it by the amount and the duration of technical provisions.

109. The current calibration of the currency risk adjustments for the Danish krone and the Bulgarian lev are based on data from EIOPA’s 2014 insurance stress test. The following approximation was used for this purpose:

$$CurrencRA =$$
$$- factor \cdot \left(\frac{BE_L + BE_{NL}}{SCR(0)_L + SCR(0)_{NL}} \right) \left(\frac{BE_L \cdot LAC_L + BE_{NL} \cdot LAC_{NL}}{BE_L \cdot Duration_L + BE_{NL} \cdot Duration_{NL}} \right) \left(\frac{RM_L + RM_{NL}}{TP_L + TP_{NL}} \right)$$

where the subscripts L and NL identify amounts that relate to life and non-life insurance obligations respectively.

6.D. Update of the adjustment

110. EIOPA will monitor the currency risk adjustment on an annual basis by means of the formula set out in paragraph 107. The currency risk adjustment will only be amended where the difference to the formula result is material. When updates are necessary they will be implemented end-January.

7. Extrapolation and interpolation

7.A. Extrapolation and interpolation method

111. For each currency the basic risk-free interest rate term structure is constructed from risk-free interest rates for a finite number of maturities. Both the interpolation between these maturities, where necessary, and the extrapolation beyond the last liquid point are based on the Smith-Wilson methodology. This methodology is described in subsection 7.E.

112. The control input parameters for the interpolation and extrapolation are the last liquid point, ultimate forward rate (UFR), the convergence point and the convergence tolerance. These parameters are specified in subsections 7.B to D. The control parameters will not be updated on a monthly basis.

113. In order to apply the Smith-Wilson method, a cash-flow matrix is derived from the observed market interest rate data. This is further explained in subsection 7.F. The Smith-Wilson method takes care that the present value function of the derived term structure exactly agrees with the empirical data for the observable maturities.

114. If the reference instruments are swap rates, the market interest rates to be used as inputs are the swap par rates after deduction of the credit and currency risk adjustments described in sections 5 and 6. If the reference instruments are zero coupon government bonds, the market interest rates to be used as inputs are the zero coupon rates after deduction of the credit and currency risk adjustments.

115. The derivation of the term structures is based on the rates for the DLT maturities set out in section 4. Where for a certain day one or several of those rates are not available, the term structure is derived on the basis of the remaining rates, provided that not more than 20% of rates are missing and the rate at the last liquid point is available. Otherwise, the market information of the preceding trading day is used to derive the term structure.

116. EIOPA publishes the risk-free interest rates for integer maturities from one year to 150 years.

7.B. Last liquid point

117. Recital 21 of the Delegated Regulation defines a criterion (referred to as the *residual volume criterion*) to calculate the LLP. The residual volume criterion is used to derive the LLP for the euro only. For that currency, it gives an LLP of 20 years.

    For all other currencies, the LLP has been chosen according to the results of the DLT assessment. It is the longest maturity for which risk-free interest rates can be derived from DLT markets.

Table 8. Last liquid points of EEA currencies

	Currency	LLP
EUR	euro	20
BGN	lev	20
CHF	Swiss franc	25
CZK	Czech koruna	15
DKK	Danish krone	20
GBP	pound sterling	50
HRK	kuna	9
HUF	forint	15
ISK	króna	8
NOK	Norwegian krone	10
PLN	zloty	10
RON	leu	10
SEK	krona	10

Table 9. Last liquid points of non-EEA currencies

AUD	Australian dollar	30
BRL	real	10
CAD	Canadian dollar	30
CLP	Chilean peso	10
CNY	renminbi-yuan	10
COP	Colombian peso	10
HKD	Hong Kong dollar	15
INR	Indian rupee	10
JPY	yen	30
KRW	South Korean won	20
MYR	ringgit	20
MXN	Mexican peso	20
NZD	New Zealand dollar	20
RUB	Russian rouble	10
SGD	Singapore dollar	20
THB	baht	15
TRY	Turkish lira	10
TWD	new Taiwan dollar	10
USD	US dollar	50
ZAR	rand	15

118. The LLP will be updated together with the DLT assessment.

7.C. Ultimate forward rate

119. The methodology to derive the UFRs is set out in the Annex to this subsection. The UFRs will be calculated in accordance with that methodology on an annual basis and updated when they are sufficiently different from the then applicable UFRs.

7.D. Convergence point and tolerance

120. The convergence point is the maximum of (LLP+40) and 60 years. Consequently, the convergence period is the maximum of (60-LLP) and 40 years.

121. The parameter alpha that controls the convergence speed is set at the lowest value that produces a term structure reaching the convergence tolerance of the UFR by the convergence point. The convergence tolerance is set at 1 bp. A lower bound for alpha is set at 0.05. The convergence criterion is assessed by EIOPA with a scanning procedure with six decimals precision for alpha. The method for deriving alpha is illustrated in the Excel tool "Smith-Wilson Risk-free Interest Rate Extrapolation" that can be found on EIOPA's website.

122. In accordance to recital 30 of the Omnibus II Directive, is is possible to account for specific cases in the derivation of the convergence period, provided they are adequately justified. In view of the characteristics of the Swedish bond market, EIOPA has decided to use a convergence period of ten years for the Swedish krona.

7.E. Description of the Smith-Wilson method with intensities

An interest trinity

123. By way of introduction, an annual interest *rate* r is considered that defines an annual interest *factor* $R=(1+r)$. From this a continuous-time interest *intensity* $\rho=\log(R)$ can be defined.[5] Negative interest rates are allowed, but the conditions $r>-1$ or $R>0$ should be met. Only the interest intensity ρ is

[5] The "log" function is to be understood as the natural logarithm. This is the case throughout the document.

unrestricted and this makes it convenient for modelling purposes. In this documentation the concise term intensity instead of instantaneous rate or infinitesimal rate is used to avoid ambiguity with annualised interest rates.

Another trinity

124. With a constant ρ the *present value* of an amount of 1 maturing after v years would be just $p(v)=\exp(-v\rho)$. Since interest intensities usually depend on the term to maturity, it is of interest to analyse present value with changing interest intensity. The *yield* intensity function is what would be the average flat interest intensity:

$$p(v) = \exp\left(-v \cdot y(v)\right) \quad \Leftrightarrow \quad y(v) = \frac{-\log p(v)}{v}$$

125. The *forward* intensity function measures the change in the present value function:

$$f(v) = \frac{-\mathrm{d}\log p(v)}{\mathrm{d}v} = \frac{-p'(v)}{p(v)}$$

126. The yield function can also be written as an averaged integral of the forward function:

$$y(v) = \frac{1}{v}\int_0^v f(z)\mathrm{d}z$$

127. For the forward and yield curve there holds that $y(0)=f(0)$, the zero spot intensity. Also in the limit $y(\infty)=f(\infty)$ is obtained, what is the ultimate forward intensity. Furthermore any turning point of the yield curve will be crossed by the forward curve. This similarity with average and marginal cost curves is mentioned by McCulloch (1971), page 24.[6]

128. A parallel shock in the forward intensity curve will translate as the same parallel shock in the yield intensity curve. This property does not transpose to annualised interest rates, however.

A Simple Econometric Model

129. Nelson & Siegel (1987)[7] proposed as a model for the forward intensity:

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[6] McCulloch, J Huston, 1971. ”Measuring the term structure of interest rates”. *The Journal of Business,* University of Chicago Press vol. 44(1) 19-31, January.

[7] Nelson, Charles R & Siegel, Andrew F, 1987. ”Parsimonious Modelling of yield curves”. *The Journal of Business,* University of Chicago Press vol. 60(4) 473-489, October.

$$f(v) = \beta_1 + \beta_2 e^{-\alpha v} + \beta_3 \alpha v e^{-\alpha v}$$

130. The implied yield curve follows as an averaged integral using the formula of paragraph 126:

$$y(v) = \beta_1 + \beta_2\left(\frac{1-e^{-\alpha v}}{\alpha v}\right) + \beta_3\left(\frac{1-e^{-\alpha v}}{\alpha v} - e^{-\alpha v}\right)$$

and the implied present value function follows using the formula of paragraph 124:

$$p(v) = \exp\left(-\beta_1 v - (\beta_2 + \beta_3)\left(\frac{1-e^{-\alpha v}}{\alpha}\right) + \beta_3 v e^{-\alpha v}\right)$$

131. Diebold & Li (2006)[8] extend this Nelson-Siegel model by incorporating a change process through calendar time *t.* This enables them to forecast future yield curves. Compared with Nelson-Siegel, Smith & Wilson (2001)[9] start the other way around. They propose a model for the present value function, from which the yield and forward intensity function follow. The specification of this present value function needs a special type of function, known as Wilson function, that we will focus on next.

Wilson function

132. The Wilson function $W(u,v)$ can be specified as:

$$W(u,v) = e^{-\omega(u+v)} H(u,v) = e^{-\omega u} H(u,v) e^{-\omega v}$$

where $H(u,v)$ is the heart of the Wilson function:

$$\begin{aligned} H(u,v) &= \alpha \min(u,v) - \exp\left(-\alpha \max(u,v)\right) \cdot \sinh\left(\alpha \min(u,v)\right) \\ &= \alpha \min(u,v) + \frac{e^{-\alpha(u+v)} - e^{-\alpha|u-v|}}{2} \\ &= \frac{\alpha(u+v) + e^{-\alpha(u+v)} - \alpha\,|u-v| - e^{-\alpha|u-v|}}{2} \end{aligned}$$

133. Here α and ω are parameters that have a dimension reciprocal to that of the time duration to maturity u and v that we take the year, and measured as number of days divided by 365.25.

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[8] Diebold, Francis X & Li, Canlin (2006). ”Forecasting the term structure of government bond yields”. *Journal of Econometrics* vol. 130 337-364.

[9] Smith, A & Wilson, T (2001). ”Fitting yield curves with long term constraints”. London: Bacon & Woodrow.

134. The parameter ω denotes the ultimate forward intensity and takes the value log(1.042) in case the ultimate forward rate equals 4.2%. The parameter α controls the speed of convergence to this asymptotic level.

135. This *H*-function and its first two derivatives happen to be continuous at *v=u*:

$$H(u,v) = \alpha \min(u,v) - \exp\left(-\alpha \max(u,v)\right) \cdot \sinh\left(\alpha \min(u,v)\right)$$

Differentiation with respect to *v* gives:

$$\frac{\mathrm{d}H(u,v)}{\mathrm{d}v} = G(u,v) = \begin{cases} \alpha - \alpha e^{-\alpha u}\cosh(\alpha v) & v \le u \\ \alpha e^{-\alpha v}\sinh(\alpha u) & u \le v \end{cases}$$

For the second order derivative the following is obtained:

$$\frac{\mathrm{d}^2 H(u,v)}{\mathrm{d}v^2} = \alpha^2 H(u,v) - \alpha^3 \min(u,v)$$

However, the third derivative shows a discontinuity at *u=v.*

Matrices and vectors

136. Matrices and vectors will be boldface. Transposition is indicated by a prime and $\circ$ denotes element-wise multiplication of conformable matrices. **1** and **0** will denote column vectors with all components equal to 1 and 0 respectively, and of appropriate order.

137. A vector **u** for the *m* observed durations to maturity is introduced, as well as an $m \times n$ matrix **C** that for the cash-flows of the *n* financial instruments:

$$\mathbf{u} = \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{bmatrix} \qquad \mathbf{C} = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & & \vdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} \qquad c_{ij} \ge 0$$

The derivation of these items is explained in the following sub-section 7.F.

138. Nonlinear functions of vectors will indicate by square brackets the component-wise operation as in:

$$\mathbf{d} = \exp[-\omega \mathbf{u}] = \begin{bmatrix} e^{-\omega u_1} \\ e^{-\omega u_2} \\ \vdots \\ e^{-\omega u_m} \end{bmatrix} \qquad p[\mathbf{u}] = \begin{bmatrix} p(u_1) \\ p(u_2) \\ \vdots \\ p(u_m) \end{bmatrix} \qquad \sinh[\alpha \mathbf{u}] = \tfrac{1}{2} \begin{bmatrix} e^{\alpha u_1} - e^{-\alpha u_1} \\ e^{\alpha u_2} - e^{-\alpha u_2} \\ \vdots \\ e^{\alpha u_m} - e^{-\alpha u_m} \end{bmatrix}$$

139. An auxiliary matrix $\mathbf{Q} = \mathbf{d}_\Delta \mathbf{C}$ will be needed where the subscript Δ denotes transforming a column vector into a diagonal matrix such that $\mathbf{d}_\Delta \mathbf{1} = \mathbf{d}$.

Furthermore there are the following three column vectors with n components:

$$\mathbf{b} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix} \qquad \mathbf{p} = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} \qquad \mathbf{q} = \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix} = \mathbf{Q}'\mathbf{1} = \mathbf{C}'\mathbf{d}$$

Here **b** is an auxiliary matrix and **p** contains the n observed market prices for the n financial instruments that will be compared with the m components of the present values in $p[\mathbf{u}]$.

140. The data can be stored in an $(m+1)\times(n+1)$ tableau containing **C** bordered by **u** and the transpose of **p**:

$$\begin{bmatrix} \mathbf{p}' & \\ \mathbf{C} & \mathbf{u} \end{bmatrix}$$

Without loss of generality the rows of this tableau may be ordered according to the components of **u** such that there holds $u_1 < u_2 < \cdots < u_m$. Likewise the columns of this tableau can be ordered such that **C** will be as upper-triangular as possible. Such a canonical format will be useful for validation purposes but is not of any importance for the mathematical formulations.

141. Zero-rows in **C** can be deleted from the tableau without loss of generality. In case of non-deletion this will imply zero components in the output vector **Qb** at the appropriate places.

142. The tableau, whether canonical or not, can be normalized by dividing the columns by the appropriate component of **p**, that is post-multiplying with the inverse of $\mathbf{p}_\Delta$:

$$\begin{bmatrix} \mathbf{1}' & \\ \mathbf{C}\mathbf{p}_\Delta^{-1} & \mathbf{u} \end{bmatrix}$$

143. In case of zero-coupon bonds, the canonical format makes **C** a diagonal matrix that can be normalized to the identity matrix **I** resulting in a canonical normalized tableau:

$$\begin{bmatrix} \mathbf{p}' & \\ \mathbf{I} & \mathbf{u} \end{bmatrix}$$

144. Of course, this case does not need a data tableau, but just **u** and **p**. In what follows data are not assumed to have a canonical or normalized format, such that the exposition holds in full generality.

Wilson matrix and H-matrix

145. On that basis of the definitions made above, the following can be displayed:

$$\mathbf{v} = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_k \end{bmatrix} \qquad \mathbf{W}(\mathbf{v},\mathbf{u}) = \begin{bmatrix} W(v_1,u_1) & W(v_1,u_2) & \cdots & W(v_1,u_m) \\ W(v_2,u_1) & W(v_2,u_2) & \cdots & W(v_2,u_m) \\ \vdots & \vdots & & \vdots \\ W(v_k,u_1) & W(v_k,u_2) & \cdots & W(v_k,u_m) \end{bmatrix} = \mathbf{W}'(\mathbf{u},\mathbf{v})$$

$$\mathbf{W}(v,\mathbf{u}) = [W(v,u_1) \quad W(v,u_2) \quad \cdots \quad W(v,u_m)] = \mathbf{W}'(\mathbf{u},v)$$

$$\mathbf{W}(\mathbf{u},\mathbf{u}) = \mathbf{W} = \mathbf{d}_\Delta \mathbf{H} \mathbf{d}_\Delta = \mathbf{H} \circ \mathbf{dd}'$$

146. The symmetric matrices **W** and **H** will be positive definite as soon as **u** contains distinct positive components. Implementation of the method with **H** is simpler as it only depends on α and not on ω.

Smith-Wilson present value function

147. This function, also known as discount pricing function, can be displayed as:

$$p(v) = e^{-\omega v} + \mathbf{W}(v,\mathbf{u})\mathbf{Cb} = e^{-\omega v} + e^{-\omega v}\mathbf{H}(v,\mathbf{u})\mathbf{Qb}$$

where the values for u correspond to the observed durations to maturity of the financial instruments and v is the duration to maturity of the present value function.

148. A set of equations can be formed by having v the values of **u**:

$$p[\mathbf{u}] = \exp[-\omega \mathbf{u}] + \mathbf{WCb} = \mathbf{d} + \mathbf{WCb} = \mathbf{d} + \mathbf{d}_\Delta \mathbf{H} \mathbf{d}_\Delta \mathbf{Cb} = \mathbf{d} + \mathbf{d}_\Delta \mathbf{HQb}$$

Pre-multiplication with the transpose of **C** gives n linear equations in **b**:

$$\mathbf{C}' p[\mathbf{u}] = \mathbf{C}'\mathbf{d} + \mathbf{C}'\mathbf{WCb} = \mathbf{q} + \mathbf{Q}'\mathbf{HQb}$$

149. **p** is the market observable counterpart of $\mathbf{C}' p[\mathbf{u}]$

$$\mathbf{p} = \mathbf{q} + \mathbf{Q}'\mathbf{HQb}$$

From this follows the solution for **b**:

$$\mathbf{b} = (\mathbf{Q}'\mathbf{HQ})^{-1}(\mathbf{p} - \mathbf{q})$$

This solution depends on ω through **Q** and **q** as well as on α through **H**. The value for α will be determined through convergence requirements.

Smith-Wilson for zero-coupon bonds

150. When m=n, the cash-flow matrix **C** may be taken as the identity matrix and we are in the zero-coupon bond case. The present value function simplifies as:

$$p(v) = e^{-\omega v}\left(1 + \mathbf{H}(v,\mathbf{u})\tilde{\mathbf{b}}\right) \qquad \text{where} \quad \tilde{\mathbf{b}} = \mathbf{d} \circ \mathbf{b}$$

and the calculation for the coefficient vector

$$\tilde{\mathbf{b}} = \mathbf{H}^{-1}\left(\mathbf{p} \circ \exp[\alpha\mathbf{u}] - \mathbf{1}\right)$$

Smith-Wilson yield and forward intensity function

151. From paragraph 147 the yield intensity function follows as:

$$y(v) = \frac{-\log p(v)}{v} = \omega - \frac{\log(1 + \mathbf{H}(v,\mathbf{u})\mathbf{Qb})}{v}$$

The forward intensity function follows as:

$$f(v) = \frac{-\mathrm{d}\log p(v)}{\mathrm{d}v} = \omega - \frac{\mathrm{d}\log(1 + \mathbf{H}(v,\mathbf{u})\mathbf{Qb})}{\mathrm{d}v} = \omega - \frac{\mathbf{G}(v,\mathbf{u})\mathbf{Qb}}{1 + \mathbf{H}(v,\mathbf{u})\mathbf{Qb}}$$

where the components of the row vector **G**(v,**u**) follow from paragraph 135.

152. As $H(u,v)$ has a continuous second order derivative, it can be concluded that the Smith-Wilson present value and yield curve are sufficiently smooth at the nodes given by the observed liquid maturities. However, the forward intensity curve is less smooth as it does not have a continuous second order derivative at these nodes.

Zero spot intensity

153. When $v \le \min(\mathbf{u})$, paragraph 135 implies:

$$\mathbf{G}'(v,\mathbf{u}) = \mathbf{G}(\mathbf{u},v) = \alpha\mathbf{1} - \alpha\cosh(\alpha v)\exp[-\alpha\mathbf{u}]$$

For $v \downarrow 0$ the following is obtained:

$$\mathbf{H}'(0,\mathbf{u}) = \mathbf{H}(\mathbf{u},0) = \mathbf{0} \qquad \mathbf{G}(\mathbf{u},0) = \alpha\mathbf{1} - \alpha\exp[-\alpha\mathbf{u}]$$

From this the zero spot intensity follows from paragraph 151 as:

$$y(0) = f(0) = \omega - \alpha\mathbf{1}'\mathbf{Qb} + \alpha\exp[-\alpha\mathbf{u}']\mathbf{Qb}$$

Analysis of convergence to ultimate forward intensity

154. When $v \ge U = \max(\mathbf{u})$ paragraph 135 implies:

$$\mathbf{H}(\mathbf{u},v) = \alpha\mathbf{u} - e^{-\alpha v}\sinh[\alpha\mathbf{u}] \qquad \mathbf{G}(\mathbf{u},v) = \alpha e^{-\alpha v}\sinh[\alpha\mathbf{u}]$$

155. Now, the upper end of the forward intensity function reduces to:

$$f(v) = \omega + \frac{\alpha}{1 - \kappa \cdot e^{\alpha v}} \qquad v \ge U$$

where κ is a quasi-constant that depends on α (and ω) but not on v:

$$\kappa = \frac{1+\alpha\mathbf{u}'\mathbf{Qb}}{\sinh[\alpha\mathbf{u}']\mathbf{Qb}}$$

If α is such that κ=0, then $f(v) = \omega + \alpha$, irrespective of the value of *v* and the ultimate forward intensity $f(\infty)$ will not approach ω.

156. The value of α is determined by requirements on the convergence speed and will automatically be chosen in such a way that $\kappa \neq 0$.

157. Adopting a convergence period $S = \max(40{,}60 - U)$ implies a point of convergence *T* as follows:

$$T = U + S = \max(U + 40{,}60)$$

158. The convergence gap at the point of convergence *T* can be analysed as a function of α:

$$g(\alpha) = | f(T) - \omega | = \frac{\alpha}{|1 - \kappa e^{\alpha T}|}$$

and the problem of determining α can be formulated as a nonlinear minimization problem:

Minimize α

with respect to α

subject to the two inequality conditions:

(1) $\alpha \geq a$ with the lower bound a =0.05

(2) $g(\alpha) \leq \tau$

159. A heuristic solution strategy is the following:

if $\alpha = a$ implies $g(\alpha) \leq \tau$ then $\alpha = a$ is optimal

else search for $\alpha > a$ such that $g(\alpha) = \tau$

160. Without the lower boundary to alpha, the second inequality $g(\alpha) \leq \tau$ should not be rewritten as $\alpha \leq \tau |1 - \kappa e^{\alpha T}|$ because it might favour a false root for α approaching the value 0.

7.F. Fitting the term structure to bond and swap rates

161. With the Smith-Wilson method the term structure can be fitted to the rates of all the relevant financial instruments.

162. For each set of instruments the input for the Smith-Wilson method is defined by:

- the vector of the market prices of the *n* instruments at valuation date,

- the vector of the m different cash payment dates up to the last maturity, and
- *the* $m \times n$ matrix of the cash-flows of the instruments at these dates.

163. We will now look at this input when the term structure is fitted to zero coupon bond rates, coupon bond rates and par swap rates.

<table>
<tr><th>Instruments</th><th>Market prices p</th><th>Cash payment dates u</th><th>Cash-flow matrix C</th></tr>
<tr><td>Zero coupon bonds</td><td>• Market prices of the n input instruments, given as the percent amount of the notional amount
• The market prices of the zero coupon input bonds translate at once into spot rates for input maturities</td><td>• The cash payment dates are the maturity dates of the n zero coupon input bonds (i.e. $m=n$)</td><td>• An $n \times n$ matrix with entries:
- $c_{ij}=1$ for $i=j$,
- $c_{ij}=0$ else.
• C is the identity matrix.</td></tr>
<tr><td>Coupon bonds</td><td>• Market prices of the n coupon input bonds, given as the percent amount of the notional amount of the bond.</td><td>• The cash payment dates are, in addition to the maturity dates of the input bonds all coupon dates.</td><td>• An $m \times n$ matrix with entries:
- $c_{ij}=r_c(i)/s$, $i<t(j)$
- $c_{t(j),j}=1+r_c(i)/s$,
- $c_{ij}=0$, $i>t(j)$,
where $r_c(i)$ is the coupon rate of bond i, s is the settlement frequency and $t(j)$ the maturity of bond j.</td></tr>
<tr><td>Par swap rates</td><td>• The market prices of the n par swap input instruments are taken as unit (i.e. 1).
• To receive the swap rate, a floating rate</td><td>• The cash payment dates are, in addition to the maturity dates of the swap agreements all swap rate payment dates.</td><td>• An $m \times n$ matrix with entries:
- $c_{ij}=r_c(i)/s$, $i<t(j)$
- $c_{t(j),j}=1+r_c(i)/s$,
- $c_{ij}=0$, $i>t(j)$,
where $r_c(i)$ is the swap rate of</td></tr>
</table>

	has to be earned, that can be swapped against the fixed rate. To earn the variable rate a notional amount has to be invested. At maturity, the notional amount is de-invested.		agreement *i*, and *s* is the settlement frequency and *t*(*j*) the maturity of arrangement *j*.

A numerical illustration is provided in Annex 14.E.

Volatility and matching adjustment

8. Introduction: Conceptual Framework.

164. According to Article 77e of the Solvency II Directive:

    EIOPA shall lay down and publish for each relevant currency the following technical information at least on a quarterly basis:

    […]

    (b) for each relevant duration, credit quality and asset class a fundamental spread for the calculation of the matching adjustment referred to in Article 77c(1)(b);

    (c) for each relevant national insurance market a volatility adjustment to the relevant risk-free interest rate term structure referred to in Article 77d(1)

165. This part of the technical documentation describes how EIOPA derives the technical information mentioned above, in accordance with Articles 77b, 77c and 77d of the Solvency II Directive and Articles 49 to 54 of the Delegated Regulation.

166. The derivation of the volatility adjustments and fundamental spreads requires decisions on the following:

    a. The range and granularity of asset classes, credit quality steps and durations for which the risk corrections of the volatility adjustment and the fundamental spreads are calculated
    b. The source data for the probability of default (PD) calculation
    c. The method of deriving PD from source data
    d. The source data for the cost of downgrade (CoD) calculation
    e. The method of deriving CoD from source data
    f. The source data for the long-term average of spreads (LTAS) calculation
    g. The method of constructing missing data of the 30 year spread history
    h. The treatment of currencies for which source data are not available

167. The methodology to derive the volatility adjustment and the fundamental spread, including the aforementioned decisions, is explained in the following sections.

8.A. Conceptual framework of the volatility adjustment

168. The volatility adjustment (VA) is an adjustment to the relevant risk-free interest rate term structure. The VA is based on 65% of the risk-corrected spread between the interest rate that could be earned from bonds, loans and securitisations included in a reference portfolio for, and the basic risk-free interest rates.

169. The VA is derived per relevant currency. It is the same for all insurance and reinsurance obligations of a currency unless a country specific increase applies. The following subsection explains the calculation of the VA before application of any country-specific increase (currency volatility adjustment). The subsequent subsection sets out the calculation of the country-specific increase.

8.A.1. Currency volatility adjustment

170. In order to determine a currency volatility adjustment, the following inputs are used:

    a. A currency **representative portfolio**[10] of bonds, securitisations, loans, equity and property covering the best estimate of insurance and reinsurance obligations denominated in that currency, based on insurance market data collected by the means of the regulatory reporting;

    b. A currency **reference portfolio** of *yield market indices* based on the aforementioned representative portfolio. The expression yield market indices covers in this section both yield curves and indices on yields.

171. Those inputs are used to calculate the following outputs:

    a. the **currency spread *S*** between the interest rate derived from the reference portfolio of indices and the rates of the relevant basic risk-free interest rate term structure;

    b. the portion of the currency spread *S*, denoted ***RC*** for **risk correction**, which corresponds to "the portion of the spread that is attributable to a realistic assessment of expected losses, unexpected credit risk or any other risk, of the assets" in the reference portfolio (Article 77d of the Solvency II Directive);

[10] Article 49 of the Delegated Regulation provides that "*the [reference] portfolio is based on relevant indices*". In order to compose the reference portfolio of indices, EIOPA needs to build first a representative portfolio of assets.

c. the **risk-corrected currency spread**, which corresponds to the difference between the spread *S* and the risk correction *RC*.

172. In accordance with Article 50 of the Delegated Regulation, the spread *S* before risk correction is equal to the following:

$$S = w_{gov} . \max(S_{gov}; 0) + w_{corp} . \max(S_{corp}; 0)$$

where:

a. w_{gov} denotes the ratio of the value of government bonds included in the reference portfolio of assets for that currency and the value of all the assets included in that reference portfolio (see also section 9.D);

b. S_{gov} denotes the average currency spread on government bonds included in the reference portfolio of assets for that currency;

c. w_{corp} denotes the ratio of the value of bonds other than government bonds, loans and securitisations included in the reference portfolio of assets for that currency or country and the value of all the assets included in that reference portfolio (see also section 9.D);

d. S_{corp} denotes the average currency spread on bonds other than government bonds, loans and securitisations included in the reference portfolio of assets for that currency.

173. Here and in the following sections 'government bonds' means exposures to central governments, central banks and exposures to regional governments and local authorities that are treated as central governments.

174. The risk correction *RC* is equal to the following:

$$RC = w_{gov} . \max(RC_{gov}, 0) + w_{corp} . \max(RC_{corp}, 0)$$

where:

a. w_{gov} and w_{corp} are defined as above;

b. RC_{gov} denotes the risk correction corresponding to the portion of the spread S_{gov} that is attributable to a realistic assessment of the expected losses, unexpected credit risk or any other risk;

c. RC_{corp} denotes the risk correction corresponding to the portion of the spread S_{corp} that is attributable to a realistic assessment of the expected losses, unexpected credit risk or any other risk.

175. The risk-corrected currency spread S_{crncy}^{RC} is equal to the following:

$$S_{crncy}^{RC} = S - RC$$

The risk-corrected currency spread may be negative when $RC > S$. The zero floor mentioned in Article 50 of the Delegated Regulation only applies at portfolio level to the spread before the risk correction.

176. For each relevant currency, the currency VA is equal to the following:

$$VA_{crncy} = 0.65 \cdot S^{RC}_{crncy}$$

Therefore also the currency VA may be negative. The following table summarizes the application of floors in the process of calculation of the currency VA:

	Market spread	Risk correction	Risk-corrected spread
For each individual bond	No floor - spread may be either positive or negative	For each individual bond and hence at portfolio level as well, the risk correction cannot be negative	No floor – risk-corrected spread may be negative
At portfolio level	Floor at zero - spread cannot be negative		No floor – risk-corrected spread may be negative

8.A.2. Country specific increase of the volatility adjustment

177. For each relevant country, the currency volatility adjustment is increased by the difference between the risk-corrected country spread $S^{RC}_{country}$ and twice the risk-corrected currency spread, whenever that difference is positive and the risk-corrected country spread is higher than 100 basis points.

178. In order to determine the country specific increase of the volatility adjustment, the following inputs are used:

   a. A **country representative portfolio** of bonds, securitisations, loans, equity and property covering the best estimate of obligations sold in that country, based on insurance market data collected by the means of the regulatory reporting;

   b. A **country reference portfolio** of indices based on the aforementioned representative portfolio.

179. Those inputs are used to calculate the following outputs:

   a. the **country spread *S*** between the interest rate derived from the reference portfolio of indices and the rates of the relevant basic risk-free interest rate term structure;

   b. the portion of the country spread S, denoted **RC** for **risk correction**, which corresponds to “the portion of the spread that is attributable to a realistic assessment of expected losses, unexpected credit risk or any other risk, of the assets" in the reference portfolio (Article 77d of the Solvency II Directive);

c. the **risk-corrected country spread**, which corresponds to the difference between the spread S and the risk correction RC.

180. The country spread, risk correction and risk-corrected country spread $S_{country}^{RC}$ are calculated in the same way as the currency spread, risk correction and risk-corrected spread S_{crncy}^{RC} for the currency of that country, but based on the inputs stemming from the country representative portfolio and the country reference portfolio.

181. For each relevant country, a country specific increase of the volatility may also apply, in such a manner that the total volatility adjustment is equal to:

$$VA_{total} = 0.65 \cdot \left(S_{crncy}^{RC} + \max\left(S_{country}^{RC} - 2.S_{crncy}^{RC}; 0\right)\right)$$

where $S_{country}^{RC}$ > 100 basis points.

182. Where $S_{country}^{RC}$ is lower than or equal to 100 basis points, there is no country specific increase of the volatility adjustment. That means we have:

$$VA_{total} = 0.65 \cdot S_{crncy}^{RC}$$

8.A.3. Publication of the volatility adjustment

183. According to Article 77d of the Solvency II Directive, the volatility adjustment is not an entity-specific adjustment. Its value should be the same for all the insurance or reinsurance obligations expressed in the same currency or, where the country specific increase applies, relating to the same country.

184. There is not a volatility adjustment at group level. The influence of the volatility adjustment at group level will be derived from the volatility adjustment applied by each component of the group, according to the method of calculation of the group solvency.

8.B. Conceptual framework of the matching adjustment

185. The matching adjustment (MA) is an adjustment to the basic risk-free interest rate, based on the spread on an undertaking's own portfolio of matching assets, less a fundamental spread that allows for default and downgrade risk.

186. Undertakings must calculate the MA themselves, based on their own assigned portfolios of eligible assets. Rather than publishing the MA, EIOPA publishes only the fundamental spreads that undertakings should use, together with the following information:

   a. for assets other than government bonds, the probability of default (PD) to use in the de-risking of the cash flows of the assigned assets,

   b. the probability of default expressed as a part of the spread used to calculate the fundamental spread,

   c. the cost of downgrade (CoD),

   d. the long-term average spread (LTAS).

187. For corporate bonds the fundamental spread is calculated as $FS = \max(PD+CoD, 35\%\cdot LTAS)$. Consequently, the fundamental spread is not always the sum of PD and CoD. Where the floor relating to the LTAS applies the fundamental spread is larger than that sum. In general, the MA should be calculated on the basis of the amount $FS - PD = \max(CoD, 35\%\cdot LTAS - PD)$.

188. EIOPA publishes both the probability of default and cost of downgrade for each relevant asset class, duration and credit quality step.

189. The steps involved in calculating the Matching Adjustment are set out in Article 77c of the Solvency II Directive and Articles 52 to 54 of the Delegated Regulation.

190. For each relevant currency, the Matching Adjustment for an undertaking will be a single number expressed in basis points. This single number should be added to the basic risk-free interest rate term structure for that currency at all maturities (i.e. it should be applied as a parallel shift of the whole of the basic risk-free interest rate term structure).

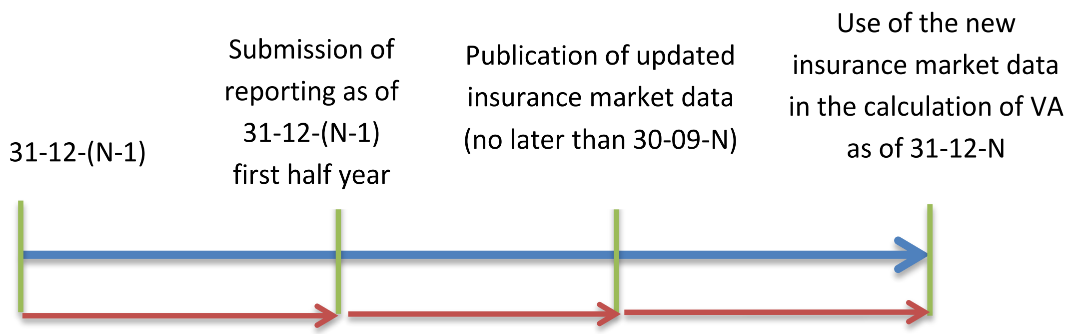
9. Deriving the representative portfolios of bonds and the reference portfolios of '*yield market indices*' for the Volatility Adjustment

9.A. Introduction

191. The organization of this section follows the conceptual framework described in the previous section. In subsection B the relationship among the representative portfolios applied for the currency VA and the country specific increase of the VA is explained. In subsection C the calculation of the representative portfolio of government bonds and the representative portfolio of other assets is introduced. In subsection D the weights referred to in Article 50 of the Delegated Regulation are set out. In subsection E the calculation of the reference portfolios of '*yield market indices'* is specified for the representative portfolio of government bonds and the representative portfolio of other assets.

192. For the purpose of the preparatory phase in 2015 and the beginning of Solvency II in 2016, the data collected to build the representative portfolios were taken from the EIOPA Stress Test 2014 exercise. In 2016 the representative portfolios were updated on the basis of data reported by insurance and reinsurance undertakings to their supervisory authority during the preparatory phase for Solvency II. In the annex to section 9.D the methodology for the update is described.

193. EIOPA intends to update the representative portfolios at the end of the year, on the basis of the annual supervisory reporting of insurance and reinsurance undertakings and of insurance groups in accordance with the methodology set out in this technical documentation. The insurance market data referred to year end N-1, (which undertakings will report in year N) will be used for the calculation of the technical information that undertakings should apply with reference to their situation at the end of year N. Updated insurance market data will be published at least three months before the year end N.



194. EIOPA will review this timeline for the annual update by the end of 2016. For a limited period of time, the date of publication of the updated representative portfolio may be deferred from 30 September to a later date, while maintaining a three-month alert period until the updated representative portfolios are used in the calculation of the VA.

9.B. Introductory remarks on the representative portfolios applied in the calculation of the currency volatility adjustment and in the calculation of the country specific increase of the volatility adjustment.

195. According to Article 77d of the Solvency II Directive, the currency volatility adjustment shall be based on a reference portfolio "*representative for the assets which are denominated in that currency and which insurance and reinsurance undertakings are invested in to cover the best estimate for insurance and reinsurance obligations denominated in that currency*".

196. According to the same Article, the country specific increase of the volatility adjustment shall be based on a reference portfolio "*representative for the assets which insurance and reinsurance undertakings are invested in to cover the best estimate for insurance and reinsurance obligations sold in the insurance market of that country and denominated in the currency of that country*".

197. Therefore, the scope of assets to include in the currency and country representative portfolios is different. However, in the Solvency II framework, insurance and reinsurance undertakings are not required to identify the assets covering their best estimate (except in the case of those covering insurance and reinsurance obligations applying the matching adjustment or under a ring fenced fund regime). It is also not required to classify the assets covering the best estimate of the insurance or reinsurance obligations according to the country where the obligations are sold.

198. In order to implement Article 77d of the Solvency II Directive in the simplest possible manner EIOPA applies the following proxies:

    a. For the currency representative portfolio: A calculation considering that all assets in a currency X cover liabilities in currency X. Hence, the currency representative portfolio of currency X is based on all assets denominated in that currency X and in which undertakings are invested in.[11]

b. For the country representative portfolio: A calculation considering that all liabilities are sold in the country of the undertaking and denominated in the currency of that country. Hence, the country representative portfolio of country A is based on all assets in which undertakings established in that particular country are invested in.

199. These assumptions will be monitored in the future and also they may be removed when there is evidence to the contrary (e.g. for a certain market). The evidence used to remove either or both of these assumptions will be centrally validated by EIOPA.

200. The calculation of the two different sets of reference portfolios (currency VA and country specific increase of the VA, respectively) is feasible for the EEA currencies, since the information contained in the individual reporting at solo level provides the data necessary for the purpose.

201. In the case of non-EEA currencies, the information contained in the reporting at group level allows a proxy only for the calculation of the currency volatility adjustment. Therefore for non-EEA currencies, the only currently feasible approach is to apply the portfolios used for the calculation of the currency adjustment also for the country specific increase of the volatility adjustment.

9.C. Representative portfolios of assets referred to in Article 50 of the Delegated Regulation

202. The derivation of the representative portfolios is based in particular on the following information:

a. The **market value** of the assets included in the representative portfolio. Those market values are required to calculate the weights w_{gov} and w_{corp} and the risk-corrected spread S_{RC}.

b. The **duration** of the bonds, loans and securitizations included in the representative portfolio. Those durations are required to make the spread S maturity-dependent and to select the relevant yield market indices.

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[11] Therefore, the representative portfolio for a currency X may include as issuer country Y with a different currency, when country Y issued bonds expressed in currency X and hold by undertakings in country X.

c. The **asset class**, understood as economic sector (financial sector or non-final sector) of the bonds other than government bonds, loans and securitizations included in the representative portfolio. Government bonds are distinguished according to issuer to form asset classes. The asset classes are required to select the relevant yield market indices.

d. The **credit quality step** (on a scale from 0 to 6) of the bonds other than government bonds, loans and securitizations included in the representative portfolio. Those credit quality steps are required to calculate the spread *S* and the risk correction *RC* and to select the relevant yield market indices.

203. On the basis of that information, the aggregated market value and the average duration per asset class and credit quality step can be calculated for each currency and country. The weights for the determination of the average duration are the market values of the assets.

9.D. The portfolio weights referred to in Article 50 of the Delegated Regulation

204. The weights w_{gov} and w_{corp} applied for the calculation of the volatility adjustments for EEA currencies and countries since 30 September 2016 are set out in the following table. The derivation of the weights is described in the annex to this section.

Table 10. EEA currencies and countries. Weights referred to in Article 50 of the Delegated Regulation

Weights for the currency representative portfolios		
	Government bonds	Other assets
EUR	27.4%	43.8%
BGN	23.5%	2.3%
CHF	23.8%	51.4%
CZK	50.8%	15.6%
DKK	19.3%	61.9%
GBP	19.4%	33.1%
HRK	29.6%	6.7%
HUF	55.4%	15.1%

ISK	77.2%	9.3%
NOK	12.0%	59.5%
PLN	38.4%	20.7%
RON	64.8%	6.7%
SEK	12.1%	31.1%

Weights for the country representative portfolios		
	Government bonds	Other assets
AT	18.3%	46.5%
BE	48.7%	34.2%
BG	53.3%	18.5%
CY	5.5%	42.5%
CZ	52.3%	27.4%
DK	19.3%	61.9%
EE	24.2%	42.4%
FI	8.2%	38.3%
FR	27.0%	46.9%
DE	15.6%	55.2%
GR	32.9%	33.1%
HR	58.9%	11.4%
HU	52.7%	19.5%
IE	17.9%	27.9%
IS	77.2%	9.3%
IT	45.5%	22.9%
LV	49.3%	18.9%
LI	2.5%	32.6%
LT	59.3%	23.7%
LU	40.2%	49.8%
MT	16.6%	25.7%
NL	30.3%	38.9%
NO	11.8%	54.3%
PL	37.2%	22.0%
PT	37.8%	37.6%

RO	46.9%	29.6%
SK	41.6%	38.1%
SI	31.9%	27.0%
ES	43.3%	33.2%
SE	10.9%	29.0%
UK	17.2%	31.3%

205. The weights and durations of the representative portfolios are set out in the Excel files of the monthly publication of the risk-free interest rate term structures on EIOPA's website.

206. For Iceland, there is not enough reliable information to calculate long-term average spreads. Therefore, Croatia has been assigned as a peer country for the VA calculation. Croatian spreads and risk corrections on the one hand and Icelandic króna weights on the other hand are used to derive a VA.

207. The last subsection of section 9 describes the approach for non-EEA currencies during the preparatory phase and the beginning of Solvency II in 2016.

9.E. Reference portfolios of 'yield market indices'

208. For the calculation of the VA the representative portfolio of bonds needs to be mapped to a given granularity of '*yield market indices*'.The expression '*yield market indices*' covers in this section both yield curves and indices on yields.

209. In order to be compliant with Articles 77b, 77c and 77d of the Solvency II Directive, the definition of the reference portfolios of '*yield market indices*' needs to be granular enough to reflect the duration, credit quality and asset class of the 'yield market indices'. This is critical to ascertain an appropriate calibration of the volatility adjustment and the matching adjustment because the spread, the risk correction and the fundamental spread depend to a great extent on those features. Furthermore, such dependence is not linear and therefore the use of simple averages or baskets materially deviates from the relevant calculation

210. EIOPA uses a reference portfolio for each relevant currency and country to calculate the volatility and matching adjustment according to the following information:

    a. **Data from the relevant government bonds yield market indices**. Those data are required to determine the interest rates of government bonds including in the representative portfolio, by duration and country of issuance. Those interest rates are then used to compute the spread *S* and the risk correction *RC* for those government bonds. For representative portfolios that could not be updated in 2016 government bond yields are also used to determine the interest rates of separately modelled non-central government bonds.

b. **Data from the relevant corporate bonds yield market indices**. Those data are required to determine the interest rates of corporate bonds including in the representative portfolio, by duration, asset class and credit quality step. Those interest rates are then used to compute the spread *S* and the risk correction *RC* for corporate bonds.

c. Currently EIOPA does not use market data to derive the spread *S* and the risk correction *RC* for **loans and securitisations included in the representative portfolios**. The assumption underlying this choice is that the spread *S* and the risk correction *RC* for loans and for securitizations are sufficiently similar to those for corporate bonds with the same credit quality and duration. EIOPA will test this assumption and may remove it in the future to the extent that there are appropriate indices for loans and for securitisations, which are readily available to the public and for which there are published criteria for when and how the constituents of those indices will be changed, in accordance with Article 49 of the Delegated Regulation.

211. The currency and country reference portfolios are built on the basis of the representative portfolios of the same currency or country. For this purpose, a mapping is made to associate the characteristics of the assets including in the representative portfolios with indices.

<u>For government bonds. Currency portfolio</u>

212. The reference portfolio of '*yield market indices*' used to calculate the VA for a given currency has as many model bonds as government bonds in that currency (and which insurance and reinsurance undertakings are invested in).

213. The calculations for each issuer are based on its specific yield curve ('*yield market index*') according to the average duration, at the currency area level, of those issuances where undertakings are invested in. Linear interpolation is used to derive the interannual rates corresponding to the average duration.

214. For the sake of simplicity, exposures are expressed in percentages and rounded to the nearest percentage.[12]

215. In the case of the euro area, all the issuers of the euro area are mapped with a single '*yield market index'*: the relevant maturity of the ECB curve for all government bonds of the euro area (daily observations of annual spot rates). EIOPA provides the necessary information to allow the reconstruction of the LTAS of this curve.

<u>For governments banks bonds. Portfolio for the country specific increase of the volatility adjustment</u>

216. For each 'country reference portfolio', EIOPA selects as many '*yield market indices*" as issuers of government bonds in which undertakings of that country are invested in. The market yield for each issuer is derived from the government bond yield curves listed in subsection 3.C, according to the relevant duration. Linear interpolation is used to derive the interannual rates corresponding to that duration.

217. In case of issuances in a currency different than the currency of the issuer, the use of the yield curve in the currency of the issuer is considered to be an acceptable proxy.

218. Using yield curves allows EIOPA to collect interest rates of government bonds for several maturities. Furthermore, the yield curves should be consistent with those used for the calculation of the basic risk-free interest rates term structures in the case of currencies without DLT swaps.

219. For the sake of simplicity, exposures are expressed in percentages and rounded to the nearest percentage as for the currency portfolio.

220. In case there is no government yield curve for a country of the euro area, EIOPA applies the following criteria:

- the national increase of the VA will be zero,
- the long term average spread of the government bonds will be approximated with the long term average spread of a peer country, considering those countries with similar credit quality and level of interest rates for the financial instruments used for the respective basic risk-free curves.

[12] In case the total exposure after rounding is not 100%, the rounding differences (positive or negative) are allocated to the largest exposure.

Table 11. Peer countries as issuers for the calculation of the long term average spreads of government bonds

Country without govts. yield curve	Peer country
Cyprus	Portugal
Estonia	Belgium
Latvia	Ireland*
Liechtenstein	Switzerland
Lithuania	Spain
Luxemburg	Netherlands**
Malta	Ireland

* For reference dates until 30 January 2017 the peer country for Latvia was Spain.
** For reference dates until 31 May 2017 the peer country for Luxembourg was France.

221. EIOPA will continuously monitor the allocation to peer countries. In case the credit quality or level of interest rate of an allocated country or of a peer country significantly changes, the allocation may be changed. Changes may be implemented at short notice in order to ensure the functionality of the volatility adjustment, in particular where the perceived credit quality of an allocated country deteriorates.

<u>For corporate bonds.</u>

222. Regarding corporate bonds, further than the duration, the following dimensions are considered:

- Assets classes, with a differentiation among 'financial' and 'non-financial exposures',
- Credit quality steps as set out in the Delegated Regulation (from 0 to 6),
- Currencies, with a differentiation where possible for the euro, GBP and USD.

223. Section 12 lists the market yield indices used for the implementation of this granularity.

224. Exposures are expressed in percentages and rounded to the nearest percentage[13]. Therefore the theoretical 42 model corporate bonds resulting from the granularity mentioned above, in practice and for most of markets, is limited to just a few market yield indices.

225. The following table reflects the allocation of the ratings used by the market providers to credit quality steps for the only purposes of this technical documentation. EIOPA states explicitly that this allocation does not pre-empt the work in progress regarding the ratings of ECAIs in relation with the Delegated Regulation

Table 12. Allocation of ratings to credit quality steps

(only for the purpose of the technical information set out in Article 77e of the Solvency II Directive)

iBoxx or S&P rating	CQS	iBoxx or S&P rating	CQS
AAA	0	BB	4
AA	1	B	5
A	2	CCC	6
BBB	3	CC, C,…	6

226. For representative portfolios that were not updated in 2016 the portfolio of '*assets other than government bonds*' includes separately modelled non-central government bonds. These bonds are not split by economic sectors and credit quality steps. Instead, they are treated in the same way as central government bonds.

227. For the time being and due to the lack of data, no specific model bonds have been developed specifically for securitizations and loans. Once the relevant information is available, it will be necessary to assess the impact on the number of model points of a specific consideration of securitizations and loans (including mortgage loans).

9.F. Volatility Adjustment for non-EEA currencies

228. Due to the incompleteness of the available information, EIOPA has carried out an ad hoc survey based on market data at group level regarding

13 In case the total exposure after rounding is not 100%, the rounding differences (positive or negative) are allocated to the largest exposure.

exposures denominated in five non-EEA currencies: Australian dollar, Canadian dollar, Swiss franc, Japanese yen and US dollar. The selection of these currencies was based on the information available.

229. EIOPA highlights the possibility of variations in the outputs, once a better set of information becomes available. The weights that EIOPA will apply during the preparatory phase and the beginning of Solvency II in 2016 are the following ones:

Table 13. Non-EEA currencies and countries. Weights referred to in Article 50 of the Delegated Regulation

	Govts.	Others
Australian dollar, Australia	76.5%	18.2%
Canadian dollar, Canada	51.9%	41.1%
Switzerland	23.8%	51.4%
Yen, Japan	85.2%	11.4%
US dollar, USA	18.2%	76.1%

230. EIOPA will assess the relevance of publishing the volatility adjustment for other non-EEA currencies on a case by case and considering, among other factors, the materiality of the currency both at the individual and market level. So far, no other need has been identified.

10. Methodology for the determination of the risk corrections and the fundamental spreads

10.A. Introduction

231. In this section the expression '*risk correction*' refers to the volatility adjustment. The expression '*fundamental spread*' refers to the matching adjustment.

232. Article 51 of Delegated Regulation specifies that the risk correction "shall be calculated in the same manner as the fundamental spread" and using the same inputs. Therefore, the methods and source data described in this section are relevant for both the risk correction used for the volatility adjustment and the fundamental spread applied for the matching adjustment.

233. In the absence of specific reference to the contrary, the content of this section refers to both the risk correction spread and the fundamental spread.

10.B. Determination of the risk-corrections and the fundamental spreads for government bonds

234. According to Article 77c of the Solvency II Directive, the fundamental spread on government bonds is equal to the maximum between:

    a. The sum of the credit spread corresponding to the probability of default of the assets considered and the credit spread corresponding to the expected loss resulting from downgrading of the assets concerned.

    b. A percentage of the long-term average of the spread, over the basic risk-free interest rate, of assets of the same duration, credit quality and asset class, as observed in financial markets. This percentage is 30% for exposures to governments of EEA member states, and 35% for exposures to other governments (Article 77c(2)(b) and (c) of the Solvency II Directive).

235. Recital 22 of the Delegated Regulation specifies that '*where no reliable credit spread can be derived from the default statistics, as in the case of exposures to sovereign debt, the fundamental spread for the calculation of the matching adjustment and the volatility adjustment should be equal to the long-term average of the spread over the risk-free interest rate set out in Article 77c(2)(b) and (c) of Directive 2009/138/EC*'.

236. Therefore, the risk correction of the spread S_{gov} and the fundamental spread on government bonds corresponds only to:

RC = FS = 30% LTAS for exposures to governments of EEA member states

RC = FS = 35% LTAS for exposures to other governments

where LTAS is the long-term average of the spread over the risk-free interest rate of assets of the same duration, credit quality and asset class.

10.B.1. Long-term average of the spread on government bonds

237. Article 54(3) of the Delegated Regulation provides the following:
    a. The long-term average shall be based on data referring to the last 30 years;
    b. Where a part of that data is not available, it shall be replaced by constructed data;
    c. The constructed data shall be based on the available and reliable data referring to the last 30 years. Data that are not reliable shall be replaced by constructed data using that methodology;
    d. The constructed data shall be based on prudent assumptions.

238. In order to determine the long-term average for each relevant currency and country, EIOPA needs the following inputs:
    a. The zero-coupon yield curve of the government bonds in the government bonds representative portfolio, over the last 30 years;
    b. The basic risk-free interest rate term structure denominated in the currency of the bonds in the government bonds representative portfolio, over the last 30 years.

239. However, in most cases there is no historical data over a 30 years period on interest rate swaps and government bonds.

240. To overcome this issue, EIOPA re-constructs missing data, in accordance with Article 54(3) of the Delegated Regulation, applying the following rule: the missing spread data for each currency and maturity are re-constructed using the average spread calculated with the data available from 1 January 1985 or, failing that, whenever reliable spread data are available.

241. Nevertheless, since the overnight market have developed only since the end of the last century, the availability of overnight swap rates (necessary to calculate the credit risk adjustment) has been limited, resulting de facto in a calculation of the LTAS since 1 January 1999 for all currencies.

242. Therefore, EIOPA assumes the average spread over the period for which data are missing is not materially different from the average spread that can be calculated with available data.

243. To illustrate the implementation of this rule, let’s take the following example. Suppose that the volatility adjustment is calculated at year end

2015. Suppose further that, for a given currency and maturity, data are only available from 01 January 1999 till 31 December 2015 (i.e. 17 years). The assumption is that the constructed data have the same average as the average obtained from the available market data:

a. From 1986 to 1998: the constructed spread for each year corresponds to the flat average spread calculated on the period 1999-2015.

b. From 1999 to 2015: the available spread data are used.

244. EIOPA will determine the constructed spread for each currency and maturity where data are missing on the basis of the data available at 31 December 2015. All the calculations are developed using daily data.

245. The LTAS for UK government bonds is a special case because reliable data, to assess the spread of these bonds, in particular pound sterling swap data, are available for the period before 1999. These additional data are taken account by applying the adjustment factors set out in Annex 14.H to the LTAS that are calculated as described in the two paragraphs above.

246. From 1 January 2016 until having the complete 30-years historical series from January 1999, at each publication the LTAS will be calculated as:

$$\frac{LTAS_{31\_12\_2015} \quad * (7800 - ntd) + \sum^{ntd} Spreads\_from\_1\_1\_2016}{7800}$$

where *ntd* denotes the number of new trading days from 1 January 2016 onwards where data are available; $\sum^{ntd} Spreads\_from\_1\_1\_2016$ means the sum of the spreads during those new dates; $LTAS_{31\_12\_2015}$ identifies the LTAS as of 31 December 2015; and it is assumed that a 30 years period is composed of 7800 trading days.

247. For the sake of transparency EIOPA will publish the long-term average spreads.

248. The calculations according to the methodology above show that for most of currencies, the markets of government bonds with more than 10 years duration have developed only from the first half of the last decade. As a consequence, the calculation of the LTAS for maturities higher than 10 years lacks of representativeness due to the reduced number of observations and to the fact that a major part of the observations refer to the current financial crisis.

249. In order to avoid this bias, the calculation of LTAS for government bonds is carried out from 1 to 10 year maturities. The LTAS resulting for maturity 10 years is applied for longer maturities. Even below 10 years, for a few currencies some maturities deliver non plausible results. The following table reflects the currencies with some maturity delivering non plausible LTAS. To derive the spreads for those maturities, linear interpolation of spreads using neighbor maturities is applied (see also subsection 10.C.3 where the same linear interpolation is used).

Table 14. Disregarded maturities for the LTAS on government bonds calculation

(0 = disregarded and then interpolated; 1 = LTAS historical data)

Country	ISO 4217	1	2	3	4	5	6	7	8	9	10
Austria	AT	1	1	1	0	1	1	1	1	1	1
Croatia	HRK	1	0	1	1	0	0	0	1	1	0
Cyprus	CY	1	1	1	1	1	0	1	1	1	1
Czech Republic	CZK	1	1	1	1	1	1	1	1	0	1
Denmark	DKK	1	1	1	1	1	1	1	1	0	1
Greece	GR	1	1	0	1	1	0	1	1	1	1
Hungary	HUF	1	1	1	1	1	1	1	1	1	1
Norway	NOK	1	1	1	1	1	1	1	1	1	0
Romania	RON	1	1	1	1	1	0	1	1	1	1
Russia	RUB	1	1	1	1	1	1	1	1	1	0
Slovakia	SK	1	1	1	0	1	1	1	1	1	1
Slovenia	SI	1	1	0	1	1	1	1	1	1	1
Sweden	SEK	1	1	1	1	1	1	1	1	0	1
Switzerland	CHF	0	1	1	1	1	1	1	1	0	1
Chile	CLP	1	1	1	1	1	1	1	0	1	1
Malaysia	MYR	1	1	1	1	1	1	1	1	1	0
Korea, South	KRW	1	1	1	1	1	0	1	0	0	0
Thailand	THB	1	1	1	1	1	0	1	1	1	1

The table sets out the maturities used to derive the government bond spreads for current reference dates that enter the calculation of the LTAS. Past changes to the maturities are set out in the Annex to subsection 10.B.1.

10.C. Determination of the risk-corrections and fundamental spreads for assets other than government bonds

10.C.1. General elements

250. The Solvency II Directive and Articles 49 to 54 of the Delegated Regulation set down several aspects of the methodology for calculating the Risk Correction and the Fundamental Spread of assets other than government bonds. The methodology to be used is different depending on whether reliable credit spreads can be determined from long-term default statistics.

251. Where reliable credit spreads *can* be derived from such statistics, the risk correction spread and the fundamental spread can be expressed as:

RC = FS = MAX (PD + CoD, 35% LTAS) where

PD = the credit spread corresponding to the probability of default on the assets;

CoD = the credit spread corresponding to the expected loss resulting from downgrading of the assets;

LTAS = the long-term average of the spread over the risk-free interest rate of assets of the same duration, credit quality and asset class.

252. Where no reliable credit spreads can be derived from long-term default statistics, the risk correction and fundamental spread can be expressed as RC = FS = 35% LTAS, where LTAS is the long-term average of the spread over the risk-free interest rate of assets of the same duration, credit quality and asset class.

253. The Delegated Regulation sets the recovery rate assumption in the event of a default at 30% for all asset classes.

254. The Delegated Regulation also specifies that the LTAS should be based on data of the last 30 years.

255. Where there is not 30 years of complete and reliable information relating to spreads, the Delegated Regulation specifies that the 'missing' data should be constructed using the data that is available, in a prudent manner. The process of reconstruction is consistent with the process described above for government bonds.

256. Where the fundamental spread is defined by the 35% LTAS, the difference among the fundamental spread and the PD will be attributed to the CoD.

10.C.2. Method for deriving the probability of default (PD) and the cost of downgrade (CoD)

257. The calculation of the PD derives an amount that is interpreted as an investor's required compensation for assuming the risk of the expected probability of default of a bond. The expectation of a default (based on historical default probabilities derived from the transition matrices) is thus combined with an assumption on the recovery value in case of default, which is assumed to be 30% of the market value as set out in Article 54(2) of the Delegated Regulation.

258. For the sake of consistency, EIOPA applies the same method to calculate both the PD and CoD, with the following difference:

- For the PD, EIOPA assumes a "buy and hold" strategy: assets are not sold after downgrade.
- For the CoD, EIOPA assumes a "buy and replace" strategy: assets downgraded are replaced by an asset of the same credit quality step as before downgrade, or higher. This difference in calculation of PD and CoD may give rise to the double-counting of risks. To avoid that, the

CoD calculation is reduced by the following difference: the PD calculated with the "buy and hold" strategy minus the PD calculated with the "buy and replace" strategy. EIOPA ensures the final outcome stays greater or equal to zero.

259. Both computations use the transition matrix adjusted for cost accounting and are based on the same inputs: empirical one-year transition matrices, the relevant basic risk-free interest rates term structure and for each credit quality step a vector of relevant portions of the market value of a risk-free benchmark instrument. These portions have been designed to be analogous to the recovery rate for the PD.

Table 15. Vector of scaling factors used in the calculation of the Cost of Downgrade

CQS	Rc	CQS	Rc
AAA	98%	BB	70%
AA	97%	B	50%
A	95%	CCC	40%
BBB	85%		

260. In case of a rating migration to a credit quality step of lower quality (downgrades), the cost is defined as difference between the two market values. This cost reflects the cost of replacing the downgraded asset with an asset of the same credit quality it was downgraded from and preserving the original cash flow pattern. Knowing that the asset did not default, the cost is reduced so that it takes account of that information.

261. For the next year of projection the asset is supposed to start from the credit quality step of the replaced bond. This cost accounting and rebalancing procedure is applied until maturity of the original bond. This procedure implements the rebalancing requirement as set out in Article 54(4) of the Delegated Regulation.

262. The total loss is defined as the loss in market value by subtracting the present value of future downgrading cost cash flows. Finally, the loss in market value is transformed into an implied (higher) yield and the result is expressed as spread over the basic risk free interest rate in basis points.

263. The annex to this subsection contains a detailed description of this method. Subsection 12.B.2. details the transition matrices used for the calculations described in this subsection.

264. For the calculation of the volatility adjustment, the value of the PD and CoD expressed in basis points are rounded to the nearest basis point. This rounded value is used as input in the relevant step of the calculation of the volatility adjustment.

265. For the matching adjustment, the PD that EIOPA publishes is the probability to apply for the de-risking of cash flows as follows:

$$\text{de-risked cash flow} = \text{cashflow} * (1 - PD_{EIOPA}) + \text{recovery\_rate} * \text{cashflow} * PD_{EIOPA}$$

266. The PD probability for de-risking cash flows expected at time 't' is derived from a Markov matrix as the last column obtained when powering 't' times the one year average transition matrices (see the annex for further details).

267. The probability of default, cost of downgrade and fundamental spread are published until 30 years maturity. From that maturity onwards the value of those magnitudes for the 30 years maturity will apply.

268. The calculation of PD and CoD is set out in the Excel tool "CoD & PD Calculation" that can be found on EIOPA's website.

10.C.3. Long-term average of the spread on other assets

269. The long-term average of the spread on other assets is calculated in the same manner as the long-term average spread on government bonds described in the subsection 10.B.1 above, with the following specificities.

270. A linear interpolation is performed to obtain complete corporate yield curves where there is missing data[14]. Where there are no market data or only market data for a single maturity, then the yields are set to zero. All yields below the first maturity available are equal to the first yield available.

271. As explained in sub-section 12.B.1, the CQS 0 corporate yields are equal to 85% of the CQS 1 corporate yields where those yields are positive or zero and otherwise equal to 115% of those yields. This operation is performed for financial and non-financial bonds and for all currencies.

272. The long-term average spread is calculated for those dates where neither the basic risk-free rate term structures nor the corporate yields of the same currency[15] are nil. The calculation is performed in the same manner than the long-term average spread on government bonds, i.e. assuming that the average spread over the period for which data is missing is not materially different from the average spread that can be calculated with available data.

273. Having in mind the content of the market input data as described in section 12, the value of the 2 year LTAS is used also as value of the 1 year LTAS.

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[14] This linear interpolation is performed for each 10^{th} of a year. See also subsection 12.B.1.

[15] Currencies for which a LTAS on other assets is calculated are EUR, GBP and USD.

274. LTAS on other assets is kept constant from the last maturity available of the market source onwards.

275. For GBP non-financial bonds, credit quality step 1, the LTAS for maturities 4 to 9 years calculated before 1st January 2016 is obtained by linear interpolation of LTAS using 3 and 10 years maturities, because the history of the indices available in the range of 4 to 9 years does not allow a reliable calculation of those LTAS. From 1st January onwards, the new data to be used in the LTAS calculation is of better quality and one does not need to interpolate anymore.

276. As for UK government bonds, there are adjustment factors for the LTAS of corporate bonds denoted in pound sterling in order to take account of reliable data for the period before 1999. The adjustment factors are set out in Annex 14.H.

277. The LTAS of GBP and USD CQS 4 and 5 corporate bonds are calculated using the approach described in sub-section 10.C.4. For LTAS, that means that, first the spread of the GBP/USD basic risk-free term structures over the EUR basic risk-free term structure is calculated; second the average of the above calculation is performed for all relevant dates; third κ=0.5 is multiplied to this long-term average; fourth the result is added to the corresponding LTAS of the EUR.

278. The LTAS of CQS 6 corporate bonds is equal to the LTAS of CQS 5 corporate bonds.

10.C.4. Currencies without yield market indices for corporates, loans and securitizations.

279. For currencies for which there are no yield market indices satisfying the calculation needs, the spread on corporate bonds denominated in euro is used with an adjustment proportionate to the difference between the basic risk-free interest rate term structure of the concerned currency and the euro. In such case, the following formulas applies:

$$S^{X}_{corp} = S^{€}_{corp} + \kappa \cdot \left(Y^{X}_{rfr} - Y^{€}_{rfr}\right)$$

$$Y^{X}_{corp} = Y^{€}_{corp} + (1+\kappa) \cdot \left(Y^{X}_{rfr} - Y^{€}_{rfr}\right)$$

where € denotes the euro, *X* refers to a currency without interest rates term structures for the assets relevant for the spread S_{corp}, Y_{corp} denotes the yield of the respective corporate bonds of the same credit quality, Y_{rfr} denotes the basic risk free interest rate and κ=0.5. The inputs of this formula are maturity dependent according to the information available.

280. EIOPA may also consider the specific case of covered bonds, once the current limitations in the information available are solved.

281. For the time being an operational solution has been identified for the Danish market of covered bonds based on the following formula:

$$S_{covered}^{DKK} = R_{covered}^{DKK} - Y_{rfr}^{DKK}$$

where *DKK* denotes Danish krone and:

$R_{covered}^{DKK}$ shall be based on the yield from *Nykredits Realkreditindeks.* (Bloomberg ticker NYKDYTM)

The maturity used for Y_{rfr}^{DKK} shall correspond to the duration of the Nykredits Realkreditindeks (7 years).

282. The resulting $S_{covered}^{DKK}$ is relevant for AAA Financials in the calculation for DKK.

283. Nykredits Realkreditindeks includes a representative extract of the Danish covered bond market. The index includes both covered bonds with short and long maturities. See also the accompanying annex to this section.

10.C.5. Inputs used to determine S_{gov} and S_{corp}

284. For determining the spread S_{gov} on government bonds, the starting point is the information of insurance market data relevant for the currency (or country) whose VA is calculated. This information is composed of two elements:

a. The composition of the reference portfolio of yield market indices of government bonds for the currency (or country). This composition is applied considering for each component of the portfolio (i.e. each issuer) its relative market value (the percentage of the total market value of the portfolio).

b. It is also necessary to know the duration of each component of the reference portfolio.

Each relative market value and its corresponding duration build a model bond (i.e. a model bond is a government bond with the duration for such bond in the currency or country where the VA is calculated).

Since in the case of government bonds the selected yield market indices are yield curves, this means that each model bond is the value of the yield curve for each issuer at the relevant maturity.

285. The following financial market inputs are also necessary:

a. The market yields corresponding to the currency and duration of each model point representing the government bonds as referred above and in section 9,

b. The basic risk-free interest rates corresponding tothe currency and durations of each model point representing the government bonds as referred above and in section 9,

c. The risk corrections corresponding to the currency and durations of each model point representing the government bonds as referred above and in section 9.

286. Where the average duration of the relevant government bond in which the insurance and reinsurance undertakings of a given market are invested in does not coincide with one of the maturities of the yield curve, EIOPA uses a linear interpolation to find the interest rate of the government bond and/or the basic risk-free rate and/or the risk correction that corresponds to the average duration.

287. For determining the spread S_{corp} on assets other than government bonds, the same approach applies *mutatis mutandis*.

Table 16. Specification of the input for the calculation of the VA

Corporate part of the VA				
		Yield	**Risk-free interest rate**	**Risk correction**
Currency VA	**Corporate bonds**	Corporate bonds in the currency for which a VA is calculated (if needed with K factor approach)	Currency for which a VA is calculated	Corporate bond FS in the currency for which a VA is calculated (if needed with K factor approach)
	RGLA bonds	Euro VA: ECB curve for all euro area issuers, government bond of the issuer for all non-euro area issuers VAs for other currencies: Government bond of the issuer	Currency of the issuer	Euro VA: ECB curve FS for all euro are issuers, government bond FS of the issuer for all non-euro area issuers VAs for other currencies: Government bond FS of the issuer
Country VA	**Corporate bonds**	Corporate bonds in the currency of the country for which a VA is calculated (if needed with K factor approach)	Currency of the country for which a VA is calculated	Corporate bond FS in the currency of the country for which a VA is calculated (if needed with K factor approach)
	RGLA bonds (only relevant for portfolios not updated in 2016)	Government bond of the country of the issuer	Currency of the issuer	Government bond FS of the issuer
Government part of the VA				
		Yield	**Risk-free interest rate**	**Risk correction**
Currency VA	**Govt bonds**	Euro VA: ECB curve for all euro area issuers, government bond of the issuer for all non-euro area issuers VAs for other currencies: Government bond of the issuer	Currency of the issuer	Euro VA: ECB curve FS for all euro are issuers, government bond FS of the issuer for all non-euro area issuers VAs for other currencies: Government bond FS of the issuer
Country VA	**Govt bonds**	Government bond of the issuer	Currency of the issuer	Government bond FS of the issuer

11. Process of calculation of the risk-corrected spread at portfolio level

288. Process of calculation of the currency volatility adjustment (the process applies *mutatis mutandis* to the calculation of the country specific increase of the volatility adjustment).

Step 1.- For each currency, identify the model bonds (and their duration) included in the representative portfolio.

Step 2.- For each model bond, input the market yield at the date of calculation, according to the table in section 12 and the duration of the model bond[16]. This yield is referred to in the process as '*yield before risk correction*'.

Step 3.- For each model bond, input the basic risk-free interest rates curve at the date of calculation, according to the duration of the model bond.[17]

Step 4.- For each model bond, calculate the risk correction as the maximum of the relevant percentage of the long-term average spread (30 or 35% as described in subsection 10.B), and the PD+CoD (probability of default and cost of downgrade, as referred to in subsection 10.C and its annex). In the case of government bonds, the risk correction is the relevant percentage of the long-term average spread (i.e. the PD+CoD component does not apply). Where the LTAS is negative, a zero floor is applied as mentioned in section 8.

Step 5.- Once completed the previous steps, a single cash flow is projected for each model bond according to the duration of the model bond, and using as capitalization rate the market '*yield before risk correction*' referred to in step 2. This means a cash flows projection with the features of each model bond.

Step 6.- The projection of single cash flows for each model bond made in step 5 is repeated but using as capitalization rate the basic risk-free rate referred to in step 3.

Step 7.- A third projection is necessary but using this time, as capitalization rate, the '*yield before risk correction*' reduced with the risk correction derived in step 4.

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[16] Where the market yield is given for a maturity that does not fit exactly the weighted average duration of the model bond, a linear interpolation of yields of the same index or the same curve is performed.

[17] The same linear interpolation as in step 2 applies if necessary.

Steps 8, 9 and 10.- Calculation of the three following internal effective rates (IER[18]) for the overall reference portfolio:

a. Step 8.- "IER_yield_before" is equal to the internal effective rate, calculated as a single discount rate that, where applied to the cash-flows calculated in step 5, results in a value that is equal to the aggregated value of the whole portfolio (since relative percentages are used, this aggregated value is 1);
b. Step 9.- "IER_basic_RFR" is equal to the internal effective rate, calculated as a single discount rate that, where applied to the cash-flows calculated in step 6, results in a value that is equal to the aggregated value of the whole portfolio (since relative percentages are used, this aggregated value is 1);
c. Step 10.- "IER_yield_corrected" is equal to the internal effective rate, calculated as a single discount rate that, where applied to the cash-flows calculated in step 7, results in a value that is equal to the aggregated value of the whole portfolio (since relative percentages are used, this aggregated value is 1).

289. Finally, for each relevant currency, the spreads S_{gov} (the same applies for S_{corp}) <u>before the risk correction</u> is equal to the following, in accordance to Article 50 of the Delegated Regulation:

$$S_{gov} = max\left(0\,;\, IER_{yield\ before\ RC} - IER_{BRFR}\right)$$

while the risk correction RC_{gov} (the same applies to RC_{corp}) is equal to the following[19]:

$$RC_{gov} = max(0\,;\, IER_{yield\ before\ RC} - IER_{yield\ RC})$$

Finally, for each relevant currency and country the VA is calculated using these four values (S_{gov}, S_{corp}, RC_{gov}, RC_{corp}) as inputs to the formula referred to in subsection 8.A

290. The volatility adjustment is rounded at the nearest integer basis point. This rounding is applied only at the end of the calculation process.

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[18] The IER is calculated by EIOPA using a pre-defined Matlab function: "xirr" with the following parameters: "GUESS" = 0.05 and "MAXITER" = 200.

[19] The risk correction at portfolio level cannot be negative because, as mentioned in section 7, the risk correction for each individual model bond cannot be negative.

Illustrative example (dummy data)

Wgov	62,00%	
Wcorp	25,10%	
Sgov	0,85%	= IER 1(step 8) - IER 2 (step 9)
Scorp	1,20%	= IER 1(step 8) - IER 2 (step 9)
RC gov	0,20%	= IER 1(step 8) - IER 3 (step 10)
RC corp	0,35%	= IER 1(step 8) - IER 3 (step 10)
S	0,83%	
RC	0,21%	
S RC crncy	0,62%	
Currency VA	0,40%	

Detailed examples of the VA calculation can be found in the two Excel files "VA calculation example IT" and "VA calculation example UK".

12. Financial market data applied for VA and MA calculation

12.A. Market data for government bonds

291. The calculation of the LTAS is based on the basic risk-free interest rates term structures and the government yield curves described in section 3.

12.B. Financial market data for assets other than government bonds

12.B.1. Market yields for corporate bonds

292. The market yields for corporate bonds are those provided by the Markit – iBoxx indices listed in the tables below in this subsection. The yield is the '*Annual Yield*' and the duration is the '*Portfolio Duration'* (rounded to the first decimal). For high-yield indices the '*Annual Yield to Maturity'* and the '*Portfolio Duration to Maturity'* (rounded to the first decimal) are used.[20]

293. The relevant yield curve is calculated by linear interpolation for those maturities provided by the source. For shorter and longer maturities the interest rate published for the nearest duration is applied. An example for the interpolation is as follows: in order to calculate the yield for a bond of duration 8.8, a linear interpolation is performed using the closest data available. For instance this could be, on the one hand the market yield of the bucket 7-10 and its duration (e.g. 8.3 years) and, on the other hand, the market yield of the bucket 10-15 and its duration (e.g. 12.1 years).

294. Having in mind the availability of both the current value of market yield indices for exposures to corporate bonds, and of their historical series (necessary to calculate the long-term average spreads), the following decisions have been adopted for pragmatic reasons:

    a. CQS0 (AAA) corporate yield indices for the euro and GBP have not been available during the last two years for a major part of the maturity buckets, and even for those maturity buckets where yields are available, the number of constituents of the index is very low. Furthermore, availability of buckets has continuously changed during the last years (i.e. not always the same buckets of duration have been available).

       In order to solve the current lack of data and avoid the exposure of the calculation to likely business contingencies, the market yields of

[20] The names of the yield and duration concepts relate to the fieldnames of the data files from the Markit FTP server.

CQS0 exposures will be 85% of CQS1 yields for the euro and for the GBP. The 0.85 reduction factor is based on the historical experience of those periods where both CQS0 and CQS1 yields have been simultaneously available. In case CQS1 yields are negative the market yields of CQS0 exposures will be 115% of CQS1 yields.

b. Regarding CQS1 non-financial bonds expressed in GBP, the available historical series of market yield indices for maturities from 4 to 9 years are incomplete and a reliable calculation of the long-term average spread (LTAS) is not possible before 1st January 2016.

   Therefore for GBP non-financial bonds, credit quality step 1, the LTAS for maturities 4 to 9 years is obtained by linear interpolation of 3 and 10 years maturities LTAS. This interpolation is performed for all data before the 31 December 2015. It won't be performed for the data afterwards as reliable data is available. This rule does not apply to the current market yields, because for the time being it is possible to use the indices GBP CQS1 Non-financial.

c. The currently available indices for CQS4 and CQS5 do not discriminate by duration. Therefore, the market yield of sub-investment grade assets CQS4 and CQS5 is used for all maturities (i.e. a flat curve is used).

d. The market yield indices available for CQS6 are based on a limited number of constituents and the historical information available is not complete enough. For these exposures the market yield indices of CQS5 are applied.

295. EIOPA will monitor the effect of these criteria and the improvements of the available financial market data

12.B.2. Market data for the calculation of the PD and CoD

296. The inputs necessary for the calculation of the probability of default and cost of downgrade are the benchmark curve used to calculate the spreads, the corporate bonds spreads to the benchmark curve, and the relevant transition matrices:

a. The benchmark curve is the basic risk-free curve,

b. The spreads are calculated as the difference between the market yields for corporate bonds described above, and the basic risk-free interest rate term structure.

c. Two transition matrices are used as inputs: financial and non-financial exposures. Both transition matrices have been obtained according to the following criteria:

   i.) the transition probabilities refer to the 1 year average calculated along the last 30 years, until 1 January 2016;

ii.) having in mind the limited number of exposures per geographical area, credit quality step and economic sector, the geographical area considered refers to all countries;

iii.) the withdrawn exposures are excluded (i.e. not considered in the initial population of names);

iv.) the statistics refer to issuers (i.e. names);

v.) having in mind the definition of the market source for ratings below CCC, those categories are included as defaults. Therefore matrices used as input have seven credit quality steps (i.e. eight rows and columns, including the situation of being defaulted, which is considered to be an absorbing state – no return to rated categories).

The input data for the transition matrices are specified in annex 14.K.

297. EIOPA will update the transition matrices on an annual basis at mid-January. The updated matrices will be applied for the first time in the calculation of end-January technical information.

Markit – iBoxx indices	1-3yr	3-5yr	5-7yr	7-10yr	10+yr
EUR_Financial AAA	85% of the EUR financial AA yields if those yields are positive or zero, otherwise 115% of those yields				
EUR_Financial AA	DE000A0JZBB2	DE000A0JZBD8	DE000A0JZBF3	DE000A0JZBH9	DE000A0JZA95
EUR_Financial A	DE000A0JZA12	DE000A0JZA38	DE000A0JZA53	DE000A0JZA79	DE000A0JZAZ3
EUR_Financial BBB	DE000A0JZBX6	DE000A0JZBZ1	DE000A0JZB11	DE000A0JZB37	DE000A0JZBV0
EUR_Financial BB	Iboxx EUR High Yield curve Financial ex crossover LC BB (GB00B1CQYN32)				
EUR_Financial B	Iboxx EUR High Yield curve Financial ex crossover LC B (GB00B1CQYW23)				
EUR_Financial CCC	Iboxx EUR High Yield curve Financial ex crossover LC B (GB00B1CQYW23				
EUR_Non Financial AAA	85% of the EUR Non financial AA yields yields if those yields are positive or zero, otherwise 115% of those yields				
EUR_Non Financial AA	DE000A0JZCH7	DE000A0JZCK1	DE000A0JZCM7	DE000A0JZCP0	DE000A0JZCF1
EUR_Non Financial A	DE000A0JZB78	DE000A0JZB94	DE000A0JZCB0	DE000A0JZCD6	DE000A0JZB52
EUR_Non Financial BBB	DE000A0JZC36	DE000A0JZC51	DE000A0JZC77	DE000A0JZC93	DE000A0JZC10
EUR_Non Financial BB	Iboxx EUR High Yield curve Non-financial ex crossover LC BB (GB00B1CR1Z75)				
EUR_Non Financial B	Iboxx EUR High Yield curve Non-financial ex crossover LC B (GB00B1CR2653)				
EUR_Non Financial CCC	Iboxx EUR High Yield curve Non-financial ex crossover LC B (GB00B1CR2653)				

Markit – iBoxx indices	1-3yr	3-5yr	5-7yr	7-10yr	10-15yr	15+yr
GBP_Financial AAA	85% of the GBP financial AA yields yields if those yields are positive or zero, otherwise 115% of those yields					
GBP_Financial AA	DE000A0JY7T1	DE000A0JY7X3	DE000A0JY7Z8	DE000A0JY712	DE000A0JY7R5	DE000A0JY7V7
GBP_Financial A	DE000A0JY7B9	DE000A0JY7F0	DE000A0JY7H6	DE000A0JY7K0	DE000A0JY696	DE000A0JY7D5
GBP_Financial BBB	DE000A0JY8R3	DE000A0JY8V5	DE000A0JY8X1	DE000A0JY8Z6	DE000A0JY8P7	DE000A0JY8T9
GBP_Non Financial AAA	85% of the GBP Non financial AA yields yields if those yields are positive or zero, otherwise 115% of those yields					
GBP_Non Financial AA	DE000A0JY9P5	DE000A0JY9T7	DE000A0JY9V3	DE000A0JY9X9	DE000A0JY9M2	DE000A0JY9R1
GBP_Non Financial A	DE000A0JY878	DE000A0JY9B5	DE000A0JY9D1	DE000A0JY9F6	DE000A0JY852	DE000A0JY894
GBP_Non Financial BBB	DE000A0JZAM1	DE000A0JZAR0	DE000A0JZAT6	DE000A0JZAV2	DE000A0JZAK5	DE000A0JZAP4

Markit – iBoxx indices	1-3yr	3-5yr	5-7yr	7-10yr	10-15yr	15+yr
USD_Financial AAA	85% of the USD financial AA yields					
USD_Financial AA	GB00B05DN483	GB00B05DN590	GB00B05DN608	GB00B05DN715	GB00B05DN822	GB00B05DNB55
USD_Financial A	GB00B05DMS57	GB00B05DMT64	GB00B05DMV86	GB00B05DMW93	GB00B05DMX01	GB00B05DN046
USD_Financial BBB	GB00B05DNS23	GB00B05DNT30	GB00B05DNV51	GB00B05DNW68	GB00B05DNX75	GB00B05DNZ99
USD_Non Financial AAA	85% of the USD Non financial AA yields yields if those yields are positive or zero, otherwise 115% of those yields					
USD_Non Financial AA	GB00B05DQD84	GB00B05DQF09	GB00B05DQG16	GB00B05DQH23	GB00B05DQJ47	GB00B05DQL68
USD_Non Financial A	GB00B05DQ270	GB00B05DQ387	GB00B05DQ494	GB00B05DQ502	GB00B05DQ619	GB00B05DQ833
USD_Non Financial BBB	GB00B05DR245	GB00B05DR351	GB00B05DR468	GB00B05DR575	GB00B05DR682	GB00B05DR807

Yields for sub-investment grade bonds denominated in pound sterling and US dollar are derived from yields of corresponding bonds denominated in euro by applying the factor described in section 10.C.4.

13. Calculation of the relevant risk-free interest rates term structures at a glance.

298. The complete process of calculation may be summarized as follows:

Basic risk-free interest rates term structure

Step A.- Use the data specified in table 1 of section 3.C as input for the market interest rates of the relevant financial instrument.

Step B.- According to the tables in section 4, removal of the rates either not meeting the DLT requirements (tables 3 to 5) or longer than the LLP (table 2).

Step C.- Calculation of the credit risk adjustment as described in section 5.

Step D.- Reduction of all the market rates remaining after step B by the amount of the credit risk adjustment (and the currency adjustment in the case of the Bulgarian and Danish currencies).

Step E.- Construction of the matrix of cash flows corresponding to the credit risk adjusted rates after step C.

One of the dimensions of this matrix reflects the maturities corresponding to DLT rates (e.g. 1 to 10, 12, 15 and 20 years in the case of the euro), while the other dimensions reflects the future terms with payments of the underlying financial instrument, according to the frequency of the financial instrument (e.g. annualized rates in the case of the euro curve). For simplicity, market conventions are not used, since its effect is negligible.

Step F.- Selection of the rest of inputs of the method of extrapolation in accordance with sections 4 and 7: LLP (table 2 and subsection 7.B), ultimate forward rate (subsection 7.C), convergence period, tolerance (1 basis point) and lower bound of alpha parameter (0.05) (subsection 7.D).

Step G.- Application of the method of extrapolation (subsection 7.E).

Risk-free interest rates term structure with the volatility adjustment

Step H.- Calculation of the volatility adjustment. This subprocess has been described in section 11 above. For each relevant currency and each relevant country, the volatility adjustment is a fixed number, expressed in basis points and rounded to the nearest integer basis point, and applied to all maturities till the last liquid point.

Step I.- Construction of the matrix of cash flows corresponding to the zero-coupon annualized rates resulting from step G. All integer maturities until the last liquid point, included, will be used to build this matrix. Furthermore, for each maturity a single payment will be considered. Therefore the matrix of this step will usually have different dimensions than the one built in step E.

Step J.- Addition of the annualized volatility adjustment to the matrix of cash flows obtained in step I.

Step K.- Application of the method of extrapolation with the same inputs used in step F and according to the method mentioned in step G.

299. The volatility adjustment is not added directly to the par swap rates adjusted for credit risk but is added to the zero-coupon spot rates of the basic risk-free interest rate term structure obtained after using the Smith-Wilson method (as described in an earlier part of this technical documentation).

300. In accordance with Article 46 of the Delegated Regulation, the volatility adjustment is added to the aforementioned zero-coupon spot rates only in the liquid part of the curve.

301. The resulting rates are the relevant risk-free interest rates including the volatility adjustment to which the extrapolation is applied, using again the Smith-Wilson method.

302. Because the volatility adjustment is applied to the liquid zero coupon rates of the basic risk-free interest rate term structure, the relevant risk-free interest rate term structure including the VA is a parallel shift of the basic risk-free interest rate term structure until the LLP. There is no parallel shift after the LLP since both the basic and relevant risk-free curves ultimately converge to the same UFR.

14. Annexes

14.A. Annex to section 3: Relevant currencies

EEA currencies

ISO 4217	**Currency**	**Countries where the currency is used**
EUR	euro	Euro area members
BGN	lev	Bulgaria
CHF	Swiss franc	Liechtenstein, Switzerland
CZK	Czech koruna	Czech Republic
DKK	Danish krone	Denmark
GBP	pound sterling	United Kingdom
HRK	kuna	Croatia
HUF	forint	Hungary
ISK	króna	Iceland
NOK	Norwegian krone	Norway
PLN	zloty	Poland
RON	leu	Romania
SEK	krona	Sweden

Other currencies

AUD	Australian dollar	Australia
BRL	real	Brazil
CAD	Canadian dollar	Canada
CLP	Chilean peso	Chile
CNY	renminbi-yuan	China
COP	Colombian peso	Colombia
HKD	Hong Kong dollar	*Hong Kong*
INR	Indian rupee	India
JPY	yen	Japan
KRW	South Korean won	South Korea
MYR	ringgit	Malaysia
MXN	Mexican peso	Mexico
NZD	New Zealand dollar	New Zealand
RUB	Russian rouble	Russia
SGD	Singapore dollar	Singapore
THB	baht	Thailand
TRY	Turkish lira	Turkey
TWD	new Taiwan dollar	*Taiwan*
USD	US dollar	United States
ZAR	rand	South Africa

14.B. Annex to section 4: Identification of reference instruments and DLT assessment

303. Solvency II sets out market consistency as a core principle for the assessment of the financial and solvency position of insurance and reinsurance undertakings. The principle of market consistency applies to both assets and liabilities.[21] In particular, for the calculation of technical provisions the relevant risk-free interest rate term structure should be used. That term structure should be based on upon up-to-date and credible information.[22]

304. These principles underpin the assessment of the depth, liquidity and transparency of markets where the interest rates are observed. As well as providing assurance that the relevant DLT requirements are met, the DLT assessment should foster the optimal use of the information provided by financial markets.[23]

305. In developing the methodology applied for the DLT assessment, EIOPA has analysed the generally applied practices and the academic literature on the issue. This analysis has dealt in particular with the process of the liquidity assessment, but has also considered the available measures of depth and transparency.

306. As part of the preparation and follow-up of the Long-term Guarantees Assessment, EIOPA developed a conceptual framework for DLT assessment based on the aforementioned analysis in 2013. This conceptual framework was put into practice on a tentative basis for the EIOPA Stress Test 2014.

307. EIOPA's work and lessons learnt during 2013 are in line with EBA's report on high quality liquid assets (HQLA).[24]

308. While acknowledging the differences between the banking and insurance sectors, EIOPA recognises the existence of commonalities between the DLT assessment for risk-free interest rate term structures and the work carried out by EBA on HQLA.

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[21] Recital 53, Articles 75 and 76 of the Solvency II Directive

[22] Recital 58 and Article 77 of the Solvency II Directive

[23] Recital 45 of the Solvency II Directive

[24] Report on appropriate uniform definitions of extremely high quality liquid assets (extremely HQLA) and high quality liquid assets (HQLA) and on operational requirements for liquid assets under Article 509(3) and (5) CRR, http://www.eba.europa.eu/documents/10180/16145/EBA+BS+2013+413+Report+on+definition+of+HQLA.pdf

309. Although there is a set of generally applied metrics for the purpose of making a DLT assessment, carrying out the assessment in practice is currently constrained by the following limitations:

310. While there is a general approach to assessing liquidity and depth, the precise definitions of these terms depend on the context. For example, the definition of 'liquidity' for the purpose of the Liquidity Coverage Ratio (LCR) in the banking sector is quite similar to its definition in the case of the DLT assessment in the insurance sector. Having said that, the purpose of the DLT assessment is focused on ensuring the reliability of market interest rates rather than the need to convert assets into cash.

311. There are several factors influencing the liquidity (and depth) of financial markets. Further, the influence of these factors varies across markets (e.g. according to their practices, conventions and operational rules) and also varies over time within the same market (e.g. according to changes in the environment). Finding a generalized way to measure the level of these factors is the subject of continuing research.

312. It is generally accepted that no single metric can be conclusive in assessing the DLT nature of a financial instrument. For example, high trading volumes and turnovers indicate that assets are liquid, while the converse does not necessarily hold true (some assets may be in high demand without being traded often, and hence could be easily liquidated if necessary).[25]

313. There are severe limitations for the calculation of some metrics, in terms of the availability and reliability of the inputs necessary for the calculation and the completeness or homogeneity of the data series. In particular for the swap market, the lack of information on real trading volumes means that it is not possible to use some of the main indicators generally used when making DLT assessments of other types of instrument. This limitation has particular importance because Solvency II prescribes swaps as the first choice of instrument for deriving the relevant risk-free interest rate term structure.

314. Finally, practitioners, academics and supervisors acknowledge the relevance of supplementing quantitative metrics with qualitative or expert judgement. EIOPA supports the appropriate consideration of qualitative information, and this view is also reflected in the EBA report on HQLA.[26] In particular, EIOPA is of the view that the assessment of the depth of a financial market should take into account the existence of appropriate supervision; such supervision can be an effective mechanism to ensure that large transactions will only affect prices according to the natural trends of the market, and not because

[25] EBA report on HQLA (p. 16)

[26] EBA report on HQLA (p. 26)

of any spurious influence. Another relevant qualitative consideration for the assessment of market depth is the way in which market prices are collected; market data providers have developed effective methods and controls that can help to give reassurance that the influence of large transactions or unusual trades on prices is likely to be immaterial.

315. The following annexes describe EIOPA's approach to the DLT assessment, separately for the following two cases:

    a. EEA currencies, for which it is feasible to obtain ad-hoc information on pricing and trading (except for traded volumes for swaps, as mentioned above).

    b. Non-EEA currencies, for which EIOPA has adapted its methodology to account for data limitations. In particular this approach includes those metrics used by EBA that do not rely on either traded volumes or on any other information that is not generally available.

316. In both cases, EIOPA's methodology aims to provide a stable DLT assessment; this is considered a necessary condition to allow insurance and reinsurance undertakings to implement the relevant calculation processes. Therefore, as a general rule, hard thresholds and the automatic use of benchmarks have not been considered appropriate. For example, comparing the bid-ask spreads of one currency against another does not necessarily provide conclusive evidence for a DLT assessment, not only because of the specifics of each financial market (level of interest rates, trends, etc.), but also because experience shows that the relative positions of two currencies may change over time.

14.C. Annex to subsection 4.B: DLT assessment of EEA currencies

317. The DLT assessment for EEA currencies is based on the conceptual framework that EIOPA developed for the purposes of the Long-term Guarantees Assessment in 2013.

318. As mentioned in the general annex to Section 4 above, each of the depth, liquidity and transparency criteria lacks a globally accepted clear definition that is of practical use. Even in academic literature a wide range of measures for depth and liquidity exist; however, none of those measures is considered authoritative and applicable in all markets.

319. Therefore, the list of criteria mentioned below should be considered as non-exhaustive. EIOPA has focused on criteria that may be helpful in assessing the credibility of market data for interest rate swaps and government bonds. Additional criteria consider the general bond market. The criteria are as follows:

    a. Bid-ask spread: the price difference between the highest price a buyer would pay and the lowest price for which a seller would sell
    b. Trade frequency: number of trades that take place within a defined period of time
    c. Trade volume
    d. Trader quotes/dealer surveys (incl. dispersion of answers);
    e. Quote counts (1): number of dealer quotes within a window of a few days;
    f. Quote counts (2): number of dealers quoting
    g. Number of pricing sources
    h. Assessment of large trades and movement of prices (depth)
    i. Only applicable to the euro: residual volume approach for bonds.

14.D. Annex to subsection 4.C: DLT assessment of non-EEA currencies

320. The DLT assessment of non-EEA currencies is based, in addition to qualitative analysis, on the joint consideration of three main methodologies:

    a. volatility analysis;

    b. analysis of bid-ask spreads (both direct observations and also using the Roll measure, as described below);

    c. quantitative analysis.

321. The DLT assessment methodology presented in this annex is going to be applied to non-EEA currencies. Results of that methodology for EEA currencies are presented only for illustration purposes. The DLT assessment for EEA currencies will be conducted according to methodology described in subsection 4.B.

14.D.1. Volatility analysis

322. For the volatility analysis, the behaviour of the available interest rates for each maturity and non-EEA currency over the past 105 business days is analysed (this is approximately a chronological period of five months).

323. The analysis is conducted for rates directly observed in markets (e.g. par swap rates where swaps are the financial instrument used as reference), for zero-coupon spot rates, and finally for the 1-year forward rate term structure.

324. For each of the three sets of rates above, and for each currency and maturity, the analysis considers both the values of the rate and the behaviour of the volatility calculated considering the last 21 days[27](approximately one chronological month). Therefore, 84 values of the

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[27] The following formula is used:

Volatility = standard deviation of natural logarithms of variations =

$= \sqrt{\sum \frac{(\ell n(c_i) - \overline{\ell nc})^2}{n-1}}$ where $\ln c_k = \ln \frac{rate_k}{rate_{k-1}}$ and $\overline{\ell nc}$ denotes the simple average of the last 21 daily logarithmic changes.

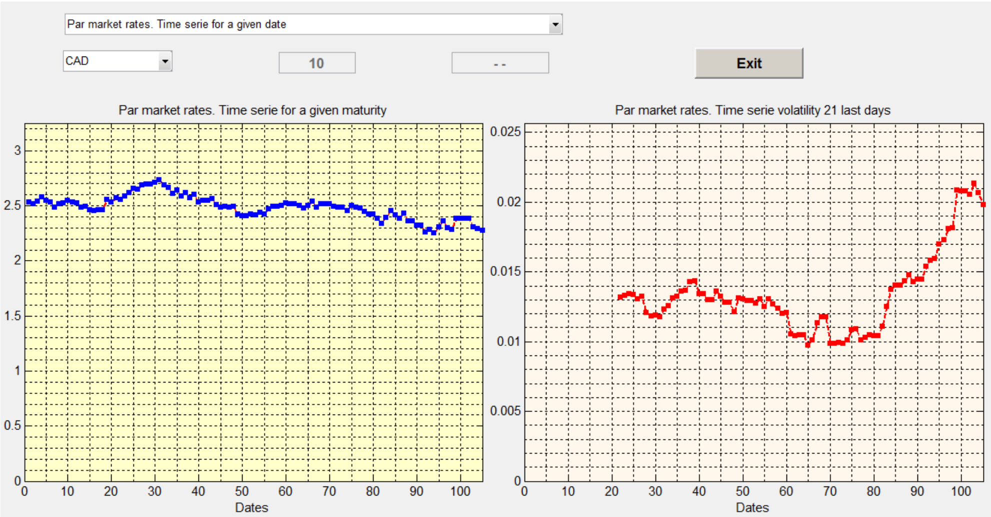
Note that no $\sqrt{t}$ adjustment is applied in order to derive annual volatilities. This has no impact on the conclusions to the extent the DLT analysis aims at comparing volatilities, not at assessing its values on an annual basis.

volatility for each rate are calculated, with rolling windows referring to the last 105 trading days (i.e. for the oldest 21 dates in the series, no volatility is calculated, as these dates do not have the 21-day period of reference necessary for the calculation).

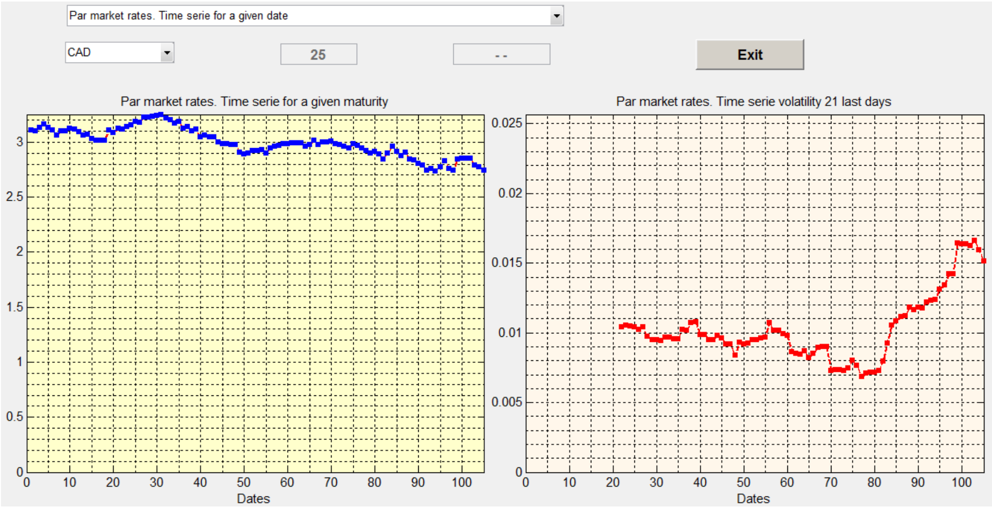
325. The analysis described in the paragraphs above is used to conduct three tests and to produce the set of statistics described below.

326. The first test focuses on how the rate for a given maturity behaves during the 105 day window (both the level of the rate itself and its 21-day volatility).

327. As an example, the charts below show the behaviour of the 10-year (first two charts) and 25-year rates and volatilities (second two charts) for the Canadian dollar, as of 31 December 2014, using the par swap market rates.

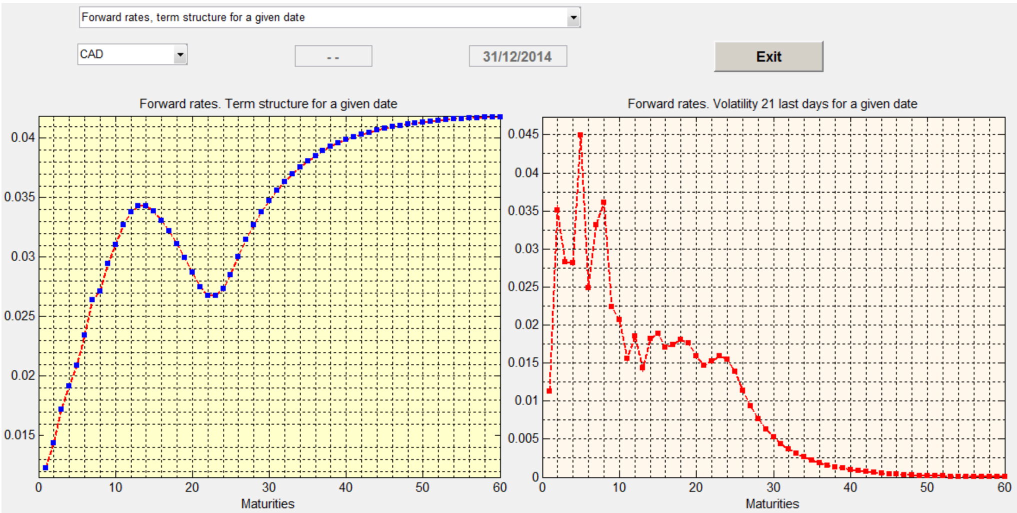


328. There are several ways of inferring an empirical view on the behaviour of the interest rates. For example, by considering the values of the rates (y-axis in the left chart) and the level of the volatility (y-axis on the right hand side), by considering the lack of/presence of repeated sudden changes in the level of the volatility, or by examining the range of variation in both charts. From these perspectives the rates for both maturities show a similar pattern, and do not convey abnormal features.



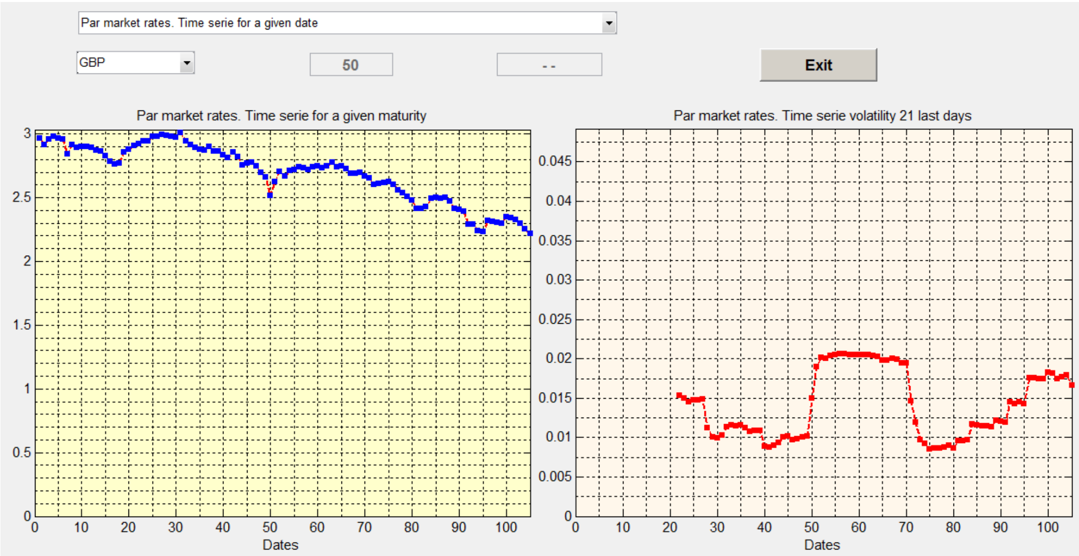
329. The second test aims to detect whether the rate for a given maturity produces humps or hollows in the term structure curve (i.e. by comparing with the behaviour of neighbouring maturities).

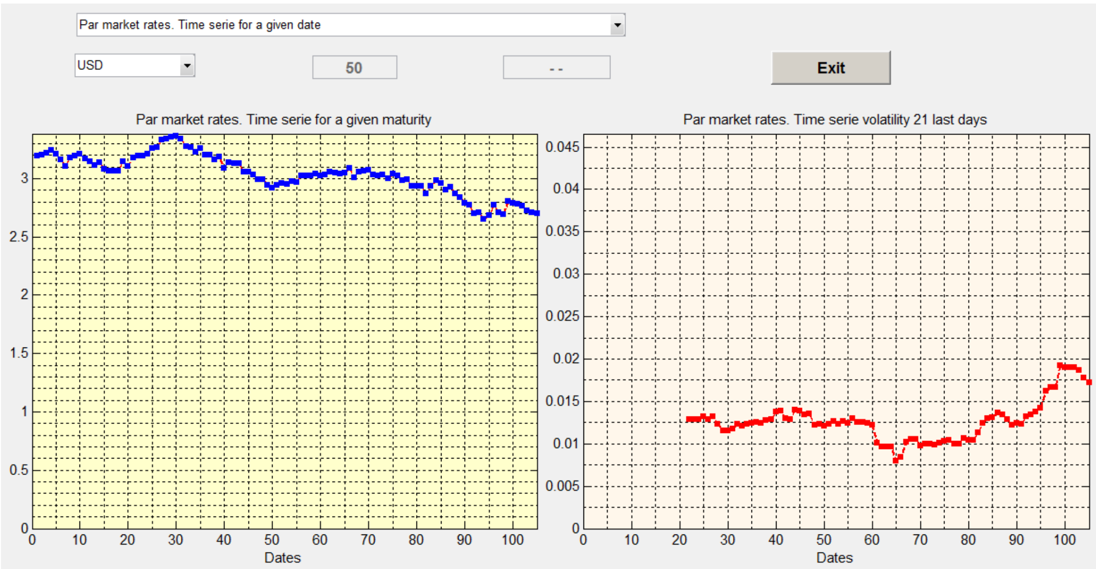
330. Again using the example of the Canadian curve as at 31 December 2014, it can be seen that the curve does not present abnormal features and the 21-days volatility of all observable maturities is in a reasonable range (note the LLP for the Canadian currency is 25 years, therefore the part of the curve for maturities longer than 25 years does not represent market data, but the Smith-Wilson extrapolation).



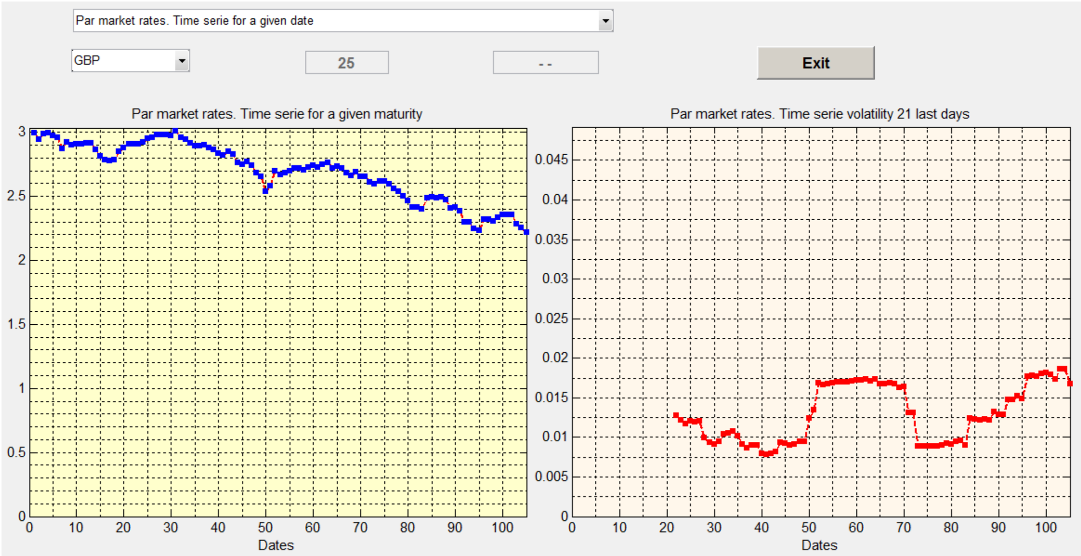
331. For the third analysis, a comparison across currencies has been developed. The comparison is used in situations where there is an adequate relationship between the non-EEA currency now being analysed and an EEA currency whose DLT nature has been tested as described in section 4.B. This third test aims to verify whether the behaviour of the non-EEA rate is sufficiently similar to its ‘peer’ EEA rate.

332. For example, the charts below compare the behaviour of 50-year maturities for GBP and USD as at 31 December 2014 using par swap rates (note that the similarity of behaviours between these currencies is also observed when using zero-coupon rates and forward rates).

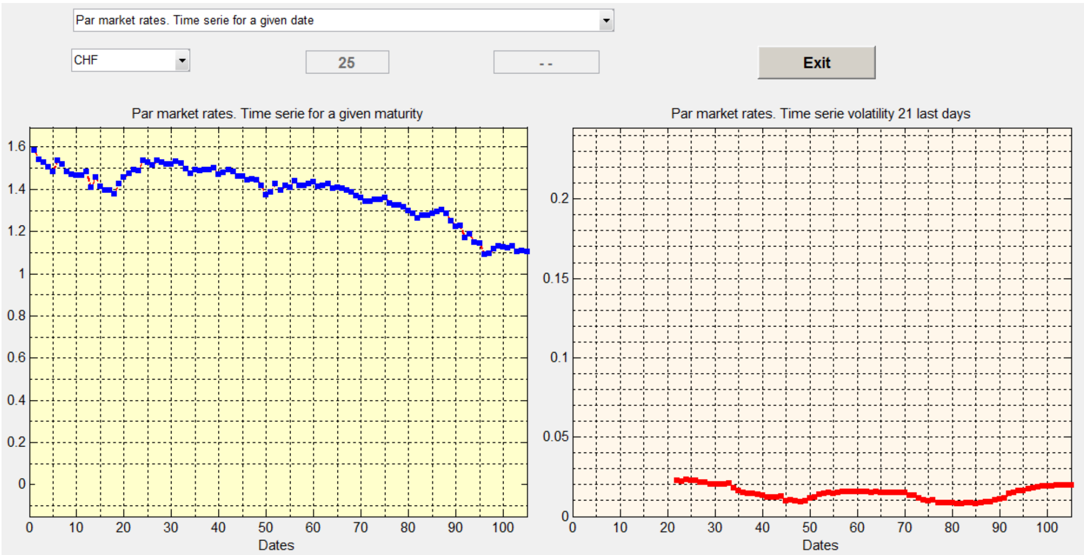




333. The charts below compare the behaviour of 25-year maturities for GBP and CHF as at 31 December 2014 using 1-year forward rates (note that the similarity of behaviours is also observed when using par swap rates and zero-coupon rates).



Par market rates. Time serie for a given date
GBP
25
- -
Exit
Par market rates. Time serie for a given maturity
Par market rates. Time serie volatility 21 last days
Dates
Dates



Par market rates. Time serie for a given date
CHF
25
- -
Exit
Par market rates. Time serie for a given maturity
Par market rates. Time serie volatility 21 last days
Dates
Dates

14.D.2. The analysis of bid-ask spreads: Direct observation

334. For all currencies where a ‘likely’ longest DLT maturity has been established, a direct investigation of the specific bid-ask spreads at these maturities is also carried out. The following metrics are obtained for the month prior to the reference date and also for the last quarter:

a. Median of bid-ask spreads during the last month

b. 80th Percentile of bid-ask spreads during the last month

c. Maximum of bid-ask spreads during the last month

d. Simple Average of bid-ask spreads during the last month

e. Last spread (at the date of reference of the curve)

f. Number of days with zero spreads.

335. The tables below summarizes some findings for long-term maturities of swaps as of 31 December 2014 (currencies identified according to ISO 4217 in all tables):

Analysis of bid-ask spread for 15-year interest rates swaps IBOR

	Last 64 days with trading						*Last 21 days with trading*					
	Zero observations	*Median non-zero spreads*	*Percentile 80 non-zero spreads*	*Maximum spread*	*Average non-zero spreads*	*Last non-zero spread*	*Zero observations*	*Median non-zero spreads*	*Percentile 80 non-zero spreads*	*Maximum spread*	*Average non-zero spreads*	*Last non-zero spread*
EUR	0	2.25	4.00	4.00	2.34	2.40	0	3.00	4.00	4.00	2.58	2.40
BGN	48	260.00	260.00	260.00	260.00	260.00	5	260.00	260.00	260.00	260.00	260.00
CZK	0	4.00	4.00	7.00	4.22	4.00	0	4.00	4.00	4.00	3.86	4.00
DKK	0	3.00	3.00	7.00	3.06	7.00	0	3.00	4.73	7.00	3.70	7.00
HUF	3	6.00	7.45	10.00	5.93	10.00	0	6.00	6.00	10.00	5.21	10.00
LIC	0	4.00	4.00	10.00	3.61	4.00	0	4.00	4.00	10.00	3.62	4.00
NOK	0	10.00	10.00	10.00	7.54	4.00	0	5.00	10.00	10.00	6.44	4.00
PLN	0	3.00	4.00	6.00	3.37	3.00	0	3.00	3.00	3.00	3.00	3.00
RON	0	140.00	140.00	140.00	140.00	140.00	0	140.00	140.00	140.00	140.00	140.00
RUB	0	14.00	14.00	14.00	14.00	14.00	0	14.00	14.00	14.00	14.00	14.00
SEK	0	3.00	3.10	6.00	3.17	3.00	0	3.00	3.00	3.10	2.88	3.00
CHF	0	4.00	4.00	10.00	3.61	4.00	0	4.00	4.00	10.00	3.62	4.00
GBP	0	1.00	1.00	1.90	1.00	1.80	0	1.00	1.56	1.90	1.13	1.80
AUD	0	3.00	4.00	8.50	3.45	4.00	0	3.00	4.00	8.50	3.60	4.00
CAD	0	3.17	4.00	6.10	3.09	4.00	0	3.42	4.00	5.90	3.06	4.00
CLP	2	4.00	5.00	5.00	4.21	4.00	2	4.00	4.70	5.00	4.21	4.00
CNY	3	40.00	40.00	59.00	40.51	40.00	0	39.00	40.00	59.00	40.33	40.00
HKD	2	7.00	7.10	10.00	7.25	10.00	2	7.00	7.10	10.00	7.48	10.00
JPY	0	2.00	2.00	8.00	2.20	2.00	0	2.00	2.00	8.00	2.24	2.00
MYR	0	10.00	10.00	10.00	9.94	10.00	0	10.00	10.00	10.00	10.00	10.00
MXN	0	4.00	4.00	6.00	4.00	4.00	0	4.00	4.60	6.00	4.27	4.00
NZD	3	1.00	1.74	8.00	2.00	0.75	1	0.75	1.00	8.00	1.39	0.75
SGD	0	7.00	7.00	7.10	5.88	7.00	0	7.00	7.00	7.00	6.12	7.00
ZAR	0	8.00	10.00	10.00	8.06	8.00	0	8.00	10.00	10.00	8.25	8.00
KRW	0	3.00	3.50	3.50	3.20	3.00	0	3.00	3.50	3.50	3.17	3.00
THB	0	9.00	10.00	12.00	8.84	9.00	0	9.00	10.00	10.00	8.71	9.00
TRY	0	40.00	40.00	42.00	40.08	40.00	0	40.00	40.00	41.00	40.05	40.00
USD	2	0.40	0.51	0.80	0.39	0.50	-	0.45	0.56	0.80	0.43	0.50

Analysis of bid-ask spread for 20-year interest rates swaps IBOR

	Last 64 days with trading						Last 21 days with trading					
	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread
EUR	0	2.18	4.00	4.00	2.28	2.40	0	2.66	4.00	4.00	2.52	2.40
BGN	48	260.00	260.00	260.00	260.00	260.00	5	260.00	260.00	260.00	260.00	260.00
CZK	0	4.00	4.00	7.00	4.20	4.00	0	4.00	4.00	4.00	3.86	4.00
DKK	0	3.00	3.00	7.00	3.12	7.00	0	3.00	4.80	7.00	3.63	7.00
HUF	4	6.00	10.00	10.00	6.67	6.00	1	6.00	6.00	6.00	5.73	6.00
LIC	0	4.00	4.00	10.00	3.66	5.00	0	3.00	4.30	10.00	3.33	5.00
NOK	0	15.50	15.50	15.50	14.66	3.70	0	15.50	15.50	15.50	12.94	3.70
PLN	1	3.00	3.97	6.00	3.25	3.00	0	3.00	3.00	3.00	2.89	3.00
RON	0	140.00	140.00	140.00	140.00	140.00	0	140.00	140.00	140.00	140.00	140.00
RUB	2	10.00	60.00	61.00	24.53	60.00	2	60.00	60.70	61.00	55.42	60.00
SEK	0	3.00	3.10	8.00	3.57	3.00	0	3.00	3.10	6.00	3.15	3.00
CHF	0	4.00	4.00	10.00	3.66	5.00	0	3.00	4.30	10.00	3.33	5.00
GBP	0	1.18	1.33	13.10	1.69	1.16	0	1.18	1.45	13.10	2.68	1.16
AUD	0	3.68	4.00	4.00	3.67	4.00	0	3.62	4.00	4.00	3.65	4.00
CAD	0	3.38	4.00	6.10	3.10	4.00	0	3.93	4.05	6.10	3.28	4.00
CLP	2	4.00	5.00	5.00	4.21	4.00	2	4.00	5.00	5.00	4.26	4.00
JPY	0	2.00	2.00	8.00	2.20	2.00	0	2.00	2.00	8.00	2.24	2.00
MYR	0	10.00	10.00	10.00	9.97	10.00	0	10.00	10.00	10.00	10.00	10.00
MXN	20	3.00	3.00	3.00	3.00	3.00	14	3.00	3.00	3.00	3.00	3.00
NZD	0	1.00	5.73	8.00	2.36	8.00	0	1.00	3.10	8.00	2.25	8.00
SGD	0	7.00	7.00	7.70	6.10	7.00	0	7.00	7.00	7.70	6.39	7.00
ZAR	0	8.00	8.00	11.00	7.24	8.00	0	8.00	8.00	11.00	8.00	8.00
KRW	0	3.25	3.50	3.50	3.24	3.50	0	3.50	3.50	3.50	3.31	3.50
THB	0	15.00	15.00	31.50	13.01	6.00	0	15.00	15.00	15.00	12.00	6.00
TRY	0	20.00	20.00	21.00	20.02	20.00	0	20.00	20.00	21.00	20.05	20.00
USD	0	0.40	0.55	0.80	0.41	0.50	-	0.48	0.57	0.80	0.44	0.50

Analysis of bid-ask spread for 25-year interest rates swaps IBOR

	Last 64 days with trading						Last 21 days with trading					
	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread
EUR	0	2.46	4.00	4.00	2.43	2.40	0	3.00	4.00	4.00	2.56	2.40
CZK	0	4.00	4.00	7.00	4.45	4.00	0	4.00	4.00	4.00	4.00	4.00
DKK	0	3.00	3.00	7.00	3.25	7.00	0	3.00	4.20	7.00	3.76	7.00
LIC	0	6.00	6.00	10.00	4.48	5.00	0	3.00	5.30	10.00	3.41	5.00
NOK	0	17.50	17.50	21.30	16.94	3.70	0	17.50	17.50	17.50	15.60	3.70
SEK	1	3.00	5.00	8.00	3.77	3.00	1	3.00	5.00	8.00	3.56	3.00
CHF	0	6.00	6.00	10.00	4.48	5.00	0	3.00	5.30	10.00	3.41	5.00
GBP	0	1.00	1.00	1.70	1.00	1.00	0	1.00	1.00	1.70	1.02	1.00
AUD	0	3.56	4.00	4.00	3.66	4.00	0	3.62	4.00	4.00	3.65	4.00
CAD	0	3.00	4.00	6.10	3.04	4.00	0	3.45	4.00	6.00	3.25	4.00
JPY	0	2.00	2.00	8.00	2.39	8.00	0	2.00	2.00	8.00	2.47	8.00
MYR	0	10.00	10.00	10.00	9.97	10.00	0	10.00	10.00	10.00	10.00	10.00
NZD	7	1.00	1.00	1.00	1.00	1.00	0	1.00	1.00	1.00	1.00	1.00
ZAR	0	8.00	10.00	10.00	7.95	8.00	0	8.00	10.00	10.00	8.40	8.00
KRW	0	3.50	3.50	3.50	3.26	3.50	0	3.50	3.50	3.50	3.33	3.50
USD	0	0.40	0.60	0.85	0.45	0.60	0	0.50	0.60	0.69	0.48	0.60

Analysis of bid-ask spread for 30-year interest rates swaps IBOR

	Last 64 days with trading						Last 21 days with trading					
	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread
EUR	0	3.00	3.00	3.00	2.28	1.00	0	3.00	3.00	3.00	2.39	1.00
CZK	0	4.00	4.00	7.00	3.95	4.00	0	4.00	4.00	4.00	3.81	4.00
DKK	0	3.00	3.00	7.00	2.94	7.00	0	3.00	4.80	7.00	3.43	7.00
LIC	0	6.00	6.00	10.00	4.91	6.00	0	6.00	6.00	10.00	4.66	6.00
NOK	0	17.50	17.50	17.50	16.55	3.70	0	17.50	17.50	17.50	15.77	3.70
PLN	0	4.00	4.00	6.00	4.08	4.00	0	4.00	4.00	4.00	4.00	4.00
SEK	0	5.37	6.00	10.00	5.05	3.00	0	3.00	6.00	10.00	4.57	3.00
CHF	0	6.00	6.00	10.00	4.91	6.00	0	6.00	6.00	10.00	4.66	6.00
GBP	0	0.95	1.00	2.00	0.98	1.80	0	1.00	1.83	2.00	1.17	1.80
AUD	0	3.75	4.00	5.00	3.64	4.00	0	3.75	4.00	4.00	3.68	4.00
CAD	0	4.00	4.00	6.10	3.92	4.00	0	4.00	4.00	6.10	4.00	4.00
JPY	0	2.00	2.00	8.00	2.40	8.00	0	2.00	2.00	8.00	2.52	8.00
SGD	0	5.00	6.00	8.00	5.24	6.00	0	5.00	6.00	8.00	5.33	6.00
ZAR	0	8.00	8.00	10.00	7.53	8.00	0	8.00	8.00	10.00	7.86	8.00
KRW	0	3.50	3.50	3.50	3.26	3.50	0	3.50	3.50	3.50	3.33	3.50
USD	1	0.44	0.70	1.45	0.47	0.72	0	0.48	0.71	0.92	0.49	0.72

Analysis of bid-ask spread for 50-year interest rates swaps IBOR

	Last 64 days with trading						Last 21 days with trading					
	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread	Zero observations	Median non-zero spreads	Percentile 80 non-zero spreads	Maximum spread	Average non-zero spreads	Last non-zero spread
EUR	0	3.00	3.00	3.00	2.39	2.00	0	3.00	3.00	3.00	2.49	2.00
LIC	0	10.00	10.00	10.00	10.00	10.00	0	10.00	10.00	10.00	10.00	10.00
CHF	0	10.00	10.00	10.00	10.00	10.00	0	10.00	10.00	10.00	10.00	10.00
GBP	0	1.00	1.00	2.00	1.07	1.80	0	1.00	1.52	2.00	1.21	1.80
USD	0	1.20	2.00	2.10	1.36	2.00	0	1.20	2.00	2.00	1.45	2.00

14.D.3. The analysis of bid-ask spreads: Roll measure

336. For this analysis, EIOPA has followed the approach used in the EBA report on HQLA. Roll (1984)[28] shows that under certain conditions, the percentage bid/ask spread equals two times the square root of minus the covariance between consecutive returns:

$$Roll_t = 2 \cdot \sqrt{-\operatorname{cov}(r_k, r_{k-1})},$$

where t is the time period over which the measure is calculated and $r_k = price_k - price_{k-1}$.

The higher value of Roll measure, the lower liquidity of the analysed interest rate.

337. EIOPA's analysis considers a daily Roll measure, using a 21 trading day rolling window in the computation of the covariance. In cases where a positive covariance is found, the Roll measure is set to zero.

338. The set of analytical tests described for the volatility analysis are also applied for the Roll measure, although in this case only the zero coupon rates are examined. This approach (examining only the zero coupon rates) does not have a material influence on the outcome of the assessment, because all the information is already captured in the chart analysis for both the volatility and the Roll measurement.

14.D.4. Quantitative analysis

339. As mentioned in Annex 3, EIOPA does not consider it appropriate to apply hard thresholds purely based on quantitative metrics, because it is necessary to make an appropriate allowance for the characteristics of each individual market and for prevailing financial conditions.

340. For the same reasons, metrics that can be calculated as at a specific date should be supplemented by examining the behaviour of these metrics during the rolling windows of the period of observation mentioned above (105 days).

341. Thus, additional relevant metrics are as follows:

    a. Number of days without any available data;

    b. Median of spot zero coupon rates during the 105 day period of observation. This provides a metric to measure the 'size effect',

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[28] Richard Roll (1984), A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market. The Journal of Finance, 39: 1127–1139.

which is currently material both across currencies and across maturities within the same currency.

c. Trend of interest rates during the period (obtained as the first degree coefficient of a linear fitting with LSM). This metric is necessary for an appropriate assessment of other metrics, to the extent that the existence of a clear and strong trend in interest rates, influences other metrics (e.g. the Roll measure).

d. For the series of zero coupon rates, the interquartile range (Q_{75} – Q_{25}) relative to the median.

e. For the series of zero coupon rates, the number of outliers, calculated as the number of interest rates falling outside of the interval (mean - 1.5 standard deviations; mean + 1.5 standard deviations). Note that these statistics are calculated using only the interest rates between the 12.5^{th} and 87.5^{th} percentiles (thus avoiding any influence on the mean or standard deviation of 'large' outliers).

f. Last 21-day volatility observed in the 105 day period.

g. For the series of first order differences of zero coupon rates, the interquartile range (Q_{75} – Q_{25}) relative to the median.

h. For the series of first order differences of zero coupon rates, the number of outliers as described above.

i. Last observed Roll measure.

j. 90^{th} Percentile for the series of Roll measurements.

k. 90^{th} Percentile of logarithmic returns.

342. The table below provides an illustrative example of the outputs of these metrics, for those non-EEA currencies where it has been possible to obtain interest rates for 40-year maturities.

343. As mentioned above, this quantitative analysis is supplemented with the other analysis mentioned in this annex.

	Zero observations	*Median zero spot rate*	*Linear growth*	*Interquartile range / Median for rates*	*Num. Rates Outliers*	*Last 21-days volat*	*Interquartile range / Median for diffs*	*Num. Diffs Outliers*	*Last Roll measure*	*Perctile 90 Roll*	*Perctile 90 log returns*
EUR	0	2.20	- 0.47	12.61	10.00	2.00	- 5.95	18.00	34.41	47.00	1.72
CHF	0	1.77	- 0.25	10.13	14.00	1.65	- 7.93	16.00	28.70	5.17	1.25
GBP	0	3.21	- 0.46	9.10	1.00	1.21	- 24.80	11.00	-	62.20	1.42
AUD	0	4.52	- 0.18	5.87	12.00	1.90	- 21.41	15.00	62.50	68.79	3.38
JPY	0	2.02	- 0.10	3.40	6.00	1.16	- 14.12	13.00	18.97	36.74	0.80
USD	0	3.49	- 0.28	5.25	16.00	1.43	19.69	15.00	33.26	41.08	2.29

14.E. Annex to Section 4: History of relevant financial instruments

344. The following tables specify the relevant financial instruments that were used to derive the risk-free interest rates in the past since 1 January 2016. For currencies that do not appear in those tables the relevant financial instruments are unchanged since 1 January 2016. The currently used financial instruments are set out in tables 2, 5 and 6 of the main text.

EEA currencies

	Financial instruments used SWP=swaps, GVT=government bonds. All maturities in years	**Period**
HRK	GVT 1-4, 10	1 January – 30 December 2016
ISK	GVT 2, 4, 5, 8, 10	1 January – 30 December 2016

Non-EEA currencies

	Financial instruments used SWP=swaps, GVT=government bonds. All maturities in years	**Period**
CAD	SWP 1-10, 12, 15, 20, 25	1 January – 30 December 2016
CLP	SWP 1-10	1 January – 30 December 2016
CNY	SWP 1-10	1 January – 30 December 2016
COP	SWP 1-5, 7, 8, 10	1 January – 30 December 2016
JPY	SWP 1-20, 25, 30	1 January – 30 December 2016
MYR	SWP 1-10, 12, 15, 20	1 January – 30 December 2016
MXN	GVT 1-10, 15, 20	1 January – 30 December 2016
	SWP 1-5, 7, 10, 16, 21	31 December 2016
RUB	SWP 1-10	1 January – 30 December 2016
SGD	SWP 1-10, 12, 15, 20	1 January – 30 December 2016

THB	SWP 1 to 10, 12, 15	1 January – 30 May 2016
USD	SWP 1-15, 20, 25, 35, 30, 40, 45, 50	1 January – 30 December 2016

14.F. Annex to Subsection 7.A: Numerical illustration of the extrapolation of term structures

345. With the data in the canonical normalized format as given on the next page and where the ultimate forward intensity ω=log(1.042) and convergence period S=40, the following results are obtained for the key parameters of the Smith-Wilson method:

				u	Qb
UFR	4,2%	ultimate forward rate			
ω	0,0411	ultimate forward intensity		1	-2,045
				2	-0,528
κ	0,7379			3	3,375
				4	-4,119
U	20	last liquid point		5	3,831
S	40	convergence period		6	-1,583
T	60	convergence point		7	-1,036
				8	5,910
$\|f(T) - \omega\|$	0,0001	gap at convergence		9	-11,183
τ	0,0001	convergence tolerance		10	19,266
				11	-28,567
target	0,123760	minimize with respect to α		12	27,689
α	0,123760			13	-12,632
a	0,05	lowerbound α		14	-2,724
				15	2,212
				16	10,182
				17	-17,203
				18	10,943
				19	-4,674
				20	2,314

346. With α, ω, **u** and **Qb** the Smith-Wilson present value function can be evaluated for any maturity v:

$$p(v) = e^{-\omega v}\left(1 + H(v,\mathbf{u})\mathbf{Qb}\right)$$

347. The yield intensity follows as:

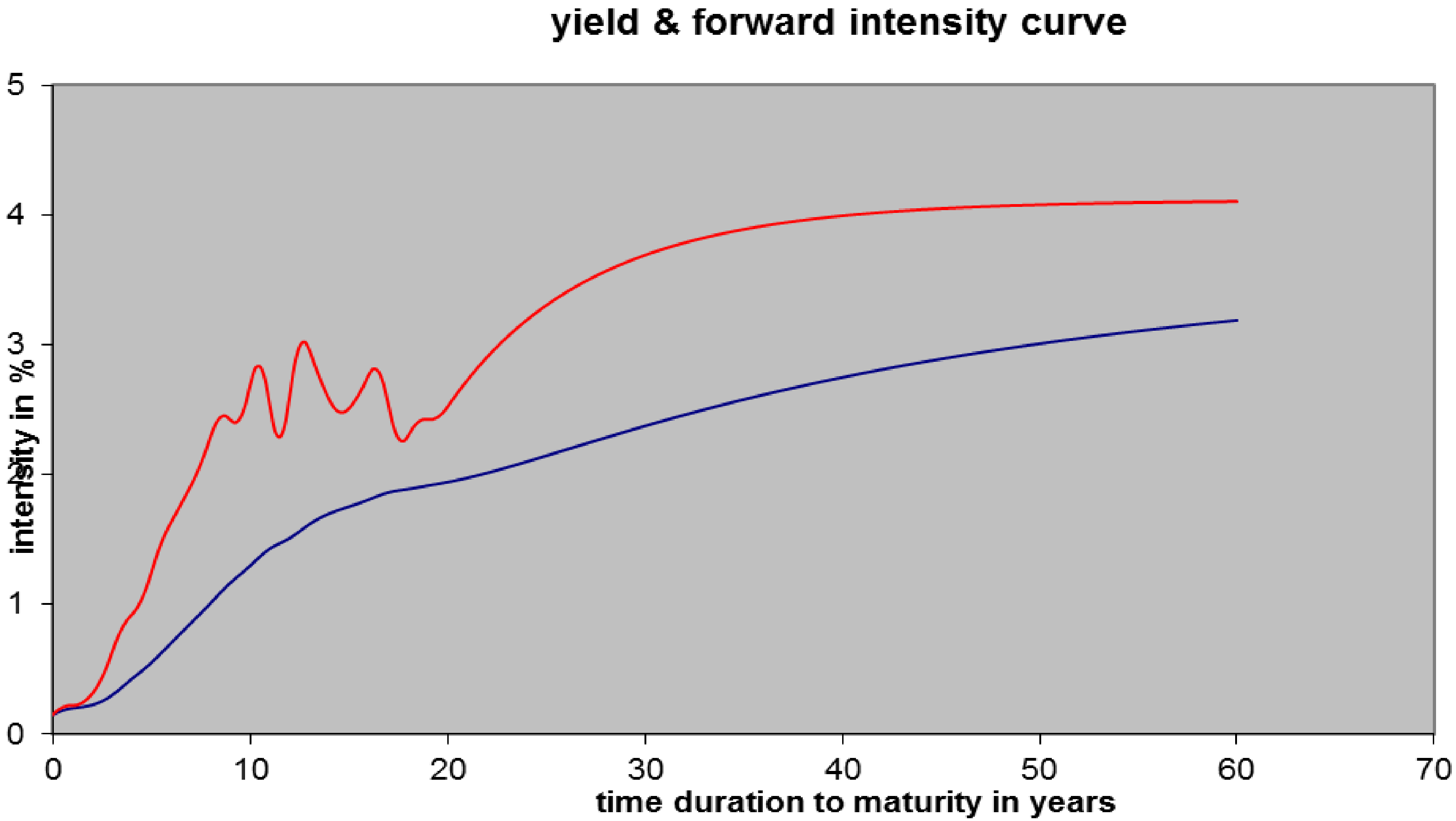
$$y(v) = \frac{-\log p(v)}{v}$$

and the annualized yield rate can be calculated as a fractional power of the present value function or as the exponential of the yield intensity:

$$\left(p(v)\right)^{-1/v} - 1 = \exp\left(y(v)\right) - 1$$

348. Besides the data tableau in canonical normalized format on the next pages, also a graph of the yield and forward intensity curve is displayed and a tabulation of yield intensity together with annualized yield rate for maturities from 0 up to 120 years.

transpose of market observed p																					
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
cash-flow matrix C																					**u**
1,002	0,00225	0,003	0,00425	0,0055	0,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		1
0	1,00225	0,003	0,00425	0,0055	0,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		2
0	0	1,003	0,00425	0,0055	0,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		3
0	0	0	1,00425	0,0055	0,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		4
0	0	0	0	1,0055	0,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		5
0	0	0	0	0	1,007	0,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		6
0	0	0	0	0	0	1,0085	0,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		7
0	0	0	0	0	0	0	1,01	0,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		8
0	0	0	0	0	0	0	0	1,0115	0,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		9
0	0	0	0	0	0	0	0	0	1,01275	0,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		10
0	0	0	0	0	0	0	0	0	0	1,014	0,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		11
0	0	0	0	0	0	0	0	0	0	0	1,01475	0,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		12
0	0	0	0	0	0	0	0	0	0	0	0	1,01575	0,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		13
0	0	0	0	0	0	0	0	0	0	0	0	0	1,0165	0,017	0,0175	0,018	0,01825	0,0185	0,01875		14
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,017	0,0175	0,018	0,01825	0,0185	0,01875		15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,0175	0,018	0,01825	0,0185	0,01875		16
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,018	0,01825	0,0185	0,01875		17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,01825	0,0185	0,01875		18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,0185	0,01875		19
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,01875		20



yield & forward intensity curve
5
4
3
2
1
0
intensity in %
0
10
20
30
40
50
60
70
time duration to maturity in years

Table of spot yield intensities (continuous curve)
and annualized spot yield rates.

maturity in years	yield **intensity** in %	yield **rate** in %	maturity in years	yield **intensity** in %	yield **rate** in %	maturity in years	yield **intensity** in %	yield **rate** in %
0	0,15043	0,15054						
1	0,19980	0,20000	41	2,77975	2,81875	81	3,42830	3,48774
2	0,22478	0,22503	42	2,80915	2,84898	82	3,43665	3,49639
3	0,29980	0,30025	43	2,83746	2,87810	83	3,44481	3,50483
4	0,42516	0,42607	44	2,86472	2,90614	84	3,45277	3,51307
5	0,55098	0,55250	45	2,89096	2,93315	85	3,46055	3,52112
6	0,70286	0,70533	46	2,91624	2,95918	86	3,46814	3,52898
7	0,85583	0,85951	47	2,94059	2,98425	87	3,47556	3,53667
8	1,01017	1,01529	48	2,96406	3,00842	88	3,48282	3,54418
9	1,16615	1,17298	49	2,98668	3,03173	89	3,48991	3,55152
10	1,29724	1,30569	50	3,00850	3,05421	90	3,49684	3,55870
11	1,43000	1,44027	51	3,02954	3,07590	91	3,50362	3,56572
12	1,50925	1,52070	52	3,04985	3,09683	92	3,51026	3,57260
13	1,61761	1,63077	53	3,06945	3,11704	93	3,51675	3,57932
14	1,69901	1,71353	54	3,08838	3,13657	94	3,52310	3,58590
15	1,75260	1,76805	55	3,10667	3,15543	95	3,52933	3,59235
16	1,80701	1,82343	56	3,12435	3,17367	96	3,53542	3,59866
17	1,86227	1,87972	57	3,14145	3,19131	97	3,54138	3,60484
18	1,88810	1,90604	58	3,15798	3,20838	98	3,54723	3,61089
19	1,91447	1,93291	59	3,17399	3,22490	99	3,55295	3,61682
20	1,94136	1,96032	60	3,18948	3,24089	100	3,55856	3,62264
21	1,97401	1,99362	61	3,20449	3,25638	101	3,56406	3,62834
22	2,01239	2,03278	62	3,21902	3,27139	102	3,56946	3,63393
23	2,05459	2,07584	63	3,23312	3,28595	103	3,57475	3,63941
24	2,09920	2,12139	64	3,24678	3,30006	104	3,57993	3,64478
25	2,14517	2,16834	65	3,26004	3,31376	105	3,58502	3,65006
26	2,19172	2,21591	66	3,27290	3,32705	106	3,59001	3,65523
27	2,23826	2,26350	67	3,28539	3,33996	107	3,59491	3,66031
28	2,28439	2,31068	68	3,29752	3,35249	108	3,59972	3,66529
29	2,32977	2,35712	69	3,30931	3,36468	109	3,60444	3,67019
30	2,37419	2,40260	70	3,32076	3,37652	110	3,60907	3,67499
31	2,41750	2,44696	71	3,33190	3,38803	111	3,61362	3,67971
32	2,45959	2,49009	72	3,34273	3,39923	112	3,61809	3,68434
33	2,50039	2,53192	73	3,35327	3,41013	113	3,62248	3,68889
34	2,53988	2,57240	74	3,36353	3,42073	114	3,62679	3,69337
35	2,57802	2,61154	75	3,37351	3,43106	115	3,63103	3,69776
36	2,61483	2,64932	76	3,38324	3,44112	116	3,63520	3,70208
37	2,65033	2,68576	77	3,39272	3,45093	117	3,63929	3,70633
38	2,68453	2,72089	78	3,40195	3,46048	118	3,64332	3,71050
39	2,71748	2,75474	79	3,41095	3,46979	119	3,64727	3,71460
40	2,74921	2,78735	80	3,41973	3,47888	120	3,65116	3,71864

14.G. Annex to subsection 7.C: Methodology for the derivation of the UFR

1. Introduction

349. This annex sets out the methodology to derive the (UFR) and its implementation as decided by EIOPA at the end of March 2017. The methodology is in accordance with Article 47 of the Delegated Regulation on Solvency II[29] which requires in particular that such a methodology shall be clearly specified in order to ensure the performance of scenario calculations by insurance and reinsurance undertakings.

2. Methodology to derive the UFR

Update of the UFRs

350. EIOPA will annually calculate the UFRs and, where they are sufficiently different according to the methodology from the then applicable UFRs, update them at the beginning of the next year. The updated UFRs will be announced every year by the end of March on EIOPA's website. Nine months after the announcement of the updated UFRs, EIOPA will use them to calculate the risk-free interest rate term structures for the term structures of 1 January of the following year.

Calculation of the UFRs

351. For each currency the change of the UFR is limited in such a way that it increases or decreases by 15 bps or remains unchanged in accordance with the following rule:

$$UFR_t^L = \begin{cases} UFR_{t-1}^L + 15\ bps & if\ \ UFR_t \geq UFR_{t-1}^L + 15\ bps \\ UFR_{t-1}^L - 15\ bps & if\ \ UFR_t \leq UFR_{t-1}^L - 15\ bps \\ \quad UFR_{t-1}^L & \quad\quad otherwise \end{cases}$$

where:

- UFR_t^L denotes the UFR of year t, after limitation of the annual change,

[29] Commission Delegated Regulation (EU) No 2015/35 of 10 October 2014 supplementing Directive 2009/138/EC of the European Parliament and of the Council on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II) (OJ L 12, 17.01.2015, p. 1)

- UFR^L_{t-1} denotes the UFR of year t+1 , after limitation of the annual change,
- UFR_t denotes the UFR of year t, before limitation of the annual change.

352. For each currency the UFR before limitation of the annual change is the sum of an expected real rate and an expected inflation rate. The expected real rate is the same for each currency. The expected inflation rate is currency-specific.

Calculation of the expected real rate

353. The expected real rate is the simple arithmetic mean of annual real rates from 1961 to the year before the recalculation of the UFRs according to the following formula:

$$R = \frac{1}{n}\sum_{i=1}^{n} r_{1960+i}$$

where:

- R is the expected real rate,
- n is the number of years since end of 1960,
- r_i is the annual real rate for the year 1960+i,

354. For each of the years since 1961 the annual real rate is derived as the simple arithmetic mean of the annual real rates of Belgium, Germany, France, Italy, the Netherlands, the United Kingdom and the United States.

355. For each of those years and each country the annual real rate is calculated as follows:

real rate = (*short-term nominal rate* – *inflation rate*)/(1 + *inflation rate*).

356. The short-term nominal rates are taken from the annual macro-economic database of the European Commission (AMECO database).[30] The inflation rates are taken from the Main Economic Indicators database of the OECD.[31]

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[30] Short-term nominal rates used for deriving the expected real rate can be found in the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs, "AMECO". On AMECO online, select 13-Monetary variables, select Interest Rates and then tick the box Short-term nominal (ISN). (http://ec.europa.eu/economy_finance/ameco/user/serie/ResultSerie.cfm)

[31] Inflation rates used for deriving the expected real rate can be found on the website of the Organisation for Economic Co-operation and Development (OECD): go to the OECD Main Economic Indicators (MEI) and select consumer price indices. When accessing the database, choose consumer prices – all items for the subject, percentage change on the same period of the previous year for the measure and percentage for the unit.

357. The expected real rate is rounded to full five basis points as follows:

- When the unrounded rate is lower than the rounded rate of the previous year, the rate is rounded upwards.
- When the unrounded rate is higher than the rounded rate of the previous year, the rate is rounded downwards.

Calculation of the expected inflation rate

358. For currencies where the central bank has announced an inflation target, the expected inflation is based on that inflation target according to the following rules:

- The expected inflation rate is:
  - 1%, where the inflation target is lower than or equal to 1%,
  - 2%, where the inflation target is higher than 1% and lower than 3%,
  - 3%, where the inflation target is higher or equal to 3% and lower than 4%,
  - 4%, where the inflation target is 4% or higher.

- Where a central bank is not targeting a specific inflation figure but tries to keep the inflation in a specified corridor, the midpoint of that corridor is relevant for the allocation to the four inflation rate buckets.

359. For currencies where the central bank has not announced an inflation target, the expected inflation rate is 2% by default. However, where past inflation experience and projection of inflations both clearly indicate that the inflation of a currency is expected in the long-term to be at least 1 percentage point higher or lower than 2%, the expected inflation rate will be chosen in accordance with those indications. The expected inflation rate will be rounded downwards to full percentage points.

360. The past inflation experience will be assessed against the average of 10 years annual inflation rates. The projection of inflation rates will be derived on the basis of an autoregressive–moving-average model.

(http://stats.oecd.org/Index.aspx?DataSetCode=MEI_PRICES). OECD data used in this document were accessed in March 2016.

3. Implementation of the methodology

361. The methodology to derive the UFR should be implemented in 2018. The first UFRs calculated according to the methodology should be announced at the beginning of April 2017. Those UFRs should be applied for the first time to calculate the risk-free interest rate term structures for 1 January 2018.

362. The initial application of the methodology in 2018 should be based on the following additional specification:

- The UFR of 2017, denoted UFR_{t-1}^{L} in paragraph 351, is:
    - 3.2% for the Swiss franc and the Japanese yen,
    - 5.2% for the Brazilian real, the Indian rupee, the Mexican peso, the Turkish lira and the South African rand,
    - 4.2% for all other relevant currencies.
- The rounded expected real rate of the previous year referred to in paragraph 353 is equal to 2.2%.

14.H. Annex to subsection 9.D: Methodology to update the representative portfolios

1. Introduction

363. The calculation of the volatility adjustment is based on representative portfolios of assets for each currency and country. The initially used representative portfolios were based on asset data for the reference date end of 2013 collected for the 2014 insurance stress test of EIOPA.

364. It is important for the accuracy and well-functioning of the volatility adjustment that the representative portfolios are based on up-to-date data. EIOPA has therefore updated the representative portfolio in 2016. The update representative portfolios have been applied since 30 September 2016.

365. This annex describes the methodology to derive the updated representative portfolios.

2. Database

366. The updated representative portfolios were derived from the supervisory reporting data collected during the preparatory phase of Solvency II. The date of reference of those data is 31 December 2014.

367. Article 77d of the Solvency II Directive distinguishes two different types of representative portfolios:

   - **The currency representative portfolio**: a portfolio "representative for the assets which are denominated in that currency and which insurance and reinsurance undertakings are invested in to cover the best estimate for insurance and reinsurance obligations denominated in that currency".

   - **The country representative portfolio**: a portfolio "representative for the assets which insurance and reinsurance undertakings are invested in to cover the best estimate for insurance and reinsurance obligations sold in the insurance market of that country and denominated in the currency of that country".

368. The reporting data of solo undertakings collected during the preparatory phase of Solvency II allowed for the update of all EEA country and EEA currency portfolios except for the following:

- The LU country representative portfolio because LU did not participate in the reporting during the preparatory phase.
- The DK country and DKK currency portfolios because DK did not participate in the reporting during the preparatory phase.
- The CHF currency portfolios because data of Swiss solo undertakings were not available.

For these currencies and countries and for the non-EEA currencies and countries the initial representative portfolios are still in use.

369. To allow for the calculation of the representative portfolios, assets from all relevant solo undertakings are aggregated line by line to create a database for each country and each currency representative portfolio. This database is enriched by several calculations and indicators to allocate the assets in the relevant portfolio and perform the calculations.

3. Composition of the representative portfolios

370. Each representative portfolio provides the following information:

- Weights (in percentages) of the
  - central government and central banks bonds – called "government portfolio"; and
  - bonds other than above, loans and securitisations – called "corporate portfolio".
- For the government portfolio, weight of and duration of the following relevant issuers:
  - AT, BE, BG, HR, CY, CZ, DK, EE, FI, FR, DE, GR, HU, IE, IT, LV, LT, LU, MT, NL, NO, PL, PT, SK, SI, ES, SE, UK, US, IS, LI, AU, CA, CH, JP.
- For the corporate portfolio, weight of and duration for each of the following issuers:
  - Financial entities, categorised in seven credit quality steps.
  - Non-financial entities, categorised in seven credit quality steps.

<u>Regional government and local authorities (RGLA):</u>

371. In the initial representative portfolio, exposures to RGLA were allocated to the corporate portfolio in their quality of "non-central government bonds" and their spreads were modelled on the basis of the corresponding government bond indices.

372. Because of the adoption of the Commission Implementing Regulation (EU) 2015/2011 on the list of regional governments and local authorities

exposures to whom are to be treated as exposures to central government[32], this allocation was changed as follows:

- the RGLA listed in the Regulation are allocated to the government portfolio;
- the remaining RGLA are allocated to the corporate portfolio and classified as non-financial assets taking into account their credit quality step.

4. Assumptions

373. Given the information available in the preparatory phase reporting, assumptions were needed to calculate the representative portfolios. Those assumptions, as explained below, are unchanged compared to the initial representative portfolios.

Currency representative portfolios

374. As in Solvency II reporting undertakings are not required to identify the assets covering their best estimate, an assumption is needed to calculate the currency representative portfolios: all assets in currency X cover liabilities in the same currency X. Therefore, the database used for the calculation of a given currency representative portfolio was composed of all the assets denominated in that same currency held by all solo undertakings which participated in the preparatory phase reporting.

Country representative portfolios

375. A calculation taking into account in which countries insurance obligations were sold would have been most precise. However, in absence of reliable information about the country of sale, the assumption was made that all liabilities are sold in the country of the undertaking and denominated in the currency of that country. Therefore, the database used for the calculation of a given country representative portfolio was composed of all the assets held by all solo undertakings of that same country which participated in the preparatory phase reporting.

5. Calculation of the weights for the government and corporate portfolios

Assets value used in the calculation

376. The weights were calculated with the value of assets as reported in the reporting field "Total SII amount", expressed in the currency of the

[32] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2011&from=EN.

reporting (specific to each undertaking). The asset value was converted to euro so that all assets can be compared. ECB exchange rates were used for that purpose.

377. The converted assets value could not be used directly as the representative portfolios needs to be representative of the assets covering the best estimate of the insurance and reinsurance obligations where the matching adjustment does not apply.

Reduction of the assets value in proportion to the best estimate

378. The value of the assets was reduced by ratios calculated with the information reported in the "balance-sheet" reporting template.

379. Two reduction factors per undertaking were calculated: one reduction factor for assets held in unit-linked/index-linked funds and another one for assets not held in unit-linked/index-linked funds. [33]

380. The first ratio was applied to assets held in unit-linked/index-linked funds only. All relevant assets have been identified line by line, and their Solvency II value has been multiplied by the ratio: (best estimate for unit-linked/index-linked products)/(overall technical provisions for unit-linked/index-linked products).

381. The second ratio was applied to all other assets. All relevant assets have been identified line by line, and their Solvency II value has been multiplied by the ratio: (best estimate for all products excluding unit-linked/index-linked products)/(overall technical provisions for all products excluding unit-linked/index-linked products).

Reduction of the assets value to take the matching adjustment into account

382. As the legislation does not allow cumulating the matching adjustment (MA) with the volatility adjustment, assets held in a matching adjustment portfolio should be excluded from the calculation.

383. However, the preparatory phase templates do not provide an indication of whether an asset is held or not in a MA portfolio. Therefore, an approximation was used. Only the countries where significant MA business has been authorised by the national supervisory authorities are affected by this approximation: Spain and the United Kingdom. For those two countries, the authorities provided figures on the share of assets in MA portfolios and their allocation to government and corporate bonds.

[33] Some unit-linked/index-linked insurance obligations are not or only partly valued as a whole, as referred to in the second subparagraph of Article 77(4) of the Solvency II Directive, but a risk margin and a best estimate is calculated for them.

384. The value of each asset not held in unit-linked/index-linked fund is reduced with a different ratio, depending on its allocation to the government or corporate portfolio.

Allocation of the assets to the government and corporate portfolios

385. CIC codes (as reported in the field "CIC") were used to allocate the assets to the government or corporate portfolio as set out in the following table:

	CIC codes
Government portfolio	11, 13*, 14*, 15, 16, 17, 19
Corporate portfolio	12, 13*, 14*, 21, 22, 23, 24, 25, 26, 27, 28, 29, 42, 43, 52, 54, 62, 64, 81, 85, 86, 89
Other	All other CIC codes

(*) The CIC codes 13 and 14 were used to identify bonds issued by RGLA. For those assets, the allocation to the government or corporate portfolio depends on the issuer (identified with the field "Issuer Country"). Where no issuer was reported, those assets were allocated to the corporate portfolio.

Calculation of the weights for the government and corporate portfolios

386. The calculation of the weights w_{gov} and w_{corp} for government and corporate bonds was done in accordance with the following formulas:

$$w_{gov} = \frac{MV_{gov}}{MV_{gov} + MV_{corp} + MV_{other}}$$

$$w_{corp} = \frac{MV_{corp}}{MV_{gov} + MV_{corp} + MV_{other}}$$

where

MV_{gov} denotes the market value of assets with CIC codes that are allocated to the government bond portfolio,

MV_{corp} denotes the market value of assets with CIC codes that are allocated to the corporate bond portfolio,

MV_{other} denotes the market value of all assets with CIC codes that are not allocated to the government or corporate bond portfolio.

387. The market values were reduced in proportion to the best estimate and to take into account the matching adjustment, as described earlier in this section.

6. Calculation of the government portfolio

Identification of issuers

388. The country of the issuer is reported in the list of assets template with the field "Issuer Country". Only assets of the following issuers were taken into account: AT, BE, BG, HR, CY, CZ, DK, EE, FI, FR, DE, GR, HU, IE, IT, LV, LT, LU, MT, NL, NO, PL, PT, SK, SI, ES, SE, UK, US, IS, LI, AU, CA, CH, JP.

Duration

389. The assets where no duration, zero duration or a duration greater than 50 years had been reported were excluded for the determination of the average durations. The average durations were calculated by means of a weighted average, using the reduced asset values as weights.

7. Calculation of the corporate portfolio

Identification of issuers

390. Two allocations needed to be made to calculate the corporate portfolio: the allocation according to the sector of issuer (financial or non-financial) and according to credit quality steps.

Determination of the sector

391. The sector was determined on the basis of the field "Issuer Sector". This field corresponds to the NACE code:

http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC&CFID=12721637&CFTOKEN=9fa1f017d5f2811e-C999B956-E7EA-A517-3AB8BA746C9C60F5&jsessionid=f90060eefcba131dc3c6

392. Section K is used to identify "Financial and Insurance activities". The code can be

- 64: financial service activities, except insurance and pension funding
- 65: insurance, reinsurance and pension funding, except compulsory social security

- 66: activities auxiliary to financial services and insurance activities

393. All those assets where the issuer sector field starts with a “K” were allocated to the financial part of the corporate portfolio. All other assets were allocated to the non-financial part of the corporate portfolio, except for those were no information on the sector was reported: those were excluded from the calculations.

Determination of the credit quality step

394. The preparatory phase template gives information on the rating agency and on the external rating (fields “Rating agency” and “External rating”). Using the field “External rating” and the draft implementing technical standards on ECAI mappings for Solvency II[34], assets were allocated a credit quality step.

395. Assets where no external rating had been reported were excluded from the allocation to credit quality steps.

Duration

396. The assets where no duration, zero duration or a duration greater than 50 years had been reported were excluded for the determination of the average durations. The average durations were calculated by means of a weighted average, using the reduced asset values as weights.

[34] See https://eiopa.europa.eu/Publications/Technical%20Standards/JC%202015%20068%20-%20Final%20Draft%20ITS%20on%20ECAIs%20mapping%20under%20Solvency%20II.PDF.

14.I. Annex to subsection 10.B.1: History of government bond rates for the calculation of the LTAS

397. The following table specifies the government bond maturities that were used to derive spreads for the government bond LTAS in the past since 1 January 2016. For currencies that do not appear in those tables the maturities are unchanged since 1 January 2016. The currently used maturities are set out in table 14 of the main text.

	Government bond maturities used All maturities in years	**Period**
HRK	1-4, 10	1 January – 30 December 2016

14.J. Annex to subsections 10.B.1 und 10.C.3: Adjustment factors for the pound sterling LTAS

398. The adjustment factors applied to $LTAS_{31\_12\_2015}$ of UK government bonds are as follows:

Maturity	Adjustment factor
1	103%
2	95%
3	94%
4	94%
5	95%
6	103%
7	99%
8	104%
9	105%
10 to 30	105%

399. The adjustment factors applied to $LTAS_{31\_12\_2015}$ of pound sterling corporate bonds are as follows:

Maturity	CQS 0, CQS 1	CQS 2	CQS 3
1 to 4 years	82%	88%	97%

5 to 8 years	80%	84%	93%
9 to 30 years	95%	93%	93%

The adjustment factors apply to financial and non-financial bonds. There are no adjustments to corporate bonds of CQS 4 to 6.

14.K. Annex to subsection 10.C.2: Calculation of the cost of downgrade (CoD) and probability of default (PD)

Legal Context

400. The two components Cost of Downgrade (CoD) and Probability of Default (PD) are required by Article 77c(2)(a) (Calculation of the matching adjustment) of the Solvency II Directive, supplemented by Article 51 (Risk-corrected spread, for volatility adjustment) and 54(4) (Calculation of the fundamental spread) of the Delegated Regulation. Furthermore, recital 31 of the Omnibus II Directive and the recitals 22 and 23 of the Delegated Regulation apply.

401. The Cost of Downgrade (CoD) is defined as the present value of costs resulting from future downgrade, expressed as spreads in base points over the risk-free interest rates. According to Article 54(4)(a) the cash flow pattern does not change, according to point (b) the replacing asset belongs to the same asset class as the replaced asset, and according to point (c) the replacing asset has the same credit quality step or a better one as the replaced asset.

402. As described below, the same approach applies to the Probability of Default (PD) with the appropriate modifications.

The three components of a present value

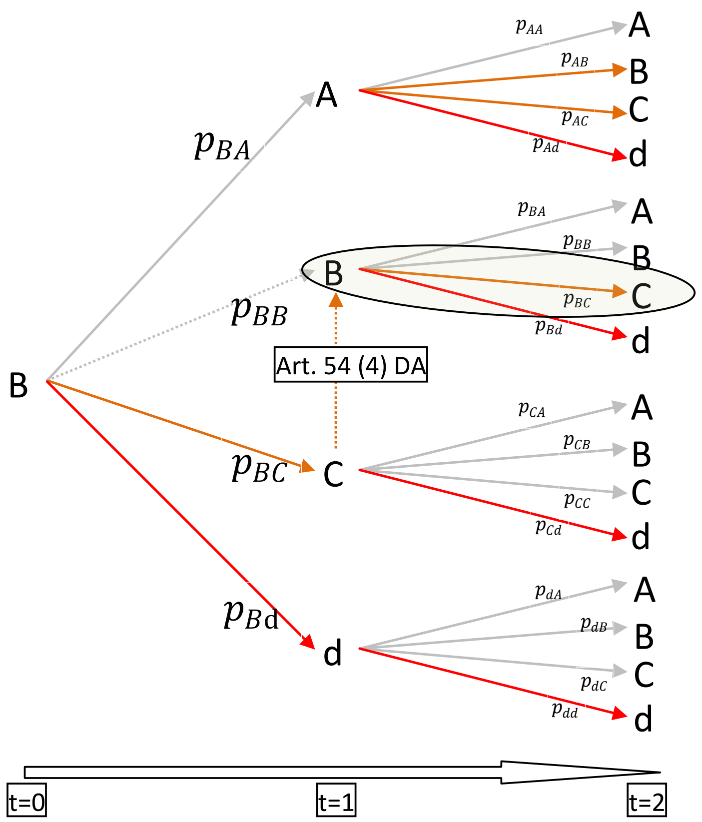
$$PV = \sum_{t=1}^{T} \frac{\mathrm{CashFlow}_t \cdot \mathrm{Probability(Cashflow)}}{(1 + \mathrm{InterestRate}_t)^t}$$

Probability

403. Looking from $t = 0$ ("today"), the probability for a downgrade event from X to Y to occur between time $t = t_0$ and $t = t_1$ is given as the probability for

the bond to be in CQS X at time $t = t_0$ and then to end in CQS Y at time $t = t_1$.

Example: Downgrade from B to C between $t=1$ and $t=2$ for a B Bond at inception $t=0$



404. The probability for being in CQS B at time $t=1$ is determined by all the paths leading to B in $t=1$. For the above example, where we only consider the initial CQS B, the path without replacement would be $B \to B \to C$. However, due to the requirement of Article 54(4) of the Delegated Regulation to *replace* bonds that have been downgraded by a bond of the CQS it was in before the downgrade event, we could have also come to B at time $t=1$ via the path $B \to C \left(\xrightarrow{Art.54\ (4)} B \right) \to B$. So, the total probability to have a downgrade event between $t=1$ and $t=2$ is given by $(P_{BB} + P_{BC}) \cdot P_{BC}$.

405. Hence, the replacement requirement of Article 54(4) of the Delegated Regulation leads to the following 'change' in that transition matrix which determines the starting credit quality step for the year in which the cost of the downgrading event is accounted:

$$
T = \begin{pmatrix} P_{AA} & P_{AB} & P_{AC} & P_{Ad} \\ P_{BA} & P_{BB} & P_{BC} & P_{Bd} \\ P_{CA} & P_{CB} & P_{CC} & P_{Cd} \\ P_{dA} & P_{dB} & P_{dC} & P_{dd} \end{pmatrix}
$$

$$
\xrightarrow{\text{Art. 54 (4) Delegated Regulation}} \begin{pmatrix} P_{AA} + P_{AB} + P_{AC} & \xleftarrow{\text{Art. 54 (4) DR}} & \xleftarrow{\text{Art. 54 (4) DR}} & P_{Ad} \\ P_{BA} & P_{BB} + P_{BC} & \xleftarrow{\text{Art. 54 (4) DR}} & P_{Bd} \\ P_{CA} & P_{CB} & P_{CC} & P_{Cd} \\ P_{dA} & P_{dB} & P_{dC} & P_{dd} \end{pmatrix} = Q
$$

406. The original transition matrix T is retained for those probabilities regarding the transitions in the year the cost accounting is done.

407. This means, the probability for a downgrade from B at $t = 1$ to C at $t = 2$ is given by the probability of being in credit quality step B at $t = 1$ (regarding possible upgrading events due to Art. 54 (4) of the Delegated Regulation between $t = 0$ and $t = 1$), multiplied by the probability P_{BC} of transitioning from credit quality step B at $t = 1$ to C at $t = 2$. In matrix notation, this can be expressed by the matrix multiplication of Q for the possible paths from $t = 0$ to $t = 1$ with T for the possible paths from $t = 1$ to $t = 2$.

408. More general, for a downgrade event to be accounted for in year m (i.e. between $t = m$ and $t = m + 1$, we consider the matrix Q the first m times and then once the matrix T. Thus, the probabilities to be used for a downgrade event in year m (i.e. between $t = m$ and $t = m + 1$) are all contained in the matrix $Q^m T$.

Zero bond cash flow $(-\mathbf{1}), \mathbf{0}, \dots, \mathbf{0}, (\mathbf{1} + \boldsymbol{r_t})^{\boldsymbol{t}}$

409. By Article 54(4) of the Delegated Regulation, the cash flow in case of downgrade is defined as the difference in market values of the original (higher) credit quality and the new (lower) credit quality. There is no specific requirement for the case of upgrade, the case of staying in the same credit quality or for the case of defaulting. The defaulting case is considered in the separate component for PD (probability of default).

410. The corresponding market values change over time. The cash flows are derived from zero bonds with investment (-1) at inception $t = 0$ and final payment $(1 + r_t)^t$ at maturity. The compound interest rate r_t is based on the financial instrument considered to be risk-free once adjusted. For Solvency II purposes, this is considered to be the basic risk-free interest rate structure.

Discount factor

411. The discount factor $1/(1 + \text{InterestRate}_t)^t$ considers the risk-free spot rate.

412. The above considerations give rise to the following nutshell description.

Cost of Downgrade and Probability of Default in a nutshell

Input Data

Transition Matrix $T = (p_{X,Y})_{X,Y\in CQS}$ for the n-element set CQS of credit quality steps including default state denoted by "d" (note that $p_{dX} = 0$ and $p_{dd} = 1$ because d is considered an absorbing state) and relevant portions R_c for credit quality steps $c \in CQS$. Any explicit reference to economic sectors or other granularity buckets is dropped, because Article 54(4) of the Delegated Regulation does not require costs of transitions between economic sectors or other granularity buckets to be considered. However, the following calculation needs to be done within each of those buckets not explicitly mentioned here.

Cost of Downgrade, step 1

Based on the basic risk-free interest rate term structure$(r_M)_{M=1\dots30}$, the market value of a zero bond of maturity M at time m is given by

$$MV_M(m) = \frac{(1 + r_M)^M}{\left(1 + f_{m,M}\right)^{M-m}},$$

where the forward rates $f_{m,M}$ are derived on an arbitrage-free basis:

$(1 + r_m)^m(1 + f_{m,M})^{M-m} = (1 + r_M)^M$.This provides the following closed formula for the market value of the risk-free reference instrument:

$$MV_M(m) = (1 + r_m)^m \ .$$

The market value of the risky instruments in CQS c is defined based on a fixed portion R_c as a portion of the risk-free instrument and given by

$$MV_{c,M}(m) = R_c^{\frac{M-m}{15}} \cdot (1 + r_m)^m.$$

The portion is a certain percentage R_c^M of the market value of the risk-free reference instrument at inception and increases to 100% at maturity. The factors are applied having in mind 15 years maturity as an approximation of the highest duration observed.

A downgrade at time m from credit quality step X to $Y > X$ results in the following cost:

$$CoD_{(X,Y),M}(m) \coloneqq MV_{X,M}(m) - MV_{Y,M}(m) > 0.$$

Define the following strictly upper triangular matrix (an upgrade or stay is not accounted for):

$$C_M^{(m)} \coloneqq \left(\begin{Bmatrix} CoD_{(X,Y),M}(m) \cdot p_{X,Y} & \text{for } Y \neq \text{default} \\ (1 - \text{RecoveryRate}) \cdot MV_{X,M}(m) \cdot p_{X,Y} & \text{for } Y = \text{default} \end{Bmatrix}\right)_{(X<Y)\in CQS}.$$

Define the matrix Q according to the replacement requirement of Article 54(4) of the Delegated Regulation

$$(q_{XY})_{X,Y\in CQS} := \left\{\begin{array}{cc} p_{XY} & \text{for } X > Y \text{ and } Y = \mathrm{n} \text{ (lower triangle and rightmost column)} \\ \sum_{k=i}^{\mathrm{n}-1} p_{i,k} & \text{for } X = Y \leq n \text{ (Art. 54 (4) DR) (main diagonal)} \\ 0 & \text{for } X < Y < n \text{ (upper triangle except rightmost column)} \end{array}\right\}.$$

The following matrix contains the expected cash flows representing the expected cost of downgrade for bonds in the credit quality step in CQS of original maturity M at times $m = 1, \ldots, M$.

$$\begin{pmatrix} CoD_{\text{best quality},M}(1) & \cdots & CoD_{\text{best quality},M}(M) \\ \vdots & \ddots & \vdots \\ CoD_{\text{lowest quality},M}(1) & \cdots & CoD_{\text{lowest quality},M}(M) \\ CoD_{\text{default},M}(1) = 0 & \cdots & CoD_{\text{default},M}(1) = 0 \end{pmatrix} := \bigcup_{m=1}^{M} \underbrace{\left(Q^{m-1} C_M^{(m)} \begin{pmatrix} 1 \\ \vdots \\ 1 \\ 0 \end{pmatrix} \right)}_{\text{colum vector}},$$

where $\bigcup_{m=1}^{M}(\vdots)$ shall denote the concatenation (to the right) of column vectors into a matrix. In base points, $CoD_{c,M}^{(bp)}$ is solved from the following equation. Note $CoD_{c,M}^{(bp)} = 0$ if $CoD_{c,M}(m) = 0$ for all c, m.

$$\frac{1}{\left(1 + r_M + CoD_{c,M}^{(bp)}\right)^M} = \frac{1}{(1 + r_M)^M}\left(1 - \sum_{m=1}^{M} \frac{CoD_{c,M}(m)}{(1 + r_m)^{m-0.5}}\right).$$

Probability of Default in a nutshell

The computation of the probability of default in *base points as spread over the basic risk-free rate* is done completely consistently with the above approach. There is no Article 54(4) requirement to replace downgraded bonds along the way. Hence, the only difference is to use the original transition matrix T instead of the "twisted Article 54(4) matrix" Q and to use the column vector $\begin{pmatrix} 0 \\ \vdots \\ 0 \\ 1 \end{pmatrix}$ instead of $\begin{pmatrix} 1 \\ \vdots \\ 1 \\ 0 \end{pmatrix}$. Rename CoD to PD in this case. The other special case corresponds to the RecoveryRate term, which is given by Article 54(2) of the Delegated Regulation as 30% of the market value of the bond.

For the risk-correction of cash flows to be considered in the matching adjustment, the *probability of default is the total probability for a zero bond's final payment at maturity* ***not*** *to occur*. This probability is independent of market values and just given by the rightmost column of the matrix powers T^m.

Cost of Downgrade, step 2

Using the same notation as before, we have now calculated:

$CoD_{c,M}^{(bp)}$

$PD_{c,M}^{(bp)}(T)$ using the original transition matrix T.

We need to calculate $PD_{c,M}^{(bp)}(Q)$: for that purpose, we proceed as before, while using the "twisted Article 54(4) matrix" Q instead of the original transition matrix T.

The final cost of downgrade becomes:

$$CoD_{c,M}^{(bp)} = max\left[0\,, CoD_{c,M}^{(bp)} - \left(PD_{c,M}^{(bp)}(T) - PD_{c,M}^{(bp)}(Q)\right)\right]$$

Reducing computational and numerical complexity

413. Please note that $C_M^{(m)}$ is strictly upper triangular. This might help to further reduce complexity if needed. One can setup an internal table of all the values $(1 + r_m)^m$ and R_c^m for $m = 1, \ldots, M$. The market values are then just given by the product of two entries of this fixed-value table.

414. Furthermore, the matrix powers Q^m and T^m can be saved in an internal (three-dimensional) array.

415. The matrix Q excluding the last row and column is lower triangular with non-zero values on the main diagonal (unless "stay or upgrade" would both be impossible for any CQS). That is, the diagonal consists of the Eigenvalues λ_c of the matrix Q which is immediate from the characteristic polynomial decomposing into linear terms of the form $(\lambda - \lambda_c)$. Write $Q = S^{-1} * \text{diag}(\lambda_c)_{c \in CQS} * S$, then $Q^m = S^{-1}\text{diag}(\lambda_c^m,)_{c \in CQS} S$, where the columns of S are the corresponding left-Eigenvectors.

A remark about probability in continuous time and why it has not been used here

416. In this notation, one could – in theory – also define matrix powers for non-integral times t by

$$Q^t := S^{-1}\text{diag}(\lambda_c^t)S.$$

417. However, the use of the continuous version of powers of Q should carefully consider whether continuous downgrade events with immediate upgrade make sense in the specific application context. Even if one would consider integrals instead of sums, downgrades would still be discrete jumps between a finite number of rating classes or credit quality steps. This could be different if spreads were considered to continuously change without regard to a rather limited number of rating categories or credit quality

steps. The choice taken in this approach stays away from this complexity in order to create consistency with the mechanics behind the creation of transition matrices.

A remark about intra-year chains of rating changes

418. In real life, if a financial instrument receives a downgrade with negative forecast, it is not unlikely that the same instrument receives a second downgrade within the same year. The approach taken here would not "see" this chain of rating changes, because it only looks at discrete points $t = 0$, $t = 1$, …,$t = M$.

419. However, this would only be influential on the result if there is an upgrade event followed by a downgrade event in that chain of rating changes, because this downgrade event would have to be accounted for. But it is not accounted for, because it would not be recognized if one only opens the "black box" at the next point in time. Since these events are quite unlikely to occur, we disregard the difference stemming from this simplified view.

420. If the chain consists of only downgrading events, there is almost no difference at all, because the CoD cashflows are defined as differences between market values:

$$CoD_{X\to Y} + CoD_{Y\to Z} = (MV_X - MV_Y) + (MV_Y - MV_Z) = MV_X - MV_Z = CoD_{X\to Z}.$$

421. The only difference would stem from the different points in time and therefore the different interest/forward rates concerned. But again, this simplification has been considered to be of negligible materiality. However, in theory, this can be recognized within this model.

Transition matrix implementing the rebalancing requirement after a downgrade event

Define the lower triangular matrix Q according to the replacement requirement of Art. 54 (4) of Delegated Regulation

$$(q_{XY})_{X,Y\in CQS} := \left\{\begin{array}{ll} p_{XY} & \text{for } X > Y \text{ and } Y = \mathrm{n} \text{ (lower triangle and rightmost column)} \\ \sum_{k=i}^{\mathrm{n}-1} p_{i,k} & \text{for } X = Y \leq n \text{ (Art. 54 (4) DA) (main diagonal)} \\ 0 & \text{for } X < Y < n \text{ (upper triangle except rightmost column)} \end{array}\right\}$$

$$= \begin{pmatrix} \sum_{k=1}^{\mathrm{n}-1} p_{1,k} & \leftarrow 0 & \cdots & \leftarrow 0 & p_{1d} \\ p_{21} & \sum_{k=2}^{\mathrm{n}-1} p_{2,k} & \leftarrow 0 & \vdots & p_{2d} \\ p_{31} & p_{32} & \sum_{k=3}^{\mathrm{n}-1} p_{3,k} & \leftarrow 0 & p_{3d} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ p_{n-1,1} & \cdots & p_{n-2,n-1} & p_{n-1,n-1} & p_{n-1,d} \\ p_{d1} = 0 & p_{d2} = 0 & \cdots & p_{d,n-1} = 0 & p_{dd} = 1 \end{pmatrix}.$$

14.L. Annex to subsection 10.C.4: Background on the treatment of Danish covered bonds

422. *Nykredits Realkreditindeks* includes a representative extract of the Danish covered bond market. The index includes both covered bonds with short and long maturities.

423. A single index which covers all maturities is preferred over a more granular approach e.g. mapping exposures to two indices with maturity 3 years and 30 years. Such a mapping will include major expert judgement on the split of insurance undertakings holdings of short and long duration covered bonds.

424. The use of a single index reflects better the exposures of the Danish insurance sector as a whole than an attempt to map exposures in to two buckets. It should also be noted that the Nykredits Realkreditindeks is the index used as input for the covered bond component in the current Danish interest rate curve.

425. Historical data for the yield of Nykredits Realkreditindeks is given in the figure below. This data corresponds to the input $R_{covered}^{DKK}$

426. The average yield to maturity of this covered bond index for the time period 1 September 2003 to 31 December 2014 is 3.86 %

14.M. Annex to subsection 10.C.2: Specification of the input data for the transition matrices

This annex sets out the input data of Standard & Poor's for the transition matrices used to calculate the probabilities of default and the cost of downgrading. The specific time period of the data used and the timing of the data download are specified in the monthly publication of the probabilities of default and the cost of downgrading.

Financial bonds

Report Type	**Transition Matrices (Percent, NR Excluded)**
Calculation Base	Number of Issuers (All)
Horizon	1Year
Industry Selection	**GICS -40 -- Financials**
Country Selection	All
Vintage Years Selection	All
Number of Pools	30

Non-financial bonds

Report Type	**Transition Matrices (Percent, NR Excluded)**
Calculation Base	Number of Issuers (All)
Horizon	1Year
Industry Selection	**GICS -10 -- Energy, 15 -- Materials, 20 -- Industrials, 25 -- Consumer Discretionary, 30 -- Consumer Staples, 35 -- Health Care, 45 -- Information Technology, 50 -- Telecommunication Services, 55 – Utilities, 60 -- Real Estate**
Country Selection	All
Vintage Years Selection	All
Number of Pools	30

14.N. Diagram of calculations