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Final Draft RTS

on the calculation of the stress scenario risk measure under Article 325bk(3) of Regulation (EU) No 575/2013 (Capital Requirements Regulation 2 – CRR2)

Contents

1 Executive summary

The amendments to Regulation (EU) No 575/2013 (the Capital Requirements Regulation – CRR) implement in EU legislation, inter alia, the revised requirements for computing own funds requirements for market risk under the Basel III package, i.e. the Fundamental Review of the Trading Book (FRTB).

One of the key features of the FRTB is the classification of risk factors that are included in the risk measurement model of an institution as modellable or non-modellable. As a result, the standards specify that institutions must calculate a separate stress scenario risk measure for each non-modellable risk factor (or bucket of non-modellable risk factors). It has to be calibrated to be at least as prudent as the expected shortfall (ES) calibration used for modelled risks (i.e. a loss calibrated to a 97.5% confidence threshold over a period of extreme stress for the given risk factor or the given bucket).

These draft regulatory technical standards (RTS) set out the methodologies that institutions are required to use for the purpose of determining the extreme scenario of future shock that, when applied to the non-modellable risk factor, provides the stress scenario risk measure. Setting out a clear methodology is deemed necessary to ensure a level playing field among institutions in the EU.

These RTS require institutions to identify a stress period for each broad risk factor category and to collect data on non-modellable risk factors for the stress period in order to determine an extreme scenario of future shock. Once the stress period is identified, institutions can use the following methods.

- **The direct method.** This method involves directly calculating the expected shortfall measure of the losses that would occur when varying the given risk factor as in the relevant stress period.

- **The stepwise method.** Using this method, institutions approximate the expected shortfall of the losses by first calculating a shock calibrated to an expected shortfall measure on the returns observed for that risk factor and then calculating the loss corresponding to the movement in the risk factor identified by that calibrated shock. The stepwise method requires significantly fewer loss calculations than the direct method.

  How the calibrated shock for the returns has to be computed under the stepwise method depends on the number of observations available for the stress period. In particular, these draft RTS also clarify how this has to be done when the number of observations for a non-modellable risk factor is insufficient to obtain meaningful statistical estimates.

As mandated in Article 325bk(3)(b) of the CRR, these draft RTS also specify a regulatory extreme scenario of future shock that should be applied where the institution is unable to determine a scenario based on the abovementioned methodologies, or where the competent authority is unsatisfied with the extreme scenario of future shock generated by the institution. In line with the international standards, these draft RTS specify that the regulatory extreme scenario of future shock is the one leading to the maximum loss that can occur due to a change in the non-modellable risk factor, and they set out a specific framework to be used where that maximum loss is not finite.

Finally, in line with the international standards:

- These draft RTS specify that institutions may calculate a stress scenario risk measure at regulatory bucket level (i.e. for more than one risk factor), where the institution uses the regulatory bucketing approach to assess the modellability of the risk factors within the regulatory buckets.
- These draft RTS specify the formula that institutions should use when aggregating the stress scenario risk measures.

2 Background and rationale

The EU implementation of the FRTB requires that institutions using the internal model approach (IMA) assess for each risk factor included in the risk measurement model whether it is modellable or not. To be precise, institutions are required to assess the modellability of a risk factor on the basis of the requirements set out in Article 325be of the CRR. Risk factors that do not meet those requirements are deemed non-modellable risk factors (NMRFs).

The FRTB standards set out that when a risk factor has been identified as non-modellable it has to be capitalised, outside the expected shortfall measure, under a stress scenario risk measure (SSRM) which the standards do not specify in detail except that it should be calibrated to be at least as prudent as the expected shortfall calibration used for modelled risks (i.e. a loss calibrated to a 97.5% confidence threshold over a period of extreme stress for the given risk factor). With respect to the calculation of this stress scenario risk measure, Article 325bk of the CRR mandates the EBA in Article 325bk(3)(a) to develop draft RTS to specify how to calculate the 'extreme scenario of future shock' and how to apply it to the non-modellable risk factors to form the stress scenario risk measure. In particular, that article specifies that in developing these RTS, the EBA should take into consideration that the level of own funds requirements for market risk of a non-modellable risk factor should be as high as the level of own funds requirements for market risk that would have been calculated if that risk factor were modellable.

In addition, Article 325bk(3)(b) mandates the EBA to develop draft RTS specifying a regulatory extreme scenario of future shock that institutions may use where they are unable to develop an extreme scenario of future shock using the methodology outlined in Article 325bk(3)(a), or which competent authorities may require an institution to apply if they are not satisfied with the extreme scenario of future shock developed by the institution.

Finally, the EBA is also required to develop draft RTS specifying the circumstances under which institutions may calculate the stress scenario risk measure for more than one non-modellable risk factor and how institutions are to aggregate the stress scenario risk measures of all non-modellable risk factors (or buckets).

In December 2017, the EBA published a Discussion Paper (DP) on the EU implementation of market risk and counterparty credit risk revised standards.[1] The paper discussed some of the most important technical and operational challenges in implementing the FRTB and standardised approach for counterparty credit risk in the EU.

In that context, the EBA put forward a first proposal for how institutions should determine the stress scenario risk measure for non-modellable risk factors, and several questions were included in order to

[1] https://eba.europa.eu/sites/default/documents/files/documents/10180/2161587/a5f47920-54be-4b68-a25c-119c70606186/Discussion%20Paper%20on%20EU%20implementation%20of%20MKR%20and%20CCR%20revised%20standards%20%28EBA-DP-2017-04%29.pdf

gather initial feedback on the methodology proposed in the discussion paper. It should be noted that this first proposal was based on the FRTB standards published in January 2016, which were not final at that stage and were superseded in January 2019.[2]

Considering the feedback received on the discussion paper, and in the light of the final international standards, the EBA launched in July 2019 a data collection exercise[3] presenting several stress scenario risk measure calculation method variants. The purpose of the data collection exercise was to apply the EBA non-modellable risk factor methodology proposals in practice and gather data to ensure an appropriate calibration of the NMRF stress scenario risk measure.

Finally, in June 2020 the EBA published the consultation paper (CP)[4] on which these final draft RTS are based; the feedback received can be found in subsection 4.2.1. Therefore, these final draft RTS should be seen as the result of the iterative process described above, during which input from market participants was sought several times.

2.1 Methodology for developing extreme scenarios of future shock applicable to non-modellable risk factors

As mentioned above, the amended CRR mandates the EBA, in accordance with Article 325bk(3)(a), to develop RTS specifying how institutions should determine the extreme scenario of future shock and how they are to apply them to non-modellable risk factors to form the stress scenario risk measure. Accordingly, this section describes the methodology that institutions should use for developing the extreme scenarios of future shock applicable to non-modellable risk factors.

As outlined in Article 325bk(1) of the CRR, once the institution has determined the extreme scenario of future shock for a non-modellable risk factor in line with these RTS, the stress scenario risk measure is the loss that is incurred when that extreme scenario of future shock is applied to that risk factor.

In general, institutions will have to determine the extreme scenario of future shock for a non-modellable risk factor on a stand-alone basis, and, accordingly, they will compute a stress scenario risk measure by identifying the loss where the risk factor is subject to that extreme scenario of future shock and all other risk factors are kept unchanged. However, in line with the international standards, the institution is allowed to determine a single extreme scenario of future shock for more than one non-modellable risk factor under certain circumstances.

The Basel standards clarify that the modellability of risk factors belonging to a curve or to a surface is determined using either (i) the own bucketing approach or (ii) the regulatory bucketing approach. Where the institution opts for the regulatory bucketing approach, a bucket may include more than one

[2] Basel Committee on Banking Supervision, *Minimum capital requirements for market risk,* https://www.bis.org/bcbs/publ/d457.pdf

[3] https://eba.europa.eu/sites/default/documents/files/documents/10180/2844292/f9f8e5a5-fe34-4ba9-90c4-77dd2fed51fe/Instructions%20on%20NMRF%20data%20collection.pdf

[4] https://eba.europa.eu/sites/default/documents/files/document_library/Publications/Consultations/2020/CP%20on%20draft%20RTS%20on%20SSRM%20-%20NMRF/884638/EBA-CP-2020-10%20CP%20on%20draft%20RTS%20on%20SSRM%20-%20NMRF.pdf

risk factor; in this case, the institution is allowed to calculate the stress scenario risk measure at the level of the regulatory bucket, meaning that a single extreme scenario of future shock is determined for all the risk factors in the regulatory bucket.

These draft RTS specify the circumstances under which institutions may calculate a stress scenario risk measure for more than one non-modellable risk factor in accordance with Article 325bk(3)(c) of CRR2. In this respect, the draft RTS aim to transpose the Basel standards into EU legislation by allowing institutions to determine an extreme scenario of future shock at regulatory bucket level. Therefore, this section will present both the methodology that institutions should use when determining the extreme scenario of future shock for a single non-modellable risk factor and the methodology that they should use when determining it for a non-modellable regulatory bucket.

As mentioned above, Article 325bk(1) of the CRR defines the term ‘stress scenario risk measure’ as the loss that is incurred when the extreme scenario of future shock (obtained in accordance with these RTS) is applied to the corresponding non-modellable risk factor. For modellable risk factors, institutions are required to first calculate an expected shortfall measure on a 10-day horizon and to rescale it in a second step to reflect the liquidity horizon of the underlying risk factors. Analogously to the treatment of modellable risk factors, the extreme scenario of future shock obtained in accordance with these draft RTS is calibrated on a 10-day horizon and the stress scenario risk measure, defined as in Article 325bk(1), is a loss calibrated on a 10-day horizon. Each stress scenario risk measure is then rescaled to reflect the liquidity horizons of the non-modellable risk factors in the aggregation formula laid down in Section 2.4, used to obtain the own funds requirements for market risk associated with all non-modellable risk factors.

2.1.1 Notation

In this subsection, the notation used below is explained.

D^*	Reference date, i.e. date for which the stress scenario risk measure is calculated
j	Identifier of the non-modellable risk factor
$D_1 < \ldots < D_M$	Dates at which a value of the non-modellable risk factor has been recorded
$D_{t+1} - D_t$	Number of business days from D_t to D_{t+1}
$r_j(D)$	Value of the non-modellable risk factor j at date D
r_j^*	Value of the non-modellable risk factor j at reference date D^*, $r_j^* \equiv r_j(D^*)$.
$LH(j)$	Liquidity horizon of the non-modellable risk factor j
$Ret(j,t,10)$	Return of the non-modellable risk factor j between D_t and $D_t + 10$ business days (or nearest approximation)
$CS(j)$	Calibrated shock for the non-modellable risk factor j
$CSSRFR_{D^*}(j)$	Calibrated stress scenario risk factor range for the non-modellable risk factor j on date D^*
$FS_{D^*}(j)$	Extreme scenario of future shock for the non-modellable risk factor j on date D^*
$\text{loss}_{D^*}^j(r)$	Loss to the portfolio on date D^* when the non-modellable risk factor j takes a value r
$\kappa_{D^*}^j$	Adjustment factor for tail non-linearity of the loss function for the non-modellable risk factor j
$SS_{D^*}^j$	Stress scenario risk measure on date D^* for the non-modellable risk factor j

2.1.2 General provisions

In this subsection, some general provisions regarding the calculation of the stress scenario risk measure are presented. Although some of those provisions are already set out in the CRR, they are restated here to provide the reader with the full picture; some others introduce techniques or requirements that will be relevant to several parts of the framework and therefore are explained here.

Frequency of the calculation of the stress scenario risk measure

The EU implementation of the FRTB requires institutions to calculate the stress scenario risk measure $SS_{D^*}^{j}$ for a single non-modellable risk factor j on a daily basis. In particular, $SS_{D^*}^{j}$ denotes the stress scenario risk measure for the non-modellable risk factor j at the reference date D^* (i.e. the date for which the stress scenario risk measure is computed). Given that this provision is already included in Article 325ba of the CRR, it is not included in these draft RTS but considered a prerequisite for implementation.

Pricing functions to use when applying extreme scenarios of future shock

Article 325bk(3)(a) requires the EBA to specify how institutions are to apply the extreme scenario of future shock once it has been determined. Under this mandate, the draft RTS specify that the extreme scenario of future shock should be applied in the same manner as in the expected shortfall model. Therefore, when calculating the loss corresponding to a future shock applied to a non-modellable risk factor, institutions must use the pricing functions of the risk measurement model.[5] Therefore, in particular, regarding the passage of time effect (the theta effect), if the expected shortfall model is based on an instantaneous shock, the same should hold for the stress scenario risk measure. This is to ensure that a risk factor can switch modellability status back and forth and be modelled consistently.

Specifications on the portfolio loss function

The portfolio loss function $loss_{D^*}(r_j)$ measures changes in the portfolio's value on the reference date when a risk factor changes, which is the difference between two present values. $PV(\vec{r})$ denotes the portfolio present value depending on all risk factors $\vec{r} = \{r_i\}$ (modellable and non-modellable).

The sign convention is that the worst losses have a positive sign, when the present value, because of the change in the risk factor, gets lower. The loss occurring when one single risk factor r_j has a value different from the initial value $r_j^* = r_j(D^*)$ at the reference date is:

$$\mathrm{loss}_{D^*}^{\mathrm{single}}(r_j) = PV(\vec{r}^*) - PV(r_j, \vec{r}_{i\neq j}^*)$$

This means that only r_j is set to a specific value, while the current values of the other risk factors $\vec{r}_{i\neq j}$ are not changed. Accordingly, the joint distribution of risk factors r_j and $\vec{r}_{i\neq j}$ is not needed because $\vec{r}_{i\neq j}$ are not changed.

[5] A specific derogation to this requirement is introduced to address the issue of 'non-pricing scenarios', as described in Section 2.1.5.

Where a risk factor belongs to a regulatory bucket B of risk factors $\{r_j \in B\}$, institutions may decide (in accordance with these draft RTS) to calculate the stress scenario risk measure at bucket level. Accordingly, it is essential to define a loss function at bucket level. For the purpose of these RTS, the loss (at bucket level) occurring when all risk factors in the regulatory bucket B have values different from the initial values $\{r_j^* \in B\}$ at the reference date is:

$$\text{loss}_{D^*}^{\text{Bucket}}(\{r_j \in B\}) = PV(\{r_j^* \in \text{B}\}, \{r_i^* \notin \text{B}\}\text{ fixed}) - PV(\{r_j \in B\}, \{r_i^* \notin \text{B}\}\text{ fixed})$$

As mentioned above, Article 325bk(3)(a) of the CRR requires the EBA to specify how institutions are to apply the extreme scenario of future shock once it has been determined. Therefore, all these aspects regarding the loss function have been reflected in the draft RTS by requiring the institutions to apply the extreme scenario of future shock by keeping unchanged all other risk factors while shocking the relevant non-modellable risk factor (or the relevant non-modellable regulatory bucket, where applicable).

Obtaining the series of 10-business-days returns from the time series of observations

In several parts of the framework, institutions are required to determine a time series of 10-business-days returns from the time series of values of a given non-modellable risk factor during a specific 1-year period P. Therefore, this subsection outlines how institutions are to determine this time series of 10-business-days returns whenever they are required to do so.

Given a 1-year period P and given a non-modellable risk factor j, in order to build the time series of 10-business-days returns, institutions must first collect a time series of risk factor values (observations) $r_j(D)$ for risk factor j, where $r_j(D_t)$ denotes the observation at date D_t.

Let $\{D_1, \dots, D_M, D_{M+1}, \dots D_{M+d}\}$ be the vector representing the observation dates within the 1-year period P extended by up to 20 business days.[6] Then, for a given non-modellable risk factor, the vector $\{D_1, \dots, D_M\}$ denotes the observation dates within the 1-year period P, and the vector $\{D_{M+1}, \dots D_{M+d}\}$ denotes the observation dates during the period of 20 business days following the 1-year period P.

The time series may not always yield returns over exactly 10 business days for all dates, as data may be sparse, so the concept of 10 business days is generalised as follows: for each date index $t \in \{1, \dots, M-1\}$, institutions should determine a 'nearest to 10 business days' candidate $t_{nn}(t)$ by applying the following formula:

$$t_{nn}(t) = \underset{\substack{t' > t \\ t' \in \{2,\dots,M,M+1,\dots M+d\}}}{\text{argmin}} \left[\left| \frac{10 \text{ business days}}{D_{t'} - D_t} - 1 \right| \right]$$

[6] Where the period P is a period in the past, it can be extended by 20 days; however, where P is a current period (i.e. during the past 12 months), then the 20 days following that period fall 'in the future'. Accordingly, the draft RTS refer to a 1-year period extended by **up to** 20 business days to reflect cases where such an extension is not possible in practice. The 20-day extension is motivated by the minimum liquidity horizon for non-modellable risk factors.

Accordingly, being $t \in \{1, \dots, M-1\}$, the starting observation used to determine a return always lies within the 1-year period P, while the ending observation $t' \in \{2, \dots, M, M+1, \dots M+d\}$ may lie in the period of up to 20 business days following the 1-year stress period.

There may be cases where there are two dates $D_{t'}$ minimising the abovementioned absolute value;[7] the draft RTS address that specific (and rare) case by specifying that institutions should select the date with a longer time horizon among those minimising the absolute value.

Once the institution has determined the date $D_{t_{nn}(t)}$ for a given t, it should determine the return over the nearest to 10 business days by first considering the return on the period between t and $t_{nn}(t)$ according to the institution's chosen return approach for this risk factor and then rescaling it in order to obtain an approximation of the return over 10 business days. For example, if the institution uses absolute returns for a given non-modellable risk factor, then the 10-business-days return is determined as:

$$Ret(r_j, t, 10) = \left(r_j\left(D_{t_{nn}(t)}\right) - r_j(D_t)\right) \times \sqrt{\frac{10 \text{ business days}}{D_{t_{nn}(t)} - D_t}}$$

If the institution uses logarithmic returns for the non-modellable risk factor, then the 10-business-days return is determined as:

$$Ret(r_j, t, 10) = \log\left(\frac{r_j\left(D_{t_{nn}(t)}\right)}{r_j(D_t)}\right) \times \sqrt{\frac{10 \text{ business days}}{D_{t_{nn}(t)} - D_t}}$$

More generally, if the institution uses another return approach, for example an approach to interest rates where absolute returns for low levels of interest are mixed with a crossover to relative returns for high levels of interest, the method for the 10-business-days return calculation outlined above should be applied analogously.

As a result, the institution obtains the time series returns of $Ret(r_j, t, 10)$ for each $t \in \{1, \dots, N\}$, where $N = M - 1$ is the number of returns in the time series.

Requirements on the data inputs for non-modellable risk factors

The EBA guidelines to be developed in accordance with Article 325bh(3) of the CRR will set out requirements for data inputs for modellable risk factors. The criteria in those guidelines are not meant to be applicable to non-modellable risk factors. These draft RTS propose some high-level requirements with respect to the data inputs to be used for developing extreme scenarios of future shock for non-modellable risk factors.

Specifically, these draft RTS set out that:

[7] Where the dates minimising the absolute value occur 6 and 30 business days after D_t, and no other observation is in between them |10/6 - 1|=|10/30 - 1|. This is the only such case for integer business days.

- For the data that are used as inputs for the calibration of the downward and upward shocks, institutions shall recognise only one risk factor value per day and no stale data shall be considered unless they represent actual market data.

- Stale data may only be used to determine the value of the risk factor at the reference date, i.e. the value that is shocked to determine the losses that would occur if the shock were applied at the reference date.

- Institutions shall use the time series that were used for calibrating shocks in the context of the expected shortfall model for risk factors that were modellable in the past and are now assessed as non-modellable.

It should be noted that Article 325bh sets out the requirements for the risk measurement model; the term 'risk measurement model' is used in a broad sense in the CRR, as it encompasses the market risk model as a whole (e.g. the expected shortfall model used to obtain the own funds requirements associated with modellable risk factors and the methodology used to calculate the stress scenario risk measure), as well as the pricing functions used by the institution to compute the risk theoretical profit and loss (RTPL) under the P&L attribution test. Therefore, the requirements set out in Article 325bh(1)(g) governing the use of proxies is relevant in the context of both modellable risk factors and non-modellable risk factors, and accordingly these draft RTS do not include any further specifications on that aspect, as they would be redundant.

2.1.3 Overarching approach for the determination of the extreme scenario of future shock and determination the stress period for non-modellable risk factors

The FRTB standards set out in paragraph 33.16 that 'the capital requirements for each non-modellable risk factor (NMRF) are to be determined using a stress scenario that is calibrated to be at least as prudent as the ES [expected shortfall] calibration used for modelled risks (i.e. a loss calibrated to a 97.5% confidence threshold over a period of stress). In determining that period of stress, a bank must determine a common 12-month period of stress across all NMRFs in the same risk class.'

The amended CRR transposed this requirement into EU legislation by requiring the EBA to develop these final draft RTS taking into consideration that the level of own funds requirements for market risk of a non-modellable risk factor should be as high as the level of own funds requirements for market risk that would have been calculated if that risk factor were modellable. Accordingly, the EBA developed these standards so that the stress scenario risk measure associated with a non-modellable risk factor corresponds to an expected shortfall measure of the losses that may occur due to a change in the non-modellable risk factor with a 97.5% confidence threshold over a period of stress.

These final draft RTS require institutions to determine the stress scenario risk measure from risk factor observations collected for the stress period. In other words, the observation period that is used to calibrate the shock applicable to the non-modellable risk factor is the stress period, i.e. institutions would have to consider the observation data $r_j(D)$ for the non-modellable risk factor j in the stress period and would apply the methodology prescribed in these draft RTS on the basis of the time series constituted by those observations to determine the extreme scenario of future shock.

In other words, institutions need to apply the following steps to determine the stress scenario risk measure.

1. The institution determines the stress period for each risk class (broad risk factor category) using one of the two approaches specified below.

2. The institution obtains the extreme scenario of future shock for each non-modellable risk factor (or non-modellable bucket, where applicable) calibrated on the stress period.

3. The institution calculates the stress scenario risk measure ($SS^{j,s}_{10\text{days},D^*}$) as the loss occurring when the extreme scenario of future shock is applied to the non-modellable risk factor j. The stress scenario risk measure is then rescaled to reflect the liquidity horizons of the non-modellable risk factors (but also other aspects, such as the non-linearity of the loss function) in the aggregation formula laid down in Section 2.4.

With respect to the notation, $SS^{j,S^i}_{10\text{days},D^*}$ denotes a 10-day stress scenario risk measure for the non-modellable risk factor j (or non-modellable bucket, where applicable) calculated on the reference date D^* and calibrated on the stress period S^i.

These final draft RTS require institutions to identify one stress period for each of the five broad risk factor categories $i \in \{\text{IR, CS, EQ, FX, CM}\}$ (risk classes) and allow institutions to determine the stress period following two main approaches: the first based on the maximisation of the stress scenario risk measures in the risk class and the second based on the maximisation of the expected shortfall measure for modellable risk factors in the risk class.

First approach to determining the stress period

The first approach requires institutions to determine the stress period at risk class level by identifying the 12-month period P maximising the value taken by the rescaled stress scenario risk measure $RSS^{j,P}_{D^*}$ associated with risk factors that are mapped to that risk class. Institutions are required to determine the 12-month stress period S^i as follows:

$$S^i = \underset{P}{argmax}\left[\sum_{j \in i} RSS^{j,P}_{D^*}\right];\ i \in \{\text{IR, CS, EQ, FX, CM}\}$$

How institutions should calculate $RSS^{j,P}_{D^*}$ depends on the methodology that is used to determine the extreme scenario of future shock; in Section 2.4, the definition of $RSS^{j,P}_{D^*}$ is provided for each of the two methodologies.

As in the treatment prescribed for modellable risk factors in Article 325bc(2) (although in that context a single stress period applicable to all risk factors has to be determined), institutions are required to scan 12-month periods starting at least from 1 January 2007. The review of the stress period S^i for each risk class should be performed at least on a quarterly basis.

As mentioned above, when calculating the loss corresponding to a future shock applied to a non-modellable risk factor, institutions must use the pricing functions of the risk measurement model. However, since it may be overly burdensome for institutions to determine $RSS_{D^*}^{j,P}$ with those pricing functions for all risk factors and for all rolling 1-year periods from 2007, these final draft RTS allow institutions to use sensitivity-based pricing methods to identify the period maximising $\sum_{j \in i} RSS_{D^*}^{j,P}$. However, it should be emphasised that this possibility is provided solely for the purpose of identifying the stress period and when evidence is provided that the sensitivity-based pricing does not alter the stress period. In other words, following the identification of the stress period, institutions are to use the pricing functions of the risk measurement model to determine the extreme scenario of future shock and, accordingly, the stress scenario risk measure.

Second approach to determining the stress period

Letting institutions use sensitivity-based P&Ls to determine the stress period as described in the first approach is expected to significantly reduce the computational burden that a full revaluation P&L could entail. However, calculating a sensitivity-based P&L could result in the implementation of sensitivity-based pricing methods just for the purpose of identifying the stress period. To ensure that the RTS provide requirements that are proportionate to the goal of the provision (i.e. the identification of the stress period), the RTS allow the possibility of identifying a period of financial stress for a given risk class by maximising the partial expected shortfall measure $PES_t^{RS,i}$ referred to in Article 325bb of the CRR on the reduced set of modellable risk factors belonging to the risk class *i*. To ensure that the period identified is a period of financial stress also for non-modellable risk factors, institutions are required to provide evidence that this is actually the case taking into consideration how their portfolio is exposed to non-modellable risk factors. Generally speaking, institutions are expected to show that worst losses actually occurred during the stress period identified.

These final draft RTS do not introduce prescriptive requirements with respect to how institutions are to provide the abovementioned evidence. However, the approach followed by institutions to fulfil this requirement will be subject to the competent authorities' scrutiny during the IMA approval process.

2.1.4 Determination of the extreme scenario of future shock

Institutions are required to determine a scenario of future shock by applying one of the methodologies described in this section. Two variants are presented for each methodology depending on whether the institution calculates the stress scenario risk measure for a single non-modellable risk factor or for non-modellable risk factors belonging to a bucket.

A high-level summary of how this section (and these final draft RTS) is structured is presented below. In particular, the methodologies that institutions may use to obtain the extreme scenarios of future shock are as follows (and are detailed in the following subsections in the same order).

- **Methodology D – direct method.** The direct method requires institutions to determine a scenario of future shock by directly calculating the expected shortfall of the portfolio losses.

  - Subsection 2.1.4.1, 'Direct method for determining the extreme scenario of future shock for a single non-modellable risk factor', is relevant where the institution calculates the stress scenario risk measure for a single risk factor.

  - Subsection 2.1.4.2, 'Direct method for determining the extreme scenario of future shock for non-modellable risk factors belonging to non-modellable buckets', is relevant where the institution calculates the stress scenario risk measure at regulatory bucket level in accordance with the possibility referred to in Article 325bk(3)(c) of the CRR.

  The direct method, although relatively straightforward from a mathematical point of view, requires essentially daily data on non-modellable risk factors and a significant computation effort on the part of institutions using it, because daily loss evaluations need to be computed for each risk factor, while the other methods require only a few.

  Methodology S – stepwise method. The stepwise method requires institutions to determine the scenario of future shock by steps, as set out below.

  - Subsection 2.1.4.3, 'Stepwise method for determining the extreme scenario of future shock for a single non-modellable risk factor', is relevant where the institution calculates the stress scenario risk measure for a single risk factor. That subsection sets out the steps that institutions should undertake.

    i. In the first step, institutions are required to determine a downward and an upward calibrated shock that are applicable to the non-modellable risk factors. Depending on the number of return observations available, these final draft RTS propose different methodologies for determining such calibrated shocks:

       (i) **Method 1**: historical method;

       (ii) **Method 2**: asymmetrical sigma method;

       (iii) **Method 3:** fallback method.

    ii. In the second step, institutions are required to determine the calibrated stress scenario risk factor range by applying the shock obtained in the previous step to the value of the non-modellable risk factor at the reference date.

    iii. In the third step, institutions are required to determine the extreme scenario of future shock by identifying the worst loss that the institution incur should the non-modellable risk factor move in the identified calibrated stress scenario risk factor range.

  - Subsection 2.1.4.4, 'Stepwise method for determining the scenario of future shock for non-modellable risk factors belonging to non-modellable buckets', is relevant where the institution calculates the stress scenario risk measure at bucket level in accordance with the possibility referred to in Article 325bk(3) of the CRR. In particular, institutions are required to apply the following steps in sequence:

i. Institutions are required to determine downward and upward calibrated shocks for all risk factors in a regulatory bucket by applying one of the options presented in subsection 2.1.4.3 (e.g. the historical method).

ii. Then scenarios are generated on the basis of the individual risk factor shock ranges by applying a fraction ranging from –1 to 1 to the individual risk factor shocks leading to a 'contoured' family of shocks; among those scenarios, the extreme scenario of future shock is the one leading to the worst loss.

Finally, it is worth highlighting that these final draft RTS set specific conditions with respect to the methodology that institutions can use to determine the extreme scenario of future shock depending on the number N of returns in the time series of 10-business-days returns for a given non-modellable risk factor. The conditions expressed below are deemed necessary to ensure that, for example, institutions use an appropriate statistical estimator to determine the extreme future shock with controlled estimation error.

Depending on the number of returns, the methods to be used are as follows.

- Where the institution computes the extreme scenario of future shock at risk factor level (i.e. not at bucket level):
  - Where $N \geq 200$, institutions can use the direct method.
  - The institution can always use the stepwise method for determining the future shock scenario. However, conditions apply with respect to the methodology to use in the first step in the methodology, i.e. the calibration of the upward and downward shocks. More precisely:
    - where $N \geq 200$, institutions must use the historical method in the first step in the stepwise method to calibrate the upward and downward shocks;
    - where $200 > N \geq 12$, institutions must use the asymmetrical sigma method in the first step in the stepwise method to calibrate the upward and downward shocks;
    - where $N < 12$, institutions must use the fallback method in the first step in the 'stepwise method' to obtain the upward and downward shocks.
- Where the institution computes the extreme scenario of future shock at bucket level:
  - Where $N \geq 200$, for all risk factors within the bucket institutions can use the direct method at bucket level.

- The institution can always use the stepwise method at bucket level. As outlined above, this method requires the calibration of upward and downward shocks at risk factor level; in this context:
  - where for all risk factors within the bucket $N \geq 200$, institutions must use the historical method to calibrate the upward and downward shocks for the risk factors in the bucket;
  - where there is a risk factor within the bucket for which $N < 12$, institutions need to calibrate the upward and downward shocks for all risk factors within the bucket using the fallback method;
  - in all other cases, the institutions must use the asymmetrical sigma method to calibrate the upward and downward shocks for the risk factors in the bucket.

The various methodologies are presented in detail below.

Methodology D – the direct method

2.1.4.1 Direct method for determining the extreme scenario of future shock for a single non-modellable risk factor

As mentioned previously, the direct method requires the institution to derive the extreme the scenario of future shock by directly calculating the expected shortfall of the worst losses. This subsection is relevant where the institution calculates the stress scenario risk measure for a single risk factor.

Step D.0 – obtain the 10-business-days returns

From the time series of observations for a given non-modellable risk factor *j* in the relevant stress period S^i, institutions need to determine the time series of 10-business-days returns in accordance with the methodology prescribed in subsection 2.1.2.

As specified above, institutions can use the direct method only where $N \geq 200$ returns in the stress period.

Step D.1 – obtain the extreme scenario of future shock

Given the sample $Ret(r_j, 1, 10)$,.....,$Ret(r_j, N, 10)$ of 10-business-days returns for the non-modellable risk factor and the portfolio loss function when those returns are applied to the value on the reference date, these final draft RTS define the extreme scenario of future shock as that which gives rise to the expected shortfall of the losses. Accordingly, in order to determine the extreme scenario of future shock the final draft RTS specify that institutions should first calculate the expected shortfall:

$$\widehat{\text{ES}}_{\text{Right}}\left[loss_{D^*}\left(r_j(D^*) \oplus Ret(r_j, t, 10)\right), \alpha\right] \quad (1)$$

where the risk factor j is shifted according to its nearest to 10-business-days returns consistently with the return approach chosen (absolute, relative, log returns, etc.), indicated by the symbol $\oplus$, and where the following definitions apply:

$$\widehat{\mathrm{ES}}_{\mathrm{Left}}(X,\alpha) \stackrel{\mathrm{def}}{=} \frac{-1}{\alpha N} \times \left\{ \sum_{i=1}^{[\alpha N]} X_{(\mathrm{i})} + (\alpha N - [\alpha N]) X_{([\alpha N]+1)} \right\} \ (2)$$

$$\widehat{\mathrm{ES}}_{\mathrm{Right}}(X,\alpha) \stackrel{\mathrm{def}}{=} \widehat{\mathrm{ES}}_{\mathrm{Left}}(-X,\alpha) \ (3)$$

where:

- $\alpha = 2.5\%$;
- X is the order statistics of the sample in question of size N;[8]
- $[\alpha N]$ denotes the integer part of the product αN.

It should be noted that the sign convention leads to a positive number for the left tail of a distribution centred on zero.

Once the expected shortfall defined in formula (1) has been calculated, the extreme scenario of future shock is that leading to a stress scenario risk measure, as defined in Article 325bk(1), equal to that expected shortfall. In other words, the extreme scenario of future shock is defined implicitly by first determining the corresponding loss.

It is worth highlighting that if the losses are not strictly monotonous (and continuous) in the risk factor movements, there could be cases where there is more than one extreme scenario of future shock that leads to a loss corresponding to that identified by the expected shortfall estimators. In general, should an institution be requested to provide the extreme scenario of future shock corresponding to a non-modellable risk factor for which the direct method has been employed, the institution is expected to provide that scenario and explain how it was obtained.

2.1.4.2 *Direct method for determining the extreme scenario of future shock for non-modellable risk factors belonging to non-modellable regulatory buckets*

Where the institution calculates a single stress scenario risk measure for all risk factors belonging to a non-modellable regulatory bucket, it may do so by implementing the direct method at bucket level. This subsection presents the methodology that institutions may use for that purpose.

Step D.0 –obtain the 10-business-days returns

For each of the risk factors in the non-modellable bucket, institutions need to determine the time series of 10-business-days returns in accordance with the methodology prescribed in subsection 2.1.2 from the time series of observations for a given non-modellable risk factor j in the relevant stress

[8] Accordingly, *X(i)* represents the *i*-th smallest observation in the time series *X*.

period S^i. Only dates for which returns are available for all risk factors in the non-modellable bucket should be retained, to ensure the consistency of the returns.

As specified above, the direct method at bucket level can be used only where in the stress period $N \geq 200$ returns for all the risk factors within the bucket.

Step D.1 – determine the extreme scenario of future shock

Analogously to the direct method for determining the extreme scenario of future shock for a single factor, institutions should determine an extreme scenario for risk factors $\{r_j \in B\}$ belonging to a bucket B by first calculating the following expected shortfall measure:

$$\widehat{\mathrm{ES}}_{\mathrm{Right}}\left[\mathrm{loss}_{D^*}^{\mathrm{Bucket}}\left(\{r_j(D^*) \oplus Ret(r_j, t, 10), r_j \in B\}\right), \alpha\right]$$

where each risk factor in the bucket $\{r_j \in B\}$ is shifted according to its nearest to 10-business-days returns (i.e. non-parallel shifts) according to the return approach chosen (absolute, relative, log returns, etc.) indicated with the symbol $\oplus$. The definition of the statistical estimator $\widehat{\mathrm{ES}}_{\mathrm{Right}}(X, \alpha)$ introduced before applies also in this context.

In this case also, there could be situations where there is more than one scenario of future shock that leads to a loss corresponding to that identified by the expected shortfall estimators. In general, should an institution be requested to provide the extreme scenario of future shock corresponding to a non-modellable regulatory bucket for which the direct method has been employed, the institution is expected to report that scenario and be able to explain how it was obtained.

Methodology S – the stepwise method

2.1.4.3 Stepwise method for determining the extreme scenario of future shock for a single non-modellable risk factor

As mentioned previously, the stepwise method requires institutions to determine the scenario of future shock by steps. This subsection is relevant where the institution calculates the stress scenario risk measure for a single risk factor.

Step S.0 – obtain the 10-business-days returns

From the time series of observations for a given non-modellable risk factor j in the relevant stress period S^i, institutions need to determine the time series of 10-business-days returns in accordance with the methodology prescribed in subsection 2.1.2.

Step S.1 – determine an upward and a downward shock

In the first step, institutions are required to determine a downward and an upward calibrated shock that are applicable to the non-modellable risk factors from the observations in the relevant observation period (i.e. see step S.0). These final draft RTS propose several methodologies for determining such calibrated shocks:

(i) **Method 1:** historical method;

(ii) **Method 2:** asymmetrical sigma method;

(iii) **Method 3:** fallback method.

The three methods are outlined below.

Method 1 – the historical method

The first step in the stepwise method must be performed using the historical method where $N \geq 200$. Given the sample $Ret(r_j, 1{,}10)$,..., $Ret(r_j, N, 10)$ of 10-business-days returns for a given non-modellable risk factor (obtained as a result of step S.0), the historical method requires institutions to first calibrate an upward and a downward shock applicable to the risk factor by estimating the empirical expected shortfalls of the returns for the right and left tails.

More precisely, institutions should calculate the two shocks using the following formulas:

$$CS_{\text{down}}(r_j) = \widehat{\text{ES}}_{\text{Left}}(Ret(j), \alpha) \times \left(0.95 + \frac{1}{\sqrt{(N-1.5)}}\right)$$

and

$$CS_{\text{up}}(r_j) = \widehat{\text{ES}}_{\text{Right}}(Ret(j), \alpha) \times \left(0.95 + \frac{1}{\sqrt{(N-1.5)}}\right)$$

where the definitions of $\widehat{\text{ES}}_{\text{Left}}(X, \alpha)$, $\widehat{\text{ES}}_{\text{Right}}(X, \alpha)$ introduced before apply also in this context.

As set out in the formula, institutions are required to derive the two shocks by multiplying the expected shortfall measures by an uncertainty compensation factor covering the uncertainty due to the lower market observability of non-modellable risk factors, statistical estimation error and the uncertainty in the underlying distribution. Annex I outlines how the uncertainty compensation factor $\left(0.95 + \frac{1}{\sqrt{(N-1.5)}}\right)$ has been derived. While the formula for determining the uncertainty compensation factor would need to be different depending on the method and underlying distribution, for the sake of simplicity and considering that for $N \geq 200$ the compensation factor is relatively small, these final draft RTS prescribe the same uncertainty compensation factor for all methods.

Method 2 – the asymmetrical sigma method (asigma method)

The first step in the stepwise method must be performed using the asymmetrical sigma method where $N \geq 12$ and $N < 200$.

The objective of the asymmetrical sigma method is the approximation of the right-tail and left-tail expected shortfalls of the returns distribution using an estimated mean and a volatility measure. In particular, the asymmetrical sigma method has been designed to capture the skewness in the observed underlying distribution; therefore, the upward and downward shocks resulting from this step are in general of different sizes.

More precisely, given the sample $Ret(r_j, 1{,}10)$,..., $Ret(r_j, N, 10)$ of 10-business-days returns for a given non-modellable risk factor (obtained as a result of step S.0), institutions should first split the returns at the median m, and should then determine the mean on the set of N_{up} returns greater than the median $\hat{\mu}^{Ret(j)}_{Ret>m}$ and the mean on the set of N_{down} returns lower than (or equal to) the median $\hat{\mu}^{Ret(j)}_{Ret\leq m}$. In formulas:

$$\hat{\mu}^{Ret(j)}_{Ret\leq m} = \frac{1}{N_{\text{down}}} \times \sum_{\substack{t=1 \\ Ret(r_j,t,10)\leq m}}^{N} Ret(r_j, t, 10)$$

$$\hat{\mu}^{Ret(j)}_{Ret>m} = \frac{1}{N_{\text{up}}} \times \sum_{\substack{t=1 \\ Ret(r_j,t,10)>m}}^{N} Ret(r_j, t, 10)$$

where:

$$N_{\text{down}} = |Ret(r_j, t, 10) \ \leq m|$$

$$N_{\text{up}} = |Ret(r_j, t, 10) > m|$$

Institutions should then calculate the following amounts, representing the rescaled standard deviations calculated on the two sets of returns (with scaling factor C_{ES}), which are then shifted by $\hat{\mu}^{Ret(j)}_{Ret\leq m}$ and $\hat{\mu}^{Ret(j)}_{Ret>m}$:

$$\widehat{\text{ASigma}}^{Ret(j)}_{\text{down}} = -\hat{\mu}^{Ret(j)}_{Ret\leq m} + C_{\text{ES}} \times \sqrt{\frac{1}{N_{\text{down}} - 1.5} \times \sum_{\substack{t=1, \\ Ret(r_j,t,10)\leq m}}^{N} \left(Ret(r_j, t, 10) - \hat{\mu}^{Ret(j)}_{Ret\leq m}\right)^2}$$

$$\widehat{\text{ASigma}}^{Ret(j)}_{\text{up}} = \hat{\mu}^{Ret(j)}_{Ret>m} + C_{\text{ES}} \times \sqrt{\frac{1}{N_{\text{up}} - 1.5} \times \sum_{\substack{t=1, \\ Ret(r_j,t,10)>m}}^{N} \left(Ret(r_j, t, 10) - \hat{\mu}^{Ret(j)}_{Ret>m}\right)^2}$$

where:

- $C_{\text{ES}} = 3$

The calibrated shocks should be then calculated as:

$$CS_{\text{down}}(r_j) = \widehat{\text{ASigma}}_{\text{down}}^{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{(N_{\text{down}} - 1.5)}}\right)$$

And

$$CS_{\text{up}}(r_j) = \widehat{\text{ASigma}}_{\text{up}}^{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{(N_{\text{up}} - 1.5)}}\right)$$

Where also in this case:

$\left(0.95 + \frac{1}{\sqrt{(N_{\text{down}} - 1.5)}}\right)$ and $\left(0.95 + \frac{1}{\sqrt{(N_{\text{up}} - 1.5)}}\right)$ are the uncertainty compensation factors.

Method 3 – the fallback method

Institutions are required to cover the first step in the stepwise method using the fallback method whenever $N < 12$.

The EBA expects that only in a few cases will institutions actually be in the situation of using the fallback method; in particular, as mentioned above, this happens where the number of observations for a risk factor in the stress period is less than one per month on average. In the light of the limited number of cases where it will be used, the fallback method is designed to be simple, considering that any extra layer of complexity may result in more costs than benefits.

These final draft RTS set out the fallback method as follows.

- Where the non-modellable risk factor coincides with one of the risk factors included in the sensitivity-based method (i.e. the risk factors defined in Section 3, subsection 1, of the amended CRR in Chapter 1a, 'Alternative standardised approach'), the institution should:

    1. identify the risk weight to be used in the sensitivity-based method for that risk factor as specified in Section 6 of the CRR in Chapter 1a;

    2. multiply that risk weight by $1.15 \cdot \sqrt{\frac{10}{LH(j)}}$, where the liquidity horizon for the risk factor is obtained in accordance with Article 325bd(7) of the CRR.

The rescaling factor $\sqrt{\frac{10}{LH(j)}}$ has been included to ensure that, regardless of the methodology used (e.g. the asymmetrical sigma method or the fallback method), institutions obtain an extreme scenario of future shock on a 10-day horizon. The risk weights in the sensitivity-based method have been calibrated to capture the liquidity horizon of the risk factors; the scalar $\sqrt{\frac{10}{LH(j)}}$ therefore excludes this effect.

The idea behind this approach is that the risk weight prescribed in the standardised approach is deemed to represent a good starting point for determining an extreme scenario of future shock for a non-modellable risk factor. The scalar 1.15 has been included in these final draft RTS to provide a further incentive for institutions to collect data for risk factors with very low observability and to ensure that the fallback method leads to a more conservative result than any other approach included in these final draft RTS (e.g. the asymmetrical sigma method).

It should be noted that the risk weights in the sensitivity-based method already provide the institutions with the type of shocks that need to be applied, i.e. relative shocks or absolute shocks. Finally, these final draft RTS specify that for (IMA) risk factors belonging to a curve or a surface that differ from the risk factors identified in the sensitivity-based method only in the maturity dimension, the institution should use the risk weight of the adjacent (alternative standardised approach) risk factor.

For example, if an institution has in its risk measurement model the risk factor representing the 1.2-year tenor of a risk-free yield curve, then the risk weight applicable to that risk factor should be 1.6%, considering that 1.6% is the absolute shock applicable in the sensitivity-based method for the 1-year tenor of a risk-free yield curve.

Where the non-modellable risk factor is not a risk factor in the sensitivity-based method, then the institution is to obtain the upward and downward calibrated shocks by means of another risk factor. More precisely, these final draft RTS specify that the institution is to identify another risk factor (r_{other}) of the same nature as the non-modellable risk factor (r_{original}) for which more than 12 observations are available in the stress period. The institution would then need to apply the first step in the stepwise method (using either the historical method or the asymmetrical sigma method) to that risk factor to obtain a downward and an upward calibrated shock for that risk factor and to then rescale it with the scalar $1.35/\left(0.95 + \frac{1}{\sqrt{(N_{\text{other}} - 1.5)}}\right)$, to obtain the shocks for the original non-modellable risk factor, i.e.:

$$CS_{\text{down}}(r_{\text{original}}) = CS_{\text{down}}(r_{\text{other}}) * 1.35/\left(0.95 + \frac{1}{\sqrt{(N_{\text{other}_{\text{down}}} - 1.5)}}\right)$$

$$CS_{\text{up}}(r_{\text{original}}) = CS_{\text{up}}(r_{\text{other}}) * 1.35/\left(0.95 + \frac{1}{\sqrt{(N_{\text{other}_{\text{up}}} - 1.5)}}\right)$$

where:

- $CS_{\text{down}}(r_{\text{other}})$ and $CS_{\text{up}}(r_{\text{other}})$ are the downward and upward calibrated shocks for the risk factor (r_{other}) that is of the same nature as the non-modellable risk factor for which the institution needs to compute the stress scenario risk measure (r_{original}).

- $N_{\text{other}_{\text{down}}}, N_{\text{other}_{\text{up}}}$ represent the number of return observations available for the risk factor r_{other} that have been used to determine $CS_{\text{down}}(r_{\text{other}}), CS_{\text{up}}(r_{\text{other}})$ in the first step in the stepwise method.

Dividing $CS_{\text{up}}(r_{\text{other}}), CS_{\text{down}}(r_{\text{other}})$ by $\left(0.95 + \frac{1}{\sqrt{(N_{\text{other}_{\text{up}}} - 1.5)}}\right)$ and $\left(0.95 + \frac{1}{\sqrt{(N_{\text{other}_{\text{down}}} - 1.5)}}\right)$ is done to offset the effect of the uncertainty compensation factor that is used by institutions when calibrating those shocks. However, institutions are also required to multiply those shocks by 1.35 to ensure that the fallback method leads to more conservative results than, for example, the asymmetrical sigma method, while at the same time limiting cases where the institution might prefer to use the maximum loss approach prescribed in point (b) of Article 325bk(3) of the CRR.

These final draft RTS specify that r_{other} is considered to be of the same nature where it captures the same type of risk as r_{original} and it differs from r_{original} only in features that are not expected to have a significant impact on the final value of the calibrated shock. In particular, the volatility characterising r_{other} in the stress period must not underestimate the volatility of r_{original}.

Step S.2 – determine the calibrated stress scenario risk factor range

In the third step in the stepwise method, institutions are required to determine the calibrated stress scenario risk factor range by applying the shock obtained in accordance with the previous step to the value of the non-modellable risk factor at the reference date.

More precisely, the calibrated shocks $CS_{down}(r_j), CS_{up}(r_j)$ determined using one of the methods outlined above (i.e. the historical method, asymmetrical sigma method or fallback method) should be applied to the risk factor at the reference date $r_j(D^*)$ in both directions to obtain the calibrated stress scenario risk factor range, i.e.

$$CSSRFR\left(r_j(D^*)\right) = \left[r_j(D^*) \ominus CS_{\text{down}}(r_j), r_j(D^*) \oplus CS_{\text{up}}(r_j)\right]$$

which means

$$CSSRFR\left(r_j(D^*)\right) = \left[r_j(D^*) - CS_{\text{down}}(r_j), r_j(D^*) + CS_{\text{up}}(r_j)\right]$$

or

$$CSSRFR\left(r_j(D^*)\right) = \left[r_j(D^*) \times e^{-CS_{\text{down}}(r_j)}, r_j(D^*) \times e^{+CS_{\text{up}}(r_j)}\right]$$

or

$$CSSRFR\left(r_j(D^*)\right) = \left[r_j(D^*) \times \left(1 - CS_{\text{down}}(r_j)\right), r_j(D^*) \times \left(1 + CS_{\text{up}}(r_j)\right)\right]$$

depending on whether absolute, logarithmic or relative returns are used for the non-modellable risk factor. More generally (i.e. in case the institution uses another return approach), the calibrated stress scenario risk factor range should be calculated consistently with the return approach.

Step S.3 – determine the extreme scenario of future shock

In the last step, in principle, institutions are required to determine the extreme scenario of future shock by identifying the shock leading to the worst loss that the institution might incur should the non-modellable risk factor move within the identified calibrated stress scenario risk factor range.

More precisely, given the calibrated stress scenario risk factor range $CSSRFR\left(r_j(D^*)\right)$ determined in accordance with the previous step, the extreme scenario of future shock should be determined as an approximation to the risk factor movement in the range leading to the highest loss. In a formula:

$$FS_{D^*}[r_j] = \underset{r_j \in Grid\left(r_j(D^*)\right)}{\operatorname{argmax}} [\text{loss}_{D^*}^{\text{single}}(r_j)]$$

Mindful of the computational burden that a revaluation of the loss on too many points of the range would entail, these final draft RTS require institutions to perform the revaluation on four points only, specifically:

$$Grid\left(r_j(D^*)\right) = \left\{r_j(D^*) \ominus i \times \frac{CS_{\text{down}}(r_j)}{5}, r_j(D^*) \oplus i \times \frac{CS_{\text{up}}(r_j)}{5} \mid i = 4, 5\right\}$$

As mentioned above, the extreme scenario of future shock corresponds to the risk factor movement among those identified in the grid leading to the worst loss. Accordingly, the stress scenario risk measure, as defined in Article 325bk(1) of CRR2, is the loss that is incurred when that extreme scenario of future shock applies.

2.1.4.4 Stepwise method for determining the extreme scenario of future shock for non-modellable risk factors belonging to non-modellable regulatory buckets

This subsection is relevant where the institution calculates the stress scenario risk measure at regulatory bucket level in accordance with the possibility referred to in Article 325bk(3)(c) of the CRR. As mentioned previously, these final draft RTS require institutions to identify the scenario of future shocks in a 'contoured' family of shocks.

Generally, the approach for buckets is completely analogous to that for single risk factors; the difference is that the shocks are defined for the set of all risk factors in a regulatory bucket.

Step C.1 – calibrate the downward and upward shocks

Analogously to the treatment proposed for single non-modellable risk factors, institutions are required to determine a downward and an upward calibrated shock for regulatory buckets.

For this purpose, for each of the risk factors in the non-modellable regulatory bucket, institutions need to determine the time series of 10-business-days returns in the stress period S^i. In contrast to the direct method, all dates for which returns are available for a risk factor in the non-modellable bucket should be retained.

As a result, the institution obtains the sample $Ret(r_j, 1{,}10), \ldots, Ret(r_j, N, 10)$ of 10-business-days returns for all risk factors $\{r_j \in B\}$ in the regulatory bucket B.

Furthermore, these final draft RTS specify that institutions should identify the upward and downward shocks, respectively $CS_{\mathrm{up}}(r_j)$ and $CS_{\mathrm{down}}(r_j)$, for all risk factors within the non-modellable bucket. To do so, the institution should apply one of the methods that have been outlined for calibrating the shocks for risk factors for which the institution calculates the stress scenario risk measure for the risk factor on a stand-alone basis, i.e. the historical method, asymmetrical sigma method or fallback method. The same method is to be used consistently for all risk factors in the bucket; specifically, as mentioned previously, (i) where for all risk factors within the bucket $N \geq 200$, institutions must use the historical method; (ii) where there is a risk factor within the bucket for which $\mathrm{N} < 12$, institutions must use the fallback method; and (iii) in all other cases institutions must use the asymmetrical sigma method.

In other words, institutions need to apply steps S.0, S.1 and S.2 of subsection 2.1.4.3 consistently for each risk factor in the non-modellable bucket.

Step C.2 – determine the extreme scenario of future shock

The second and last step determines a single extreme scenario of future shock from the individual risk factor shock ranges.

In particular, the methodology requires banks to multiply the calibrated shocks $CS_{\mathrm{down}}(j)$ and $CS_{\mathrm{up}}(j)$ that have been derived for each risk factor within the regulatory bucket by a bucket shock strength $\beta \in [0, 1]$ and to obtain accordingly a vector of upward shocks and downward shocks:

$$v_\beta^{\mathrm{up}} = [\beta * CS_{\mathrm{up}}(1); \beta * CS_{\mathrm{up}}(2); \beta * CS_{\mathrm{up}}(3); \ldots]$$

and

$$v_\beta^{\mathrm{down}} = [\beta * CS_{\mathrm{down}}(1); \beta * CS_{\mathrm{down}}(2); \beta * CS_{\mathrm{down}}(3); \ldots]$$

As a result, the scenario of future shock should be the vector of upward shocks v_β^{up} or the vector of downward shocks v_β^{down} leading to the worst loss when scanning $\beta \in [0, 1]$, where the loss corresponding to the upward shocks is defined as:

$$\mathrm{loss}_{D^*}^{\mathrm{Bucket,contoured\ up}}(\beta) = PV(\{r_j^* \in B\}, \{r_i^* \notin B\} \text{ fixed}) - PV\left(\left\{r_j(D^*) \oplus v_\beta^{up}(j), r_j \in B\right\}, \{r_i^* \notin \mathrm{B}\} \text{ fixed}\right)$$

and the loss corresponding to the downward shocks is defined as:

$$\text{loss}_{D^*}^{\text{Bucket,contoured down}}(\beta)$$
$$= PV\big(\{r_j^* \in B\}, \{r_i^* \notin B\} \text{ fixed}\big) - PV\big(\{r_j(D^*) \ominus\ v_\beta^{down}(j), r_j \in B\}, \{r_i^* \notin \text{B}\} \text{ fixed}\big)$$

In this case also, in principle, institutions should scan several values of β to identify the shock leading to the worst loss. However, mindful of the computational burden to which evaluating the loss on too many points may lead, these final draft RTS require institutions to evaluate the loss function for four contoured shocks only.

More precisely, institutions are required to consider the following values of β to determine the extreme scenario of future shock:

$$\beta = [0.8, 1]$$

They will obtain the shocks $v_{0.8}^{\text{up}}$, v_1^{up}, $v_{0.8}^{\text{down}}$, v_1^{down}, from which they have to select the one leading to the worst loss as the extreme scenario of future shock.

2.1.5 Non-pricing scenarios

As mentioned in subsection 2.1.2, ‘General provisions’, these final draft RTS specify that the extreme scenario of future shock should be applied in the same manner as in the expected shortfall model. Therefore, when calculating the loss corresponding to a future shock applied to a non-modellable risk factor, institutions must use the pricing functions of the risk measurement model.

There may be cases where the scenarios generated by the methodologies presented in these final draft RTS could lead the pricers (i.e. the pricing methods and pricing model parametrisations used by institutions for pricing financial instruments) to not provide a meaningful result when applied to some instrument positions. This subsection refers to these scenarios as ‘non-pricing scenarios’. It is worth mentioning that those scenarios are not non-pricing per se; usually, they are non-pricing only in the context of certain products (or even certain pricers).

The same problem may occur when a shock is applied to modellable risk factors while keeping the non-modellable risk factors fixed, resulting in a non-pricing scenario when calculating the partial expected shortfall figures under the IMA expected shortfall model in accordance with Article 325bc(3)(4). Furthermore, it may occur under the current IMA when scenarios are generated for computing the (stressed) value-at-risk figures.

The EBA consulted on what current banking practices to address the abovementioned issue are and sought proposals for addressing it. The aim was, following the consultation process, to include in the RTS requirements that would prevent practices that are not deemed prudentially sound. In particular, the EBA considers practices whereby the loss corresponding to a non-pricing scenario is set to zero, capped or discarded as inappropriate, and it sought potential solutions that would address the issue only where it occurs (i.e. solutions that would target the specific product for which the scenario is a non-pricing one, rather than global measures that would impact instruments for which the scenario is not non-pricing).

In the light of the feedback received on the CP, these final draft RTS specify that where the pricing functions of the institution cannot determine the corresponding loss for some financial instruments under a scenario of future shock applied to one or several non-modellable risk factors, institutions should identify these financial instruments and use sensitivity-based pricing methods to calculate the corresponding loss. It is important to highlight the following points.

(i) Institutions are to derive a sensitivity-based loss only for the financial instruments for which the pricers in the risk measurement model cannot determine the loss corresponding to a shock. For all other instruments, the loss is to be determined in accordance with the pricing functions of the risk measurement model.

(ii) Institutions are expected to include at least the material first order and material second order terms of a Taylor series approximation to reflect the change in the price due to changes in non-modellable risk factors.

(iii) Competent authorities are expected to exercise the power granted in Article 325bk(3)(b) and require institutions to apply the regulatory extreme scenario of future shock if they assess that institutions are not treating non-pricing scenarios in line with the previous points. Specific documentation requirements are included in these final draft RTS to support competent authorities in ascertaining that there is no abuse on the part of institutions when it comes to implementing the provisions for non-pricing scenarios.

2.2 Regulatory extreme scenario of future shock that institutions may use (or may be required to use) when unable to develop an extreme scenario of future shock

Article 325bk(3)(b) of the CRR mandates the EBA to specify in these final draft RTS a regulatory extreme scenario of future shock that institutions may use when they are unable to develop an extreme scenario of future shock in accordance with Article 325bk(3)(a) or that the competent authority may require an institution to use when it is not satisfied with the extreme scenario of future shock developed by the institution.

In general, these final draft RTS are fairly prescriptive with respect to the methodology that institutions should use to generate the extreme scenario of future shock, in order to ensure a harmonised approach in the Union. However, in the light of the variety of risk factors and positions that may be found in an internal risk measurement model, a methodology for extreme scenarios of future shocks may not yield meaningful results for all risk factors under all circumstances.

For example, in the fallback method forming part of the stepwise method, under the ‘same type of risk factor’ option, it may not be an easy matter for the institution to identify a risk factor of the same nature as the non-modellable risk factor from which a meaningful shock can be calibrated, or, for example, the competent authority may assess that the risk factor that was deemed of the same nature as the non-modellable risk factor is not fit for the purpose of generating a shock that is meaningful (and conservative enough) for the original risk factor.

Moreover, risk factors that are parameters for curves or surfaces in particular may pose specific challenges. Therefore, there is a need to identify a 'last resort' approach that can be used for all kinds of risk factors that the institution may have.

The Basel standards specify that if the competent authority is not satisfied with the shock generated by the institution, it may require the institution to consider the maximum loss that might occur due to a change in the non-modellable risk factor as the stress scenario risk measure for that non-modellable risk factor.

In line with that requirement, these final draft RTS specify that the regulatory extreme scenario of future shock is that leading to the maximum loss that might occur due to a change in the non-modellable risk factor. If the losses are not strictly monotonous (and continuous) in the shocks, several shocks may lead to the same maximum loss (e.g. for binary options) and one such shock is to be considered the regulatory extreme scenario of future shock.

Where such a maximum loss does not take a finite value (e.g. for short positions in shares or for other derivatives), institutions should take an approach using the quantitative and qualitative information available to determine a prudent value for the loss that could occur due to a change in the value of the non-modellable risk factor. That loss must be determined targeting a level of certainty equal to 99.95%. In other words, the expert-based approach should result in the identification of a loss that cannot be exceeded in 99.95% of cases on a 10-business-days horizon (i.e. the 99.95% quantile). To that end, institutions are to consider the skewness and the excess kurtosis that may characterise the returns of the non-modellable risk factors in a period of financial stress.

From a mathematical point of view, the maximum loss is a loss that cannot be exceeded in any case (i.e. a level of certainty equal to 100%). Therefore, the level of confidence if the maximum loss is not finite should not be too distant from 100%, while allowing the methodology to identify a loss that might actually occur (albeit with low probability). For a Gaussian distribution, the 99.95% quantile is about 1.4 times the expected shortfall at 97.5%, so the maximum loss under the regulatory extreme scenario of future shock may not actually be significantly higher than that obtained using the other methods (to which the uncertainty compensation factor is applied additionally).

The value of the loss calibrated on a 10-business-days horizon should then be multiplied by $\sqrt{\frac{\mathrm{LH_{adj}(j)}}{10}}$, where $\mathrm{LH_{adj}(j)}$ is the relevant liquidity horizon floored at 20 days.

2.3 Circumstances under which institutions may calculate a stress scenario risk measure for more than one non-modellable risk factor

Article 325bk(3)(c) of the CRR mandates the EBA to specify the circumstances under which institutions may calculate a stress scenario risk measure for more than one non-modellable risk factor. The FRTB standards specify that a bank may be permitted to calculate stress scenario capital requirements at the bucket level (using the same buckets that the bank uses to assess modellability) for risk factors that belong to curves, surfaces or cubes (i.e. a single stress scenario capital charge for all the non-modellable risk factors that belong to the same bucket).

In its final draft RTS on the assessment of modellability of risk factors under Article 325be(3), the EBA included the possibility for institutions to use a 'regulatory bucketing approach', assessing the modellability of risk factors at bucket level rather than at risk factor level. In accordance with the regulatory bucketing approach, institutions may include more than one risk factor within the same regulatory bucket; this cannot be done under the 'own bucketing approach', where banks are required to include only one risk factor within each bucket.

On this basis, these final draft RTS plainly implement the FRTB standards by specifying that institutions may calculate a single stress scenario risk measure for more than one non-modellable risk factor if those risk factors belong to the same regulatory bucket and the institutions use the regulatory bucketing approach for assessing the modellability of those risk factors.

2.4 Aggregation of the stress scenario risk measures

The EBA is mandated by Article 325bk(3)(d) of the CRR to specify how institutions are to aggregate the stress scenario risk measures that correspond to the losses incurred by the institution's portfolio when the extreme scenario is applied to the non-modellable risk factors (or, where applicable, to a non-modellable regulatory bucket). In other words, the EBA has to define the weights applicable to each stress scenario risk measure and the aggregation formula that has to be used to determine the capital requirements corresponding to non-modellable risk factors.

These final draft RTS propose an aggregation formula that aims to capture the effects described below.

- The non-linearity of the loss function for non-modellable risk factors for which the institution has identified the extreme scenario of future shock using the stepwise method. Unlike the direct method, where institutions are required to calculate directly the expected shortfall of the losses, the stepwise method is based on the assumption that $ES\left(loss\left[r_j(D_t)\right]\right)$ is approximately equal to $loss\left(ES\left[r_j(D_t)\right]\right)$. However, when losses grow faster than linearly, the expected shortfall of losses for varying $r_j(D_t)$ is higher than the loss of the expected shortfall $r_j(D_t)$ (see Annex 3 to the 2017 EBA discussion paper for details). Accordingly, such non-linear effects should be captured in the aggregation formula.

- Uncertainty due to the lower observability of non-modellable risk factors, statistical estimation error and uncertainty in the underlying distribution for non-modellable risk factors. It should be noted that where the institution applies the stepwise method this uncertainty is already captured when identifying the extreme scenario of future shock; accordingly, these effects have to be captured in the aggregation formula only for risk factors for which the extreme scenario of future shock has been identified using the direct method.

- The liquidity horizons of the relevant non-modellable risk factors, since the general methodology has been designed to obtain a 10-business-days stress scenario risk measure, i.e. the general methodology does not capture the liquidity horizon of the risk factor.

- The correlation effects among non-modellable risk factors.

The aggregation formula to be used to calculate the capital charge associated with the non-modellable risk factors is the following, transposing FRTB standard 33.17:

$$OFR_{NMRF} = \sqrt{\sum_{\substack{m=1,\\ m \text{ idiosyncratic}\\ \text{credit spread risk}}}^{N_{P,ICSR}} \left(RSS_{D^*}^{m,S}\right)^2 + \sqrt{\sum_{\substack{k=1,\\ k \text{ idiosyncratic}\\ \text{equity risk factor}}}^{N_{P,IERF}} \left(RSS_{D^*}^{k,S}\right)^2}$$

$$+ \sqrt{\left(\rho \times \sum_{\substack{j=1,\\ j \text{ not idiosyncratic}\\ \text{credit spread}\\ \text{nor}\\ \text{idiosyncratic}\\ \text{equity risk factor}}}^{N_P - N_{P,ICSR} - N_{P,IERF}} RSS_{D^*}^{j,S}\right)^2 + (1-\rho^2) \times \sum_{\substack{j=1,\\ j \text{ not idiosyncratic}\\ \text{credit spread nor}\\ \text{idiosyncaratic}\\ \text{equity risk factor}}}^{N_P - N_{P,ICSR} - N_{P,IERF}} \left(RSS_{D^*}^{j,S}\right)^2}$$

where:

$$RSS_{D^*}^{j,S} = \begin{cases} \sqrt{\dfrac{LH_{\text{adj}}(j)}{10}} \times SS_{10\text{days},D^*}^{j,S} \times \kappa_{D^*}^{j} \text{ where } SS_{10\text{days},D^*}^{j,S} \text{ is obtained with the stepwise method} \\ \sqrt{\dfrac{LH_{\text{adj}}(j)}{10}} \times SS_{10\text{days},D^*}^{j,S} \times UCF \text{ where } SS_{10\text{days},D^*}^{j,S} \text{ is obtained with the direct method} \\ \text{maximum loss where provisions in Section 2.2 are applied} \end{cases}$$

Thus, where institutions determine the maximum loss in accordance with Section 2.2 to obtain the stress scenario risk measure, they should consider that loss as the rescaled stress scenario risk measure corresponding to the non-modellable risk factor (or non-modellable bucket, where applicable) in the aggregation formula.

And:

- $\rho = 0.6$.
- $i \in \{\text{IR}, \text{CS}, \text{EQ}, \text{FX}, \text{CM}\}$ denotes the risk class of the risk factor j.
- $SS_{10\text{days},D^*}^{j,S}$ denotes the 10-business-days stress scenario risk measure for the non-modellable risk factor j (or non-modellable bucket, where applicable) calculated on the reference date D^* and calibrated on the stress period S^i.

- $LH_{\text{adj}}(j)$ is the liquidity horizon of the non-modellable risk factor j adjusted to take into account the 20-day floor to be applied to non-modellable risk factors in accordance with FRTB 33.16(1), i.e.:

$$LH_{\text{adj}}(j) = \max(20, LH(j))$$

  Where $LH(j)$ is the liquidity horizon of the risk factor j obtained in accordance with the final draft RTS on the determination of the liquidity horizon for a given risk factor in accordance with Article 325bd(7) of the CRR.

- $\kappa_{D^*}^{j}$ denotes the non-linearity adjustment for the non-modellable risk factor j (or non-modellable bucket, where applicable) and is relevant only where the institution has used the stepwise method to obtain the extreme scenario of future shock. The methodology to be used to compute such parameter is set out in subsection 2.4.1, 'Calculation of the non-linearity adjustment'.

- UCF is the uncertainty compensation factor capturing uncertainty due to sample estimation error and to the lower observability of non-modellable risk factors and is relevant only where the institution has used the direct method to obtain the extreme scenario of future shock. Subsection 2.4.2, 'Calculation of the uncertainty compensation factor' sets out how institutions should calculate the uncertainty compensation factor UCF.

It should be noted that the stress scenario risk measures are to be floored to zero.

In addition, these final draft RTS identify conditions for institutions to classify a risk factor as reflecting idiosyncratic equity (or credit spread) risk only; these requirements are in line with the FRTB standards, which require institutions to prove by means of statistical tests that aggregating the stress scenario risk measures with a zero-correlation assumption is appropriate. Risk factors belonging to the same curve or surface are in general not expected to be aggregated with a zero-correlation assumption, since risk factors that differ only in the maturity or moneyness dimension are typically highly correlated.

2.4.1 Calculation of the non-linearity adjustment

As mentioned above, the stepwise method is based on the assumption that $ES\left(loss\left[r_j(D_t)\right]\right)$ is approximately equal to $loss\left(ES\left[r_j(D_t)\right]\right)$, which is true for linear loss profiles. However, when losses grow faster than linearly, the expected shortfall of losses for varying $r_j(D_t)$ is higher than the loss of the expected shortfall $r_j(D_t)$. The same reasoning applies also where the institution is allowed to calculate the stress scenario risk measure at bucket level.

Non-linearity adjustment $\kappa_{D^*}^{j}$ for a single non-modellable risk factor

For a given non-modellable risk factor j, institutions have to calculate the non-linear adjustment $\kappa_{D^*}^{j}$ where the extreme scenario of future shock is calculated in accordance with the stepwise method and that extreme scenario occurs at the boundaries of the calibrated stress scenario shock range at reference date $CSSRFR\left(r_j(D^*)\right)$.

Where the extreme scenario of future shock does not coincide with one of the boundaries of the range (i.e. it does not coincide with either $CS_{\mathrm{up}}(r_j)$ or $CS_{\mathrm{down}}(r_j)$), then $\kappa_{D^*}^{j}$ should be set to 1.[9]

More precisely, these final draft RTS require institutions to determine the adjustment as follows:

$$\kappa_{D^*}^{j} = \min(\max\left[\kappa_{\min}, 1 + \frac{\mathrm{loss}_{D^*}(r_{j,-1}) - 2 \times \mathrm{loss}_{D^*}(r_{j,0}) + \mathrm{loss}_{D^*}(r_{j,1})}{2 \times \mathrm{loss}_{D^*}(r_{j,0})} \times (\phi - 1) \times 25\right]; \kappa_{\max})$$

Where the tail shape parameter $\phi \geq 1$ is a measure of the quadratic dispersion of the risk factor returns in the tail around ES(97.5%). In particular:

- Where the institution has used the historical method of the stepwise method to calibrate the upward and downward shocks, and the extreme scenario of future shock corresponds to a downward shock:

$$\phi = \hat{\phi}_{\mathrm{Left}}(Ret(j), \alpha) = \frac{\frac{1}{\alpha N} \times \left\{\sum_{i=1}^{[\alpha N]} Ret(j)_{(\mathrm{i})}^{2} + (\alpha N - [\alpha N]) Ret(j)_{([\alpha N]+1)}^{2}\right\}}{\left\{\widehat{\mathrm{ES}}_{\mathrm{Left}}(Ret(j), \alpha)\right\}^2}$$

  where:

  - $Ret(j)$ is the order statistics of the time series of 10-business-days returns for the non-modellable risk factor j. In other words, $Ret(j)_{(\mathrm{i})}$ represents the *i*-th smallest observation in that time series.
  - $\alpha = 2.5\%$.
  - N is the number of observations in the time series of 10-business-days returns for the non-modellable risk factor j.
  - $[\alpha N]$ denotes the integer part of the product αN.

- Where the institution has used the historical method of the stepwise method to calibrate the upward and downward shocks, and the extreme scenario of future shock corresponds to an upward shock:

$$\phi = \hat{\phi}_{\mathrm{Right}} = \hat{\phi}_{\mathrm{Left}}(-Ret(j), \alpha)$$

i.e. institutions have to calculate the $\hat{\phi}_{\mathrm{Left}}$ for the order statistics $(-Ret(j))$.

[9] Where the loss is a continuous function of the risk factor shock, if the extreme scenario of future shock coincides with a point in the middle of the range, at that point the loss function is concave (point of local max.). Therefore, there is no need to capture the non-linearity effect.

- Where the institution has used the asymmetrical sigma method or the fallback method of the stepwise method to calibrate the upward and downward shocks, a fixed value is used:

$$\phi = 1.04$$

And where:

$$h = \begin{cases} \dfrac{CS_{\text{up}}(r_j)}{5} \text{ where the extreme scenario of future shock is } \mathrm{CS_{up}}(\mathrm{r_j}) \\ \dfrac{CS_{\text{down}}(r_j)}{5} \text{ where the extreme scenario of future shock is } \mathrm{CS_{down}}(\mathrm{r_j}) \end{cases}$$

$$r_{j,0} = \begin{cases} r_j(D*) \oplus CS_{\text{up}}(r_j) \text{ where the extreme scenario of future shock is } CS_{\text{up}}(r_j) \\ r_j(D*) \ominus CS_{\text{down}}(r_j) \text{ where the extreme scenario of future shock is } CS_{\text{down}}(r_j) \end{cases}$$

And:

$$r_{j,-1} = r_{j,0} \ominus h$$

$$r_{j,+1} = r_{j,0} \oplus h$$

It should be noted that the size of the step h has been set such that institutions can re-use the values of the loss function for the two outermost points in scanning the calibrated stress scenario risk factor range.

Finally:

- κ_{min} = 0.9, which sets the lower boundary of κ^j_{D*}
- $\kappa_{\text{max}} = 5$, which caps the value of κ^j_{D*}

Non-linearity adjustment κ^B_{D*} for a non-modellable bucket

For a given non-modellable regulatory bucket B, institutions have to calculate the non-linear adjustment κ^B_{D*} where the extreme scenario of future shock occurs for $\beta = 1$ (when applied either to the vector of upward shocks or to the vector of downward shocks). If the extreme scenario of future shock occurs for $\beta < 1$, then κ^B_{D*} should be set to 1.

In particular:

- Where the extreme scenario of future shock corresponds to a downward shift in the risk factors in the bucket, the final draft RTS require the institution to determine the adjustment as follows

$$\kappa_{D^*}^{B} = \min(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{D^*}^{\text{bucket,contoured,down}}(\beta_{-1}) - 2\times\text{loss}_{D^*}^{\text{bucket,contoured down}}(\beta_0) + \text{loss}_{D^*}^{\text{bucket,contoured down}}(\beta_1)}{2\times\text{loss}_{D^*}^{\text{bucket,contoured down}}(\beta_0)} \times (\phi_{median} - 1) \times 25\right];\ \kappa_{\max})$$

- Where the extreme scenario of future shock corresponds to an upward shift in the risk factors in the bucket, these final draft RTS require the institution to determine the adjustment as follows:

$$\kappa_{D^*}^{B} = \min(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{D^*}^{\text{bucket,contoured,up}}(\beta_{-1}) - 2\times\text{loss}_{D^*}^{\text{bucket,contoured up}}(\beta_0) + \text{loss}_{D^*}^{\text{bucket,contoured up}}(\beta_1)}{2\times\text{loss}_{D^*}^{\text{bucket,contoured up}}(\beta_0)} \times (\phi_{median} - 1) \times 25\right];\ \kappa_{\max})$$

Where in both cases:

- $\beta_{-1} = 0.8$
- $\beta_0 = 1$
- $\beta_1 = 1.2$

And where ϕ_{median} is the median of the ϕ_i calculated for each risk factor belonging to the bucket in accordance with the methodology for calculating ϕ at risk factor level set out above.

Finally:

- $\kappa_{\min}$ = 0.9, which sets the lower boundary of $\kappa_{D^*}^{B}$
- $\kappa_{\max} = 5$, which caps the value of $\kappa_{D^*}^{B}$

2.4.2 Calculation of the uncertainty compensation factor

UCF is the uncertainty compensation factor capturing uncertainty due to the lower observability of non-modellable risk factors and is relevant only where the institution has used the direct method to obtain the extreme scenario of future shock.

Where the institution uses the stepwise method, then when calibrating the downward and upward shocks (e.g. using the historical method), the institution captures the uncertainty when estimating those shocks by means of an uncertainty compensation factor set equal to $\left(0.95 + \frac{1}{\sqrt{(N-1.5)}}\right)$ and applied in the calibrated shock.

When using the direct method, institutions calculate the expected shortfall on the losses in the stress period directly. As a result, the extreme scenario of future shock is implicitly defined; in other words, the extreme scenario of future shock is a shock for which the stress scenario risk measure (on a 10-business-days horizon) corresponds to the expected shortfall of the losses estimated using the direct method. Given this peculiarity of the direct method (i.e. the fact that the extreme scenario of future shock is implicitly defined), the uncertainty in estimating the expected shortfall of the losses is captured in the aggregation formula. The same compensation factor applied in the context of the stepwise method, $UCF = \left(0.95 + \frac{1}{\sqrt{(N-1.5)}}\right)$ is also to be used where institutions use the direct method.

3 Draft regulatory technical standards on the calculation of the stress scenario risk measure under Article 325bk(1) of Regulation (EU) No 575/2013 (Capital Requirements Regulation 2 – CRR2)

COMMISSION DELEGATED REGULATION (EU) No …/..

of XXX

supplementing Regulation (EU) No 575/2013 of the European Parliament and of the Council with regard to regulatory technical standards on the calculation of the stress scenario risk measure under Article 325bk(1) of Regulation (EU) No 575/2013

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EU) No 575/2013 of 26 June 2013 of the European Parliament and of the Council on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012[10], and in particular the fourth subparagraph of Article 325bk(3) thereof,

Whereas:

(1) The market risk own funds requirements under the alternative internal model approach set out in Part Three, Title IV, Chapter 1b of Regulation (EU) No 575/2013 for risk factors that are not assessed to be modellable in accordance with Article 325be of that Regulation may significantly contribute to the total own funds requirements for market risk that an institution, for which the permission referred to in Article 325az has been granted, is required to meet. Accordingly, in order to ensure a level playing field among institutions in the Union and to minimise regulatory arbitrage, this Regulation should, in accordance with the international standards, set out specific and detailed methodologies for developing extreme scenarios of future shock for non-modellable risk factors.

(2) The quality of the data and the number of observations that are available to determine future shocks for non-modellable risk factors may vary significantly from one non-modellable risk factor to another. In order to ensure an appropriate development of extreme scenarios of future shock for a wide range of cases, this Regulation should provide alternative sets of methodologies that institutions may use depending on the number of observations that are available for each non-modellable risk factor. In addition, this Regulation should require institutions to reflect in their calculations that when less data are available, the estimates or values used to determine the extreme scenarios of future shock have a higher uncertainty and should become more conservative.

(3) One method to determine the extreme scenario of future shock for a non-modellable risk factor should consist of directly calculating the expected shortfall measure of the losses that would occur when varying that risk factor to its historically observed levels during the relevant stress period. However, such a direct method would provide reliable results only where the institution has a significant amount of data in the stress period and would require many loss calculations per risk factor leading to a high computational effort. Thus, this regulation should identify an alternative method aiming at mitigating those drawbacks.

(4) The alternative method mitigates those drawbacks by a stepwise approach. It is possible to approximate the expected shortfall measure of the losses that may occur following a change in a non-modellable risk factor by first calculating an expected shortfall measure on the returns observed for that risk factor, and then calculating the

[10] [10] OJ L 176, 27.6.2013, p. 1.

loss corresponding to the movement in the risk factor identified by that expected shortfall measure. Since such an approximation requires a significant lower number of loss calculations than the direct method, it constitutes an appropriate alternative method.

(5) In addition, such stepwise method should also address the specific case where the number of observations for a non-modellable risk factor in the relevant observation period is insufficient to obtain accurate and prudent estimates. Since this situation can be expected to occur only in a limited number of cases, those cases should be addressed by leveraging on methodologies that institutions have implemented for other non-modellable risk factors for which they have more observations or, where possible, on the alternative standardised approach.

(6) To ensure the alignment of the Union with the international standards, the market risk own funds requirements under the alternative internal model approach in relation to non-modellable risk factors should be calibrated to a period of stress that is common to all non-modellable risk factors in the same broad risk factor category referred to in Article 325bd of Regulation (EU) No 575/2013. Therefore, this Regulation should require institutions to identify a stress period for each broad risk factor category and to collect data for non-modellable risk factors for the stress period identified for the category to which they belong, in order to determine extreme scenarios of future shock on the basis of data observed during that period.

(7) In order to ensure harmonisation of practises in the Union, this Regulation specify how institutions identify the stress period. Those specifications should be proportionate to the purpose, and should neither require an excessive computational effort, nor the implementation of specific pricing methods.

(8) In line with the international standards, institutions should be required to determine extreme scenarios of future shock by using the pricing functions of their risk measurement model. Given that there could be scenarios of future shock for which those pricing functions cannot determine the corresponding loss for some financial instruments or commodities, this Regulation should ensure that institutions address those cases in a prudentially sound manner and targeting only those instruments affected by the pricing failure.

(9) In line with subparagraph (2) of Article 325bk(3) of Regulation (EU) No 575/2013, this Regulation requires that the level of own funds requirements for market risk for a non-modellable risk factor is as high as the expected shortfall measure for that risk factor referred in Article 325bb of Regulation (EU) No 575/2013, i.e. an expected shortfall of losses at a 97.5% confidence level over a period of stress. Accordingly, the statistical estimators and the parameters included in this Regulation should be set to ensure such confidence level is met.

(10) In order to ensure the alignment of the Union with the international standards, the regulatory extreme scenario of future shock should be the one leading to the maximum loss that may occur due to a change in the non-modellable risk factor. This regulation should also clarify what institutions should consider as maximum loss in cases where the maximum loss is not finite.

(11) In accordance with the international standards institutions may determine the stress scenario risk measure for more than one non-modellable risk factors, where those

risk factors are part of a curve or a surface and they belong to the same non-modellable bucket among those set out in Commission Delegated Regulation (EU) xx/2020 [RTS on criteria for assessing the modellability of risk factors under Article 325be(3) of Regulation (EU) No 575/2013] and their modellability has been assessed in accordance with the standardised bucketing approach referred to in that Regulation. To avoid any deviation of the Union from the international standards, this regulation should allow institutions to compute a single stress scenario risk measure for more than one non-modellable risk factor under those conditions only.

(12) Institutions should be required to reflect in the aggregation of the stress scenario risk measures risks that were not yet captured when determining the extreme scenario of future shock, e.g. the liquidity horizons of the non-modellable risk factors, and to apply the aggregation formula agreed in the international standards.

(13) This Regulation is based on the draft regulatory technical standards submitted by the European Banking Authority to the Commission.

(14) EBA has conducted open public consultations on the draft regulatory technical standards on which this Regulation is based, analysed the potential related costs and benefits, and requested the opinion of the Banking Stakeholder Group established in accordance with Article 37 of Regulation (EU) No 1093/2010[11],

HAS ADOPTED THIS REGULATION:

SECTION 1

DEVELOPMENT AND APPLICATION OF THE EXTREME SCENARIOS OF FUTURE SHOCK

Article 1

Development and application of the extreme scenarios of future shock at risk factor level

1. Institutions shall develop the extreme scenario of future shock for a non-modellable risk factor for the purposes of Article 325bk(2) of Regulation (EU) No 575/2013 by applying either the direct method in accordance with paragraph 2 and under the conditions set out in paragraph 3, or the stepwise method in accordance with paragraph 4.

2. Institutions determining the extreme scenario of future shock for a non-modellable risk factor with the direct method shall apply the following steps in sequence:

[11] Regulation (EU) No 1093/2010 of the European Parliament and of the Council of 24 November 2010 establishing a European Supervisory Authority (European Banking Authority), amending Decision No 716/2009/EC and repealing Commission Decision 2009/78/EC (OJ L 331, 15.12.2020, p. 12).

(a) they shall determine a time series of losses as follows:

(i) they shall determine in accordance with Article 3 the time series of 10 business days returns for the non-modellable risk factor for the stress period determined in accordance with Article 8;

(ii) they shall shock the value of the non-modellable risk factor by each value in the time series obtained in point (i);

(iii) they shall determine the time series of losses by calculating the losses which would occur if the non-modellable risk factor had the values in the time series obtained in point (ii).

(b) they shall calculate the estimate of the right-tail expected shortfall in accordance with Article 7(2) for the time series of the losses obtained in accordance with point (a).

(c) a shock leading to the loss equal to the estimate of the right-tail expected shortfall obtained in accordance with point (b) shall constitute the extreme scenario of future shock for the non-modellable risk factor.

3. Institutions may use the direct method referred to in paragraph 2 where all of the following conditions are met:

(a) institutions have defined criteria establishing whether to use the direct or the stepwise method, which are consistent over time;
(b) institutions document any change between the direct method and the stepwise method for determining the extreme scenario of future shock, including a justification of the change;
(c) institutions complementarily identify, the extreme scenario of future shock in accordance with the stepwise method on a daily basis for the twenty business days preceding each date for which the own funds requirements for market risk are reported;
(d) the number of losses in the time series referred to in paragraph 2(a)(iii) is greater than or equal to 200.

4. Institutions determining the extreme scenario of future shock for a non-modellable risk factor with the stepwise method shall apply the following steps in sequence:

(a) they shall determine in accordance with Article 3 the time series of 10 business days returns for the non-modellable risk factor for the stress period determined in accordance with Article 8;

(b) they shall determine an upward and a downward calibrated shock from the time series of 10 business days returns referred to in point (a) in accordance with:

(i) the historical method set out in Article 4, where the number of returns in the time series referred to in point (a) is greater than or equal to 200;

(ii) the asymmetrical sigma method set out in Article 5, where the number of returns in the time series referred to in point (a) is lower than 200 and greater than or equal to 12;

(iii) the fallback method set out in Article 6, where the number of returns in the time series referred to in point (a) is lower than 12.

(c) for each shock included in the following grid, institutions shall calculate the loss that occurs when that shock is applied to the non-modellable risk factor:

$$grid = \left\{ \frac{4}{5} \cdot CS_{\mathrm{down}}, CS_{\mathrm{down}}, \frac{4}{5} \cdot CS_{\mathrm{up}}, CS_{\mathrm{up}} \right\}$$

where:

- CS_{down} is the downward calibrated shock obtained as a result of point (b);
- CS_{up} is the upward calibrated shock obtained as a result of point (b).

(d) from the shocks included in the grid referred to in point (c), the shock which leads to the highest loss shall constitute the extreme scenario of future shock for the non-modellable risk factor.

Article 2

Development and application of the extreme scenarios of future shock at standardised bucket level

1. Where institutions calculate a stress scenario risk measure for more than one non-modellable risk factor, institutions shall determine the extreme scenario of future shock for the non-modellable standardised bucket to which those risk factors belong in accordance with Commission Delegated Regulation (EU) xx/2020[12] [to insert RTS on criteria for assessing the modellability of risk factors under Article 325be(3) of Regulation (EU) No 575/2013] by applying either the direct method in accordance with paragraph 2 and under the conditions set out in paragraph 3, or by applying the stepwise method in accordance with paragraph 4.

2. Institutions determining the extreme scenario of future shock for a non-modellable standardised bucket with the direct method shall apply the following steps in sequence:

(a) they shall determine a time series of losses as follows:

[12] Full title + Reference to inserted

(i) for each non-modellable risk factor within the non-modellable bucket, they shall determine in accordance with Article 3 the time series of nearest to 10 business days returns for the stress period determined in accordance with Article 8;

(ii) they shall remove from each time series obtained in accordance with point (i), the values corresponding to dates for which not all those time series have a return;

(iii) for each non-modellable risk factor within the non-modellable bucket, they shall shock the value of the non-modellable risk factor by each value in the corresponding time series obtained as result of point (ii);

(iv) they shall determine the time series of losses by calculating for each date corresponding to a value in the time series obtained as a result of point (iii), the loss that would occur if the non-modellable risk factors in the non-modellable bucket had the values included in those time series for that date.

(b) they shall calculate the estimate of the right-tail expected shortfall in accordance with Article 7(2) for the time series of the losses obtained as a result of point (a);

(c) a scenario of shocks leading to a loss equal to the estimate of the right-tail expected shortfall obtained as a result of point (b) shall constitute the extreme scenario of future shock for the non-modellable bucket;

3. Institutions may use the direct method referred to in paragraph 2 where all of the following conditions are met:

(a) institutions have defined criteria establishing whether to use the direct or the stepwise method, which are consistent over time;
(b) institutions document any change between the direct method and the stepwise method for determining the extreme scenario of future shock, including a justification of the change;
(c) institutions complementarily identify the extreme scenario of future shock in accordance with the stepwise method on a daily basis for the twenty business days preceding each date for which the own funds requirements for market risk are reported;
(d) the number of losses in the time series referred to in paragraph 2(a)(iv) is greater than or equal to 200.

4. Institutions determining the extreme scenario of future shock for a non-modellable standardised bucket with the stepwise method shall apply the following steps in sequence:

(a) for each non-modellable risk factor within the non-modellable standardised bucket they shall determine in accordance with Article 3 the time series of 10 business days returns for the stress period determined in accordance with Article 8;

(b) for each non-modellable risk factor within the non-modellable standardised bucket, they shall determine an upward and a downward calibrated shock from the corresponding time series of 10 business days returns referred to in point (a) in accordance with:

(i) the historical method set out in Article 4, where the number of returns in all the time series of 10 business days returns referred to in point (a) corresponding to the non-modellable risk factors in the non-modellable bucket is greater than or equal to 200;

(ii) the asymmetrical sigma method set out in Article 5, where the condition referred to in point (i) for using the historical method is not met, and the number of returns in all the time series of 10 business days returns referred to in point (a) corresponding to the non-modellable risk factors in the non-modellable bucket is greater than or equal to 12;

(iii) the fallback method set out in Article 6, where there is at least one non-modellable risk factor in the non-modellable bucket for which the number of returns in the time series of 10 business days returns referred to in point (a) is lower than 12;

(c) they shall calculate both of the following:

(i) the loss corresponding to a scenario where each risk factor in the non-modellable bucket is shocked by the corresponding upward shock resulting from step (b) multiplied by β, in two cases: where $\beta = 1$ and where $\beta = \frac{4}{5}$;

(ii) the loss corresponding to a scenario where each risk factor in the non-modellable bucket is shocked by the corresponding downward shock resulting from step (b) multiplied by β, in two cases: where $\beta = 1$ and where $\beta = \frac{4}{5}$;

(d) the scenario of shocks leading to the highest loss among those computed in accordance with point (c) shall constitute the extreme scenario of future shock for the non-modellable standardised bucket.

Article 3

Determination of the time series of 10 business days returns

1. Institutions shall determine the time series of 10 business days returns for the stress period in relation to a given non-modellable risk factor by applying the following steps in sequence:

(a) they shall determine the time series of observations for the non-modellable risk factor for the stress period; they shall include in this time series only one observation per business day that shall represent actual market data;

(b) they shall extend the time series referred to in point (a) by including the observations available within the period of 20 business days following the stress period; where the reference date for the calculation of the stress scenario risk measure is less than 20 business days after the end of the stress period, institutions shall include those observations that are available from the end of the stress period to the reference date;

(c) in relation to each date D_t, for which there is an observation in the time series resulting from point (a) excluding the last observation, institutions shall determine among the dates with an observation in the extended time series referred to in point (b) the date $D_{t'}$ following D_t, that minimises the following value:

$$v = \left| \frac{10 \text{ business days}}{D_{t'} - D_t} - 1 \right|$$

where:

- D_t is the date for which there is an observation in the time series referred to in point (a), excluding the last observation;

- $D_{t'}$ is a date following D_t with an observation in the extended time series referred to in point (b);

- the difference $D_{t'} - D_t$ is expressed in business days;

Where there is more than one date minimising that value, the date $D_{t'}$ shall be the date among those minimising that value that occurred later in time;

(d) for each date D_t, for which there is an observation in the time series resulting from point (a) excluding the last observation, they shall determine the corresponding 10 business days return by determining the return for the non-modellable risk factor over the period between the date D_t of the observation and the date $D_{t'}$ minimising the value v in accordance with point (c), and subsequently rescaling it to obtain a return over a 10 business days period by multiplying the return with $\sqrt{\frac{10 \text{ business days}}{D_{t'} - D_t}}$.

2. The time series referred to in paragraph 1(a) shall at least include the observations that were used for calibrating the scenarios of future shocks referred to in Article 325bc of Regulation (EU) No 575/2013, where that risk factor was previously assessed to be modellable in accordance with Article 325be of Regulation (EU) No 575/2013.

Article 4

Downward and upward calibrated shock with the historical method

1. For determining the downward calibrated shock from a time series of 10 business days returns for a non-modellable risk factor with the historical method institutions shall use the following formula:

$$downward\ calibrated\ shock = \widehat{\mathrm{ES}}_{\mathrm{Left}}(Ret) \cdot \left(0.95 + \frac{1}{\sqrt{N - 1.5}}\right)$$

where:

- Ret denotes the time series of 10 business days returns of the non-modellable risk factor;
- $\widehat{\mathrm{ES}}_{\mathrm{Left}}(Ret)$ is the estimate of the left-tail expected shortfall for the time series Ret calculated in accordance with Article 7(1)
- N is the number of returns in the time series Ret

2. For determining the upward calibrated shock from a time series of 10 business days returns for a non-modellable risk factor with the historical method institutions shall use the following formula:

$$upward\ calibrated\ shock = \widehat{\mathrm{ES}}_{\mathrm{Right}}(Ret) \cdot \left(0.95 + \frac{1}{\sqrt{N - 1.5}}\right)$$

where:

- Ret denotes the time series of 10 business days returns of the non-modellable risk factor;
- $\widehat{\mathrm{ES}}_{\mathrm{Right}}(Ret)$ is the estimate of the right-tail expected shortfall for the time series Ret calculated in accordance with Article 7(2);
- N is the number of returns in the time series Ret.

Article 5

Downward and upward calibrated shock with the asymmetrical sigma method

1. For determining the downward and upward calibrated shock from a time series of 10 business days returns for a non-modellable risk factor with the asymmetrical sigma method, institutions shall apply the following steps in sequence:

(a) they shall determine the median of the returns within the time series, and split the 10 business days returns comprised in that time series into the following two subsets:

(i) the subset of 10-business-days returns the value of which is lower than or equal to the median;

(ii) the subset of 10-business-days returns the value of which is greater than the median.

(b) for each subset referred in point (a), they shall compute the mean of the 10 business days returns in the subset;

(c) they shall determine the downward calibrated shock in accordance with the following formula:

$$\mathit{downward\ calibrated\ shock}$$

$$= \left(-\hat{\mu}_{Ret \leq m} + C_{ES} \cdot \sqrt{\frac{1}{N_{\text{down}} - 1.5} \times \sum_{\substack{i=1, \\ Ret_i \leq m}}^{N} (Ret_i - \hat{\mu}_{Ret \leq m})^2} \right) \cdot \left(0.95 + \frac{1}{\sqrt{N_{\text{down}} - 1.5}} \right)$$

where:

- Ret denotes the time series of 10 business days returns of the non-modellable risk factor;
- Ret_i is the i-th return in the 10 business days returns time series Ret;
- m is the median of the 10 business days returns time series Ret;
- $\hat{\mu}_{Ret \leq m}$ denotes the mean of the 10 business days returns obtained as a result of point (b) on the subset identified in point (a)(i);
- N_{down} is the number of 10 business days returns in the subset identified in point (a)(i);
- N is the number of returns in the 10 business days returns time series Ret;
- $C_{ES} = 3$;

(d) they shall determine the upward calibrated shock in accordance with the following formula:

$$\mathit{upward\ calibrated\ shock}$$

$$= \left(\hat{\mu}_{Ret > m} + C_{ES} \cdot \sqrt{\frac{1}{N_{\text{up}} - 1.5} \times \sum_{\substack{i=1, \\ Ret_i > m}}^{N} (Ret_i - \hat{\mu}_{Ret > m})^2} \right) \cdot \left(0.95 + \frac{1}{\sqrt{N_{\text{up}} - 1.5}} \right)$$

where:

- Ret denotes the time series of 10 business days returns of the non-modellable risk factor;
- Ret_i is the i-th return in the 10 business days returns time series Ret;
- m is the median of the 10 business days returns time series Ret;
- $\hat{\mu}_{Ret > m}$ denotes the mean of the 10 business days returns obtained as a result of point (b) on the subset identified in point (a)(ii);
- N_{up} is the number of returns in the subset identified in point (a)(ii);
- N is the number of returns in the 10 business days returns time series Ret;
- $C_{ES} = 3$;

Article 6

Downward and upward calibrated shock with the fallback method

1. For determining the downward and upward calibrated shock from the time series of 10 business days returns for a non-modellable risk factor with the fallback method, institutions shall apply one of the methodologies set out in this Article.

2. Where the non-modellable risk factor is equal to one of the risk factors defined in Part Three, Title IV, Chapter 1a, Section 3, Subsection 1 of Regulation (EU) No 575/2013, institutions shall determine the downward and upward calibrated shock by applying the following steps in sequence:

(a) they shall identify the risk-weight assigned to that risk factor in accordance with Part Three, Title IV, Chapter 1a of Regulation (EU) No 575/2013;

(b) they shall multiply that risk-weight by $1.15 \cdot \sqrt{\frac{10}{LH}}$ where LH is the liquidity horizon of the non-modellable risk factor referred to in Article 325bd of Regulation (EU) No 575/2013;

(c) the downward and upward calibrated shock shall be the result of point (b).

3. Where the non-modellable risk factor is a point of a curve or a surface and it differs from other risk factors as defined in Part Three, Title IV, Chapter 1a, Section 3, Subsection 1 of Regulation (EU) No 575/2013 only in relation to the maturity dimension, institutions shall determine the downward and upward calibrated shocks by applying the following steps in sequence:

(a) from those risk factors defined in Part Three, Title IV, Chapter 1a, Section 3, Subsection 1 of Regulation (EU) No 575/2013 differing from the non-modellable risk factor only in the maturity dimension, they shall identify the risk factor that is the closest in the maturity dimension to the non-modellable risk factor;

(b) they shall identify the risk-weight assigned in accordance with Part Three, Title IV, Chapter 1a of Regulation (EU) No 575/2013 to the risk factor identified in accordance with point (a);

(c) they shall multiply that risk-weight by $1.15 \cdot \sqrt{\frac{10}{LH}}$

where LH is the liquidity horizon of the non-modellable risk factor referred to in Article 325bd of Regulation (EU) No 575/2013

-

(d) the downward and upward calibrated shock shall be the result of point (c).

4. Where the non-modellable risk factor does not meet the conditions of neither paragraph 2 nor paragraph 3, institutions shall determine the corresponding downward and upward calibrated shocks by selecting a risk factor that meets the conditions set out in paragraph 5 and apply the method set out in paragraph 6 to the selected risk factor.

5. The risk factor to be selected in accordance with paragraph 4 shall meet all of the following conditions:

(a) it belongs to the same broad risk factor category and broad risk factor subcategory referred to in Article 325bd of Regulation (EU) No 575/2013 of the non-modellable risk factor;

(b) it is of the same nature as the non-modellable risk factor;

(c) it differs from the non-modellable risk factor for features that do not lead to an underestimation of the volatility of the non-modellable risk factor, including under stress conditions;

(d) its time series of 10-business-days returns referred to in paragraph 6(a) contains at least 12 returns.

6. The method referred to in paragraph 4 to be applied to the selected risk factor determined in line with paragraph 5 shall consist of the following sequential steps:

(a) for the selected risk factor, institutions shall determine the time series of 10 business days returns in accordance with Article 3 for the stress period determined in accordance with Article 8;

(b) institutions shall determine the downward and upward calibrated shocks for the selected risk factor with:

(i) the historical method set out in Article 4, where the number of returns in the time series of 10 business days returns for the selected risk factor referred to in point (a) is greater than or equal to 200;

(ii) the asymmetrical sigma method set out in article 5, where the number of returns in the time series of 10 business days returns for the selected risk factor referred to in point (a) is lower than 200;

(c) institutions shall determine the downward calibrated shock for the non-modellable risk factor by multiplying the downward shock for the selected risk factor obtained in accordance with point (b) by $1.35/\left(0.95+\frac{1}{\sqrt{N_{\text{other}}^{\text{down}}-1.5}}\right)$

where:

- $N_{\text{other}}^{\text{down}}$ is one of the following, depending on which method has been used to determine the downward calibrated shock for the selected risk factor in accordance with point (b):

  (i) the number of returns in the time series of 10 business days returns for the selected risk factor referred to in point (a), where the institution used the historical method for determining the downward calibrated shock for the selected risk factor;

  (ii) the number of returns in the subset identified in Article 5(1)(a)(i) where the institution used the asymmetrical sigma method for determining the downward calibrated shock for the selected risk factor;

(d) institutions shall determine the upward calibrated shock for the non-modellable risk factor by multiplying the upward shock for the selected risk factor obtained in accordance with point (b) by $1.35/\left(0.95+\frac{1}{\sqrt{N_{\text{other}}^{\text{up}}-1.5}}\right)$

where:

- $N_{\text{other}}^{\text{up}}$ is one of the following, depending on which method has been used to determine the upward calibrated shock for the selected risk factor in accordance with point (b):

  (i) the number of returns in the time series of 10 business days returns for the selected risk factor referred to in point (a), where the institution used the historical method for determining the upward calibrated shock for the selected risk factor;

  (ii) the number of returns in the subset identified in Article 5(1)(a)(ii), where the institution used the asymmetrical sigma method for determining the upward calibrated shock for the selected risk factor;

7. By way of derogation from paragraph 4(b)(i) and 4(b)(ii), where the institution applies the method in paragraph 4 to all non-modellable risk factors in a non-modellable standardised bucket, the upward and downward shocks for all the corresponding selected risk factors shall be determined in accordance with either of the following:

(a) the historical method set out in Article 4, where the number of returns in the time series of 10 business days returns referred to in paragraph 6(a) is greater than or equal to 200 for all the selected risk factors;

(b) the asymmetrical sigma method set out in Article 5, where the condition referred to in point (a) for applying the historical method is not met.

Article 7

Estimators of the expected shortfall

1. Institutions shall calculate the estimate of the left-tail expected shortfall of a time series X with the following formula:

$$\widehat{\mathrm{ES}}_{\mathrm{Left}}(X) = \frac{-1}{\alpha N} \times \left\{ \sum_{i=1}^{[\alpha N]} X_{(\mathrm{i})} + (\alpha \cdot N - [\alpha \cdot N]) \cdot X_{([\alpha \cdot N]+1)} \right\}$$

where:

- N is the number of observations in the time series;
- α = 2.5%;
- $[\alpha \cdot N]$ denotes the integer part of the product $\alpha \cdot N$;
- $X_{(\mathrm{i})}$ denotes the i-th smallest observation in the time series X.

2. Institutions shall calculate the estimate of the right-tail expected shortfall of a time series X with the following formula:

$$\widehat{\mathrm{ES}}_{\mathrm{Right}}(X) = \widehat{\mathrm{ES}}_{\mathrm{Left}}(-X)$$

where:

- $\widehat{\mathrm{ES}}_{\mathrm{Left}}(-X)$ is the estimate of left-tail expected shortfall for the time series $-X$ calculated in accordance with paragraph 1.

Article 8

Determination of the stress period

1. Institutions shall determine the stress period for the non-modellable risk factors in a broad risk factor category by identifying the 12-months observation period maximising the following value:

$$\sum_{j \in i} RSS^j$$

where:

- i denotes the broad risk factor category;
- j is the index denoting the non-modellable risk factors or the non-modellable standardised buckets for which the institution calculates the stress scenario risk measure belonging to the broad risk factor category i;
- RSS^j is the rescaled stress scenario measure for the non-modellable risk factor or the non-modellable standardised bucket j calculated in accordance with Article 12;

2. By way of derogation from paragraph 1, institutions may determine the stress period for the non-modellable risk factors in a broad risk factor category by identifying the 12-months observation period maximising the partial expected shortfall measure $PES^{\mathrm{RS,i}}$ referred to in Article 325bb(1) of Regulation (EU) No 575/2013. Where the institution applies this derogation, it shall provide evidence that the stress period identified represents a period of financial stress for its non-modellable risk factors; when doing so, it shall take into account how its portfolio is exposed to the non-modellable risk factors in the broad risk factor category.

3. For the purposes of identifying the stress period, institutions shall use an observation period starting at least from 1 January 2007, to the satisfaction of the competent authorities.

4. Institutions shall review the stress period identified at least with a quarterly frequency.

Article 9

Computation of the losses

1. For the purposes of this Regulation, institutions shall calculate the loss corresponding to a scenario of future shock applied to one or more non-modellable risk factors by calculating the loss on the portfolio of positions for which the institution calculates the own funds requirements for market risk in accordance with the alternative internal model approach in Part Three, Title IV, Chapter 1b of Regulation (EU) No 575/2013, and that occurs if that scenario of future shock is applied to that non-modellable risk factor or those non-modellable risk factors in a standardised bucket, and all other risk factors are kept unchanged.

2. For the purpose of this Regulation, institutions shall calculate the loss corresponding to a scenario of future shock applied to one or more non-modellable risk factors by using the pricing methods used in the risk measurement model.

3. Where the pricing functions of the institution cannot determine the loss for some financial instruments or commodities included in the portfolio referred to in paragraph 1, corresponding to a scenario of future shock applied to one or several non-modellable risk factors, institutions shall, by way of derogation from paragraph 2, apply the following steps in sequence:

(a) identify those financial instruments or commodities and the cause of the pricing failure,

(b) use sensitivity-based pricing methods including at least the material first order and material second order terms of Taylor series approximations to reflect the change in the price of those financial instruments or commodities due to changes in the non-modellable risk factors in this scenario of future shock.

4. By way of derogation from paragraph 2, institutions may only for the purpose of identifying the stress period in accordance with Article 8(1), calculate the loss corresponding

to a scenario of future shock applied to one or more non-modellable risk factors, using sensitivity-based pricing methods. Institutions shall demonstrate that the price changes that are not captured by the sensitivity-based pricing methods would not modify the stress period identified by the institution.

SECTION 2
REGULATORY EXTREME SCENARIO OF FUTURE SHOCK

Article 10

Determination of the regulatory extreme scenario of future shock

1. The regulatory extreme scenario of future shock referred to in Article 325bk(3)(b) of Regulation (EU) No 575/2013 shall be a shock leading to the maximum loss that may occur due to a change in the non-modellable risk factor where such maximum loss is finite.

2. Where the maximum loss referred to in paragraph 1 is not finite, an institution shall apply the following steps in sequence for determining the regulatory extreme scenario of future shock:

(a) it shall use an expert-based approach using qualitative and quantitative information available to identify a loss due to a change in the value taken by the non-modellable risk factor that will not be exceeded with a level of certainty equal to 99.95% on a 10 business day horizon in a future period of financial stress equivalent to the stress period identified for the non-modellable risk factor; when doing so, institutions shall take into account the skewness and the excess kurtosis that may characterise the returns of the non-modellable risk factor in a period of financial stress and shall justify any distributional or statistical assumptions taken for identifying that loss.

(b) it shall multiply the loss obtained in accordance with point (a) by $\sqrt{\frac{LH_{\text{adj}}}{10}}$;

where:

- $LH_{adj} = \max(20, LH)$, and where LH is the liquidity horizon for the non-modellable risk factor or for the risk factors within the non-modellable standardised bucket referred to in Article 325bd of Regulation (EU) No 575/2013;

(c) it shall identify the regulatory extreme scenario of future shock as the shock leading to the loss resulting from points (a) and (b).

3. Where institutions calculate a stress scenario risk measure for more than one non-modellable risk factor as referred to in Article 325bk(3)(c) of Regulation (EU) No 575/2013, the regulatory extreme scenario of future shock referred to in Article 325bk(3)(b) of Regulation (EU) No 575/2013 shall be a scenario leading to the maximum loss that may occur due to a change in the values taken by those non-modellable risk factors.

4. Where institutions calculate a stress scenario risk measure for more than one non-modellable risk factor as referred to in Article 325bk(3)(c) of Regulation (EU) No 575/2013 and the maximum loss referred to in paragraph 3 is not finite, an institution shall apply the following steps in sequence for determining the regulatory extreme scenario of future shock:

(a) it shall use an expert-based approach using qualitative and quantitative information available to identify a loss due to a change in the values taken by the non-modellable risk factors that will not be exceeded with a level of certainty equal to 99.95% on a 10 business day horizon in a future period of financial stress equivalent to the stress period for the non-modellable risk factors; when doing so, institutions shall take into account the skewness and the excess kurtosis that may characterise the returns of the non-modellable risk factors in a period of financial stress and shall justify any distributional or statistical assumptions taken for identifying that loss

(b) it shall multiply the loss obtained in accordance with point (a) by $\sqrt{\frac{LH_{\text{adj}}}{10}}$;

where:

- $LH_{\text{adj}} = \max(20, LH)$, and where LH is the liquidity horizon for the non-modellable risk factors referred to in Article 325bd of Regulation (EU) No 575/2013;

(c) it shall identify the regulatory extreme scenario of future shock as the scenario leading to the loss resulting from points (a) and (b).

SECTION 3

CIRCUMSTANCES UNDER WHICH INSTITUTIONS MAY CALCULATE A STRESS SCENARIO RISK MEASURE FOR MORE THAN ONE NON-MODELLABLE RISK FACTOR

Article 11

Circumstances for the calculation of a stress scenario risk measure for more than one non-modellable risk factor

The circumstances under which institutions may calculate a stress scenario risk measure for more than one non-modellable risk factor as referred to in Article 325bk(3)(c) of Regulation (EU) No 575/2013 shall be the following:

(a) the risk factors belong to the same standardised bucket as referred to in Article 5(2) of Commission Delegated Regulation (EU) xx/2020 [RTS on criteria for assessing the modellability of risk factors under Article 325be(3) of Regulation (EU) No 575/2013];

(b) the institution assessed the modellability of those risk factors, by determining the modellability of the standardised bucket to which they belong in accordance with Article 4(1) of Commission Delegated Regulation (EU) xx/2020 [RTS on criteria for assessing the modellability of risk factors under Article 325be(3) of Regulation (EU) No 575/2013];

SECTION 4

AGGREGATION OF THE STRESS SCENARIO RISK MEASURES

Article 12

Aggregation of the stress scenario risk measures

1. For the purposes of aggregating the stress scenario risk measures as referred to in Article 325bk(3)(d) of Regulation (EU) No 575/2013, an institution shall, for each stress scenario risk measure it has computed, determine the corresponding rescaled stress scenario risk measure as follows:

(a) where the institution determined the extreme scenario of future shock for a single risk factor in accordance with the stepwise method referred to in Article 1(4), the corresponding rescaled stress scenario risk measure shall be calculated with the following formula:

$$RSS = \max\left(0; \sqrt{\frac{LH_{\text{adj}}}{10}} \times SS \times \kappa\right)$$

where:

- RSS is the rescaled stress scenario risk measure for the non-modellable risk factor;
- SS is the stress scenario risk measure for the non-modellable risk factor;
- $LH_{\text{adj}} = \max(20, LH)$, and where LH is the liquidity horizon referred to in Article 325bd(1) of Regulation (EU) No 575/2013 for the non-modellable risk factor;
- κ is the non-linearity coefficient for the non-modellable risk factor calculated in accordance with Article 13;

(b) where the institution determined a stress scenario risk measure for more than one risk factor by determining an extreme scenario of future shock in accordance with the stepwise method referred to in Article 2(4) for a non-modellable standardised bucket comprising those risk factors, the corresponding rescaled stress scenario risk measure shall be calculated with the following formula:

$$RSS = \max\left(0; \sqrt{\frac{LH_{\text{adj}}}{10}} \times SS \times \kappa\right)$$

where:

- RSS is the rescaled stress scenario risk measure for the non-modellable standardised bucket;
- SS is the stress scenario risk measure for the non-modellable standardised bucket;
- $LH_{\text{adj}} = \max(20, LH)$, and where LH is the liquidity horizon referred to in Article 325bd(1) of Regulation (EU) No 575/2013 for the risk factors within the non-modellable standardised bucket;
- κ is the non-linearity coefficient for the non-modellable standardised bucket to be calculated in accordance with Article 14;

(c) where the institution determined the extreme scenario of future shock for a single risk factor in accordance with the direct method referred to in Article 1(2), the corresponding rescaled stress scenario risk measure shall be calculated with the following formula:

$$RSS = \max\left(0; \sqrt{\frac{LH_{\text{adj}}}{10}} \times SS \times UCF\right)$$

where:

- RSS is the rescaled stress scenario risk measure for the non-modellable risk factor;
- SS is the stress scenario risk measure for the non-modellable risk factor;
- $LH_{\text{adj}} = \max(20, LH)$, and where LH is the liquidity horizon referred to in Article 325bd(1) of Regulation (EU) No 575/2013 for the non-modellable risk factor;
- UCF is the uncertainty compensation factor to be calculated in accordance with Article 16.

(d) where the institution determined a stress scenario risk measure for more than one risk factor by determining an extreme scenario of future shock in accordance with the direct method referred to in Article 2(2) for the non-modellable bucket comprising those risk factors, the corresponding rescaled stress scenario risk measure shall be calculated with the following formula:

$$RSS = \max\left(0; \sqrt{\frac{LH_{\text{adj}}}{10}} \times SS \times UCF\right)$$

where:

- RSS is the rescaled stress scenario risk measure for the non-modellable standardised bucket;
- SS is the stress scenario risk measure for the non-modellable standardised bucket;
- $LH_{\text{adj}} = \max(20, LH)$, and where LH is the liquidity horizon referred to in Article 325bd(1) of Regulation (EU) No 575/2013 for the risk factors within the non-modellable bucket;
- UCF is the uncertainty compensation factor to be calculated in accordance with Article 16.

(e) where the institution determined a stress scenario risk measure by determining a regulatory extreme scenario of future shock in accordance with Article 10, the corresponding rescaled stress scenario risk measure shall be calculated with the following formula:

$$RSS = \max(0; SS)$$

where:

- RSS is the rescaled stress scenario risk measure;
- SS is the stress scenario measure.

2. Institutions shall aggregate the stress scenario risk measures by applying the following formula:

$$\sqrt{\sum_{k \in ICSR} (RSS^k)^2} + \sqrt{\sum_{l \in IER} (RSS^l)^2} + \sqrt{\left(\rho \times \sum_{j \in OR} RSS^j\right)^2 + (1-\rho^2) \times \sum_{j \in OR} (RSS^j)^2}$$

where:

- $ICSR$ denotes the set of non-modellable risk factors or non-modellable standardised buckets for which the institution determined a stress scenario risk measure that was classified as reflecting idiosyncratic credit spread risk only, in accordance with paragraph 3;

- k is an index denoting the non-modellable risk factors or non-modellable standardised buckets belonging to $ICSR$;
- EIR denotes the set of non-modellable risk factors or non-modellable standardised buckets for which the institution determines a stress scenario risk measure that was classified as reflecting idiosyncratic equity risk only, in accordance with paragraph 4;
- l is an index denoting the non-modellable risk factors or non-modellable standardised buckets belonging to EIR;
- OR denotes a non-modellable risk factor or non-modellable standardised bucket for which the institution determines a stress scenario risk measure that was neither classified as reflecting idiosyncratic credit spread risk only, in accordance with paragraph 3, nor idiosyncratic equity risk only, in accordance with paragraph 4;
- j is an index denoting the non-modellable risk factors or non-modellable standardised buckets belonging to OR;
- RSS^k, RSS^l, RSS^j are respectively the rescaled stress scenario measures for the non-modellable risk factors or the non-modellable standardised buckets k, l, j calculated in accordance with paragraph 1;
- $\rho = 0.6$.

3. The non-modellable risk factors that the institution classifies as reflecting idiosyncratic credit spread risk only shall meet all the following conditions:

(a) the nature of the risk factor is such that it shall reflect idiosyncratic credit spread risk only;
(b) the value taken by the risk factor shall not be driven by systematic risk components;
(c) the correlation among risk factors is negligible;
(d) the institution performs and documents the statistical tests used to verify the condition in point (c).

4. The non-modellable risk factors that the institution classifies as reflecting idiosyncratic equity risk only shall meet all the following conditions:

(a) the nature of the risk factor is such that it shall reflect idiosyncratic equity risk only;
(b) the value taken by the risk factor shall not be driven by systematic risk components;
(c) the correlation among risk factors is negligible;
(d) the institution performs and documents the statistical tests used to verify the condition in point (c).

Article 13

Non-linearity coefficient for a single risk factor

Where the stress scenario risk measure for which an institution is determining the non-linearity coefficient has been determined for a single risk factor, such non-linearity coefficient shall be determined as follows:

(a) where the extreme scenario of future shock for the non-modellable risk factor does not coincide with either the downward calibrated shock or the upward calibrated shock obtained as a result of point (b) of Article 1(4), the institution shall set $\kappa = 1$ for that non-modellable risk factor.

(b) where the extreme scenario of future shock for the non-modellable risk factor coincides with the downward calibrated shock obtained as a result of point (b) of Article 1(4), the institution shall calculate the non-linearity coefficient with the following formula:

$$\kappa = \min\left(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{-1} - 2 \times \text{loss}_0 + \text{loss}_{+1}}{2 \times \text{loss}_0} \times (\phi - 1) \times 25\right]; \kappa_{\max}\right)$$

where:

- $\kappa_{\min} = 0.9$;
- $\kappa_{\max} = 5$;
- ϕ is the estimate of the tail parameter for the non-modellable risk factor calculated in accordance with Article 15;
- loss_0 is the loss that occurs when the non-modellable risk factor is shocked with the downward shock CS_{down} obtained as a result of point (b) of Article 1(4);
- loss_{-1} is the loss that occurs when the non-modellable risk factor is shocked with a downward shock equal to $\frac{4}{5} \cdot CS_{\text{down}}$, where CS_{down} is the downward shock obtained as a result of point (b) of Article 1(4);
- loss_{+1} is the loss that occurs when the non-modellable risk factor is shocked with a downward shock equal to $\frac{6}{5} \cdot CS_{\text{down}}$, where CS_{down} is the downward shock obtained as a result of point (b) of Article 1(4).

(c) where the extreme scenario of future shock for the non-modellable risk factor coincides with the upward calibrated shock obtained as a result of point (b) of Article 1(4), the institution shall calculate the non-linearity coefficient with the following formula:

$$\kappa = \min\left(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{-1} - 2 \times \text{loss}_0 + \text{loss}_{+1}}{2 \times \text{loss}_0} \times (\phi - 1) \times 25\right]; \kappa_{\max}\right)$$

where:

- $\kappa_{\min} = 0.9$;
- $\kappa_{\max} = 5$;

- ϕ is the estimate of the tail parameter for the non-modellable risk factor calculated in accordance with article 15;
- loss_0 is the loss that occurs when the non-modellable risk factor is shocked with the upward shock CS_{up} obtained as a result of point (b) of Article 1(4);
- loss_{-1} is the loss that occurs when the non-modellable risk factor is shocked with an upward shock equal to $\frac{4}{5} \cdot CS_{\text{up}}$, where CS_{up} is the upward shock obtained as a result of point (b) of Article 1(4);
- loss_{+1} is the loss that occurs when the non-modellable risk factor is shocked with an upward shock equal to $\frac{6}{5} \cdot CS_{\text{up}}$, where CS_{up} is the upward shock obtained as a result of point (b) of Article 1(4).

Article 14

Non-linearity coefficient for a bucket

Where the stress scenario risk measure for which an institution is determining the non-linearity coefficient has been determined for a non-modellable standardised bucket, the non-linearity coefficient shall be determined as follows:

(a) where the extreme scenario of future shock does not correspond to a scenario identified in Article 2(4)(c) for $\beta = 1$, the institution shall set the non-linearity coefficient $\kappa = 1$ for that non-modellable bucket;

(b) where the extreme scenario of future shock is a scenario where each risk factor in the non-modellable bucket is shocked by the corresponding downward shock resulting from point (b) of Article 2(4), institutions shall calculate the non-linearity coefficient with the following formula:

$$\kappa = \min\left(\max\left[\kappa_{\text{min}}, 1 + \frac{\text{loss}_{-1} - 2 \times \text{loss}_0 + \text{loss}_{+1}}{2 \times \text{loss}_0} \times (\phi_{\text{median}} - 1) \times 25\right];\ \kappa_{\text{max}}\right)$$

where:

- $\kappa_{\text{min}} = 0.9$;
- ϕ_{median} is the median of the estimates of the tail parameters calculated in accordance with Article 15 for each of the risk factors within the bucket;
- loss_0 is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding downward shock resulting from point (b) of article 2(4);
- loss_{-1} is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding downward shock resulting from point (b) of article 2(4) multiplied by $\frac{4}{5}$;

- loss_{+1} is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding downward shock resulting from point (b) of article 2(4) multiplied by $\frac{6}{5}$.

(c) where the extreme scenario of future shock is a scenario where each risk factor in the non-modellable bucket is shocked by the corresponding upward shock resulting from point (b) of Article 2(4), institutions shall calculate the non-linearity coefficient with the following formula:

$$\kappa = \min\left(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{-1} - 2 \times \text{loss}_0 + \text{loss}_{+1}}{2 \times \text{loss}_0} \times (\phi_{\text{median}} - 1) \times 25\right];\ \kappa_{\max}\right)$$

where:

- $\kappa_{\min} = 0.9$;
- $\kappa_{\max} = 5$;
- ϕ_{median} is the median of the estimates of the tail parameters calculated in accordance with Article 15 for each of the risk factors within the bucket;
- loss_0 is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding upward shock resulting from point (b) of article 2(4);
- loss_{-1} is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding upward shock resulting from point (b) of article 2(4) multiplied by $\frac{4}{5}$;
- loss_{+1} is the loss occurring when each risk factor in the non-modellable bucket is shocked by the corresponding upward shock resulting from point (b) of article 2(4) multiplied by $\frac{6}{5}$.

Article 15

Calculation of the estimate of the tail parameter

1. Institutions shall calculate the estimate of the tail parameter for a given non-modellable risk factor as follows:

(a) where institutions used the historical method referred to in Article 4 for determining the downward and upward calibrated shock of that non-modellable risk factor and the extreme scenario of future shock is the downward calibrated shock, they shall calculate the estimate of the tail parameter by applying the following formula:

$$\phi = \frac{\frac{1}{\alpha N} \times \left\{ \sum_{i=1}^{[\alpha N]} {Ret_{(\mathrm{i})}}^2 + (\alpha \cdot N - [\alpha \cdot N]) \cdot {Ret_{([\alpha N]+1)}}^2 \right\}}{\left\{ \widehat{\mathrm{ES}}_{\mathrm{Left}}(Ret) \right\}^2}$$

where:

- $\alpha = 2.5\%$;
- Ret is the time series of 10 business days returns for the non-modellable risk factor used in the historical method referred to in Article 4;
- $Ret_{(\mathrm{i})}$ represents the smallest i-th return in the time series Ret
- $[\alpha \cdot N]$ denotes the integer part of $\alpha \cdot N$;
- $\widehat{\mathrm{ES}}_{\mathrm{Left}}(Ret)$ is the estimate of the left-tail expected shortfall for the time series Ret calculated in accordance with Article 7(1).

(b) where institutions used the historical method referred to in Article 4 for determining the downward and upward calibrated shock of that non-modellable risk factor and the extreme scenario of future shock is the upward calibrated shock, they shall calculate the estimate of the tail parameter by applying the following formula:

$$\phi = \frac{\frac{1}{\alpha N} \times \left\{ \sum_{i=1}^{[\alpha N]} {(-Ret)_{(\mathrm{i})}}^2 + (\alpha N - [\alpha N])(-Ret)_{([\alpha N]+1)}{}^2 \right\}}{\left\{ \widehat{\mathrm{ES}}_{\mathrm{Right}}(Ret) \right\}^2}$$

where:

- $\alpha = 2.5\%$;
- Ret is the time series of 10 business days returns for the non-modellable risk factor used in the historical method referred to in Article 4;
- $-Ret_{(\mathrm{i})}$ represents the smallest i-th return in the time series $-Ret$
- $[\alpha \cdot N]$ denotes the integer part of $\alpha \cdot N$;
- $\widehat{\mathrm{ES}}_{\mathrm{Right}}(Ret)$ is the estimate of the right-tail expected shortfall for the time series Ret calculated in accordance with Article 7(2).

(c) in all other cases institutions shall set the estimate of the tail parameter $\phi = 1.04$.

Article 16

Calculation of the uncertainty compensation factor

1. Where the stress scenario risk measure for which the institution is determining the uncertainty compensation factor has been determined for a single risk factor, the uncertainty compensation factor shall be equal to:

$$UCF = 0.95 + \frac{1}{\sqrt{N} - 1.5}$$

where:

- N is the number of losses in the time series referred to in Article 1(2)(a)(iii) from which the extreme scenario of future shock has been determined for the non-modellable risk factor in accordance with that Article.

2. Where the stress scenario risk measure for which the institution is determining the uncertainty compensation factor has been determined for a non-modellable standardised bucket, the uncertainty compensation factor shall be equal to:

$$UCF = 0.95 + \frac{1}{\sqrt{N} - 1.5}$$

where:

- N is the number of losses in the time series referred to in Article 2(2)(a)(iv) from which the extreme scenario of future shock has been determined for the non-modellable bucket in accordance with that Article.

SECTION 5
QUALITATIVE REQUIREMENTS

Article 17

For the purposes of developing extreme scenarios of future shock, determining the regulatory extreme scenario of future shock, and aggregating the stress scenario risk measures, the set of internal policies which institutions shall have in place in accordance with point (e) of Article 325bi(1) of Regulation (EU) No 575/2013, shall include documentation of any information necessary to demonstrate that the applicable criteria and methodological prescriptions established in this Regulation are met, in particular in relation to criteria on the application of choices, assumptions made, conditions, required steps for applying the derogations, and justifications where applicable.

SECTION 6

FINAL PROVISIONS

Article 18

This Regulation shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

Done at Brussels,

For the Commission
The President

[For the Commission
On behalf of the President]

4 Accompanying documents

4.1 Draft cost–benefit analysis/impact assessment

Article 325bk(3) of CRR2 mandates the EBA to develop draft RTS specifying:

a) how institutions are to develop extreme scenarios of future shock and how to apply those to non-modellable risk factors to calculate the stress scenario risk measure;

b) a regulatory scenario of future shock that institutions may use where they are unable to develop an extreme scenario of future shock using the methodology outlined in point (a) or which competent authorities may require institutions to apply;

c) the circumstances under which institutions may calculate a stress scenario risk measure for more than one non-modellable risk factor;

d) how institutions are to aggregate the stress scenario risk measures of all non-modellable risk factors included in their trading book positions and non-trading book positions that are subject to foreign exchange risk or commodity risk.

Article 10(1) of Regulation (EU) No 1093/2010 (the EBA Regulation) provides that any RTS developed by the EBA should be accompanied by an analysis of 'the potential related costs and benefits'. This analysis should provide an overview of the different options considered in drafting the RTS, relevant findings regarding them, the options proposed and the potential impact of these options.

This section presents a cost–benefit analysis of the provisions included in the draft RTS. The analysis provides an overview of the problems identified, the options proposed to address those problems, and the costs and benefits of those options.

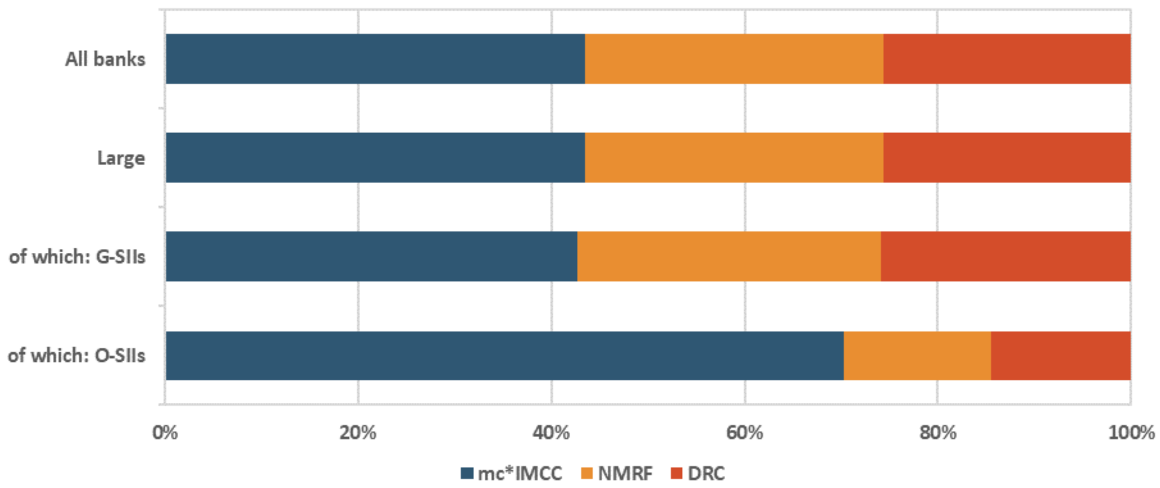
A. Background and problem identification

In accordance with Article 325be of CRR2, institutions using the alternative IMA (i.e. an internal expected shortfall model) are required to identify for each risk factor included in the risk measurement model whether it is modellable or not. A risk factor is deemed modellable when it passes the assessment of modellability of risk factors set out in the pertaining draft RTS, i.e. mainly based on the characteristics of representative real price observations.[13] Risk factors that do not pass the requirements of the modellability assessment are deemed non-modellable risk factors.

CRR2 specifies that when a risk factor has been identified as non-modellable it has to be capitalised, outside the expected shortfall measure, by calculating the stress scenario risk measure for that risk factor.[14] This measure represents the loss that is incurred in all trading book positions and non-trading book positions that are subject to foreign exchange or commodity risk of the portfolio that includes that non-modellable risk factor when an extreme scenario of future shock is applied to the risk factor. However, CRR2 does not specify how to develop such extreme scenarios of future shocks or how to apply them to non-modellable risk factors. The lack of such specification could lead to the inconsistent application of the market risk framework for non-modellable risk factors across EU institutions.

According to data from the EBA Quantitative Impact Study (QIS), 2018 Q4, a sizeable share of the market risk requirements of IMA banks can be attributed to non-modellable risk factors. On average, the overall contribution of non-modellable risk factors to total IMA capital requirements stands at around 30% (see Figure 1). Although these figures do not take into account the methodology put forward in these draft RTS, they still indicate the relevance of non-modellable risk factors for European banks.

Figure 1: Composition of FRTB–IMA own funds requirements, by bank type



Sources: EBA 2018 Q4 QIS data and EBA calculations.

[13] EBA/RTS/2020/03, EBA FINAL draft Regulatory Technical on criteria for assessing the modellability of risk factors under the Internal Model Approach (IMA) under Article 325be(3) of Regulation (EU) No 575/2013 (revised Capital Requirements Regulation – CRR2)

[14] Similarly, the FRTB standards specify that the capital requirements for each non-modellable risk factor are to be determined using a stress scenario that is calibrated to be at least as prudent as the expected shortfall measure used for modelled risks (i.e. a loss calibrated to a 97.5% confidence threshold over a period of extreme stress for the given risk factor). In determining that period of stress, a bank must determine a common 12-month period of stress across all non-modellable risk factors in the same risk class. The FRTB standards do not provide any other details regarding this stress scenario.

Notes: Based on a sample of 13 banks: large, 13; of which global systemically important institutions (G-SIIs), 7; of which other systemically important institutions (O-SIIs), 6. DRC, default risk capital requirements; IMCC, capital requirements for modellable risk factors; mc, multiplication factor; NMRF, capital requirements for non-modellable risk factors.

The non-modellable risk factor capital requirements reported by banks are highly dependent on portfolio composition as well as the assumptions and methodological choices made by the banks. That being the case, reported values show significant variation, with the median non-modellable risk factor contribution standing at around 10% and the interquartile range at 34%.[15] Based on the qualitative information provided alongside the 2018 QIS templates, it appears that the assumptions and methodologies used by banks to calculate non-modellable risk factor capital requirements are subject to significant differences. This indicates that banks are currently facing technical and operational challenges in estimating non-modellable risk factor capital requirements, given the lack of clarity and harmonisation related to the non-modellable risk factor implementation methodology and the early stage of implementation, which forces banks to rely on approximations and expert judgement in many cases.

B. Policy objectives

The specific objective of these draft RTS is to establish a common universal methodology for calculating the extreme scenario of shock and applying it to non-modellable risk factors to estimate the stress scenario risk measure. In this way, these draft RTS aim to ensure the consistent implementation of the market risk framework across EU institutions.

Moreover, they also aim to provide institutions with a regulatory scenario of future shock as a fallback in cases where they are unable to calculate an extreme scenario of future shock using the prescribed methodology.

Generally, these draft RTS aim to create a level playing field, promote convergence of institutions practices and increase the comparability of own funds requirements across the EU. Overall, these draft RTS are expected to promote the effective and efficient functioning of the EU banking sector.

C. Options considered, cost–benefit analysis and preferred options

EBA non-modellable risk factor data collection

The EBA conducted an extensive voluntary data collection exercise in 2019 to inform the impact assessment and policy choices in these draft RTS.[16] The data collection was addressed to all institutions that use an IMA to calculate capital requirements for market risk. Institutions were asked to apply the EBA stress scenario risk measure methodology, as put forward in the accompanying instructions, for the relevant risk factors in the following portfolios:

[15] Some banks reported a 0% contribution from non-modellable risk factors, possibly because either all risk factors pass the risk factor eligibility test or banks at the time did not have the capability to calculate the stress scenario risk measure and reported zero to bypass aggregation checks within the QIS template.

[16] https://eba.europa.eu/eba-publishes-its-roadmap-for-the-new-market-and-counterparty-credit-risk-approaches-and-launches-consultation-on-technical-standards-on-the-ima-under

- at minimum, the 2019 EBA market risk benchmarking exercise portfolios;
- prospective FRTB desks that are relevant for the institutions;
- portfolios with non-linear and/or non-monotonic loss profiles; and/or
- portfolios that depend on a curve, surface or cube.

It should be noted that the EBA stress scenario risk measure methodology described in the instructions for the data collection exercise was, to a certain extent, different from the methodology put forward in these draft RTS. In fact, the input received from the data collection was used to improve, adjust and extend the methodology and to ensure the appropriate calibration of its key parameters.

Methodology and data quality

The analysis presented in this section uses all the data on risk factors provided, not only the data on risk factors assessed as non-modellable. The rationale behind this choice is as follows: (i) to maximise the use of data provided; (ii) at the time of the data collection, the modellability assessment had not been implemented and thus the assessment was done on a best-effort basis; (iii) the outcome of the modellability assessment can change for the same risk factor (i.e. it can switch between modellable and non-modellable). In addition, the historical estimates presented below are based on all risk factors, without distinguishing them based on the minimum number of observations needed for each stepwise method.[17]As part of the data collection, institutions were requested to submit the time series of their risk factors relevant for the portfolios or desks reported. The EBA calculated risk factor returns based on the return type (absolute returns, relative returns, etc.) specified by participants. For some specific return types, there are deviations for returns whose values do not depend only on the two risk factor values on two dates (e.g. returns on underlyings adjusted by volatility).

Given that most institutions submitted data for the EBA benchmarking portfolios, some of the risk factors used in the analysis below may overlap. However, institutions have used different models for the same portfolio, and therefore all the risk factors were retained. As a robustness check, the analysis was repeated on different sets of risk factors, e.g. for each institution separately. The results were qualitatively the same.

Sample and summary statistics

A total of eight institutions participated in the non-modellable risk factor data collection exercise (Table 1). All institutions reported figures for the 2019 or 2020 EBA market risk benchmarking exercise portfolios and four institutions reported figures for some of their own desks up to the top of the house.[18]

[17] Specific thresholds were set on the minimum number of observations to ensure that the historical estimates could be calculated.

[18] Some participants preferred to submit data based on the 2020 EBA market risk benchmarking exercise.

Table 1: Non-modellable risk factor data collection sample, by country

Country	Number of banks
DE	1
FR	4
IT	2
UK	1
Total	**8**

Sources: EBA non-modellable risk factor data collection and EBA calculations.

The portfolios for which data was provided covered a total of 48 285 risk factors, of which 15 546 were classified by participants as non-modellable risk factors (Table 2). The numbers of risk factors for which each bank provided data varied significantly, with some providing data on as few as around 60 risk factors and others providing data on up to around 40 000 risk factors (Table 3). The median bank provided data on around 800 risk factors. The majority of the risk factors related to the equity risk, general interest rate risk and credit spread risk categories. This was also true for the non-modellable risk factors.

On average, 32% of all the risk factors for which data were provided were considered to be non-modellable risk factors, bearing in mind that the assessment of modellability was not considered mature and done on a best-effort basis. The credit spread risk and general interest rate risk categories appear to have the highest shares of non-modellable risk factors relative to all risk factors belonging to those risk categories. The commodity risk category appears to have the lowest share.

Table 2: Total number of risk factors and non-modellable risk factors included in the data collection, by risk category

Risk factor category	Total number of risk factors	Of which: time series provided	Total number of NMRFs	Of which: time series provided	Average share of NMRFs
COMM	2 921	2 921	211	211	7%
CS	11 510	11 448	4 943	4 913	43%
EQ	16 016	15 686	4 485	4 482	28%
FX	3 389	3 276	685	685	20%
IR	14 449	10 737	5 222	4 516	36%
Total	**48 285**	**44 068**	**15 546**	**14 807**	**32%**

Sources: EBA non-modellable risk factor data collection and EBA calculations.

Table 3: Distribution of number of risk factors and non-modellable risk factor included in the data collection, by bank and risk category

	Number of banks	Min.	Q1	Median	Q3	Max.	Average
ALL RFs: of which	**8**	**58**	**370**	**825**	**2 321**	**40 603**	**6 036**
COMM	8	0	0	8	101	2 614	417
CS	8	0	30	72.5	124	11 058	1 439
EQ	8	0	5	53	192	15 486	2 002
FX	8	0	3	40	72	3 155	424
IR	8	27	184	508	1 909	8 290	1 806
ALL NMRFs: of which	**8**	**0**	**81**	**537**	**818**	**12 367**	**1 943**
COMM	8	0	0	0	10	187	30
CS	8	0	0	34	113	4 645	618
EQ	8	0	0	35	96	4 193	561
FX	8	0	0	0	65	553	86
IR	8	0	47	271	777	2 789	653
Share of NMRFs in total RFs	**8**	**0%**	**15%**	**27%**	**55%**	**100%**	**37%**

Sources: EBA non-modellable risk factor data collection and EBA calculations.

Policy options

Overarching approaches: Option A and Option B for calibration to a period of stress

The CP presented two options for calibrating an extreme scenario of future shock to a period of stress (Options A and B).

Option 1a: Determination of the stress scenario risk measure directly from the stress period (Option A in the CP).

Option 1b: Rescaling a shock calibrated on the current period to obtain a shock calibrated on the stress period (Option B in the CP).

Option 1a uses the risk factor observations for a stress period directly to obtain calibrated shocks for the stress period. The stress period for each risk category is the period that maximises the rescaled stress scenario risk measure RSS for that risk category.

Option 1b uses the risk factor observations for the current period[19] − for which data availability is generally higher − to obtain intermediate shocks, which are then rescaled, by means of a scalar, to obtain calibrated shocks for the stress period. The scalar represents the volatility ratio for the current and stress periods for each risk class and is computed using the reduced set of modellable risk factors in the expected shortfall model as specified in Article 325bc(2)(a) of CRR2, which are available for both periods. The stress period is the period that maximises the scalar for that risk category. The use of modellable factors to compute the scalar is intended to reduce the operational burden for institutions, as it would allow them to collect data on non-modellable risk factors only for the current period (and not for the stress period).[20] It is expected that the volatility ratios for the current and stress periods would be similar for modellable and non-modellable risk factors belonging to the same risk category. This is because a risk factor can switch modellability status between modellable and non-modellable, given that the modellability assessment is based on real price observations, which do not necessarily correspond to the data used to calibrate the shocks (typically daily data). The analysis of the data collected confirms that there is no significant difference in the volatility ratios for the current stress periods for modellable and non-modellable risk factors.

While Option 1a appears to be a straightforward way of obtaining calibrated shocks for the stress period, data availability for non-modellable risk factors in a past stress period (which for most institutions currently corresponds to the great financial crisis) may be limited. This is because trading strategies, instruments and, therefore, the risk factor landscape are likely to have changed since then.

Option 1b recognises these challenges and allows institutions to use data on non-modellable risk factors for the current period only, for which data availability is expected to be better. For the stress period, only the data for the reduced set of modellable factors that would be used for the calculation of the scalar are needed, which are expected to be readily available, as these are used for the calculation of expected shortfall. Nevertheless, the scaling of these intermediate shocks from the current year to a period of stress remains a source of inaccuracy.

In terms of operational burden, Option 1a could be more burdensome for institutions, as they would be required to scan and apply the entire non-modellable risk factor stress scenario risk measure methodology to all 12-month periods starting at least from 1 January 2007 in order to identify the stress period. In contrast, under Option 1b, institutions have to scan and calculate only the scalar for all 12-month periods starting at least from 1 January 2007, in particular without the

[19] As explained in the draft RTS, institutions may use as the ‘current period’ either the actual past 12 months or the period used for assessing the modellability of risk factors.

[20] Data on the reduced set of modellable risk factors in the expected shortfall model, as specified in Article 325bc(2)(a) of CRR2, would have to be collected in any case as part of the expected shortfall model calculation.

need to evaluate portfolio losses, which would be needed for the entire non-modellable risk factor stress scenario risk measure methodology under Option 1a.

Both options were put forward for consultation. While some respondents expressed a preference for Option 1a – as it would provide a direct way of determining the extreme scenario of future shock for a non-modellable risk factor from the selected stressed period – most respondents considered the way in which the stress period was determined under this option too computationally intensive. Therefore, most respondents recommended disentangling the determination of the stress period from the determination of the extreme scenario of future shock, in order to make Option 1a implementable in practice. Most respondents noted that, if no amendments to the determination of the stress period under Option 1a were to be considered by the EBA, Option 1b would be preferable from a practical perspective.

The EBA acknowledges that, while the determination of the stress period under Option 1a is operationally burdensome, it provides a more straightforward way of determining the stress risk scenario measure directly from the stress period. To alleviate concerns raised by respondents to the CP, the EBA has decided on the following amendments to the draft RTS proposed in the CP. First, the default approach to identifying the stress period would be to maximise the sum of rescaled stress scenario measures across non-modellable risk factors or buckets within a broad risk category, as proposed in the CP. However, institutions would be allowed to use sensitivity-based pricing methods when calculating the loss corresponding to a scenario of future shock applied to one or more non-modellable risk factors, but only for the sole purpose of identifying the stress period.[21] In addition, the EBA decided to include a derogation to the aforementioned (default) approach to determining the stress period. In particular, institutions may determine the stress period for a broad risk factor category by identifying the 12-month observation period maximising the partial expected shortfall measure $PES^{\mathrm{RS,i}}$ referred to in Article 325bb(1) of CRR2. These changes are expected to make Option 1a operational and reduce the burden associated with the determination of the stress period, which was highlighted as one of the main concerns that respondents had in relation to this option.

Option 1a is retained.

Direct method under Option A

Under the direct method of determining the extreme scenario of future shock, institutions should first calculate the expected shortfall using the following historical estimator:

$$\widehat{\mathrm{ES}}_{\mathrm{Right}}\left[loss_{D^*}\left(r_j(D^*)\oplus Ret\left(r_j,t,10\right)\right),\alpha\right]\ (1)$$

[21] Full revaluation pricing methods remain the only possible method when calculating the loss for the purpose of determining non-modellable risk factor capital requirements.

The extreme scenario of future shock is then determined as the weighted set of shocks leading to a stress scenario risk measure, as defined in Article 325bk(1), equal to the historical estimator of the expected shortfall.

The EBA considered the following options:

Option 2a: Allow the use of the direct method.

Option 2b: Do not allow the use of the direct method.

From a mathematical point of view, the direct method provides a conceptually simple and accurate estimate of the extreme scenario of future shock, as it is directly derived from the expected shortfall of the corresponding loss function. However, it would require significant computational effort on the part of institutions to compute loss evaluations for each risk factor. For daily data (250 returns) it would require at least 250/6 = 41.7 times more portfolio loss evaluations for each risk factor than the stepwise method (at maximum, six evaluations are needed to scan the maximum loss and pre-compute the non-linearity adjustment for both calibrated stress scenario risk factor range boundaries). Given this, it is expected that only a limited number of institutions will be willing to use the direct method.

In the data collection exercise, only one institution provided figures based on the direct method. The remaining institutions indicated that, given the high operational burden of the direct method, they could not provide such estimates within the time frame for the data collection. In the case of the institution that provided data on the direct method, the results were very close to those obtained using the historical method.

Some respondents to the CP confirmed that the direct method was much more computationally burdensome than the stepwise method and would not be used in practice. However, some respondents preferred to keep the direct method, as this was the most accurate method of estimating the extreme scenario of future shock. In addition, they provided an analysis to support their argument that the direct method would be preferable for some non-modellable risk factors or buckets as it would capture their properties better than the stepwise historical method. For example, in the case of non-modellable buckets, the direct method can determine a more realistic extreme scenario of future shock than the contoured approach, which assumes that the risk factors within the bucket would shift according to a contour shape.

The EBA acknowledges the benefits that the direct method has for selected non-modellable risk factors or buckets. As a result, the EBA decided to keep the direct method in the draft RTS. However, to avoid any regulatory arbitrage, the draft RTS require institutions to document the criteria used in deciding whether to employ the direct method or the stepwise historical method. Those criteria should be consistent over time. In addition, for any non-modellable risk factors for which the institution uses the direct method, the institution should calculate and document the rescaled stress scenario risk measure using the stepwise method to allow supervisors to compare the results of the two methods if necessary.

Option 2a is retained.

Symmetrical or asymmetrical sigma method

Under the historical method, institutions calibrate an upward and a downward shock applicable to the risk factor by estimating the empirical expected shortfalls of the returns for the right and left tails. Given that financial time series are usually skewed, this method often results in upward and downward shocks of different sizes. The EBA considered incorporating such asymmetry into the sigma method, i.e. when the historical method is not available.

Option 3a: Calculate symmetrical shocks (sigma method).

Option 3b: Calculate asymmetrical shocks (asigma method).

Under Option 3a, the calibrated shocks are calculated as:

$$CS_{\text{down}}(r_j) = C_{ES} \times \hat{\sigma}_{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{N - 1.5}}\right)$$

and

$$CS_{\text{up}}(r_j) = C_{ES} \times \hat{\sigma}_{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{N - 1.5}}\right)$$

This option uses the estimate of the standard deviation and results in symmetrical shocks, i.e. the upward and downward shocks are of the same size.

Under Option 3b, the calibrated shocks are calculated as:

$$CS_{\text{down}}(r_j) = \widehat{\text{ASigma}}_{\text{down}}^{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{N_{\text{down}} - 1.5}}\right)$$

and

$$CS_{\text{up}}(r_j) = \widehat{\text{ASigma}}_{\text{up}}^{Ret(j)} \times \left(0.95 + \frac{1}{\sqrt{N_{\text{up}} - 1.5}}\right)$$

where:

$$\widehat{\text{ASigma}}_{\text{down}}^{Ret(j)} = -\hat{\mu}_{Ret \le m}^{Ret(j)} + C_{\text{ES}} \times \sqrt{\frac{1}{N_{\text{down}} - 1.5} \times \sum_{\substack{t=1, \\ Ret(r_j,t,10) \le m}}^{N} \left(Ret(r_j, t, 10) - \hat{\mu}_{Ret \le m}^{Ret(j)}\right)^2}$$

$$\widehat{\text{ASigma}}_{\text{up}}^{Ret(j)} = \left|\hat{\mu}_{Ret > m}^{Ret(j)}\right| + C_{\text{ES}} \times \sqrt{\frac{1}{N_{\text{up}} - 1.5} \times \sum_{\substack{t=1, \\ Ret(r_j,t,10) > m}}^{N} \left(Ret(r_j, t, 10) - \hat{\mu}_{Ret > m}^{Ret(j)}\right)^2}$$

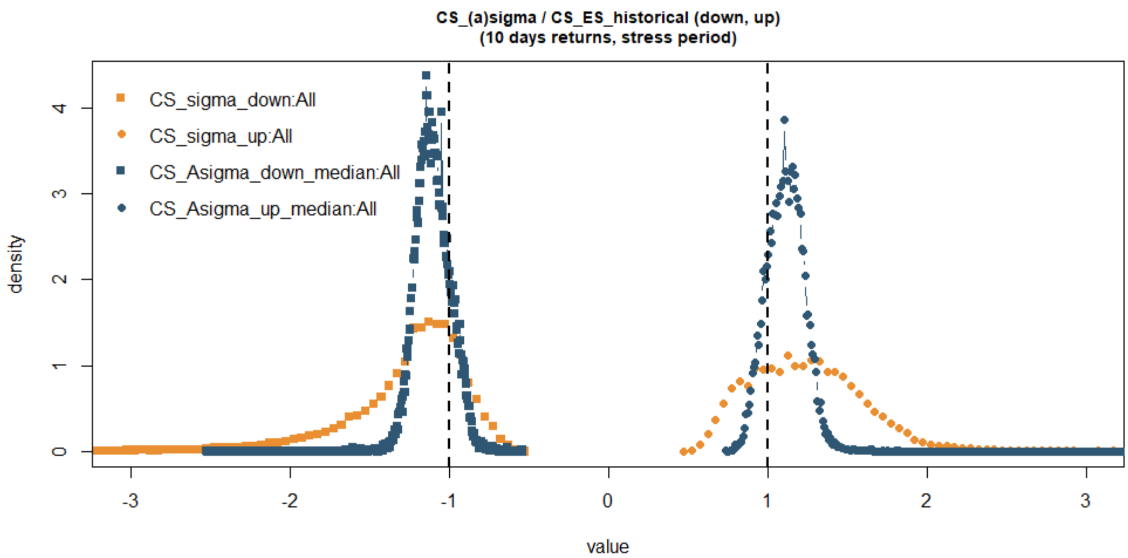
This option splits the returns along the median value m, and calculates the mean and the standard deviation for the upper and lower half of the returns.[22] This results in asymmetrical shocks for skewed return distributions, i.e. the upward and downward shocks are of different sizes.

Option 3b caters better for skewed distributions and increases the accuracy of the calibrated shocks compared with the historical method. However, more quantities need to be estimated and the uncertainty compensation is higher by about $\sqrt{2}$, because the number of returns below and above the median is half the full set of data points, so the statistical uncertainty is higher.

Figures 2 and 3 show the ratios of the downward and upward calibrated shocks under the sigma and asigma methods relative to the downward and upward calibrated shocks under the historical method, for the stress and current periods, respectively. As can be seen, the ratios based on the asigma method are much more narrowly centred on 1 than those based on the sigma method. In particular, very large absolute values (i.e. the calibrated shock is much larger than the historical expected shortfall) are much rarer under the asigma method.

The sigma method under Option 3b is less complex and therefore more robust than the asigma method, requires somewhat less computational effort on the part of institutions and works well on average when data for the historical method are insufficient. The uncertainty compensation is smaller, because more data points are used in the estimation of sigma. However, it cannot cater for asymmetrical returns.

Figure 2: Comparison of calibrated shocks based on the historical method, sigma method and asigma method, stress period

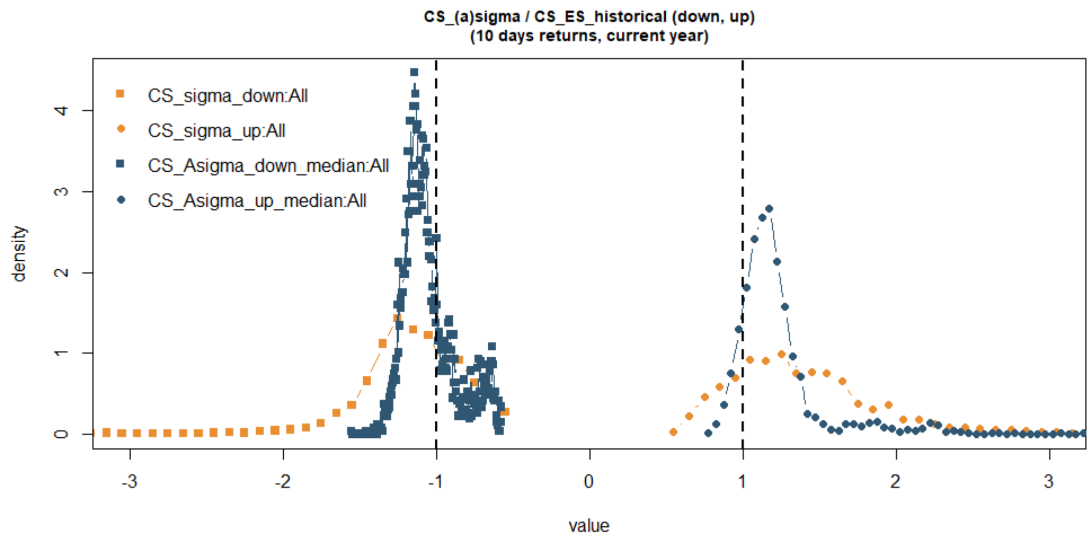


Sources: EBA non-modellable risk factor data collection and EBA calculations.

[22] The EBA also considered splitting the returns into a 'down' and an 'up' part using as a split point the zero value or the mean of the returns. Overall, the split at the median performed well and has the practical advantage that the time series of returns is split exactly in half, while e.g. there could be much fewer positive than negative returns in the observation period.

Note: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS.

Figure 3: Comparison of calibrated shocks based on the historical method, sigma method and asigma method, current period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Note: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS.

Both options were put forward for consultation. Respondents to the CP were split between the two options. Proponents of the asigma method highlighted that the calibrated shocks under this method would better match those under the historical method and therefore provide a smoother transition between the historical method and the asigma method when a non-modellable risk factor moved between the two methods. In addition, the asigma method caters better for the skewness of returns. Opponents of the asigma method considered the Sigma method preferable because it was simpler.

The EBA acknowledges that there was no strong preference on the part of respondents for one of the proposed methods (sigma or asigma). Considering that the asymmetrical sigma method better fits the historical data, and specifically the asymmetrical features commonly seen in financial series, the EBA decided to retain the asymmetrical sigma method in the draft RTS.

Option 3b is retained.

Bucketing approach

Option 4a: Representative risk factors and parallel shifts.

Option 4b: Contoured shifts.

Under Option 4a, institutions are required to first identify the representative risk factor for a given regulatory bucket for which the institution computes the stress scenario measure at bucket level.

Second, they need to calibrate the upward and downward shocks for the representative factor. Finally, they apply a parallel shift to all risk factors within the bucket based on the calibrated shock for the representative factor.

Under Option 4b, institutions are required to calibrate the upward and downward shocks for all risk factors within a given regulatory bucket. The resulting shocks are then multiplied by a scalar $\beta \in [0, 1]$ – the 'bucket shock strength' – to obtain a vector of upward shocks (v_{β}^{up}) and a vector of downward shocks (v_{β}^{down}), following the contour of the shock strengths of the risk factors in the regulatory bucket (hence the name). The scenario of future shock is the vector of upward shocks v_{β}^{up} or the vector of downward shocks v_{β}^{down} leading to the worst loss when scanning β in $[0, 1]$.

While Option 4a is simpler, Option 4b has the potential to result in shifts in regulatory buckets that are more closely aligned with historical risk factor movements.[23] Moreover, it could alleviate to a certain extent concerns about the discontinuity created by shocking the risk factors within a bucket while keeping those in the adjacent buckets fixed. However, it is more complex and potentially more burdensome for institutions to implement.

Both options were put forward for consultation. The majority of respondents supported the contoured shift option, arguing that the contoured shift would represent a good approximation in most cases. The option also alleviates some of the issues associated with the representative factor and parallel shift option, such as possible discontinuities between adjacent buckets, overly conservative shocks and potential penalisation when more risk factors are set up. One respondent pointed out that, when using the stepwise method in conjunction with the contour method, there might be cases where some risk factors within the bucket would qualify for the historical method while others would not. The respondent recommended that in those cases the EBA allow the use of the same method for all risk factors in the same bucket.

The EBA acknowledges the broad support for the contoured shift option and that respondents deemed that the option would better represent the behaviour of risk factors within a bucket.

Option 4b is retained. In addition, the EBA decided to amend the draft RTS to ensure that shocks corresponding to risk factors in the same bucket are calibrated using the same method (i.e. historical, sigma or fallback).

Calibration of C_{ES}

Under the stepwise method, the calibrated shocks correspond to the expected shortfall with the specified confidence level of 97.5% for a non-modellable risk factor. Under the historical method, the expected shortfall is estimated directly from the observed data if a sufficient number of observations are available to obtain an accurate estimate. In the sigma method, however, institutions first calculate an estimate of the standard deviation and then rescale it to get an approximation of the expected shortfall used for the calibrated shocks. This rescaling is performed

[23] During the data collection, some participants highlighted that, particularly at the short end of a curve, the movements are not parallel; rather, the very short end is moving more strongly than longer maturities.

by a scalar C_{ES}, which approximates the ratio of the expected shortfall to the standard deviation. More precisely:

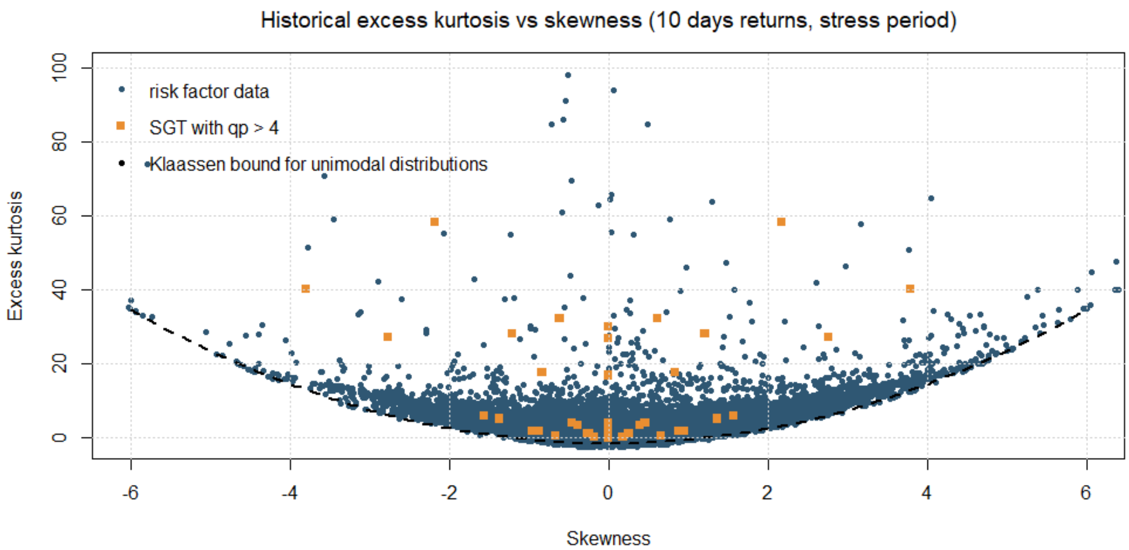
$$C_{\mathrm{ES}}(Ret(j),\alpha) = \mathrm{ES}(Ret(j),\alpha)/\hat{\sigma}_{Ret(j)}$$

The value of C_{ES} depends on the distribution of the non-modellable risk factor and the confidence level.[24] When the confidence level is set at 97.5%, the distribution of non-modellable risk factor returns can vary widely and so can the exact value of C_{ES} calculated for a particular non-modellable risk factor.

Skewness and excess kurtosis were computed for risk factor returns based on the data collection data, showing that the time series are often significantly non-Gaussian in both the stress period and the current period.[25] Figures 4 and 5 show that on average excess kurtosis is positive, suggesting fatter tails than the Gaussian distribution. In addition, the risk factor distribution is generally skewed (i.e. leans to one side).

The orange dots correspond to theoretical skewed generalised *t* (SGT) distributions as used in Annex I. Overall, the SGT distributions capture the effects of skewness and kurtosis present in the data well, while skewness is somewhat understated by the SGT distributions analysed.

Figure 4: Historical (excess) kurtosis and skewness of 10-business-days returns, stress period



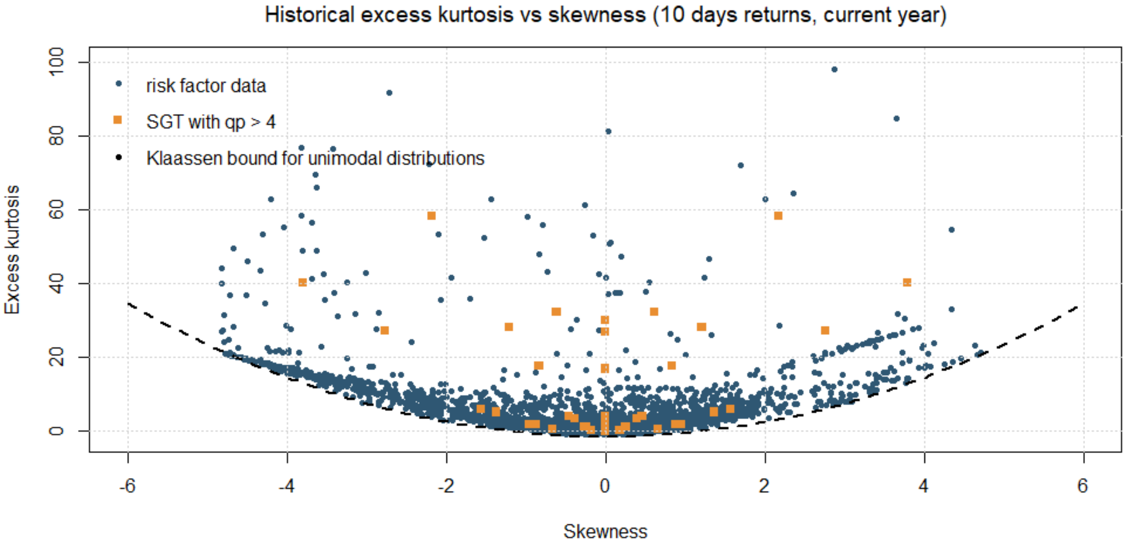
Sources: EBA non-modellable risk factor data collection and EBA calculations.
Notes: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS. For unimodal distributions, excess kurtosis is bounded from below by squared skewness plus 186/125 – 3 (Klaassen bound), which is indicated by a dashed line.[26]

[24] Strictly speaking, the value of C_{ES} also depends on whether the sigma or asigma method is used.

[25] The normal (Gaussian) distribution has zero skewness (i.e. is symmetrical) and zero excess kurtosis.

[26] Chris A. J. Klaassen, Philip J. Mokveld, Bert Van Es, 'Squared skewness minus kurtosis bounded by 186/125 for unimodal distributions', *Statistics and Probability Letters*, Vol. 50, No 2, 1 November 2000, pp. 131-135, doi:10.1016/S0167-7152(00)00090-0.

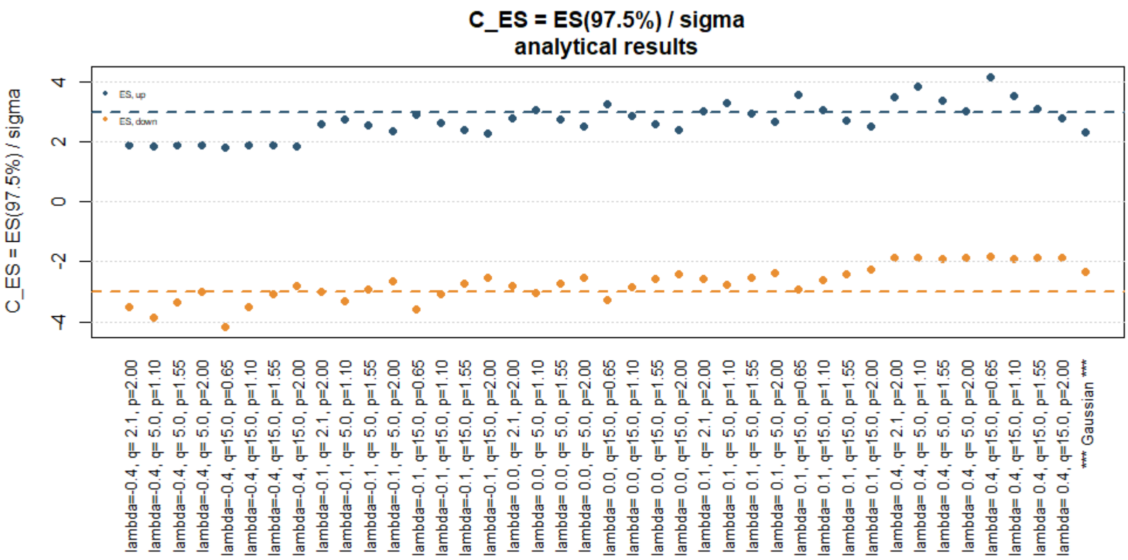
Figure 5: Historical (excess) kurtosis and skewness of 10-business-days returns, current period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Notes: The current period uses data provided for the most recent year, which for most time series corresponds to mid-2018 until mid-2019. For unimodal distributions, excess kurtosis is bounded from below by squared skewness plus 186/125 – 3 (Klaassen bound), which is indicated by a dashed line.

Under the Gaussian distribution, $C_{\mathrm{ES}}(Ret(j), 0.975) = 2.3378$. However, for skewed or more fat-tailed distributions as exemplified by the SGT distributions, the expected shortfall can be substantially higher (Figure 6). The scalar increases both with skewness (increasing with the parameter $lambda$) and with fat-tailedness (increasing with lower values for $q * p$), and it varies substantially based on the underlying distribution. In order to cover a wide range of plausible underlying distributions, C_{ES} needs to be set sufficiently higher than the value for the normal distribution. That being the case, the question of the calibration of C_{ES} can be formulated in terms of how much non-normality should be captured.

Figure 6: Estimates of C_{ES} for different SGT distributions

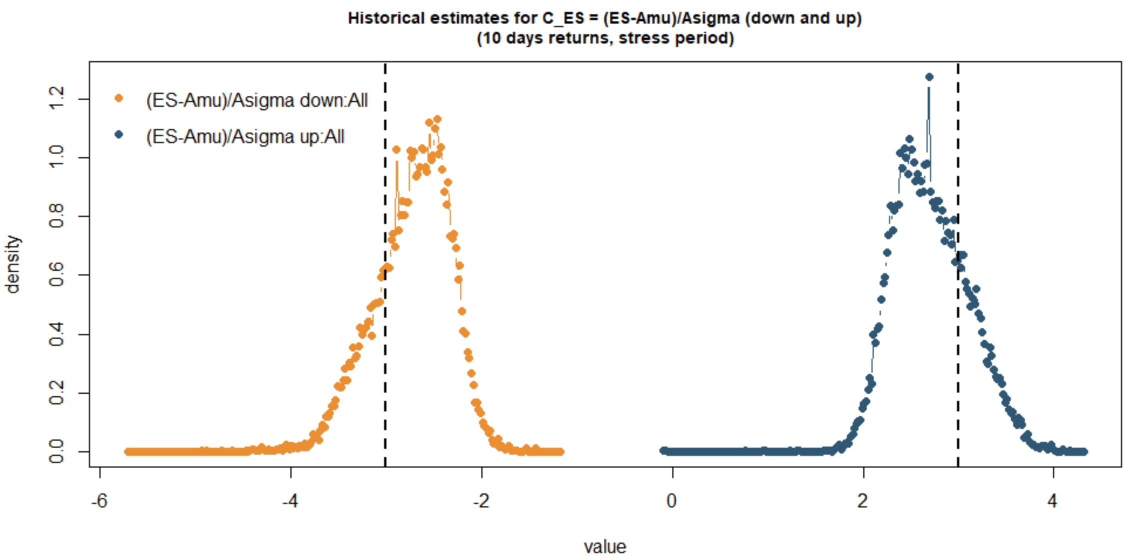


Sources: EBA non-modellable risk factor data collection and EBA calculations.

Figures 7 and 8 show the distribution of the historical estimates of C_{ES} based on the asigma method for the stress and current periods, respectively. The historical estimates of C_{ES} are presented separately for the left and right tail expected shortfalls.

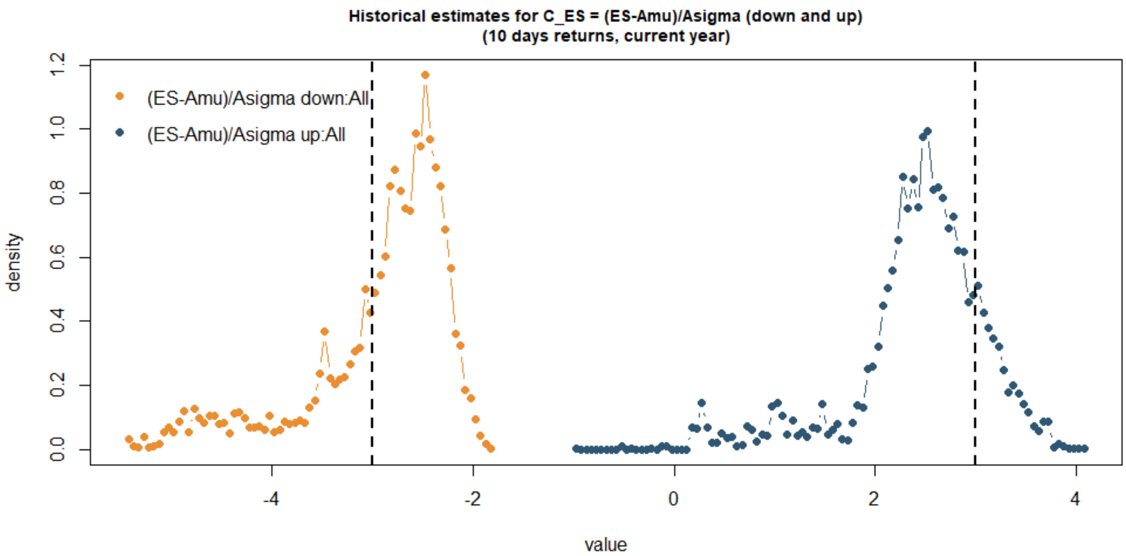
The peaks of the histograms are somewhat narrow for the asigma method, implying that there is a low degree of variation in the empirical values of C_{ES}. This is because skewness can be better reflected in the asigma method, which has four estimated parameters (two means and two sigmas).

Figure 7: Historical estimates of C_{ES} based on the asigma method, stress period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Note: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS.

Figure 8: Historical estimates of C_{ES} based on the asigma method, current period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Note: The current period uses data provided for the most recent year, which for most time series corresponds to mid-2018 until mid-2019.

Table 4 shows summary statistics for historical estimates of C_{ES}. The (absolute) median C_{ES} ranges from 2.5 to 2.7 and the mean from 2.5 to 2.9. The third quartile of $|C_{\mathrm{ES}}|$ is about 3 for most shocks (ranging from 2.9 to 3.4, noting that the downward shocks were assigned a negative sign, so that the first quartile corresponds to the third quartile of $|C_{\mathrm{ES}}|$).

The choice of $C_{\mathrm{ES}} = 3$ will be moderately conservative for some combinations of method and period and close to the mean for some others. It roughly corresponds to the third quartile of observed values, suggesting that 75% of the underlying distributions would be covered, while for 25% of risk factors C_{ES} would be too small.

Table 4: Summary statistics for historical estimates of C_{ES} based on the sigma and asigma methods, stress and current periods

	Count	Mean	Median	Std dev.	Q1	Q3	Min.	Max.
Asigma method, 10-business-days returns, stress period								
(ES-Amu)/asigma down	28 467	−2.73	−2.69	0.40	**−2.98**	−2.44	−5.71	−1.16
(ES-Amu)/asigma up	28 467	2.71	2.68	0.40	2.42	**2.98**	−0.09	4.30
Asigma method, 10-business-days returns, current period								
(ES-Amu)/asigma down	5 352	−2.91	−2.72	0.70	**−3.14**	−2.44	−5.42	−1.84

	Count	Mean	Median	Std dev.	Q1	Q3	Min.	Max.
(ES-Amu)/asigma up	5 352	2.45	2.52	0.66	2.22	**2.85**	−0.96	4.06

Sources: EBA non-modellable risk factor data collection and EBA calculations.
Notes: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS. The current period uses data provided for the most recent year, which for most time series corresponds to mid-2018 until mid-2019.

Many respondents to the CP considered this choice somewhat conservative and proposed lowering the value of C_{ES}. The EBA believes that C_{ES} = 3 strikes the right level of conservatism, considering that this single constant is used for all risk factors under the asigma method, including those with very non-Gaussian features. The EBA also notes that the choice of C_{ES} only affects the asigma method, which is a simplified method and a first fallback where the more accurate historical method is not possible. As some of the concerns related to the level of C_{ES} were of a capital nature, the EBA decided to lower the uncertainty compensation factor in its draft RTS, which affects all methods, not only the asigma method (see below and Annex I).

Calibration of the uncertainty compensation factor

The uncertainty compensation factor $\left(0.95 + \frac{1}{\sqrt{N-1.5}}\right)$ has been designed for the purpose of capturing and compensating for uncertainty in computing calibrated shocks in order to avoid undue underestimation. See Annex I for more details.

Number of observations needed for the different stepwise methods

The draft RTS prescribe three different methods for calibrating shocks based on the minimum number of returns available for each risk factor. In addition, to ensure that one consistent method is used for all risk factors in the non-modellable risk bucket, the same type of method (i.e. historical, sigma or fallback) should be used for all risk factors in the same bucket, depending on the minimum number of returns for the risk factors within that bucket.

The historical method can be used for risk factors with more than 200 returns and the sigma method for risk factors with more than 12 returns; otherwise, the fallback method should be used. The aim of the proposed waterfall approach is to cater for all non-modellable risk factors with different data availability, ranging from daily data to almost no observations at all. The guiding principle of the waterfall approach is that the more data that are available the more detailed the calibration that can be performed, while for fewer data a simpler and more robust approach is needed.

In particular, the expected shortfall at 97.5% confidence is a tail measure that takes into account only 2.5% of data points. By setting the minimum number for the historical method at 200, the historical expected shortfall estimator uses at least 200 × 2.5% = 5 points in the tail. This value seems appropriate in order to allow time series that have about a total of two months of data missing within a year. Conversely, for a risk factor with fewer than 200 data points, fewer than five data points would be taken into account, making the expected shortfall unstable and entailing higher estimation error (see Annex I).

The estimation of the standard deviation is statistically much more robust than that of the expected shortfall, as can be seen from the standard deviation of the quantities (see Annex) I shows the standard deviation of the estimated standard deviation (sigma). Twelve returns seems to lead to a still acceptable estimation error. Note that *N* = 12 for the asigma method means six points above and below the median, similar to the requirement for the historical method (five).

Fallback method

In the instructions for the data collection exercise, the EBA put forward a fallback method that included a list of prescribed calibrated shocks for each broad risk factor subcategory. The shocks were calibrated based on the risk weights applied to these subcategories in the sensitivity-based approach (i.e. standardised method). Given the feedback received during the data collection, the EBA has substantially redesigned the fallback method. The following options were considered:

Option 5a: Provide a list of prescribed calibrated shocks for each broad risk factor subcategory (as in the data collection instructions).

Option 5b: For risk factors that coincide with one of the risk factors included in the sensitivity-based method, calibrate shocks based on their respective risk weights. For all remaining risk factors, use the 'other risk factor' fallback method.

Option 5a is a simple and harmonised method of calculating calibrated shocks. However, it covers only the risk factors that are included in the sensitivity-based method (i.e. the prescribed list). Option 5b allows the use of the fallback method for all other risk factors. It is also more flexible if data are available for the same type of risk factor. It is also expected to be less conservative than Option 5a.

Option 5b is retained.

Nearest to 10-business-days return method

In the instructions for the data collection exercise, the EBA requested institutions to calculate the nearest to 10-business-days returns using a 5-day 'block-out period'. The aim was to avoid the last observation within the observation period being used very often when computing the returns from the last 11 observations in the period. Given the experience gained from the data collection, the EBA considered the following options:

Option 6a: Use a 5-day block-out period.

Option 6b: Extend the 1-year period by 20 business days.

Under Option 6a, for each date index $\mathrm{t} \in \{1, \dots, \mathrm{M}-1\}$ for which an observation is available a nearest to 10 business days candidate $\mathrm{t_{nn}(t)}$ should be determined by applying the following formula:

$$t_{nn}(t) = \underset{\substack{t' > t \\ D_M - D_t > 5\text{ days} \\ t' \in \{2,\dots,M\}}}{\operatorname{argmin}} \left[\left| \frac{10\text{ days}}{D_{t'} - D_t} - 1 \right| \right]$$

The return for date index t' should be considered only when $D_M - D_t > 5$ days, in order to avoid having too many returns using the last data point $r_j(D_M)$. As a result of this 'block-out period', the number N of sample returns might be smaller than the number of risk factor value observations minus 1, $M - 1$.

Let $\{D_1, \dots, D_M, D_{M+1}, \dots D_{M+d}\}$ be the vector representing the observation dates within the 1-year stress period extended by 20 business days. Then, for a given non-modellable risk factor, the vector $\{D_1, \dots, D_M\}$ represents the observation dates within the 1-year stress period, and the vector $\{D_{M+1}, \dots D_{M+d}\}$ represents the observation dates during the 20 business days following the 1-year stress period.

Under Option 6b, for each date index $t \in \{1, \dots, M-1\}$ a nearest to 10 business days candidate $t_{nn}(t)$ should be determined by applying the following formula:

$$t_{nn}(t) = \underset{\substack{t' > t \\ t' \in \{2,\dots,M,M+1,\dots M+d\}}}{\operatorname{argmin}} \left[\left| \frac{10\text{ days}}{D_{t'} - D_t} - 1 \right| \right]$$

Accordingly, being $t \in \{1, \dots, M-1\}$ and $t' \in \{2, \dots, M, M+1, \dots M+d\}$, the starting observation used to determine a return always lies in the 1-year stress period, while the ending observation may lie in the 20-day period following the 1-year stress period. In this case, $N = M - 1$.

While participants in the data collection exercise did not provide any comment on the block-out period method, some did not implement it correctly. Therefore, the EBA considered Option 7b, which extends the observation dates by up to 20 business days without using a block-out period. The choice of 20 days corresponds to the minimum liquidity horizon assumed for non-modellable risk factors.

The choice of the method has little influence on the final calibrated shocks. Option 6b has the advantage that it ensures that the number of returns equals the number of observations minus 1, which makes the implementation of the required IT simpler. Moreover, it allows slightly more data points to be used, improving statistical stability.

Option 6b is retained.

Identifying the maximum loss in the calibrated stress scenario risk factor range

In the last step in the stepwise method, institutions are required to determine the extreme scenario of future shock by identifying the worst loss incurred when the non-modellable risk factor moves within the identified calibrated stress scenario risk factor range.

Institutions participating in the data collection exercise were required, in order to identify the extreme shock in $CSSRFR\left(r_j(D^*)\right)$, to evaluate the loss function on a grid of 11 equidistant points (the current value and 10 scanning points) splitting the range into 10 intervals. The set of those points was formally defined as follows:

$$Grid_{\text{data collection exercise}} = \left\{ r_j(D^*) \ominus i \times \frac{CS_{\text{down}}(r_j)}{5}, r_j(D^*), r_j(D^*) \oplus i \times \frac{CS_{\text{up}}(r_j)}{5} \mid i = 1, \dots, 5 \right\}$$

However, a majority of participating institutions expressed concerns with respect to the computational effort that a valuation of the loss on 10 points in addition to the current value would require and claimed that in many cases the highest loss would occur at the boundaries of the calibrated stress scenario risk factor range.

Following this feedback, the EBA considered the following options:

Option 7a: Evaluate the loss function on a grid of 11 equidistant points splitting the range into 10 intervals.

Option 7b: Evaluate the loss function on a grid of four points (the two outer points in each direction).

Under Option 7b, the identification of the maximum loss by scanning the calibrated stress scenario risk factor range is done by searching a grid consisting of four points:

$$\text{Grid}_{\text{draft RTS}} = \begin{Bmatrix} r_j(D^*) \ominus 100\%\ CS_{\text{down}}(r_j), r_j(D^*) \ominus 80\%\ CS_{\text{down}}(r_j), \\ r_j(D^*) \oplus 80\%\ CS_{\text{up}}(r_j), r_j(D^*) \oplus 100\%\ CS_{\text{up}}(r_j) \end{Bmatrix}$$

While in theory the maximum loss could occur at any point in the calibrated stress scenario risk factor range, it is more likely to occur at the boundaries, i.e. for the strongest shocks. Indeed, the loss incurred if a risk factor stays constant is typically very small (if the passage of time effect is not captured, it is exactly zero). The data collection exercise asked institutions to identify where the highest loss was observed and indeed this was mostly (but not always) at the boundaries of the range.

Option 7b has the advantage of reducing significantly the computational burden on institutions, by requiring them to compute the loss at only four points, the two outer points in both directions. The idea is that the maximum loss is unlikely to occur because of small risk factor movements, while it will not necessarily always occur as a result of the strongest shocks in the calibrated stress scenario risk factor range. Therefore, under Option 7b, scanning for the maximum loss is performed not at the centre of the range, as in Option 7a, but only at the 80% and 100% downward or upward calibrated shock. Moreover, the grid points correspond to the step width h for the non-linearity adjustment and can be directly re-used for the computation of this adjustment, reducing further the computational burden for institutions.

Option 7b is retained.

Calibration of the tail parameter ϕ

The stepwise method is based on the idea that $ES(loss[r_j(D_t)])$ is approximately equal to $loss(ES[r_j(D_t)])$. However, when losses grow faster than linearly (e.g. when the loss function is convex), the expected shortfall of losses for varying $r_j(D_t)$ is higher than the loss under the expected shortfall of $r_j(D_t)$. As a result, for a given non-modellable risk factor j, institutions have to calculate the 'non-linearity adjustment' $\kappa_{D^*}^{j}$ where the extreme scenario of future shock is calculated in accordance with the stepwise method and such extreme scenario occurs at the boundaries of the calibrated stress scenario shock range at figure date $CSSRFR\left(r_j(D^*)\right)$. The non-linearity adjustment $\kappa_{D^*}^{j}$ is determined as follows:

$$\kappa_{D^*}^{j} = \min\left(\max\left[\kappa_{\min}, 1 + \frac{\text{loss}_{D^*}(r_{j,-1}) - 2 \times \text{loss}_{D^*}(r_{j,0}) + \text{loss}_{D^*}(r_{j,1})}{2 \times \text{loss}_{D^*}(r_{j,0})} \times (\phi - 1) \times 25\right]; \kappa_{\max}\right)$$

where:

$$r_{j,0} = \begin{cases} r_j(D*) \oplus CS_{\text{up}}(r_j) \text{ where the extreme scenario of future shock } is\ CS_{\text{up}}(r_j) \\ r_j(D*) \ominus CS_{\text{down}}(r_j) \text{ where the extreme scenario of future shock is } CS_{\text{down}}(r_j) \end{cases}$$

$$r_{j,-1} = r_{j,0} \ominus h$$

$$r_{j,+1} = r_{j,0} \oplus h$$

$$h = \begin{cases} \dfrac{CS_{\text{up}}(r_j)}{5} \text{ where the extreme scenario of future shock is } \mathrm{CS}_{\text{up}}(\mathrm{r_j}) \\ \dfrac{CS_{\text{down}}(r_j)}{5} \text{ where the extreme scenario of future shock is } \mathrm{CS}_{\text{down}}(\mathrm{r_j}) \end{cases}$$

The step width h was set to a value that balances the need to grasp a meaningful part of the tails of the returns and the need for it to be small enough to provide a meaningful local curvature measure at the left or right boundary of the calibrated stress scenario risk factor range. In other words, it is a compromise between wide enough and local enough. In the data collection exercise, the step width 20% appeared to work well in practice, as no feedback was received that this value was unsuitable in any way.

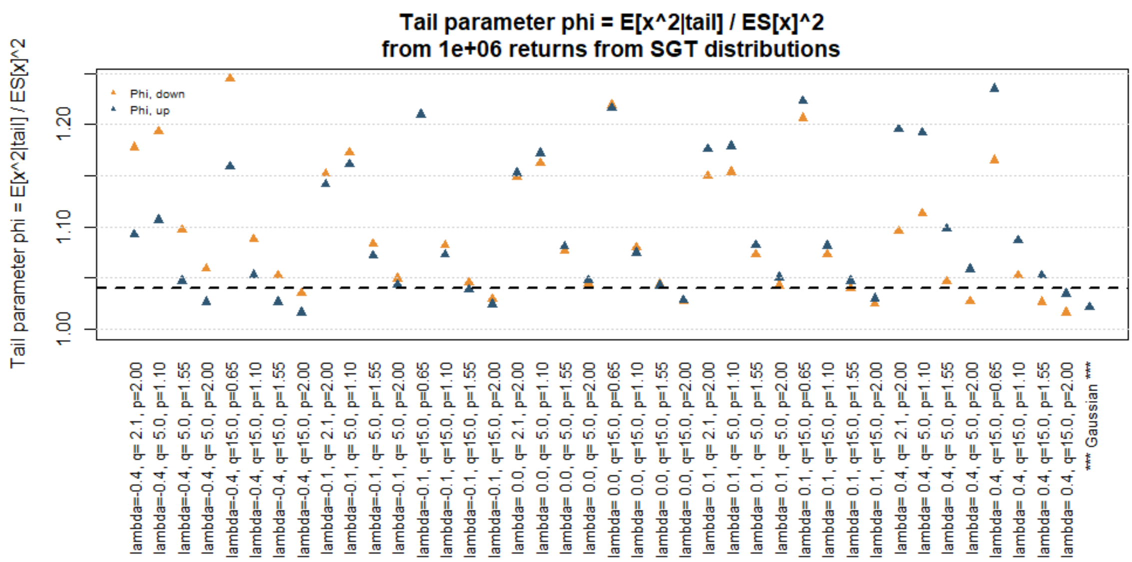
One institution participating in the data collection exercise pointed out that portfolios the value of which depends linearly on the given non-modellable risk factors can also attract a non-linearity correction $\kappa_{D^*}^{j}$ different from 1. In fact, this can be the case when the application operator $\oplus/\ominus$ of the chosen return type is non-linear (e.g. for log returns). In this situation, the three stencil points $r_{j,-1}$, $r_{j,0}$ and $r_{j,1}$ (which correspond to the application of 80%, 100% and 120% of $CS_{\mathrm{up/down}}$, respectively) may exhibit unequal spacing, thereby yielding a non-zero estimate for the second derivative. This behaviour is compatible with the derivation of the quadratic approximation formula, and therefore intentional.

The tail parameter ϕ is used in the formula to approximate the relative difference of the expected shortfall of losses due to risk factor movements and the loss of the expected shortfall of risk factor movements in the tail of the risk factor movements in a quadratic approximation. More precisely, ϕ measures how the expectation value of squares in the tail of a distribution relates to the square of the expectation value, the expected shortfall:

$$\hat{\phi}_{\mathrm{Left/Right}}\big(Ret(j)\big) \stackrel{\mathrm{def}}{=} \frac{E\left[Ret(j)^2 \;|Ret(j) \text{ in left/right } \alpha - \text{tail}\right]}{\left\{\widehat{\mathrm{ES}}_{\mathrm{Left/Right}}\big(Ret(j), \alpha\big)\right\}^2}$$

The tail parameter depends very strongly on the distribution of the non-modellable risk factors. As Figure 9 shows, the tail parameter ϕ can vary substantially for SGT distributions. It increases strongly with decreasing peakedness parameter p.

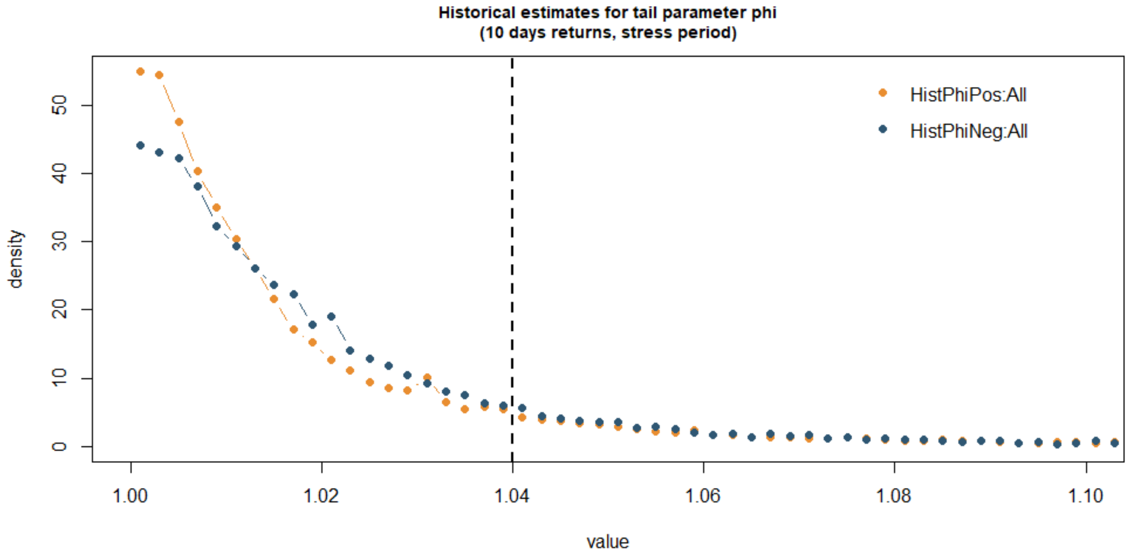
Figure 9: Tail parameter ϕ for different SGT distributions



Figures 10 and 11 show the histogram of the values for ϕ in the stress period and the current year, respectively. Table 5 shows summary statistics for ϕ. The historical estimates of ϕ range from 1 to 6.1, with a mean of about 1.04 and with 75% of the estimates being below 1.03, as shown by the third quartile.

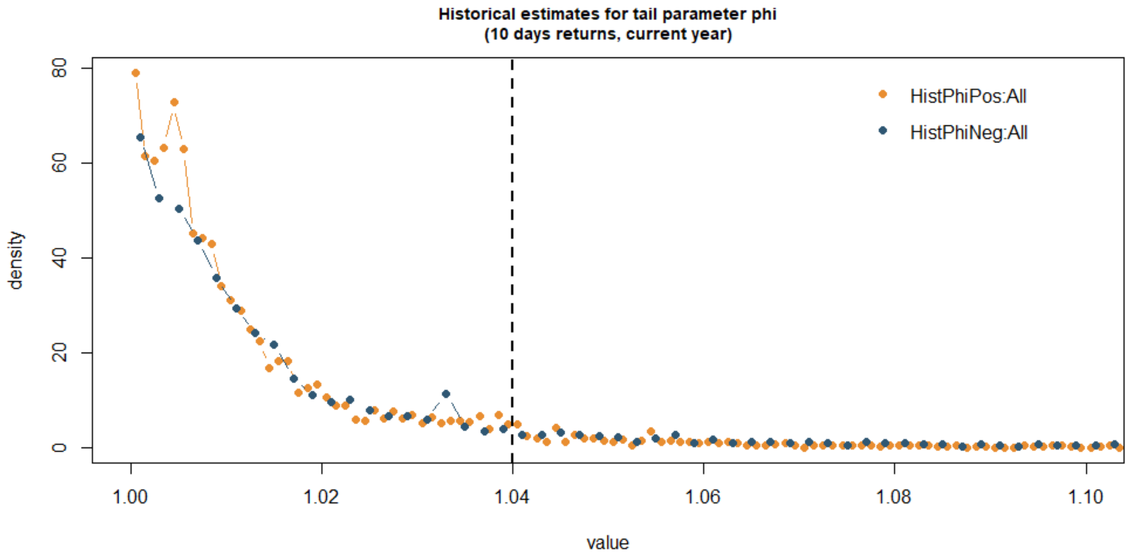
Under the asigma method, institutions are not allowed to estimate ϕ based on historical data, as the estimate is based on an expected shortfall calculation for which too few data points are available (hence the choice of the sigma method in the first place). It is proposed that the value of ϕ be fixed at 1.04, which is close to the average of all mean values reported individually for the left and right tails and the stress and current period (the actual value is 1.043). This value, $\phi = 1.04$, was previously proposed in industry feedback and is slightly lower than the value used in the data collection exercise (1.05).

Figure 10: Historical estimates of tail parameter ϕ, stress period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Note: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS.

Figure 11: Historical estimates of tail parameter ϕ, current period



Sources: EBA non-modellable risk factor data collection and EBA calculations.
Note: The current period uses data provided for the most recent year, which for most time series corresponds to mid-2018 until mid-2019.

Table 5: Distribution of historical estimates of tail parameter ϕ, stress and current periods

	Count	Mean	Median	Std dev.	Q1	Q3	Min.	Max.
10-business-days returns, stress period								
Phi left	28 800	1.04	1.01	0.19	1.01	1.03	1.00	5.71
Phi right	28 800	1.03	1.01	0.12	1.01	1.03	1.00	6.23
10-business-days returns, current period								
Phi left	5 387	1.03	1.01	0.14	1.00	1.02	1.00	3.90
Phi right	5 387	1.06	1.01	0.32	1.00	1.03	1.00	5.76

Sources: EBA non-modellable risk factor data collection and EBA calculations.
Notes: The stress period used for each category was that defined by the institution – on a best-effort basis – and does not necessarily correspond to that prescribed in the draft RTS. The current period uses data provided for the most recent year, which for most time series corresponds to mid-2018 until mid-2019.

Under the historical method, the EBA considered the following options:

Option 9a: Estimate the tail parameter ϕ using historical data.

Option 9b: Set ϕ at 1.04.

While the historical estimate under Option 9a provides a number that is more accurate than a global estimate, there is estimation error in ϕ. Option 9b provides a simpler approach.

Some respondents to the CP preferred the option of setting the tail parameter at the constant value 1.04 to simplify the framework. Others considered that the RTS should allow the possibility of estimating the tail parameter based on historical data.

The EBA acknowledges that some respondents deemed it beneficial to calculate the tail parameter using a historical estimator where possible. Considering that the estimator provides a more accurate result, the EBA decided not to amend the draft RTS in this respect.

Option 9a is retained.

Floor and cap for the non-linear adjustment κ

Most financial instruments are non-linear (longer dated bonds and put and call options at the money being simple examples). Therefore, a non-linearity adjustment is generally required in order not to ignore the effects of non-linearity. In practice, for some portfolios the non-linearity effect may be small, while for others it will be more material. However, without a quantitative measure it is difficult to assess if a noticeable non-linearity effect occurs and how strong it is.

The non-linearity adjustment is a simple quadratic approximation for adjusting for losses growing non-linearly for very large risk factor shocks. In computing the quadratic approximation, the curvature of the loss function is determined using a three-point stencil with a step width h set to 20% of the relevant calibrated shock. Due to the limitations of the approach, the benefit of the non-linearity adjustment is floored at $\kappa_{\text{min}} = 0.9$.

To identify an appropriate lower boundary for the non-linearity adjustment, the exact adjustment can be evaluated in the very beneficial situation where the loss function, hypothetically, increases linearly until hitting the left or right boundary of the calibrated stress scenario risk factor range and then is flat. Under distributional assumptions compatible with the choice $\phi = 1.04$, this yields a non-linearity adjustment of $\kappa_{\text{min}} = 0.9$. Adjustments smaller than this value are therefore probably due to inaccuracies in the quadratic approximation and should not be recognised. In addition, to avoid extreme values for the non-linearity adjustment, the EBA introduced a cap of $\kappa_{\text{max}} = 5$.

4.2 Feedback on the public consultation

The EBA undertook a public consultation on the guidelines contained in this paper. The consultation period lasted for 3 months and ended on 4 September 2020.

Seven responses were received, of which four were non-confidential and were published on the EBA website. This section presents a summary of the key points and other comments arising from the consultation, the analysis and discussion triggered by these comments and the actions taken to address them if deemed necessary.

In a number of cases, some industry bodies made similar comments or the same body repeated its comments in response to different questions. These comments and the EBA's analysis of them are included in the section of the feedback table that the EBA considers most appropriate'. Changes to the draft RTS have been incorporated as a result of the responses received during the public consultation.

4.2.1 Summary of key issues and the EBA's response

In the feedback table that follows, the EBA has summarised the comments received and explains which responses have and have not led to changes, and the reasons for this.

Summary of responses to the consultation and the EBA's analysis

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
General comments			
Level of prescription.	Some respondents expressed concerns with respect to the level of prescription of the draft RTS. They argued that a high-level, principles-based approach would provide a more proportionate alternative.	The EBA is of the view that it is in the primary interest of the industry to be able to make reference to an accurate regulatory framework. This also benefits the level playing field. Thus, the amendments made to the draft RTS proposed for consultation should not increase variability in the calculation and application of the extreme scenario of future shock.	No amendments.
Responses to questions in Consultation Paper EBA/CP/2020/10			
Q1. What is your preferred option among Option A (stress period-based extreme scenario of future shock) and Option B (extreme scenario of future shock rescaled to stress period)? Please elaborate, highlighting pros and cons.	Some respondents stated that the direct determination of the extreme scenario of future shock for a non-modellable risk factor over the selected stressed period (Option A) was clearly preferable to any rescaling of a current window shock that could be obtained by looking at modellable risk factors (Option B). However, most respondents considered the stressed period determination of Option A was computationally too intensive to be implemented in practice. Most respondents considered that, if the stress period determination approach could be disentangled from the determination of capital requirements, Option A would be preferable to Option B, at least for those risk factors with sufficient data for the stressed period. One respondent noted that, for risk factors with sufficient data for the stress period, Option A avoided the use of current to stressed period scaling resting on assumptions.	The EBA acknowledges that both Option A and Option B have merits and drawbacks. The EBA understands that Option A entails a full calculation of the stress scenario risk measure for each rolling 12-month period from 2007, which is operationally burdensome. The EBA understands that many respondents considered that Option B should only be used in case of insufficient data. The EBA shares the view expressed by some respondents that the determination of the stress period could be disentangled from the determination of the extreme scenario of	Option A is retained and Option B removed. See other questions for specific amendments to Option A.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	Moreover, under Option A the calibrated shocks for a given stress period in the past would not be influenced by new, current period data. Most respondents noted that, if amendments to the calibration of the stress period under Option A were not considered, then Option B would be the only implementable solution. One respondent raised a concern about data quality for the stress period for some groups of non-modellable risk factors, particularly for equity and credit risk factors where the fallback method would be applied. They were concerned that this would result in an excessively conservative capital charge. For those risk factors, the use of current to stressed period scaling would allow the use of current period data that could be considered to have some resemblance to the IMA expected shortfall approaches (with regard to the full and reduced set of risk factors). Some respondents proposed specific alternative approaches to determining the stress period. These are summarised under Q12.	future shock, which would make Option A preferable to Option B. As stated in the CP, the EBA intends to retain only one option. Therefore, the EBA considers it the most appropriate approach to disentangle the stress period determination from the capital calculation and use a modified Option A, addressing the drawbacks of that option. Please also refer to the analysis of the Q12 responses.	
Q2. What are characteristics of the data available for NMRF in the data observation periods under Options A and B?	Two respondents remarked that Option A was applicable only to non-modellable risk factors with sufficient data quality over a stressed period. In contrast, Option B was more suitable for non-modellable risk factors without enough observations over the stressed period. It was concluded that the approaches to the determination of the extreme scenario of future shock could be contextually used for risk factors with different data quality. One respondent remarked that, for each risk factor, they had been able to collect the entire historical time series. Therefore, they stated, they had been able to compute the time series of nearest to 10-business-days returns irrespective of the 1-year period (current or stressed). One respondent pointed out the different availability of data depending on risk factors. They stated that, for rates and foreign exchange data, there are often long data histories available. Option A will often, but not always, be suitable for these. In contrast, for idiosyncratic risk factors, it is presumed	The EBA acknowledges that data for the observation period under Option A are of higher quality than those for the current period (i.e. the observation period under Option B) and that availability depends on risk factors: • for interest rate and foreign exchange risks, data tend to be available; • for idiosyncratic risk factors data tend to be rather less available. The EBA also notes that, even under Option A, only a relatively small amount of	Option A is retained and Option B removed. See other questions for specific amendments to Option A.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	that data for the stress period may not be available for the expected shortfall model. For these, the use of Option B might often be more suitable, whereas the sole use of Option A would be particularly challenging.	risk factors would fall under the fallback method. Thus, in the light of the pros and cons laid down in the EBA's analysis in relation to Q1, the EBA decided to retain Option A in the final draft RTS.	
Q3. Do you think that institutions will actually apply the direct method to derive the extreme scenario of future shock or do you think that, given the computational effort that it requires and considering that the historical method typically provides very similar results, it will not be used in practice? As stated in the background section of this CP, the EBA will drop the direct method from the framework if not provided with clear evidence of a need for it.	Two respondents did not believe that the direct method would be used in practice. They cited the computational effort it would require, especially to derive the stressed period. Furthermore, they stated that the calculation of the expected shortfall in a full revaluation for each non-modellable risk factor would require many more revaluations than the modellable risk factors calculation. One respondent concluded that the direct method would not be applied. Their reasoning was as follows: the direct approach has some advantages as it works properly with non-modellable risk factors where each tenor can have its own shift characteristics, capturing the true dynamics of a historical scenario for non-modellable buckets. Furthermore, it is straightforward and it is better aligned with the expected shortfall calculation. However, due to the multitude of non-modellable risk factors that would require a stand-alone expected shortfall calculation, the direct method is overly burdensome in terms of computational effort. In addition, empirical analysis done by the respondent found similar results from the direct method and the historical method, while the latter is less costly from an operational point of view. The respondent provided results evidencing this assessment, which had previously been shared during the June 2019 data collection exercise. One respondent remarked that the direct approach should be retained; the EBA should not consider dropping this methodology. In particular, they stated that the direct method should be available to be applied to risk factors for which current period data are used. It was stressed that the direct	The EBA agrees with some of the comments received with respect to the pros and cons of the direct method, and it acknowledges that there could be cases in which the direct method would be better suited to capturing the properties of risk factors than the stepwise method. As a result, the EBA decided to retain the direct method in the final draft RTS. However, retaining the direct method should not lead to regulatory arbitrage. Thus, requirements ensuring that for a given risk factor or bucket the direct method and the stepwise method are not used interchangeably for the purpose of obtaining lower capital requirements have been included.	Amendments to Articles 1 and 2

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	approach was the most straightforward way to compute the stress scenario risk measure in accordance with the international standards. Furthermore, the direct method was deemed to capture non-modellable risk factors appropriately for non-standard non-modellable risk factor P&L profiles and to work well with non-modellable risk factor buckets and grids where each tenor has its own shift characteristics. In summary, including the direct approach in the framework was deemed to make the framework more robust and applicable across a wide range of risk types and situations. These statements were evidenced by an ad hoc impact analysis comparing the non-modellable risk factor charge resulting from the direct approach and that resulting from the stepwise (historical and contoured shift) approach. On the basis of an analysis of a foreign exchange options desk (at the money and smile risk factors), it was concluded that the non-modellable risk factor charge was overestimated by 21% using the contoured approach as opposed to the direct approach. This was regarded as an inducement for institutions to increase their computational power in order to use the direct approach. The analysis concluded that the contoured approach was close to the direct approach by around 20%. In summary, this analysis showed the importance of having the direct method as part of the overall framework so that it could be used to capture risk features where required. The stepwise contoured approach was regarded as the best approach, mimicking the true dynamics with some conservatism. Further analysis was done to analyse scaling of the current period under the direct approach. This study compared the direct approach using the stressed period as defined under Option A and the current period using shocks scaled by the volatility scalar as defined under Option B. The analysis showed that, under the direct approach, the current SES scaled shock was 1% lower than the stressed SES.		
Q4. What is your preferred option among (i) the	The majority of the respondents supported the contoured shift option.	The EBA acknowledges the broad support for the contoured shift option and that	The contoured shift option is retained.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
representative risk factor – parallel shift option, and (ii) the contoured shift option? Please elaborate, highlighting pros and cons.	Two respondents considered that the contoured shift option would represent more accurately the characteristics of the individual risk factors embedded in a regulatory bucket. One respondent also considered that the approach would mitigate discontinuities between adjacent buckets and avoid bumps influenced by outliers. In addition, one respondent commented on the following advantages: provides a good estimation of the risk in most cases (can be used instead of the direct approach); better treatment of different sizes of shifts in the same bucket, not penalising a more granular risk factor set up; and more reasonable and not biased towards over-conservatism compared with the representative factor approach. On the other hand, one respondent pointed out that, when the stepwise method is used in conjunction with the contour shift method, there may be cases where some risk factors within a bucket have sufficient data for the historical method and others only sufficient data for the asigma/sigma method. The respondent recommended giving the option to use the same method consistently for all risk factors. One respondent also pointed out that the use of additional non-linearity scenarios in conjunction with the contour approach could be wasteful compared with allowing firms to make alternative adjustments. Therefore, the respondent proposed including in the contour approach the provision that firms could use an internally developed kappa adjustment methodology (appropriate for use with curves and surfaces) subject to local regulatory approval. Finally, one respondent proposed a third option whereby the shock for the bucket would be derived from the 'most relevant' risk factor (i.e. for a standard maturity bucket $0 \le t < 0.75$ could be 6M, for $0.75 \le t \le 1.5$ it could be 1Y and so on), arguing that it would require less computational effort.	respondents deemed the option to better represent the behaviour of risk factors within a bucket. The EBA decided to retain the contoured shift option and remove the parallel shift option. In addition, the EBA decided to amend the draft RTS to ensure that shocks corresponding to risk factors in the same bucket are calibrated using the same type of method (i.e. historical, sigma or fallback).	The parallel shift option was removed from Article 2.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
Q5. What are your views on how institutions are required to build the time series of 10-business-dayss returns? Please elaborate.	No concerns were raised regarding the method for building series of 10-business-days returns. One respondent agreed with the approach, which was consistent with the methodology applied in the context of modellable risk factors and took into account the limitations in the data and time series. One respondent commented that the approach avoided using differences of 5 days or less, and thus avoided issues when scaling up from shorter periods. The extension of the period by 20 days was also seen reasonable and practical.	Considering the feedback from the respondents, the EBA deems the approach to building 10-business-days returns appropriate and considers that no changes in the methodology are needed.	No amendments.
Q6. What is your preferred option among (i) the sigma method and (ii) the asymmetrical sigma method for determining the downward and upward calibrated shocks? Please highlight the pros and cons of the options. In addition, do you think that in the asymmetrical sigma method returns should be split at the median or at another point (e.g. at the mean or at zero)? Please elaborate.	Respondents were divided between the two options. One respondent in favour of the asymmetrical sigma method pointed out the following advantages: allows for asymmetrical empirical data; matches the historical approach more closely; less change when a risk factor moves from the historical method to the asymmetrical sigma method (compared with the sigma method); data are not forced to be mean-centred (as in the sigma method). The respondent also supported the split at the median, listing the following pros: sufficient data in each half to calibrate; less complicated than other methods; operates reasonably under sample testing. One respondent also supported the asymmetrical sigma method, considering it more robust and a method that would cater to the skewness of returns. The respondent supported the use of the median, since it would ensure that institutions would have the same number of returns to calibrate upward and downward shocks (splitting at zero could lead to a lower number of returns to estimate upward shocks). Two respondents supported the sigma method, which would not open additional degrees of freedom at the split point.	The EBA acknowledges that there was no strong preference on the part of respondents for one of the proposed methods (sigma or asigma). Considering that the asymmetrical sigma method better fits the historical data, and specifically the asymmetrical features commonly seen in financial series, the EBA decided to retain the asymmetrical sigma method in the final draft RTS. Although it is true that the asigma method raises the question of where to split the distribution, the median seems to be a natural choice and has the advantage of guaranteeing that upward and downward shocks are estimated using the same amount of data.	The asigma method option is retained. The sigma option was removed from Article 5.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
		Accordingly, the EBA decided not to amend the way in which the returns are to be split and to retain the median as the split point. As a result, the sigma method was removed from the final draft RTS.	
Q7. What are your views on the value taken by the constant C_ES for scaling a standard deviation measure to approximate an expected shortfall measure?	Some respondents noted that the constant C_ES clearly depended on the empirical distribution of the non-modellable risk factor returns. The proposed value, C_ES = 3, was considered rather conservative by those respondents. One respondent noted that, because empirical results confirmed that non-modellable risk factor returns had a fat-tailed distribution, the value of C_ES should be lowered. One respondent stated that a value for C_ES closer to the median of the non-modellable risk factor returns should be used, because other compensations for uncertainty were built into the methodology, and proposed C_ES = 2.75.	The EBA deliberately and transparently set the constant C_ES to a prudent value, because this single constant is used for all risk factors under the asymmetrical sigma method, including very non-Gaussian ones. The EBA accordingly decided to leave C_ES = 3 unchanged. Setting the value to 3 is a result of the analysis presented in the CP annex (see Figure 12). The EBA also notes that lowering this number would affect the calibration only of shocks corresponding to risk factors for which institutions use the asymmetrical sigma method. Thus, if the concerns are merely of a capital nature, reducing the uncertainty compensation factor would better address such concerns, as it is applied regardless of the method used (e.g. it has to be applied also in the context of the historical method).	No amendments.
Q8. What are your views on the uncertainty compensation factor $(1+ C\_UC / \sqrt{2(N-1.5)})$? Please note that this question is also relevant for the	One respondent deemed the calibration of the uncertainty compensation factor with C_UC = 1.28 sufficiently conservative and acceptable for the scope of non-normal distributions, including for the historical method.	As explained in the CP, the uncertainty compensation factor takes into account the poorer observability of non-modellable risk factors and uncertainty in the parameter	Changes to Articles 4 to 6 and Article 16 to reflect the amendments made to the

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
purpose of the historical method.	Many respondents suggested that the uncertainty compensation factor should be adjusted such that it was one if full daily data were available (i.e. at least 250 data points in the historical method). One respondent stated that an unchanged uncertainty compensation factor implied a systematic 5.75% conservative buffer in the stress scenario risk measure over the IMA expected shortfall, which should be taken into account in assessing simplifications applied to the stress scenario risk measure.	assumptions and non-linearity assumptions, as well as statistical estimation error. That said, the EBA considers that the uncertainty compensation factor can be lowered so that it becomes closer to 1 for daily data, in order not to add several layers of conservatism while still maintaining a prudent approach. As a result, the EBA reviewed the formula for computing the uncertainty compensation factor and set it to: UCF = 0.95 + 1/sqrt(N – 1.5)	uncertainty compensation factor.
Q9. What are your views on the fallback method that is envisaged for risk factors that are included in the sensitivity-based method? Please elaborate.	Several respondents proposed extending the use of the sensitivity-based method fallback to some types of basis risk factors. Respondents mentioned that the fallback method would be of limited use under Option B and accordingly considered the fallback method more relevant under Option A. The merits of all three methods (fallback, other risk factor and changing period) could be perceived and, depending on the non-modellable risk factor in question, one or the other might be deemed preferable on a case-by-case basis. As mentioned above, it was proposed that the use of the SBM fallback method be extended to cases where a non-modellable risk factor is a basis or a spread between risk factors that coincide with SBM risk factors. The respondents mentioned that the risk weight to be used for the SBM fallback method is the one that would result in the same SBM capital charge when applied to the basis or spread position in the standardised approach. In general, the risk weight to be used is a function of the correlation between	The proposed extension of the application of the sensitivity-based method to basis risk factors under the fallback method is not seen as a viable option, as it might not lead to a prudent result. In addition, considering that the other risk factor option can be applied to basis risk factors, the EBA deems that there is no need to have in place another treatment for basis risk factors. The EBA considers that the multiplier used in the context of the fallback sensitivity-based method can be lowered while still maintaining a prudent approach. As a result, the EBA amended its value, setting it to 1.15.	Amendments to the multiplier in Article 6.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	the two SBM risk factors and the SBM risk weights applicable to each of the SBM risk factors: $$rw_{NMRF} = \sqrt{rw_1^2 - 2 \cdot \rho_{1,2} \cdot rw_1 \cdot rw_2 + rw_2^2}$$ where '1' and '2' refer to the SBM risk factors 1 and 2. It was considered by some respondents that this approach was appropriate only for a bucket basis risk or spread risk to an SBM tenor, everything else being equal. However, it was mentioned that a case of basis risk between a single-name credit spread and a credit index or a single-equity stock and an equity index would be better addressed using the same type of risk factor fallback method. Since the SBM risk weights have been calibrated to be conservative for most SBM risk factors within a bucket, including those with limited observability, some respondents proposed not applying any multiplier to the risk weight provided in the SBM. Finally, it was mentioned that, when a non-modellable risk factor coincides with an SBM risk factor except in the maturity dimension, instead of the risk weight of the SBM risk factor closest in maturity, the weighted average of the risk weights of the two closest surrounding SBM risk factors could be considered.		
Q10. What are your views on the fallback method that is envisaged for risk factors that are not included in the sensitivity-based method? Please comment on both the 'other risk factor' method,	Respondents in general saw some merits in both methods. However, some revisions to the multipliers applied to determine the final shocks were proposed. In particular, it was proposed that the uncertainty multiplier be set at the same value as that of the representative risk factor when using the same type of risk factor fallback method. Some revisions were also proposed to the multiplier applicable in the context of the 'changing period' method.	The EBA acknowledges that respondents agreed with the general overarching framework of the 'other risk factor method', while not agreeing with the value set for the uncertainty compensation factor. The EBA considers that the uncertainty multiplier of the fallback 'other risk factor' method can be	Amendments to the multiplier in Article 6.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
and the 'changing period method'.		lowered while still maintaining a prudent approach. As a result, the EBA amended the draft RTS, lowering the scalar used to determine the downward and upward calibrated shocks from 2 to 1.35. The fallback 'changing period method' was removed, since Option A was retained for the overarching framework in the final draft RTS.	
Q11. What are your views on the conditions identified in paragraph 5 that the 'selected risk factor' must meet under the 'other risk factor' method? What would be other conditions ensuring that a shock generated by means of the selected risk factor is accurate and prudent for the corresponding non-modellable risk factor?	One respondent deemed the conditions in place for the 'selected risk factor' accurate and prudent for calibrated stress scenario computation. In general, respondents considered the criteria applied to the selected risk factor adequate as long as they could be extended to basis risk factors.	The EBA confirms that any risk factor that does not correspond to a risk factor in the sensitivity-based method is not subject to the fallback method. Thus, in most cases, basis risk factors would be subject to the other risk factor fallback method. The EBA acknowledges that in general respondents agreed with the conditions for identifying the selected risk factor and decided not to amend the draft RTS in this respect.	No amendments.
Q12. What are your views on the definition of the stress period under Option A (i.e. the period maximising the rescaled stress scenario risk measure for risk factors belonging to the same broad	Some respondents remarked that the algorithm for the identification of the stress period under Option A was not manageable and would drive institutions to choose Option B. By way of justification, the numbers of revaluations required for the direct and the stepwise approaches, assuming a simple portfolio, were quantified. It was concluded that, although the calibration using the stepwise method	The feedback clearly indicated that the identification of the stress period under Option A was regarded as unmanageable. This was due to the requirement for full RSS calculation over the entire period since	Amendments to Articles 8 and 9.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
risk factor category)? What would be an alternative proposal?	might look computationally less burdensome than the direct approach, for a real-life portfolio with hundred thousands of instruments and thousands of non-modellable risk factors, the computational burden under the stepwise method would clearly be very substantial. It was proposed that firms be allowed to use a sensitivity P&L approach to determine the stress period, even for those risk factors that might be modelled in the expected shortfall under a full revaluation approach. Alternatively, another approach would be to use a risk factor-based approach as in Option B to identify the stressed period per broad risk category and to make the assumption that a worse stress period for the modelled risk factors would be a suitable period to use for the SES for that broad risk class. Furthermore, one respondent proposed approaches similar to Option B, stating that, potentially, within one asset class there might be non-modellable risk factors with good data for the stressed period and others for which sufficient data were available only for the current period. The same stress period would need to be selected for both of these types. The respondent proposed choosing the period that would maximise the scale-up ratio for all risk factors within a broad risk class, outlining three possible alternative approaches. One respondent remarked that the method for identifying the stress period under Option A was extremely computationally intensive and not workable in practice. However, the respondent considered this approach reliable and believed that identifying a different stress period for each broad risk factor category was appropriate. For institutions having a sufficient number of observations, the respondent proposed that they apply a methodology similar to that adopted in the modellable risk factors framework. This means that, for the *i*-th asset class, the scenario of future shocks applied to non-modellable risk factors should be calibrated to historical data from a continuous 12-month period of financial stress (starting at least from	January 2007 for each risk class (see Q1, Q2 and Q3). To mitigate this requirement and taking into account proposals put forward by the respondents, the EBA introduced two options in addition to that presented for consultation (which is retained): (1) An option based on the maximisation of the rescaled stress scenario risk measure using sensitivity-based pricing methods. (2) An option based on the maximisation of the partial expected shortfall for modellable risk factors. Those two options have been complemented by requirements ensuring that the identification of the stress period is prudentially sound.	

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	1 January 2007) that should be selected by the institution in order to maximise the value of the expected shortfall at risk class level for modellable risk. In other words, the respondent proposed using a risk factor-based approach to identify the stressed period for each asset class, assuming that the stress period for the modelled risk factors would be a suitable period to use for the SSRM for that broad risk class.		
Q13. What are your views on the definition of maximum loss that has been included in these draft RTS for the purpose of identifying the loss to be used as maximum loss when the latter is not finite? What would be an alternative proposal?	In general, all respondents considered that when the maximum loss is non-finite, banks should be allowed to propose alternative stress scenarios as conservative as a 97.5% stressed expected shortfall (to the supervisor's satisfaction, as pointed out by two respondents). In this regard, one respondent considered that the non-finite loss could result from the use of the regulatory approach, rather than the inability of the bank to identify a stress scenario at least as conservative as a 97.5% stressed expected shortfall. Two respondents considered that the 99.95% level of certainty would result in the addition of another element of conservatism to the framework, and another two respondents proposed that this targeting level should be used only as a last resort (if the alternative was found unacceptable). Two respondents also commented that there might be cases where, although the loss was finite, it exceeded a 97.5% stressed expected shortfall, proposing in these cases to cap the loss.	The framework proposed to fulfil point (a) of the EBA's mandate already offers a fallback method, which is supposed to address cases where data are not available. Thus, the framework proposed to fulfil point (b) of the EBA's mandate represents a last resort solution that, for example, is to be used where the institution cannot even properly employ the fallback method (e.g. because it cannot find a suitable selected risk factor from which a shock to the original non-modellable risk factor can be derived). Given this, the EBA decided to retain the general framework proposed to fulfil point (b) of the mandate unchanged. The EBA emphasises that the objective is to define a maximum loss where that loss is not finite. Thus, the percentile defining the confidence level in the expert-based approach should not materially deviate from 100%.	No amendments.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
Q14. How do you currently treat non-pricing scenarios (see section 3.2.5 of the background section) if they occur where computing the VaR measures? How do you envisage implementing them in (i) the IMA ES model and (ii) the SSRM, in particular in the case of curves and surfaces being partly shocked? What do you think should be included in these RTS to address this issue? Please put forward proposals that would not provide institutions with incentives that would be deemed non-prudentially sound and that would target only the instruments and the pricers for which the scenario can be considered a 'non-pricing scenario'.	Most respondents stated that in the value-at-risk and expected shortfall model shifts to curves or surfaces were applied in a consistent way in one scenario in that all points on that curve or surface were shifted. Therefore, the potential issue of applying large shifts to only one part or portion of the curve or surface would not systematically arise. Many respondents stated that in the stress scenario risk measure calculation a stress shift was applied to only one part (regulatory bucket) of a curve or surface. When a small portion of a curve is shifted and the other parts are left constant, the shift size amount is unrealistically large compared with the parts that are not shifted, which breaks the consistency of the curve or surface. Thus, shifting only a portion of a curve or surface could lead to pricing errors. Therefore, respondents argued that there was a need to consider mechanisms that could be applied to such cases in these RTS. According to many respondents, in practice, many risk factors would be decomposed into a portion that would be modelled in the expected shortfall model and a residual non-modellable basis to be capitalised under the stress scenario risk measure. Because those basis shifts would be smaller than the outright risk factor shifts, natural mitigation was already embedded. Proposals by respondents included the following. Some respondents suggested that if a non-pricing scenario is identified for certain product/pricer combination, an adjustment to the scenario for the product/pricer combination in question should be allowed. The adjusted scenario should be permitted as long as institutions provide sufficient documentation on the methodology and justification for each case to competent authorities. Some respondents proposed reducing the risk factor shift size for buckets liable to a non-pricing scenario by a fixed factor. Then the loss amount incurred under this scaled shock could be scaled up by the inverse of the factor. This should be applied to all instruments susceptible to risk factors in	The responses confirmed that the issue of non-pricing scenarios needed to be addressed. The EBA decided to include a specific treatment requiring institutions to use sensitivity-based pricing methods for the purpose of calculating the loss corresponding to a non-pricing scenario. Institutions are required to capture at least first and second order sensitivities. The provision is applicable only to instruments for which the institution cannot determine the loss, i.e. it cannot be used for all instruments with a specific risk factor, unless the institution cannot determine the loss for all those instruments. Competent authorities are expected to not be satisfied (in the sense of Article 325bk(3)(b)) by the scenario provided by the institution if not all material sensitivities are captured.	Amendments to Article 9.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	the bucket, irrespective of whether a non-pricing scenario would occur for each instrument or not. In this way, a consistent scenario would be applied to the whole bucket. These respondents noted that such scaling back of a stress scenario could alter the loss amount that would result from the non-linearity of the loss function (e.g. gamma). The cases where such scaling was applied should be limited in number and should be notified to competent authorities.		
Q15. What are your views on the conditions included in these draft RTS for identifying whether a risk factor can be classified as reflecting idiosyncratic credit spread risk only (or idiosyncratic equity risk only)? Please elaborate.	Most respondents considered that the condition set out under Article 12(3)(b) to identify whether a risk factor can be classified as reflecting idiosyncratic credit spread risk only (or idiosyncratic equity risk only) could be too specific (i.e. 'the value taken by the risk factor shall not be driven by systematic risk components'). They suggest an alternative condition to be met: 'i.e. the value taken by the risk factor shall not be driven by systematic risk components'. One of the respondents considered the conditions acceptable but argued that they would be more suitable if relaxed.	The EBA decided to retain the general conditions for identifying whether a risk factor reflects idiosyncratic risk only. In the light of the comments made by the respondents, the EBA clarifies that those risk factors that are classified as reflecting idiosyncratic credit spread (or equity) risk only should be uncorrelated, and decided to require institutions to prove that condition via statistical tests (instead of requiring them to prove via statistical tests that the risk factor is not driven by systematic risk components).	Amendment to Article 12.
Q16. What are your views on flooring the value taken by non-linearity coefficient κ to 0.9? Please elaborate.	One respondent considered, based on empirical evidence, that flooring the non-linearity coefficient κ to 0.9 was reasonable. Another respondent considered that the floor should be equal to 0 or, alternatively, that a cap should be introduced (500% was suggested) and that the floor should be lower (20% was suggested) should it not be set to 0. It was highlighted that the floor value of the non-linearity coefficient was not univocal throughout the CP. Other respondents did not comment.	The EBA takes note of the comments of the respondents. As mentioned in the CP, adjustments smaller than 0.9 are probably due to inaccuracies in the quadratic approximation and should not be recognised. Thus, the value flooring κ (i.e. 0.9) is unchanged. However, in order to avoid extreme values for the non-linearity coefficient κ, the EBA	Amendments to Articles 13 and 14 to introduce a cap to κ.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
		agrees to cap the non-linearity coefficient to 5, and the draft RTS have been amended accordingly.	
Q17. What are your views on the definition of the tail parameter ϕavg where a contoured shift is applied (i.e. average of the tail parameters of all risk factors within the regulatory bucket)? Please elaborate.	Some respondents considered that, due to the empirical dispersion of tail parameter phi between data series, the median or a heavily trimmed mean should be considered instead of a simple average for the tail parameter ϕavg where a contoured shift is applied. It was suggested by one respondent that at the bucket level (phi-1) should be computed based on a square root transformation (as shown in the formula below), which would provide two advantages: (1) the square root transformation removes some asymmetry (that makes the mean and the average materially different) and (2) the square root of (phi-1) is a more intuitive unit for measuring the width of the tail. $(\emptyset - 1)_{bucket} = \left(\frac{1}{N}\sum_{j=1}^{N}\sqrt{(\emptyset - 1)_j}\right)^2$ One respondent also suggested that computing the non-linearity coefficient κ using an internal model should be allowed under Articles 13 and 14 in order to make the framework more robust.	The EBA takes note of the comments of the respondents. The tail parameter definition where a contoured shift is applied is changed to the median of the tail parameters calculated in accordance with Article 15 for each of the risk factors within the bucket, in order to account for its empirical dispersion between data series.	Amendments to Article 14 (‘mean’ changed to ‘median’).
Q18. Would you consider it beneficial to set the tail parameter ϕ to the constant value 1.04 regardless of the methodology used to determine the downward and upward calibrated shock (i.e. setting ϕ = 1.04 also under the historical method, instead of	Some respondents considered that setting ϕ at 1.04 would simplify the framework, whereas some others considered the framework should be kept as is (i.e. allowing the use of the historical estimator for ϕ under the historical method), as otherwise it would lead to overestimation. One respondent considered that the tail parameter used under methods other than the historical method should be determined based on empirical estimates.	The EBA acknowledges that some respondents deemed it beneficial to calculate the tail parameter using a historical estimator where possible. Considering that the estimator provides a more accurate result, the EBA decided not to amend the draft RTS in this respect.	No amendments.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
using the historical estimator)? Please elaborate.			
Q19. Do you agree with the definition of the rescaling factor $m_{S,C}$, under option B or do you think that the rescaling of a shock from the current period to the stress period should be performed differently? Please elaborate.	Two respondents remarked that the scalar in its current definition is prone to spikes in those cases where a broad risk category is dominated by modellable risk factors with a very low standard deviation over the current period. It was stated that, where the difference in volatility between the current and stressed periods was the result of a change in market regime (e.g. negative rates), rescaling would not necessarily be appropriate, especially because it would affect any other risk factor in that broad risk category. In particular, current trimming at 1% can be effective in reducing such extreme cases only to the extent that these risk factors represent 1% of the modellable risk factor for the affected broad risk category. For a portfolio dominated by euro instruments this might not be the case. Therefore, it was proposed that trimming at a higher rate be allowed for broad risk categories (i.e. interest rate risk) where this effect was visible, to an amount that reflected the relative presence of these types of risk factor among the modellable risk factors. The refinement of the trimming confidence level would have to be documented. One respondent commented that the ratio at broad asset class level should be revised because the proposed approach could be affected by the following issues: • Within the same asset class, risk factors could have different features (i.e. interest rate curves/volatility for which additive/log returns are computed). • The standard deviation is not a pure number. Therefore, to compute a trimmed mean would entail taking into account non-homogeneous values.	As mentioned in the EBA's analysis regarding Q1, the EBA decided to retain Option A for the overarching framework in the final draft RTS. Thus, a scalar for rescaling a shock from the current period to the stress period does not need to be designed.	Option B is removed.

Comments	Summary of responses received	EBA analysis	Amendments to the proposals
	One respondent remarked that the multiplier proposed by the EBA was biased. They justifies this assessment using theoretical reasoning applying Jensen's inequality. For correction, they proposed the reciprocal of the multiplier proposed by the EBA, thus the value $\frac{1}{m_{S.C}}$. By application of the same reasoning. the respondent argued that the modified multiplier was unbiased. To substantiate that, an empirical study was presented, showing regression tests comparing the EBA's multiplier and the modified value.		
Q20. The scalar $m_{S.C}$ is obtained by using data related to modellable risk-factors in a specific risk class (i.e. the class i). As a result, such a scalar is not defined where an institution does not have any modellable risk factor in this risk class. How do you think the scalar mS, should be determined in those cases? Please elaborate.	Two respondents proposed applying a scaling comparable to the modellable risk factors portion of the IMA, i.e. using the factor $ES_{(R,S)}/ES_{(R,C)}$ for these risk classes. One respondent commented that this situation would rarely occur. However, where the whole set of risk factors within a specific asset class was non-modellable, institutions might be allowed to use directly non-modellable risk factors if the number of observations was deemed acceptable. The following solutions were proposed. (1) Institutions may calibrate the prescribed scalar to be at least as prudent as the coefficient computed on the other asset classes $m^i_{P_1P_2} = \max(m^i_{P_1P_2}), i \neq j$, $i, j \in \{\text{CM, FX, IR, CR, EQ}\}$ (2) An average scaling factor for each asset class could be evaluated. Using these, the regulatory scaling factor could be calibrated to be at least as prudent as the estimated value. One respondent deemed this a rare case. In such cases, it could be clarified how the trimmed mean should work in the case of one or two risk factors (probably by including no trimming).	As mentioned in the EBA's analysis regarding Q1, the EBA decided to retain Option A for the overarching framework in the final draft RTS. Thus, a scalar for rescaling a shock from the current period to the stress period does not need to be designed.	Option B is removed.

Annex I: Uncertainty compensation factor

Introduction

Non-modellable risk factors are characterised by lower market observability and potentially lower data availability. The guiding idea behind the uncertainty compensation factor (UCF) employed in the stress scenario risk measure is that higher uncertainty should be compensated for in the calibrated shocks.

The sources of uncertainty in the calibrated shocks obtained by the different methods as described in the main text are:

A. statistical estimation error;

B. parameter choice uncertainty and parent distribution uncertainty;

C. uncertainty of each data point due to low market observability.

Statistical estimation error arises when using $N = 12 \ldots {\sim}255$ returns[27] for the computation of a calibrated shock from returns in the 1-year stress period, because such a relatively small number (in relation to $N \to \infty$) does not provide a high degree of statistical accuracy. Parameter choice uncertainty is present in the parameters of the asigma method, as well as in the non-linearity correction, and the true parent distribution is not known and not necessarily constant in time. The uncertainty of each data point due to low market observability is due to the nature of non-modellable risk factors.

For the purpose of the stress scenario risk measure, all these effects are addressed by a single uncertainty compensation factor for all methods given by:

$$UCF(C_{\mathrm{UCF\_A}}, C_{\mathrm{UCF\_B}}, N) \stackrel{\mathrm{def}}{=} C_{UCF\_A} + \frac{C_{\mathrm{UCF\_B}}}{\sqrt{(N - 1.5}}$$

where $C_{\mathrm{UCF\_A}} = 0.95$ and $C_{\mathrm{UCF\_B}} = 1$.

Note that in the asigma method the number of relevant returns below and above the median is $\frac{N}{2} + \{0 \text{ or } 1\}$, depending on N even or odd, and if the shock is estimated for the set of returns below or above the median.

The proposed uncertainty compensation factor, and in particular its functional form in the number of relevant returns N, can be understood from the central limit theorem (CLT). The calibrated shocks are random variables converging on a normal distribution in the large N limit, which can be understood from the following arguments: the expected shortfall of the historical method is a tail average, as well as the mean of the returns below or above the median in the asigma method. The

[27] Target 2 has typically 255 operating days, so that even in leap years 256 business days are a plausible upper bound for the number of risk factor observations, so that the upper bound for the number of returns is 256 – 1 = 255.

sum of squares of the returns minus the mean below or above the median in the asigma method is chi-distributed if they are Gaussian, and the Chi-distribution converges quickly on a normal distribution as well. For other distributions, generalisations of the CLT lead to the same result. So, for all calibrated shock methods, the sampling distribution should converge on a Gaussian distribution when N increases, according to the CLT.

Figure 12 shows that the sample distribution for the upward calibrated shock in the asigma method converges on a distribution resembling a normal distribution as the sample size N increases. The vertical dashed line indicates the true value.

It can be seen that for the smallest sample size, $N = 12$, the sampling distribution is quite wide,

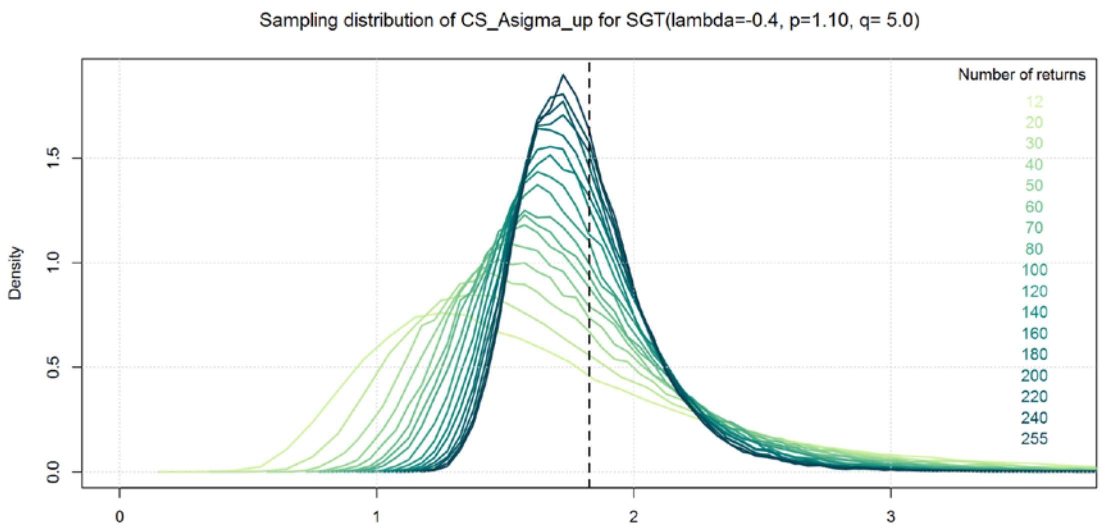


Figure 12

while it narrows and becomes more Gaussian when the number of returns is increased up to daily data ($N = 255$). The sampling distribution extends to very high values and has positive skewness (left tilted), although the parent SGT distribution has negative skewness (right tilted).

If the sampling distribution is wide, the statistical estimation error is large and the uncertainty compensation factor must be large. Now, the statistical estimation error for the shocks is strongly driven by the standard deviation, which is scaling like $\propto \frac{1}{\sqrt{N-1.5}}$, where the –1.5 (instead of the usual –1) is more accurate for small N. Besides the standard deviation, the uncertainty compensation depends on the shape of the sampling distribution, which changes with N as well, and on the targeted level of confidence. Therefore, the N dependency of the uncertainty compensation factor is more complex, and not proportional to $\frac{1}{\sqrt{N-1.5}}$ in general for all distributions and confidence levels. In practice, $\frac{1}{\sqrt{N-1.5}}$ was found to be a robust choice for the N dependency in the uncertainty compensation factor also for non-Gaussian distributions.

Generally speaking, the absolute term parameter $C_{\mathrm{UCF\_A}}$ reflects any bias in the estimator for the calibrated shock; for example, if the calibrated shock has a conservative bias, the uncertainty compensation factor can be smaller. For our purposes, the parameter $C_{\mathrm{UCF\_A}} = 0.95$ was chosen such that for daily return data the uncertainty compensation factor becomes close to 1, while maintaining a small uncertainty compensation for non-modellable risk factors over modellable risk factors for the uncertainty sources B and C. $UCF = 1$ would mean that the stress scenario risk measure is equivalent to the expected shortfall estimate in the expected shortfall model.

For the sake of simplicity, the same uncertainty compensation factor is applied to all methods for the calibrated shocks, although they are based on different statistical quantities (e.g. historical expected shortfall or asymmetrical sigma), and all (unobservable) parent distributions. For the calibration of the uncertainty compensation factor a simulation study using normalised SGT distributions[28] for risk factor returns was performed (as in the 2017 discussion paper), in order to have well-defined distributional properties and to be able to compare distribution metrics for small N samples with their large N limit, approximating the true values of the parent distribution.

To this end, the distribution parameters for random distributions that are used in the study in this annex are described in the next section, before the results are presented.

Setting the SGT parameters

SGT distributions replicate stylised facts of risk factor returns well, in particular skewness and fatter tails than a normal distribution.[29] The parameter $lambda$ controls the skewness, the parameter q controls the tail thickness and the parameter p controls the peakedness.

The normal distribution is obtained for $lambda = 0$, $q = \infty$, and $p = 2$, and the Student-t distribution family with $n = qp$ degrees of freedom is obtained for $lambda = 0$, and $p = 2$.

Figure 13 shows some examples of SGT distributions investigated in the analysis. It can be seen that they can exhibit skewness, sharper peaks and fatter tails.

[28] P. Theodossiou, 'Financial data and the skewed generalized t distribution', *Management Science*, Vol. 44, December 1998, pp. 1650–1661, available at https://ssrn.com/abstract=65037.

[29] J. B. McDonald and R. A. Michelfelder, 'Partially adaptive and robust estimation of asset models: accommodating skewness and kurtosis in returns', *Journal of Mathematical Finance*, Vol. 7, 2017, pp. 219–237. https://doi.org/10.4236/jmf.2017.71012

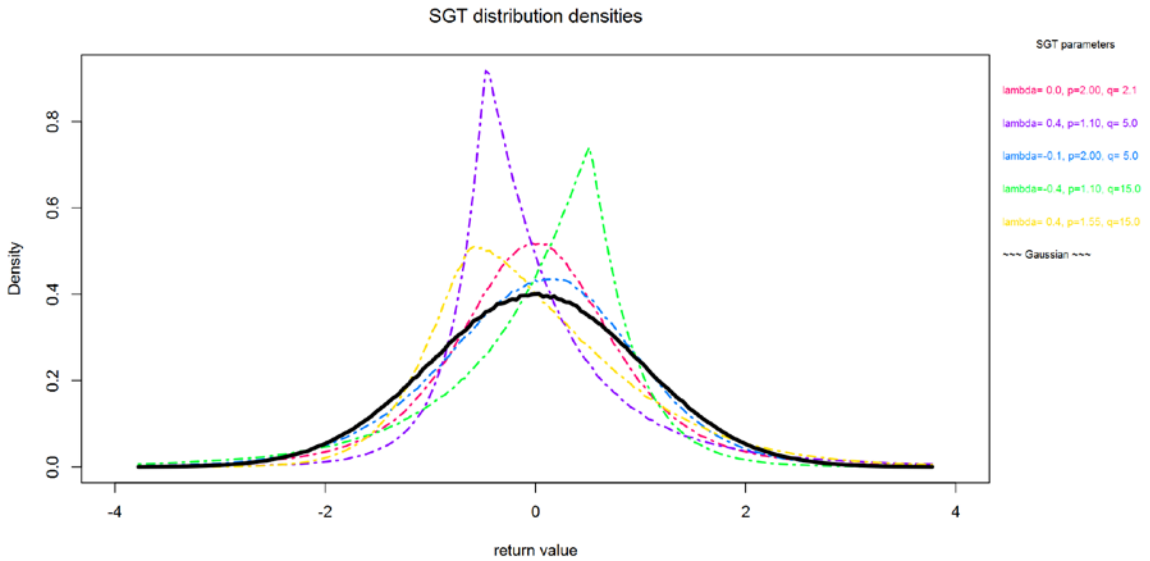


Figure 13

SGT distributions can be used to approximate a wide range of the non-modellable risk factor return data distributions that are to be capitalised under the stress scenario risk measure. To determine the relevant parameter ranges, SGT distributions were fitted to the nearest to 10-business-days risk factor returns generated from the data gathered in the stress scenario risk measure data collection exercise.[30]

In order to take all risk classes into account, summary statistics for the SGT parameters per risk class were calculated. In particular, per risk class the first and third quartile of each SGT parameter were computed and used as a basis for obtaining relevant SGT parameter ranges. Half of the parameters for risk factors of a risk class would fall within these ranges (unconditionally on other parameters). Those ranges are more robust than, for example, high quantiles. The analysis was performed for the stress period, the most recent year of data and full time series from 2007 to 2019 when available.

Values in Table 6 are rounded and correspond to values in the ranges of historical skewness and excess kurtosis values observed for the stress and current periods (see relevant figures in the cost–benefit analysis/impact assessment section).

SGT parameter	Low	High
lambda	–0.4	0.4
q (tail)	2.1	15 (∞ is Gaussian)
p (peakedness)	0.65	2 (Gaussian)

Table 6

[30] Using the R package ‘SGT’, https://cran.r-project.org/web/packages/sgt/index.html and its fit function sgt.mle().

In the simulation study only SGT parameter combinations leading to finite first four moments, i.e. $pq > 4$, were used. To illustrate the range of distributions investigated, Figure 14 shows the standardised excess kurtosis versus the standardised skewness for all SGT parameter combinations analysed. The Gaussian distribution corresponds to the point at the origin. The dashed parabola is the Klaassen bound[31] for unimodal distributions, which is $Excess\ kurtosis\ \geq\ skew^2\ + \frac{186}{125} - 3$.

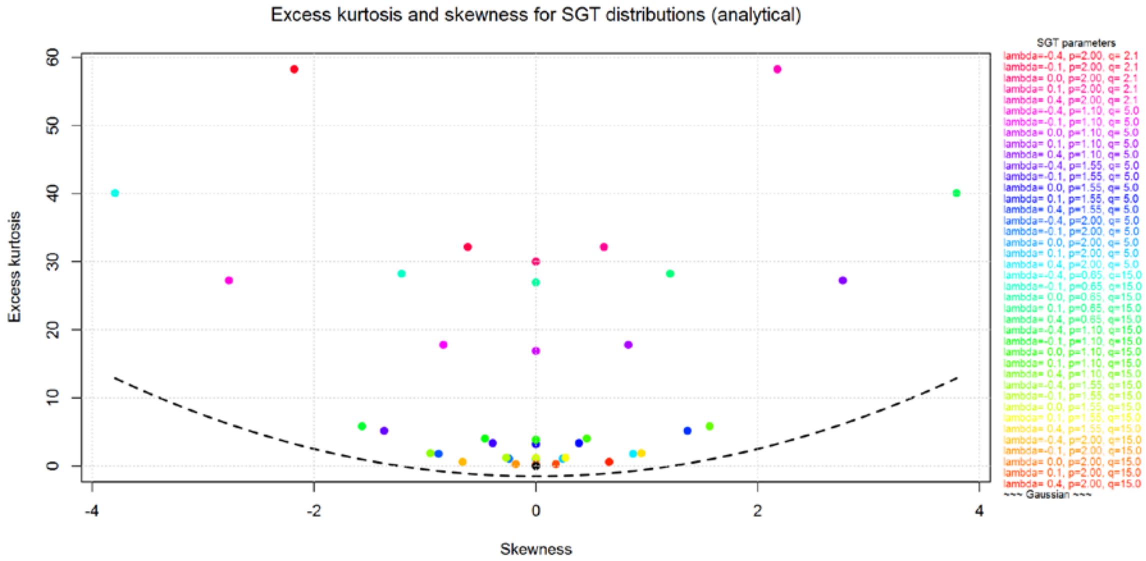


Figure 14

More extreme values for the SGT parameters were observed. For the purpose of this analysis, the choice of the SGT parameters is not crucial: a different range of SGT distribution parameters would modify the dispersion of the values presented in the following sections without altering the conclusions.

The SGT distribution parameter ranges in Table 6 are in line with the parameter ranges of the analysis presented in the 2017 discussion paper, which was based on literature values. The parameter ranges considered here somewhat extend those ranges, which is due to the greater variety of risk factors considered.

Description of the simulation method

In a first step, a large N sample ($N = 2.5 \cdot 10^7$) was drawn from an SGT distribution for a given SGT parameter triplet from which risk metrics and calibrated shocks according to the different methodologies in the main part of these final draft RTS were computed to obtain an approximation of the 'true' values by using historical estimators.[32]

[31] Chris A. J. Klaassen, Philip J. Mokveld, Bert Van Es, 'Squared skewness minus kurtosis bounded by 186/125 for unimodal distributions', *Statistics and Probability Letters*, Vol. 50, No 2, 1 November 2000, pp. 131–135, doi:10.1016/S0167-7152(00)00090-0.

[32] There are analytical results for risk measures for the SGT distribution (e.g. expected shortfall). See P. Theodossiou, 'Risk measures for investment values and returns based on skewed-heavy tailed distributions: analytical derivations and

In a second step, small samples of returns of size 12 to 255 mimicking the returns in a 1-year calibration period were drawn, from which the calibrated shocks were obtained according to the historical and asigma methods. These are random quantities themselves and show fluctuations. Therefore, this small return sample step was repeated many times ($5 \cdot 10^4$) to obtain statistical information on the small-sample calibrated shocks to make it possible to extract information on their properties, for example the probability of underestimation of the true (large-sample) value.

Simulation results: standard deviations

The first analysis results show the standard deviation of the calibrated shocks, which makes it possible to gain an impression of the estimation error.

Figure 15 shows the standard deviation of the asigma method calibrated downward shocks. It can be seen that the overall shape of the curves are similar for all SGT parameter sets. The stronger the deviations from the normal distribution, the larger the sampled standard deviation.

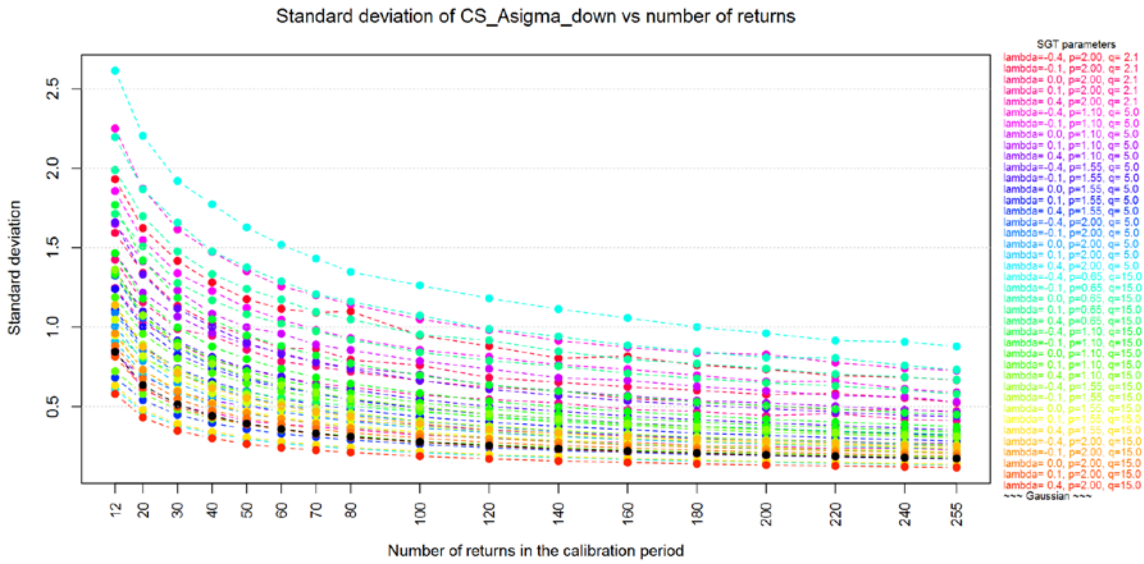


Figure 15

Figure 16 shows a similar behaviour for the standard deviation of the sampled 97.5% expected shortfall in the historical method.

comparison', 11 May 2018, available at https://ssrn.com/abstract=3194196. Theodossiou uses a different parametrisation that needs to be converted into the q, p notation here.

For the asigma method, no analytical results are known to the EBA. Therefore, for all large *N* values the same simulation-based estimation method as for the small-sample returns was used, for which it had to be developed anyway. For the expected shortfall the large *N* simulated values were compared with the analytical results and the deviations were negligible at the sample size used.

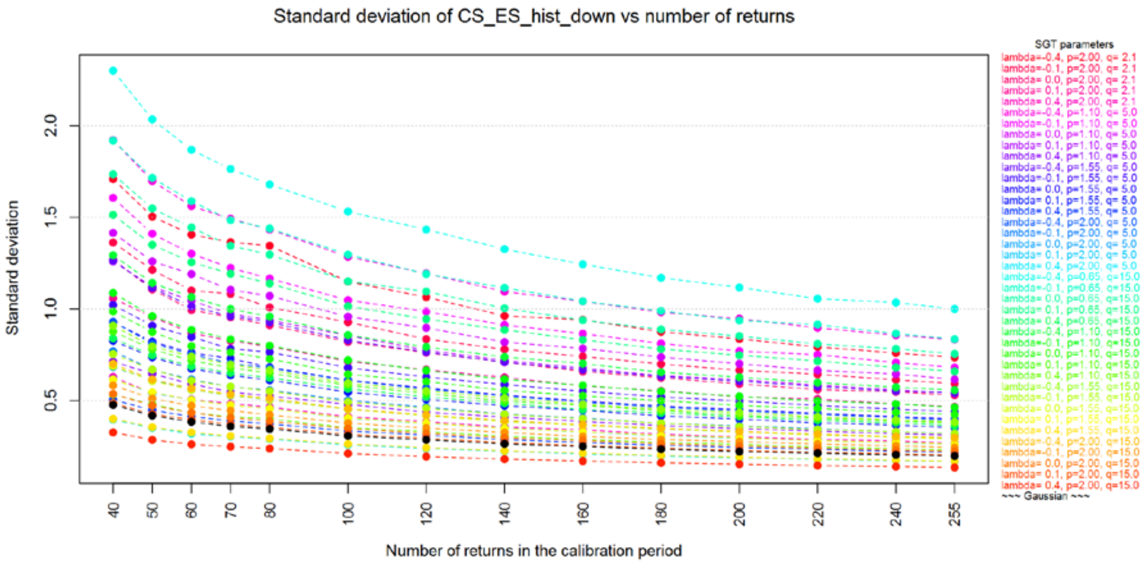


Figure 16

The standard deviation (and thus the estimation error) of the expected shortfall is larger than that of the asigma calibrated shocks. This can be qualitatively understood from the observation that the 97.5% expected shortfall is computed only from $N/40$ points in the tail, while the asigma calibrated shock is more robust, because it is computed from $N/2$ returns. From these figures, one can infer that the statistical uncertainty in the historical method is somewhat higher than in the asigma method, which, however, has a much higher parameter uncertainty. One also sees that the SGT distribution parameters have a strong influence on the estimation error, as measured with the standard deviation, as does the number of returns when N decreases.

Simulation results: empirical values for the uncertainty compensation factor

To assess the uncertainty compensation factor, we define the 'empirical' uncertainty compensation factor ($EUCF$), which is the factor that would ensure that a calibrated shock obtained for the small sample in the calibration period $CS_{\text{calibration}}$ does not underestimate the true (large N) value of the left or right expected shortfall $CS_{N\to\infty}^{\text{ES hist}}$ with a given confidence level CL:

$$P\left(EUCF \cdot CS_{\text{calibration}} < CS_{N\to\infty}^{\text{ES hist}}\right) = CL$$

Our target is that the uncertainty compensation factor ensures that the true value is not underestimated in more than 50% of the cases, i.e. the median does not underestimate the true value.

In Figure 17, we plot the empirical uncertainty compensation factor for the asigma method for the various SGT distribution parameter triplets versus the number of returns. The thick dashed line indicates $UCF(C_{\text{UCF}_\text{A}}, C_{\text{UCF}_\text{B}}, N/2)$ (note that it is applied with $N/2$ in the asigma method), which overall describes the uncertainty compensation factor well.

$EUCF$ for the asigma method depends implicitly on the parameter choice for C_{ES}: if C_{ES} is increased, then the calibrated shock is higher and the probability of underestimating $CS_{N\to\infty}^{\text{ES hist}}$ gets smaller. For example, for the Gaussian case, the theoretical value[33] is $C_{\mathrm{ES}}^{\mathrm{Gaussian}} = 2.34$, such that the empirical uncertainty compensation for $C_{\mathrm{ES}} = 3$ is lower than 1 for the chosen confidence level.

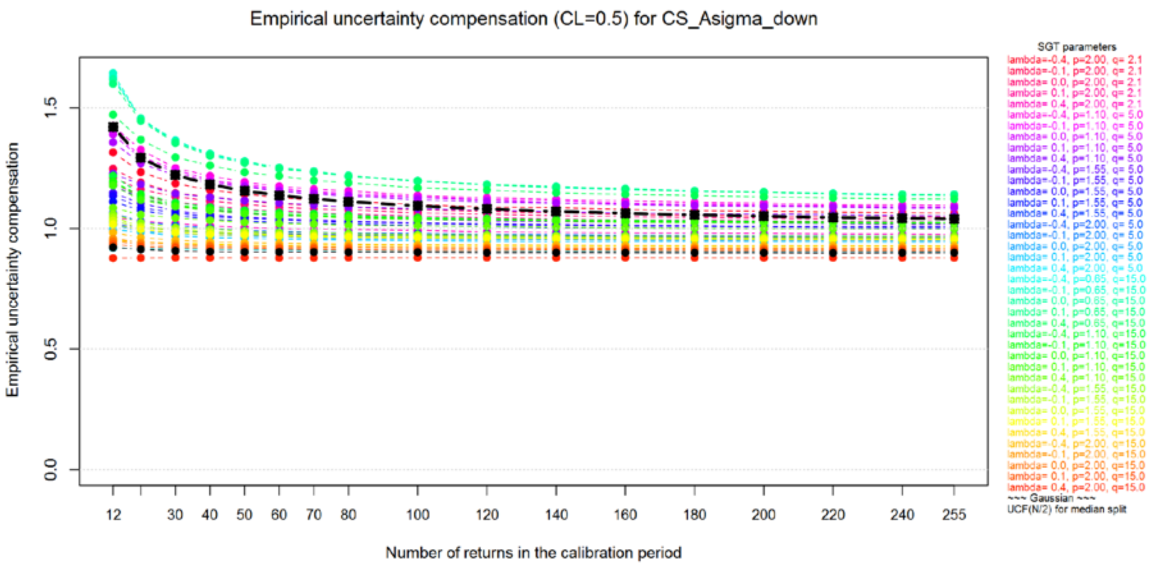


Figure 17

In Figure 18, we plot the empirical uncertainty compensation factor for the historical method (i.e. the sampled expected shortfall) for the various SGT distribution parameter triplets versus the number of returns. The thick dashed line indicates $UCF(C_{\mathrm{UCF\_A}}, C_{\mathrm{UCF\_B}}, N)$, which is appropriate for SGT distributions close to the normal distribution, while being too low for the more pronounced non-normal distributions, which means that the true value is underestimated with a probability of more than 50%. We will investigate the probability of underestimation in a separate section.

[33] See Annex 4 to the 2017 discussion paper for details.

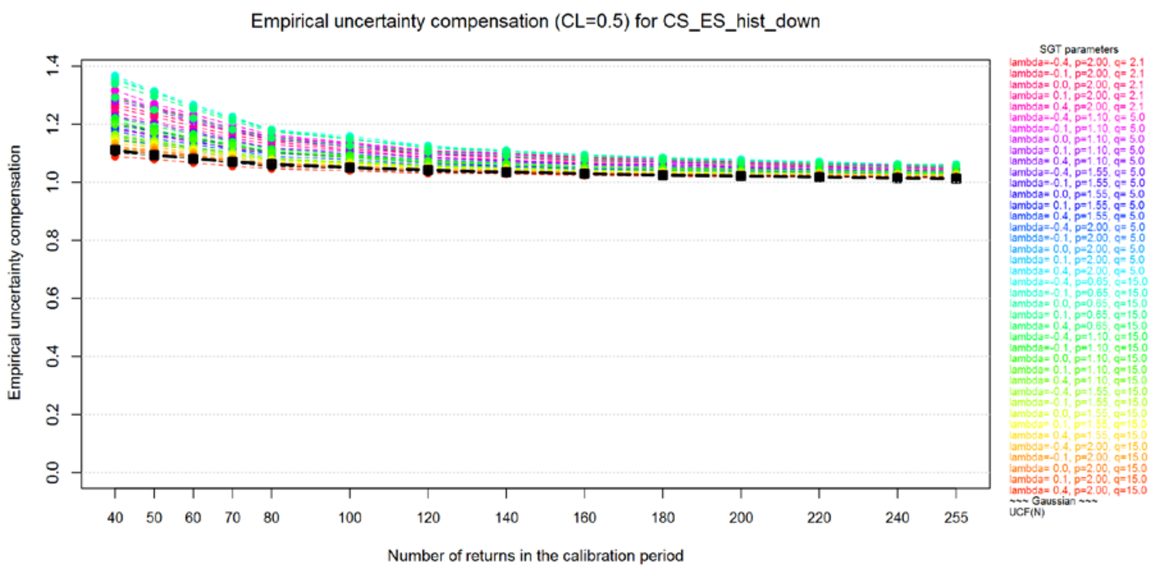


Figure 18

$UCF(C_{\text{UCF\_A}}, C_{\text{UCF\_B}}, N)$ can be equated to the empirical uncertainty compensation factor (assuming that the functional form is correct). When keeping the absolute constant $C_{\text{UCF\_A}} = 0.95$ fixed, we can back out the empirical value for the nominator:

$$EUCF = C_{\text{UCF\_A}} + \frac{C_{\text{EUCF\_B}}}{\sqrt{N - 1.5}} \Leftrightarrow C_{\text{EUCF\_B}} = \sqrt{N - 1.5} \cdot (EUCF - C_{\text{UCF\_A}})$$

The corresponding values for the constant $C_{\text{EUCF\_B}}$ are presented in Figure 19 for the asigma method and Figure 20 for the historical method. If horizontal lines were obtained when plotting versus N, the N dependency would be well described. Overall, the values are roughly on horizontal lines, with noticeable deviations in particular for small N. The dashed horizontal line is the value 1, which appears to be appropriate for the asigma method, while for the historical method it appears somewhat too low for non-normal distributions. This observation mirrors the observation made with regard to the plots of the empirical uncertainty compensation factor above.

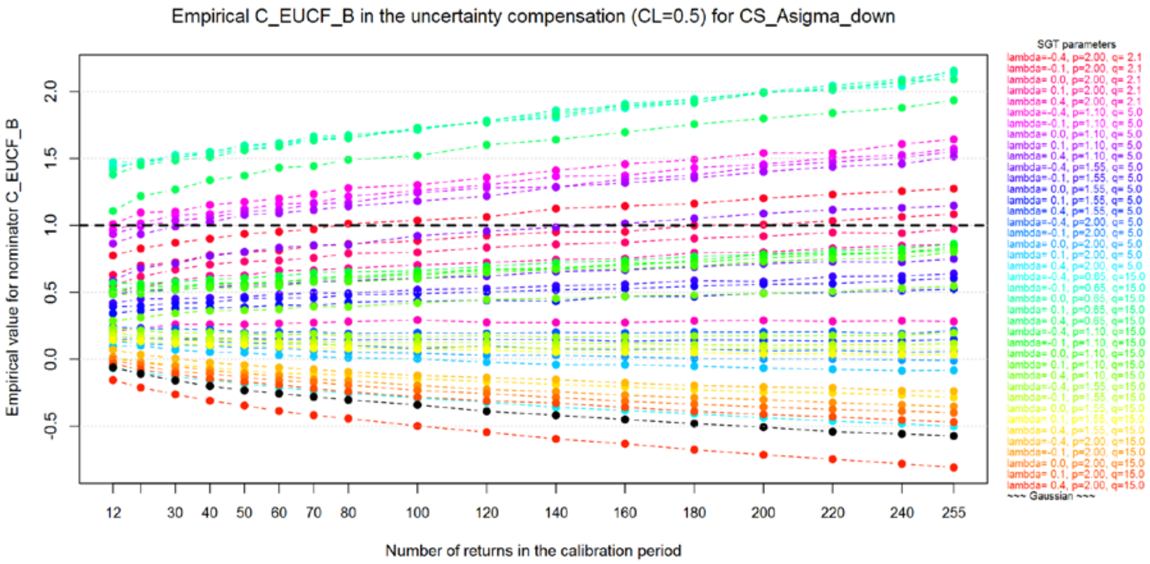


Figure 19

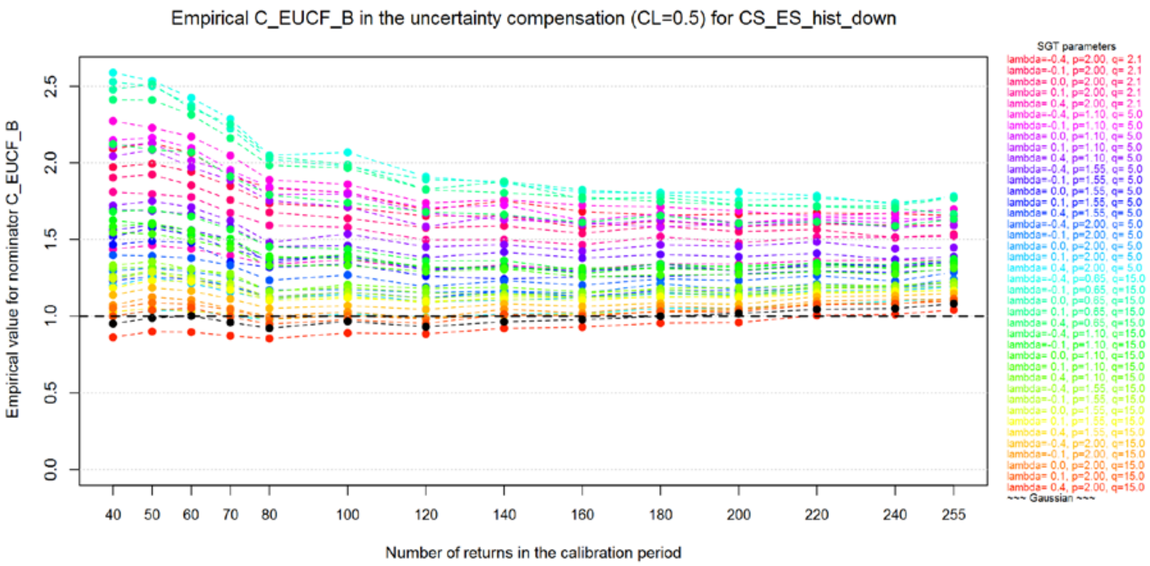


Figure 20

To summarise, the proposed uncertainty compensation factor $UCF\left(C_{\mathrm{UCF_A}}, C_{\mathrm{UCF_B}}, N\right) = C_{UCF\_A} + \frac{C_{\mathrm{UCF\_B}}}{\sqrt{(N-1.5}}$ is overall suitable for the calibrated shock methods, with deviations occurring for small N and being more pronounced in the case of non-Gaussian distributions for the historical method.

One can also see clearly that the parameter $C_{\mathrm{UCF\_B}}$ would need to be set to different values depending on the method used for the calibrated shock, on the distributional parameters and on the given targeted confidence level, which we refrain from discussing further for the sake of simplicity.

Simulation results: probabilities of underestimation

The stress scenario risk measure methodology aims to provide calibrated shocks based on the small sample of returns in the stress period that do not underestimate the true value. In this section, we show the probability that a calibrated shock according to the different methods multiplied by $UCF\left(C_{\mathrm{UCF_A}}, C_{\mathrm{UCF_B}}, N\right) = C_{UCF\_A} + \frac{C_{\mathrm{UCF\_B}}}{\sqrt{(N-1.5}} = 0.95 + \frac{1}{\sqrt{(N-1.5}}$ underestimates the true value, being the expected shortfall in the large sample. We show heat maps of

$$P\left(UCF \cdot CS_{\mathrm{calibration}} < CS_{N\to\infty}^{\mathrm{ES\ hist}}\right)$$

in Figures 21 and 22 below for all SGT distributions investigated.

The asigma method is strongly dependent on the parameter choice for C_{ES} entering the calibrated shock of the asigma method (CS_Asigma_down), leading to more dispersion in the probabilities of underestimation, as shown in Figure 21. For a near-Gaussian SGT distribution, the probability of underestimation is low (because C_{ES} is too high for those distributions, as the theoretical Gaussian result is 2.34), while for more non-Gaussian SGT distributions, the probability of underestimation can get higher than 50% (because C_{ES} is too low compared with the theoretical values). The probability of underestimation reaches 66% in the asigma method (in the red fields for strongly non-Gaussian distributions). Because the empirical values for $C_{\mathrm{EUCF\_B}}$ for these SGT distributions are decreasing, the probability of underestimation gets smaller for smaller N, which is desirable to ensure the asigma method is well suited for small N. The near-Gaussian cases are almost never underestimated.

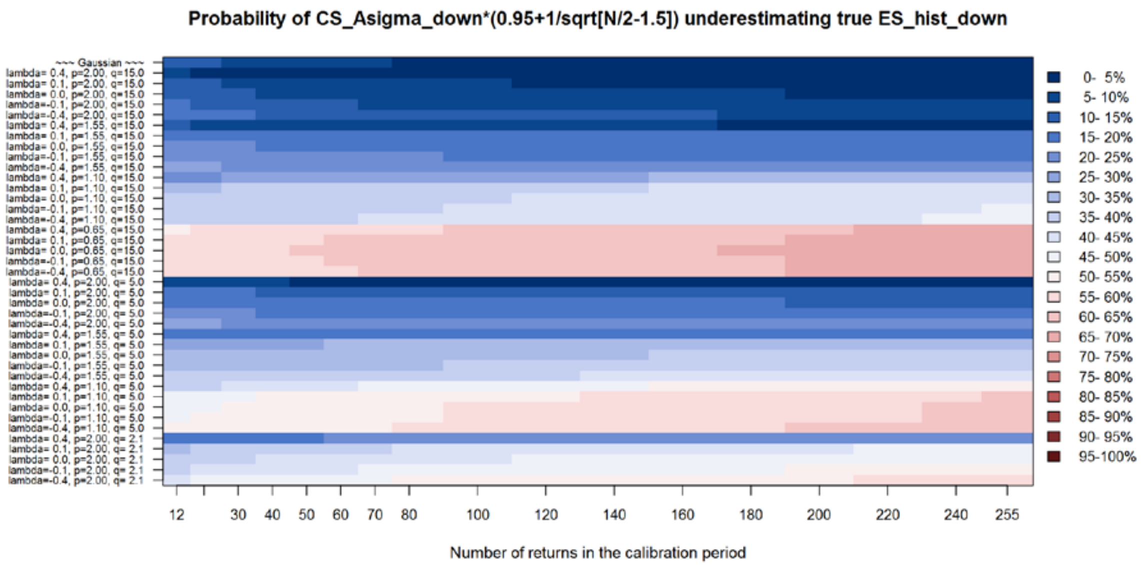


Figure 21

The uncertainty compensation factor for the historical method does not need to be conservative, and the probability that the calibrated shocks in the historical method underestimate the true values should be about 50%, while accepting that this value may lead to a slightly higher probability of underestimation. Because $N \geq 200$ in the historical method, UCF gets small for those N, so that the uncertainty correction does not have a material impact anyway.

Figure 22 confirms that UCF leads to about 50% probability of underestimation for the calibrated shocks obtained using the historical method (CS_ES_hist_down) in the relevant range $N \geq 200$. The colours indicate that the underestimation probability is often around 50% (light colours), with somewhat lower probabilities for near-Gaussian distributions and somewhat higher probabilities for more non-Gaussian distributions. The probability of underestimating the true value for $N \geq 200$ and all SGT parameters has a minimum value of 49% and a maximum of 58%

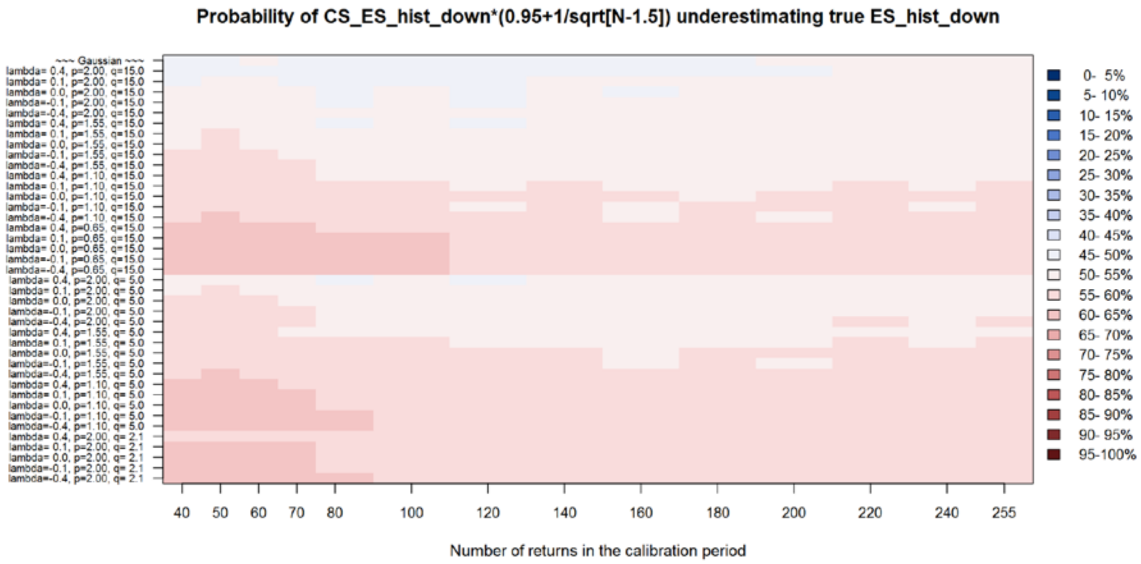


Figure 22

In summary, under the condition that universal constants instead of different constants for each method are used, the calibration constants $C_{\mathrm{UCF\_A}} = 0.95$ and $C_{\mathrm{UCF\_B}} = 1$ for the uncertainty compensation factor can be considered appropriate for the purpose of the stress scenario risk measure.