Solvency Assessment and Management: Pillar 1 – Quantitative Requirements Sub Committee

Steering Committee

Position Paper 94[1] (v 4)

Interest Rate Risk

EXECUTIVE SUMMARY

This document discusses the structure and calibration of the interest rate risk sub-module of the market risk module. It includes discussion of the Solvency II developments, considers the approaches within other jurisdictions, highlights issues, considers alternatives, derives stresses based on historical market data, and recommends an approach for use in the Solvency Assessment and Management standard formula

The working group recommends that the interest rate risk module be split between nominal and real interest rate risk. It further recommends stresses to each derived from historical South African yield curve data. Details of the recommendation are provided in section 7.

Splitting the nominal interest rate risk sub-module between three principal components (level, slope, and curvature) was also considered. Not splitting the three principal components would mean that the standard formula for (re)insurers hedging level risk only would understate their nominal interest rate risk, since it would not cover the slope and inflection risks. The majority of the working group felt this to be an unnecessary increase in the complexity of the standard formula, and that any additional risk not captured in the standard formula would be captured in the Own Risk and Solvency Assessment (ORSA). There was a dissenting minority view. The recommendation of the working group follows the majority view.

1. INTRODUCTION AND PURPOSE

This document sets out the recommendations of the market risk working group with respect to interest rate risk stresses to be applied for the Solvency Assessment and Management (SAM) standard formula.

2. INTERNATIONAL STANDARDS: IAIS ICPs

ICP17 (Capital Adequacy), the relevant ICP, does not consider the details of interest rate risk specifically.

3. EU DIRECTIVE ON SOLVENCY II: PRINCIPLES (LEVEL 1)

Not applicable.

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4. MAPPING ANY PRINCIPLE (LEVEL 1) DIFFERENCES BETWEEN IAIS ICP & EU DIRECTIVE

Not applicable.

5. STANDARDS AND GUIDANCE (LEVELS 2 & 3)

5.1 IAIS standards and guidance papers

This is discussed in section 2.

5.2 CEIOPS CPs (consultation papers)

5.2.1 CEIOPS-DOC-66/10 (formerly CP70):

Interest rate risk is considered in section 4.2 of CEIOPS-DOC-66/10 (henceforth CP70). The following points are made:

- The interest rate risk charge, Mkt_{int}, is set equal to the change in the insurer's economic net asset value arising from the stress (¶4.9).
- Two variations in two risk factors are considered, leading to four stresses. The risk factors considered are the term structure of interest rates and the interest rate implied volatility surface (¶4.10 and 4.56). The variations considered are level increases or decreases to each risk factor.
- Shocks to the term structure of interest rates:
    - Stresses for four datasets were calibrated, namely EUR government zero curves (approximately 12 years), GBP government zero curves (approximately 30 years), and EUR and GBP LIBOR/swap rates (approximately 12 years) (¶4.16).
    - A principal components analysis (PCA) was performed on each dataset, and four components were retained explaining 99.98% of the variability of the annual percentage rate change at each term to maturity (¶4.18 and ¶4.19).
    - A regression of the annual percentage change at each term to maturity was then performed on the principal components for each dataset. This was done in order to obtain "beta sensitivity" factors of each yield to each principal component (¶4.23). The sum was taken to determine the stress factor.
    - The final stress for each term to maturity was then determined as the average of the stress factors for that term to maturity across the four datasets, allowing for some smoothing (¶4.27).
    - The absolute change in the interest rate under the downward scenario is set to a minimum of 1%. Furthermore, where the pre-stress interest rate is less than 1%, the post-stress interest rate is set to 0% (¶4.59).
- Shocks to the implied volatility surface of interest rates:
    - Datasets of the EUR and GBP implied volatility surfaces, with approximately 11 years of data, were considered (¶4.36). Data for at-the-money swaptions were considered (¶4.38).
    - Multiplicative stress percentages were determined for each term–tenor pair. Both upward and downward stresses were considered (¶4.39 and ¶4.40).
    - A representative term and tenor were chosen in order to collapse the matrix of stresses into a single upward and single downward stress. The selected term was ten years, as was the selected tenor (¶4.42).
    - The relative stresses calculated for the implied volatility at term and tenor ten years were converted into absolute stresses. The upward stress was 12%; the downward stress was –3% (¶4.47).
- The change in the insurer's NAV is determined under each of the four above scenarios separately (¶4.52), i.e.:
    - an increase in the term structure of interest rates (Mkt_{int}^{UP}),
    - a decrease in the term structure of interest rates (Mkt_{int}^{DN}),

- an increase in the implied volatility surface of interest rates (Mkt_{ivol}^{UP}), and
- a decrease in the implied volatility surface of interest rates (Mkt_{ivol}^{DN}).

– From the above, four combined scenarios are determined: $Mkt_{int}^{UP}\cdot_{ivol}^{UP}$, $Mkt_{int}^{UP}\cdot_{ivol}^{DN}$, $Mkt_{int}^{DN}\cdot_{ivol}^{UP}$, and $Mkt_{int}^{DN}\cdot_{ivol}^{DN}$. These are determined as the correlated aggregation of the relevant single-factor changes in NAV. The correlation between the term structure level and the implied volatility assumed in the aggregation is zero (¶4.51).
– The interest rate risk capital requirement is then set equal to the maximum of the four combined scenarios, with a lower bound of zero (¶4.50).

5.2.2 Solvency II Quantitative Impact Study (QIS) 5:

The interest rate stress tested under QIS5 differs from the stress proposed in CEIOPS-DOC-66/10 in that:

– QIS5 does not stress interest rate implied volatilities;
– QIS5 explicitly makes reference to index-linked bonds, whereas CEIOPS-DOC-66/10 does not; and
– QIS5 explicitly doesn't apply a lower bound of zero percent to post-stress real interest rates (¶SCR.5.22).

5.3 Other relevant jurisdictions (e.g. OSFI, APRA)

5.3.1 Canadian approach (OSFI)

The relevant information was obtained from the http://www.osfi-bsif.gc.ca website.

The current methodology, as specified in the document "Minimum Continuing Capital and Surplus Requirements (MCCSR) for Life Insurance Companies", runs broadly as follows:

– Capital is required in respect of:
  - asset default risk "C–1";
  - mortality, morbidity, and lapse risk;
  - changes in the interest rate environment risk "C–3";
  - segregated funds risk; and
  - foreign exchange risk.
– The total capital requirement is determined as the sum of the above five components.
– The minimum ratio of capital available to capital required is 120%.
– The interest rate capital requirement is determined using a factor-based approach. There are four subsections included:
  - Insurance (excluding universal life) and immediate annuity liabilities;
  - "Accumulation funds", deferred annuities, retirement income policies, and universal life products;
  - Debt obligations; and
  - Asset cash-flow uncertainty risk.

  For each of these the appropriate values (e.g. policy values for immediate annuities) are multiplied by stipulated factors (e.g. 0.01). These products are then summed to obtain the capital requirement.

The OSFI has also put out QIS#3 in which a different interest rate risk methodology is considered. It defines interest rate risk as "the risk of economic loss resulting from market changes in interest rates". The method is discussed at a high level below:

– Best-estimate annual asset, liability, and net cash-flows are projected in respect of the insurer's business. They are grouped by liability category and currency. The present value is calculated for each year for each category.

- These best-estimate cash-flows may include some margins.
- The interest rate shock method then involves calculating the present value under a base case and four test scenarios. These test scenarios are as follows:
    - Lower short-term rates, lower long-term rates;
    - Lower short-term rates, higher long-term rates;
    - Higher short-term rates, lower long-term rates; and
    - Higher short-term rates, higher long-term rates;

  The shocks are the estimated 99.5% percentiles of the relevant changes in interest rates.
- From the above the "resulting solvency buffer" is calculated as the difference between the total net present value under the base case and the lowest total net present value of the test scenarios. This is done on a per-jurisdiction basis, although allowance is made for the close link between Canada and the United States of America.

5.3.2 Australian approach (APRA)

The relevant information was obtained from the http://www.apra.gov.au website. On 1 January 2013 new prudential standards came into force.

The now-revoked prudential standards can be found at the following address:

- http://www.apra.gov.au/lifs/PrudentialFramework/Pages/life-revoked-prudential-standards.aspx

Referencing the "Prudential Standard LPS 3.04 Capital Adequacy Standard":

- The capital adequacy requirement consists of five components:
    - The "capital adequacy liability",
    - The "other liabilities",
    - The "inadmissible assets reserve",
    - The "resilience reserve", and
    - The "new business reserve".
- The resilience reserve assesses the effect of mismatching of asset and liability exposures.
- The overall the level of confidence targeted is 99.75% over a one-year period (corresponding to a 1-in-400-year event, see ¶2.4). However, the targeted confidence for the resilience reserve is 99% over a one-year period (¶5.2.5 refers to 1-in-100-year events).
- As per ¶5.2.5, where the resilience reserve does not adequately capture the company's exposure to changes in investment market conditions, the Actuary must make an additional provision.
- The resilience reserve is determined as a function of the change in the value of assets and liabilities after adjusting the relevant yields. The change in yield varies by asset class, and the change in the discount rate for the liabilities is set to that used for bonds.

The new prudential standards can be found at the following addresses:

- http://www.apra.gov.au/lifs/PrudentialFramework/Pages/prudential-standards.aspx, and
- http://www.apra.gov.au/GI/PrudentialFramework/Pages/general-insurance-prudential-standards-and-guidance-notes.aspx

The former considers life assurance; the latter general insurance. Broadly the interest rate components appear similar. The "standard method" consists of six (seven) portions:

- An "insurance risk charge",
- An "insurance Concentration Risk Charge" (general insurers only),
- An "asset risk charge",
- An "asset concentration risk charge",
- An "operational risk charge",
- An "aggregation benefit", and
- An adjustment for tax benefits and management actions.

The “asset risk charge” considers changes in interest rates, and does so in two parts: a change in real interest rates and a change in expected inflation. This is detailed in the draft LPS114 (Capital Adequacy: Asset Risk Charge).

- Real interest rates (RIR)
    - An upward and a downward level stress are specified.
    - The upward stress is determined by multiplying the nominal risk-free rate by 0.25 and then adding the result to the real and nominal yield curves (¶38).
    - The downward stress is determined by multiplying the nominal risk-free rate by 0.20 and then subtracting the result from the real and nominal yield curves (¶38).
    - The stress is subject to a maximum absolute adjustment of 200 basis points (¶39).
    - The effect of the upward stress and that of the downward stress are each subject to a minimum of zero.
- Expected inflation (EI)
    - An upward and a downward level stress are specified.
    - The upward stress is determined by adding 125 basis points to expected inflation and the nominal yield curve (¶43).
    - The downward stress is determined by subtracting 100 basis points from expected inflation and the nominal yield curve (¶43).
    - The effect of the upward stress and that of the downward stress are each subject to a minimum of zero.
- Aggregation
    - The calculation aggregating market risks needs to be performed for every possible combination of upward stresses and downward stresses, where appropriate (i.e. a non-zero risk charge exists). This is because the correlation matrix used in the aggregation varies depending on whether an upward or downward stress is being considered.
    - LPS114 sets the correlations for RIR and EI as follows (¶80–82) (note that only the correlations between RIR and EI are considered below since the other correlations fall outside the scope of the interest rate risk module of SAM):
        - RIR has an upward stress, EI has an upward stress: 0.2;
        - RIR has an upward stress, EI has a downward stress: –0.2;
        - RIR has a downward stress, EI has an upward stress: –0.2; and
        - RIR has a downward stress, EI has a downward stress: 0.2.

5.4 Mapping of differences between above approaches (Level 2 and 3)

The following are felt to be noteworthy regarding the six above methodologies (CP70, Solvency II QIS5, OSFI, OSFI QIS#3, APRA revoked regulations, and new APRA regulations):

- The current OSFI methodology appears to be outdated (e.g. the use of risk charges). The revised methodology appears more in line with Solvency II and SAM. Thus the existing OSFI methodology is not considered further.
- CP70 includes an interest rate volatility stress in the interest rate stress, whereas the other methodologies do not. Provided the effect of changes in interest rate volatilities is captured elsewhere, for example in an implied volatility risk module, it would not be appropriate to include an interest rate volatility stress in the interest rate risk module.
- With the exception of the OSFI QIS#3 methodology, all the methodologies apply level stresses to the yield curve. Thus only the OSFI QIS#3 methodology captures the risk of changes in the slope of the yield curve.
- With the exception of the new APRA regulations, none of the methodologies splits out the risk arising from real interest rates from that arising from nominal interest rates / inflation. Furthermore, the new APRA regulations provide proposed correlations between the risk charges for real interest rates and expected inflation.
- A number of the methodologies apply limits to the stresses (e.g. rates cannot be negative in CP70, the real interest rate stress cannot be greater than 200 basis points in the new APRA regulations).

6. ASSESSMENT OF AVAILABLE APPROACHES GIVEN THE SOUTH AFRICAN CONTEXT

6.1 Discussion of inherent advantages and disadvantages of each approach

6.1.1 Considerations regarding the nominal and real yield curve:

When considering interest rate exposure, an insurer's or reinsurer's balance sheet can be split conceptually into two components: nominal cash-flows and real cash-flows. Changes in the nominal yield curve will affect the nominal cash-flows only. Similarly, changes in the real yield curve will affect the real cash-flows only.

These yield curves are related through the market's expectations of future inflation. Broadly, the nominal interest rate equals the sum of the expected inflation rate and the real interest rate (if continuously compounded returns are considered).

The following factors are therefore desirable in the interest rate stress methodology:

- Two (sets of) stresses are appropriate. This ensures that the effects of both sources of interest rate risk are captured. Hypothetically, stresses could be applied to the nominal yield curve, the real yield curve, and/or the market's expectations of future inflation.
- The stress methodology should reflect the fact that the sources of interest rate risk may not move together (in quantum and/or direction), especially in an extreme stress event. Thus, it should be feasible that nominal and real rates move in opposite directions, resulting in an increase/decrease in inflation expectations greater than that in either of the yield curves.
- The stresses should be designed to avoid double-counting of risk. Thus, the one stress should affect only the value of nominal cash-flows, and the other only the value of real cash-flows.

In SAM QIS1, under each of the interest rate up and interest rate down shocks, a single stress at each term to maturity was applied to both the nominal and real yield curves. This was consistent with the methodology followed for Solvency II QIS5. While both yield curves are stressed (which will also result in a stress being applied to inflation expectations), the following issues arise with this methodology:

- The nominal yield curve, real yield curve and inflation expectations are all assumed to move together.
- The stress applied to the real yield curve is based on an analysis of the nominal yield curve, which may not be appropriate.

Given the above, it is proposed that the interest rate stress methodology be changed under SAM. Two alternatives present themselves based on the discussion above:

1. Calibrate and apply stresses separately to the nominal and real yield curves; and
2. Calibrate and apply stresses separately to the real yield curve and inflation expectations, such that the inflation expectations stress affects only the nominal yield curve.

The first of these is preferred due to data constraints. In order to estimate inflation expectations, both the nominal and real yield curves are required. This is because there is no explicit market for inflation expectations, while there is one for nominal and real interest rates. There exists a greater quantity of more-granular data for the nominal yield curve than for the real yield curve. Calibrating the stress to inflation expectations would therefore result in much of the nominal interest rate data being discarded.

The recommended methodology is set out below:

– Two sets of stresses are applied separately: nominal yield curve stresses and real yield curve stresses.
– *Nominal yield curve stress:*
Stress percentages are determined with reference to the changes observed in nominal interest rates. These stress percentages are applied only to the nominal yield curve. There is no change in the real yield curve.
– *Real yield curve stress:*
Stress percentages are determined with reference to the changes observed in real interest rates. These stress percentages are applied only to the real yield curve. There is no change in the nominal yield curve.
– *Aggregation:*
The nominal and real yield curve stresses are aggregated assuming a particular correlation to obtain the interest rate risk SCR.

Mathematically, the aggregation calculation is:

$$Mkt_{int} = \sqrt{(Mkt_{int\_nom})^2 + (Mkt_{int\_real})^2 + 2 * \rho_{nom\_real} * Mkt_{int\_nom} * Mkt_{int\_real}},$$

where Mkt_{int} is the interest rate risk SCR;

Mkt_{int_nom} is the nominal interest rate risk SCR;

Mkt_{int_real} is the real interest rate risk SCR; and

ρ_{nom_real} is the correlation between Mkt_{int_nom} and Mkt_{int_real}.

The advantages of the proposed approach are as follows:

– The assumption that nominal and real interest rates move in the same direction is not made. For example, it is conceivable that the effect of an increase in nominal interest rates gives Mkt_{int_nom}, while a decrease in real interest rates gives Mkt_{int_real}.
– The capital requirements in respect of nominal and real interest rate risks are assessed separately. This will result in more granular risk information being made available to management, which should lead to an enhanced understanding of the behaviour of the balance sheet under interest rate shocks.
– The nominal and real interest rate stresses can be calibrated separately. Thus, differences in the variability of nominal and real interest rates can be reflected in the stresses used. Furthermore, the method of calibration can be modified if necessary to reflect the reduced data available for the real yield curve.

It should be noted that:

– Both the nominal and real interest rate stresses will cause changes in the market's expectations of future inflation, since in both one yield curve remains static while the other is stressed.
– Although the assumption that the nominal and real interest rates move in the same direction is no longer made, an explicit assumption of the correlation between nominal and real interest rate risk is required.

An additional consideration is the limits placed upon the stresses of the yield curves. SAM QIS1 sets the minimum change under a downward stress equal to 1 percentage point (pp), with a minimum post-stress interest rate of 0%. While the latter may be appropriate for nominal interest rates, persistent negative real interest rates in some developed nations cast doubt on the assumption that real interest rates cannot fall below zero. Furthermore, if a PCA stress methodology is used (see section 6.1.3 subsection *i)*), then some of the stresses will reduce the rates at some points on the yield curve by less than 1pp by design. The following is therefore proposed:

- Under a downward level stress (i.e. a stress in which all points on the yield curve are made to decrease), the minimum reduction in the interest rate at any point on the yield curve is set to 1pp.
- Where a post-stress nominal yield curve has any points lying below 0%, those points on the post-stress nominal yield curve are set to 0%.

Finally, an issue arises when stressing near-zero real interest rates. If the real yield curve fluctuates above and below zero, then applying an upward level stress to it will result in its fluctuating around zero more wildly. A pragmatic approach is required in this instance, as simply applying the stress as-is will result in a post-stress yield curve that does not correspond intuitively with how one might expect a level stress to behave. The following are suggested as possible approaches to this issue:

1. Currently, under a downward level stress, the minimum reduction in the interest rate for any term to maturity is set to 1pp. A similar minimum increase in the interest rate could be set under an upward level stress, say 1pp. This approach has the advantage of being formulaic. However, its application may result in “kinks” in the post-stress yield curve. Furthermore, should real interest rates become very negative (e.g. –5%), applying these restrictions may understate the extent of the variation in the real yield curve under a stress event.
2. The level stresses for the real yield curve could be specified in absolute, rather than relative, terms. This has the advantage of being simple to apply. However, where real interest rates become very positive or very negative, the stress may understate the level of variation in the real yield curve.

6.1.2 <u>Considerations regarding the dataset used in calibrating the stress</u>

Ideally the dataset to which the SAM interest rate stresses are calibrated should cover as long a period as possible. This is particularly important since an extreme tail-event is being calibrated. The actual period considered will be limited by the following factors, however:

- Changes in interest rate regime, since data from different regimes (e.g. one that does not target inflation) may not be representative of prevailing circumstances; and
- The period for which data of an acceptable quality are available.

The JSE provided a history of NACQ nominal interest rates dating from 2002/07/31 to 2011/05/31, amounting to 107 months of data. Ideally a greater volume of data would be available for the calibration.

The above-mentioned data contained a number of yield curves for each date. Considerations regarding which of these to use are discussed below. It should be noted that the eight sets of data resulting from the variations below were all analysed for the period from 2004/01/30 to 2010/12/31 in order to inform the discussion regarding the relative merits of each approach. The full dataset was used in the final calibration, however. Some data cleaning was required.

Data for the real yield curve from 2004/12/01 to 2011/05/03 were obtained. These data were not as credible as the nominal interest rate data since the market for the relevant instruments is illiquid. Furthermore:

- only data derived from real swaps were included (i.e. the dataset did not include bond curves);
- the variation in the spot rates for the first two terms to maturity (6 months and 1 year) was particularly large, and so the real yield curve was only considered from year two onwards; and
- three months' data were missing from the dataset, and so the yield curves at those dates were interpolated from the previous and subsequent data points'.

i) Swap curve vs bond curve

The swap curve was used in the calibration of SAM QIS1, and CEIOPS-DOC-66/10 considers both swap and bond rates in determining the stress percentages.

As at the date of initial calibration (February 2012), SAM specifies that the risk-free rate to be used in insurers' valuations is that derived from the swap curve. In order to achieve consistency it was therefore felt that the (nominal) interest rate stresses should be calibrated using the swap curve.[2]

ii) Best decency vs perfect fit

"Best decency" (BD) and "perfect fit" (PF) refer to the way in which the yield curve is fitted to the market data points. PF provides a more accurate fit to the data points, while BD smoothes the curve somewhat. The Actuarial Society of South Africa (ASSA) and the Bond Exchange of South Africa (BESA) released a document describing the two methodologies in 2003. This document can be found at the following web address:

http://www.jse.co.za/Libraries/BESA_related_documents/An_introduction_to_the_BEASSA_zero_coupon_yield_curves.sflb.ashx

An investigation into the implications of calibrating the nominal interest rate stresses to the PF or BD curves was performed on data from 2004/01/30 to 2010/12/31. (See the introduction to section 6.1.2 for more information on the source of these data.) The average standard deviations (across terms to maturity) of the log-changes are presented in table 6.1.2-1 below:

Sigma (%)		Spot	Forward
Swaps	PF	4.60	6.46
	BD	4.58	5.40
Bonds	PF	4.81	7.12
	BD	4.77	6.30

Table 6.1.2-1: Comparison of standard deviation of log-changes

The PF curves on average exhibit greater volatility than the BD curves. Furthermore, the PF curves result in much less smooth pre- and post-stress yield curves. Given the potential issue with forward rates (see section 6.1.2 subsection *iii)* below), it was felt that calibrating to BD curves was preferable.

iii) Forward vs spot yield curves

A concern was raised regarding the yield curve to which the stresses are applied. For SAM QIS1 the stresses were calculated using and applied to spot (i.e. zero) yield curves.

[2] Note: This changed in SAM QIS3, and so the nominal yield curve stresses were recalibrated. See section 6.1.6.

Applying stresses to spot curves can cause irregularities in the post-stress forward curve, however, such as:

- post-stress forward rates can vary in an unintuitive fashion, e.g. by moving from above to below the pre-stress forward rates under a level upward stress, and
- post-stress forward rates becoming negative.

It is desirable to avoid the above irregularities. For example, negative forward rates imply a negative cash rate is expected at some future time, which is counterintuitive.

While these issues are exacerbated by using a discrete base spot curve and curve of stress factors, they could still arise in the case where the curves are defined as differentiable functions of term to maturity. That is, the irregularities are not purely a function of approximating a theoretical continuous curve with a discrete one. This is shown in annexure 8.3. Furthermore, the annexure derives a criterion in the continuous case for post-stress forward rates to be negative: the derivative of the stress curve (if the stress percentages were to be expressed as a function of the term to maturity to which they apply) must be less than a defined ratio. Thus, if the stress curve is smooth (especially at the long end) then negative post-stress forward rates will be avoided. This corresponds with CEIOPS-DOC-66/10 ¶4.27, in which it is stated that the derived stress curve was smoothed.

The choice of whether to apply the stresses to the spot or forward curve will affect to which curve the stresses should be calibrated. Some stresses were therefore calibrated to the datasets from 2004/01/30 to 2010/12/31 in order to assess the suitability of the various datasets. The results are discussed in the bullets below:

- The stresses derived through calibrating to the forward curves, especially those derived using principal component analysis (PCA), exhibited odd-looking behaviour. This was caused by the following:
  - i) The standard deviation of the log-changes in the forward rates for a given term was significantly greater than that for the spot rates at that term.
  - ii) The levels of correlation between terms for log-changes in forward rates were significantly smaller than those for spot rates.

  Item ii) means that the first three components of the PCA explained less of the total variation in rates. This has the following implications for applying a PCA stress:
  - a) The explanatory power of the PCA is greater for spot rates than for forward rates. This means that more components (and hence interest rate stresses) would be required for forward rates in order to explain the same level of variation in the yield curve. This can be seen from the table in annexure 8.4.
  - b) The intuitive nature of the first three components of the PCA breaks down for forward rates. For spot rates, the first three components can be understood as "level, slope, and curvature", corresponding to zero, one and two terms to maturity where the stress changes sign. This breaks down when the PCA is applied to forward curves.

- The post-stress forward rates derived from applying stresses to the spot rates behaved sensibly (that is, the theoretical issues raised regarding stressing spot rates did not arise in practice).

In summary, while calibrating and applying the interest rate stresses to the forward rates and not the spot rates avoids the possibility of having nonsensical post-stress forward curves:

- It reduces the explanatory power of the PCA stresses,
- The intuitive nature of the PCA stresses derived from the spot rates is lost, and
- The theoretical issues that may arise from applying stresses to spot rates do not appear to arise (and, furthermore, should be controllable through ensuring a reasonably smooth curve of stress percentages, especially at greater terms to maturity).

It was therefore felt that calibrating and applying the stresses to the spot curves was preferable.

iv) Dataset to which stresses were calibrated

Given the discussions in sub-sections *i)* to *iii)*, it was decided that the stress percentages for the nominal yield curve would be determined by considering the best decency spot rates determined from the swap curve. The full dataset (from 2002/07/31 to 2011/05/31) was used for the final calibration.

The stress percentages for both the nominal and real yield curves are presented in annexures 8.1, 8.2, and 8.8.4. Because the stress percentages are to be applied to NACA rates, the data were converted to NACA for analysis.

It should be noted that the calculated stress percentages are based upon the datasets described above. Should a more appropriate dataset become available, the stress percentages should be updated to reflect it. In particular the following should be borne in mind:

– The base curve used for the valuation. The base curve is currently derived using swap rates, and the calculated stress percentages have been derived to be consistent with this. If the source of the base curve changes, e.g. to bond rates, then the stress percentages should also be recalibrated.[3]
– Data useful in assessing stress percentages. The market may experience a period with large changes, e.g. interest rates drop significantly over a short period of time. Reflecting this drop in the dataset used for the calibration could help to obtain more robust stress percentages (since the dataset would contain events closer to the extreme changes being modelled).
– Changes in regime. Current South African monetary policy uses short-term interest rates to target inflation. Past experience of interest rates may become a poor predictor of future experience if this changed.

6.1.3 Methodology used in stressing a yield curve

There are a number of ways of determining possible stresses for interest rates (both nominal and real). This section discusses the approaches considered in SAM QIS2 at a high level. The remaining approaches are discussed in annexure 8.5.

Before discussing the stress methodology it should be noted that the standard formula will apply instantaneous stresses to the yield curve (as well as to other market variables). The stress will be calibrated to a one-year time horizon, however. In practice, extreme changes are unlikely to occur instantaneously (even in a 1-in-200-year event). This means that the stress will potentially overstate the true value at risk of the (re)insurer, since in most cases the company should be able to rebalance its portfolio appropriately over the course of the year. This would partially offset the losses arising under the stress event.

[3] Note: This changed in SAM QIS3, and so the nominal yield curve stresses were recalibrated. See section 6.1.6.

i) Principal Components Analysis (PCA):

The PCA methodology is described (at a high level) below:

1. Consider a set of month-on-month log-changes in interest rates for each term to maturity.
2. The correlation matrix of the log-changes is calculated.
3. A PCA is performed on the correlation matrix, providing a set of eigenvalue–eigenvector pairs. The first three pairs are selected in order to explain the majority of the interdependence (approximately 99% in the case of nominal spot interest rates). Note that this is equivalent to a scaled analysis of the covariance matrix.
4. A Normal distribution is fitted to each term to maturity's log-changes.
5. Using the Normal distribution and the three eigenvalue–eigenvector pairs, six stresses to the yield curve are determined. These should be adjusted to remove the expected change in the interest rate under the model.

Each eigenvalue–eigenvector pair determined through the process above produces a particular type of interest rate stress. These will be referred to as level, slope and curvature stresses (determined using the first, second and third principal components respectively). Each can be applied in either direction, resulting in the total of six stresses.

The six stresses determined above are applied as follows:

1. For each type of stress (level, slope or curvature), the change in the insurer's or reinsurer's economic net asset value is assessed under both the upward and downward stress.
2. The (undiversified) capital requirement attributable to each type of stress is taken as the maximum reduction in economic net asset value between the upward and downward stress.
3. The interest rate capital requirement is taken as the aggregation of the capital requirement under each type of stress. Note that the PCA will result in orthogonal stresses, i.e. the stress types are independent. Hence the aggregation should be performed using the identity matrix as the correlation matrix.

Advantages

- The PCA allows for the interdependence between different terms to maturity of the yield curve.
- The PCA produces a number of stresses which test the insurer's or reinsurer's exposure to different portions of the yield curve. For example, even if an insurer has hedged its interest rate exposure based on the modified duration of its liabilities (in the extreme case, hedging annuity payments with a zero-coupon bond), it may be exposed to changes in the slope of the nominal yield curve. The use of the PCA stresses will therefore lead to a greater understanding of the interest rate risk faced by the company.
- As the PCA is performed on log-changes, it provides asymmetric stresses.

Disadvantages

- The PCA assumes that the log-change in each month is independently and identically distributed Normal.
- There is additional complexity involved with performing multiple stresses.
- The PCA methodology deviates from the Solvency II standard formula.

Stresses determined based upon the nominal yield curve data described in section 6.1.2 above are given in table 8.1-1 in annexure 8.1.

In addition to the separate level, slope, and curvature stresses, a single combined stress (the single interest rate stress scenario) was determined for each direction.

ii) *The real yield curve:*

Given the poor credibility of the real yield curve data (see section 6.1.2) it was not felt appropriate to apply the above methodology. Also, the fact that the real yield curve can become negative (and does in the dataset available) meant that log-changes in the interest rate could not be analysed. Thus two sets of stresses for the real yield curve were calculated:

- The first was determined by fitting a Normal distribution to the percentage point changes in the real yield curve. The resultant stresses were therefore absolute stresses.
- The second was determined by fitting a Normal distribution to the percentage changes in the real yield curve. The resultant stresses were therefore relative stresses.

Applying the absolute stress will result in a more onerous stress when real interest rates are low. Similarly, applying the relative stress will be more onerous when real interest rates are high. Relative stresses capture the increased variability arising from higher base real interest rate levels, and hence are preferable. However, if relative stresses are used then allowance will need to be made for the fact that real interest rates can become negative. This could be done by setting minimum and maximum percentage point changes in the real yield curve under each stress. This is discussed in section 6.1.1, in which the absolute bounds suggested are +1pp and –1pp.

Applying the absolute stress to low real interest rates, e.g. those as at 2011/12/31, would be more onerous. However, in the long-term it may be more appropriate to apply the relative stress percentages with minimum changes in the real yield curve under each stress.

Stresses determined based upon the real yield curve data described above are given in table **Error! Reference source not found.**-2 in annexure **Error! Reference source not found.**. Furthermore, the absolute stresses determined by fitting a Normal distribution to the percentage changes in the real yield curve are included in table 8.2-1 in annexure 8.2.

6.1.4 Results of SAM QIS2

SAM QIS2 was used to test the relative impact of two possible methodologies for applying interest rate stresses under the standard formula. A detailed specification of these is given in annexure 8.7. A discussion of the results is included here.

i) *Methodologies tested*

The base interest rate methodology used for the purposes of SAM QIS2 was the single interest rate stress scenario, under which the nominal and real yield curves were stressed together and by the same percentages.

The alternative interest rate methodology split the nominal and real yield curve stresses. The nominal yield curve stresses determined using the PCA methodology were applied to the nominal yield curve; the single-direction real yield curve stresses were applied to the real yield curve.

ii) Qualitative results

SAM QIS2 participants expressed a variety of views in the qualitative submissions. While many were supportive of stressing real and nominal interest rates separately (and stressing the different components of nominal interest rates separately), many also felt that this introduced unnecessary complexity into the SCR calculation. There was broader support for the split of real and nominal interest rate risk than for the split of nominal interest rate risk between the principal components.

The following were also noteworthy:

– Many participants felt that the prescribed policyholder behaviour under the interest rate level stresses was potentially inappropriate, adding that this should instead be determined by the company concerned.
– Some participants asked that it be made clear into which market risk module preference shares should be categorised (interest rate or equity).
– Some participants expressed views showing a failure to understand what SAM QIS2 prescribed, thereby casting doubt on the quality of the SAM QIS2 results.
– Some participants highlighted the risk of a double-count of inflation risk between the interest rate and expense risk modules.

The final recommendation regarding the split of the interest rate risk module is discussed further below. Regarding the other items:

– The market risk working group was in agreement that prescribing policyholder behaviour under interest rate and equity stresses was inappropriate. Insurers should include dynamic policyholder behaviour in their valuation of technical provisions, both in the base case and under stress scenarios. The standard formula should not prescribe the nature of this, however.
– A paragraph was added to the final recommendation clarifying that preference shares should be included under the interest rate risk module where they do not exhibit material equity-like characteristics.
– Caution was applied in the analysis of the quantitative results of SAM QIS2.
– The inflation risk implicitly assessed in the interest rate risk module considers marketing inflation. The expense inflation risk in the expense risk module considered company-specific expense inflation in excess of market inflation.

iii) Quantitative results

The quantitative results were analysed to determine which of the two approaches tested in SAM QIS2 was more appropriate. In particular: did the base single interest rate stress scenario adequately capture the industry's interest rate risk? Furthermore, did the additional accuracy of the alternative approach outweigh its additional complexity?

SAM QIS2 Report

The regulator produced a report on the results of SAM QIS2. Pages 35 to 37 of this report discuss the interest rate risk sub-module. Chart 6.1.4-1 below shows figure 6.11 from this report ("Aggregate results of the alternative interest rate calculation (% of base interest rate result)").

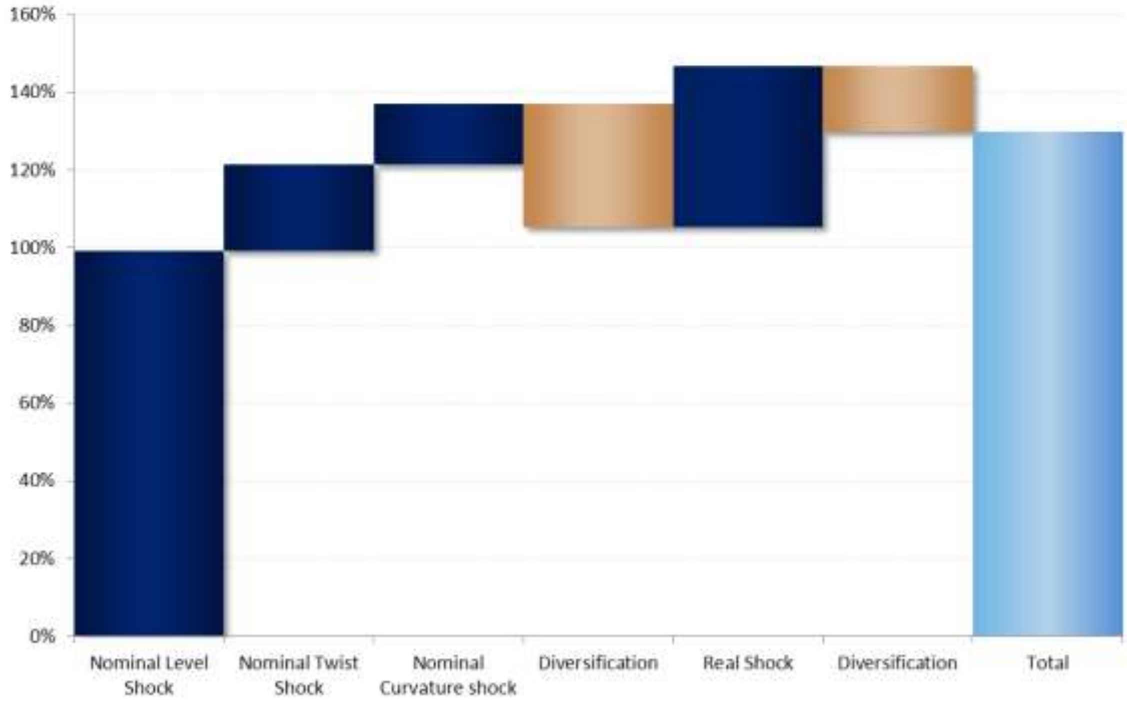

Chart 6.1.4-1: Aggregate results of the alternative interest rate calculation (% of base interest rate result).

In its analysis, the report considered 55 insurers (31 life and 24 non-life). The above chart shows that:

– Although the undiversified slope and curvature stresses are not insignificant relative to the level stress, their effect was more-or-less diversified away.
– The real stress is both significant relative to the nominal stress and does not diversify away to the same extent as the additional nominal principal components.

There was consensus in the working group that the results of the report support the separate application of nominal and real stresses, which are then aggregated together allowing for diversification. It was felt that the additional accuracy gained outweighed the additional complexity.

However, two interpretations of the results for the split of the nominal principal components were expressed:

1. Applying the three nominal principal component stresses separately did not produce a significantly different result from applying only the level stress. The additional complexity therefore was not justified by the greater accuracy since the level stress adequately captured the nominal interest rate risk of the industry.
2. While the SAM QIS2 effect of the slope and curvature stresses was largely diversified away, the undiversified results were significant relative to the level undiversified result. This implies that only considering level interest rate risk could understate the capital requirement in the future if (re)insurers hedge only their level interest rate risk (leaving slope and curvature risk unhedged).

SAM QIS2 Results

In addition to the analysis on the SAM QIS2 report, the working group performed some analysis of quantitative results provided by the regulator. There were a number of data issues present in the quantitative results. This was evidenced by some of the qualitative feedback as well as the nature of some of the quantitative results. The participants considered in the SAM QIS2 report were not specified. As a result, the following rules were applied in an attempt to discard inappropriate results:

– Where the division of the base interest rate scenario's capital requirement by the alternative's resulted in an error (mostly divide by zero errors), the results were discarded. This was because the participant must not have performed the alternative interest rate calculation. This resulted in the exclusion of 25 sets of results.
– Where the split in the alternative scenario of nominal interest rate risk between level, twist, and inflection risk was even (to 15 decimal places), it was assumed that the split was not performed appropriately. This resulted in the exclusion of 29 sets of results.
– The results of the remaining 67 participants were then sorted by the result of the division of the base interest rate scenario's capital requirement by the alternative's, and the top and bottom deciles were excluded. This prevented the results from being skewed by outliers in either direction.

Chart 6.1.4-2 below shows the resultant average ratio across participants of the base vs the alternative interest rate scenario. The results have been split by insurer category. "* - *" shows the average ratio across all included participants. The number of participants per category is as follows:

Life - Direct Writer	21
Life - Reinsurer	3
Life - Pure Linked Insurer	6
Life - Cell Captive	2
Non-Life - Direct Writer	20
Non-Life - Reinsurer	1
Non-Life - Cell Captive	1
Non-Life - 1st Party Captive	0
* - *	54

Thus the participants considered do not correspond exactly with the SAM QIS2 report.

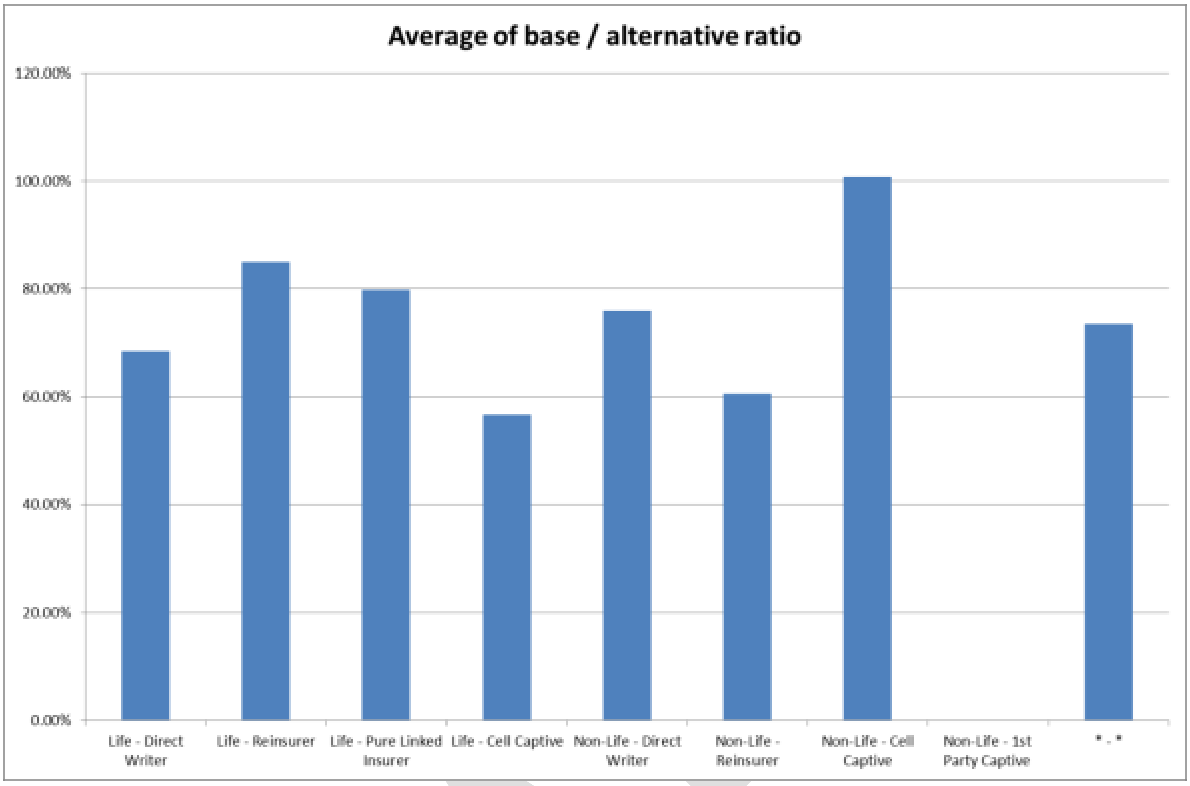

Chart 6.1.4-2: Average ratio of base to alternative interest rate risk scenario.

The above chart shows that on average the base scenario understates the interest rate risk capital requirement relative to the alternative scenario. Furthermore, non-parametric tests were performed to assess the statistical significance of this deviation. The sign test and Wilcoxon signed-rank test were performed to test whether the median was significantly different from one. The null hypothesis that the median equalled one was rejected with a p–value of 0.00% in both cases. The failure of a χ^2 test indicated that a student-t test for the mean could not be performed.

The above implies that some level of split of the interest rate risk calculation is appropriate.

Chart 6.1.4-3 below shows the split of the alternative interest rate risk capital requirement between nominal and real interest rate risk. Chart 6.1.4-4 shows the split of the nominal interest rate risk capital requirement between level, slope, and curvature risk. In all cases the contribution to the diversified total is calculated (i.e. allowing for diversification).

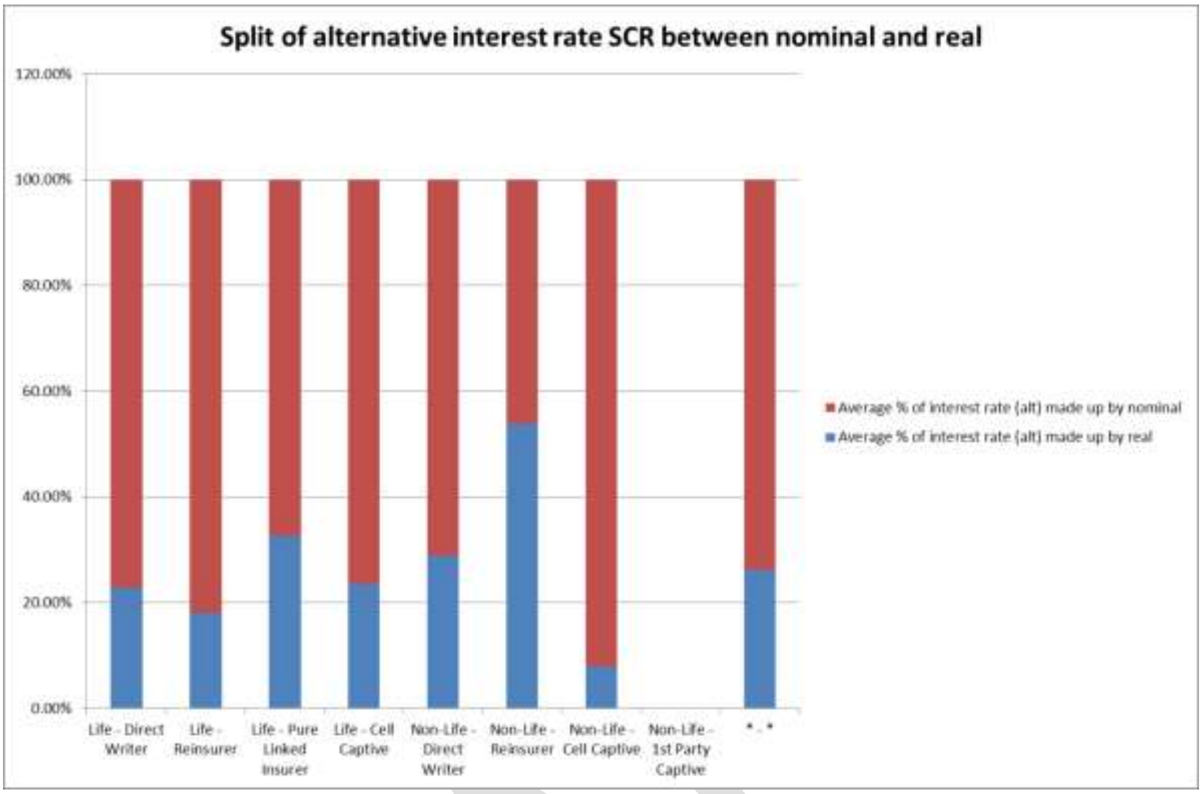

Chart 6.1.4-3: Average contributions of nominal and real interest rate risk to total (alternative) interest rate risk.

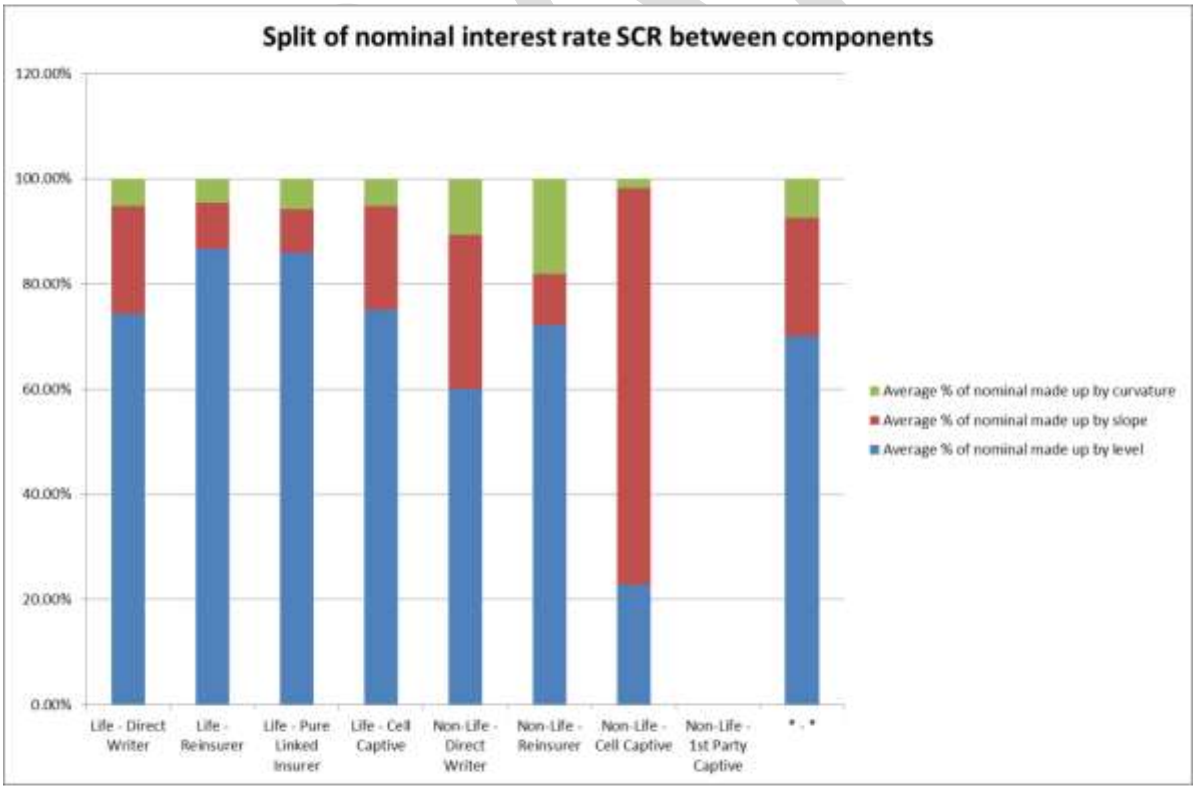

Chart 6.1.4-4: Average contribution of components of nominal interest rate risk.

On average for the alternative scenario:

- Real interest rate risk contributed approximately 26% of the total interest rate risk capital requirement; and
- Level contributed 70%, slope 23% and curvature 7% of the nominal interest rate risk capital requirement.

The conclusions of the above analysis were broadly consistent with that of the SAM QIS2 report.

6.1.5 Working group discussion points

In light of the above, the working group unanimously supported splitting nominal and real interest rate risk.

Consensus was not reached on whether nominal interest rate risk should be split into the three principal components, with a majority against the split. The points that support combining the principal components were:

- Calculating six stresses rather than two adds complexity to the standard formula. This additional complexity is not felt to be outweighed by the increased accuracy. This is shown in the SAM QIS2 report, since diversification of the separate principal components reduces the nominal interest rate capital requirement to near the level risk component.
- Where companies are not exposed to level interest rate risk (e.g. due to hedging programmes):
    - The non-level nature of the single interest rate stress scenario (its stress percentages are significantly more extreme at short terms) will mitigate any inappropriate impact on the total interest rate risk capital requirement.
    - Any residual risks should be captured under the Own Risk and Solvency Assessment (ORSA). The regulator can then deal with these through a capital add-on.

The points against combining the principal components were:

- The additional complexity of the standard formula would not necessarily translate into a significantly larger regulatory burden provided (re)insurers had automated processes.
- In the SAM QIS2 report and results, the undiversified slope and curvature stresses were significant relative to the undiversified level stress. Combining the principal components into a single stress would therefore cause companies hedging only level risk to understate their interest rate risk. It is more difficult for (re)insurers to game multiple stresses.

The working group was not in favour of splitting the three principal components but allowing companies to apply a single interest rate stress scenario as a simplification. (This would be in line with a number of other risk sub-modules, e.g. credit risk, lapse risk and longevity risk.) The reason for this was that alternatives reduce the comparability of companies' results.

Interest rate risk is an industry-wide (as opposed to company-specific) risk. This is because the events are external to the (re)insurers affected, although the extent to which a particular (re)insurer is affected will be determined by its individual exposures.

The effect of the interest rate stresses should be determined allowing for any risk-mitigating contracts. It may be appropriate to allow for credit risk on these. Any impairment to risk-mitigating contracts should be done as specified in the relevant SAM credit risk position paper.

6.1.6 Considerations post SAM QIS3

The preceding sections discuss the derivation of the interest rate curve stresses prior to SAM QIS3. This section updates the discussion to reflect considerations post SAM QIS3.

As discussed in section 6.1.2 *i)*, at the time of the initial calibration of the interest rate stresses, the base valuation curve used was the swap curve. This was subsequently changed, as specified in TP.26.1 of the SAM QIS3 technical specifications:

> "The government bond curve will be the default to be used for the risk free rate. For those insurers that match liabilities with swap-based assets, these insurers may use the swap curve to value these liabilities."

The calibration of the nominal and real interest rate curve stresses therefore had to be revisited, in line with section 6.1.2-*iv)*. There was no other significant feedback from the SAM QIS3 exercise.

i) The nominal yield curve

The nominal yield curve data introduced in section 6.1.2 were considered. NACA best decency spot rates based on the bond curve were used. Data to term 30 years were available from 2003-01-30 to 2011-05-31. As with the stresses based on the swap curve, a principal components analysis was performed and the results combined to obtain a single up and down stress. The chart below compares the results based on the bond and swap curves (a table is provided in annexure 8.9):

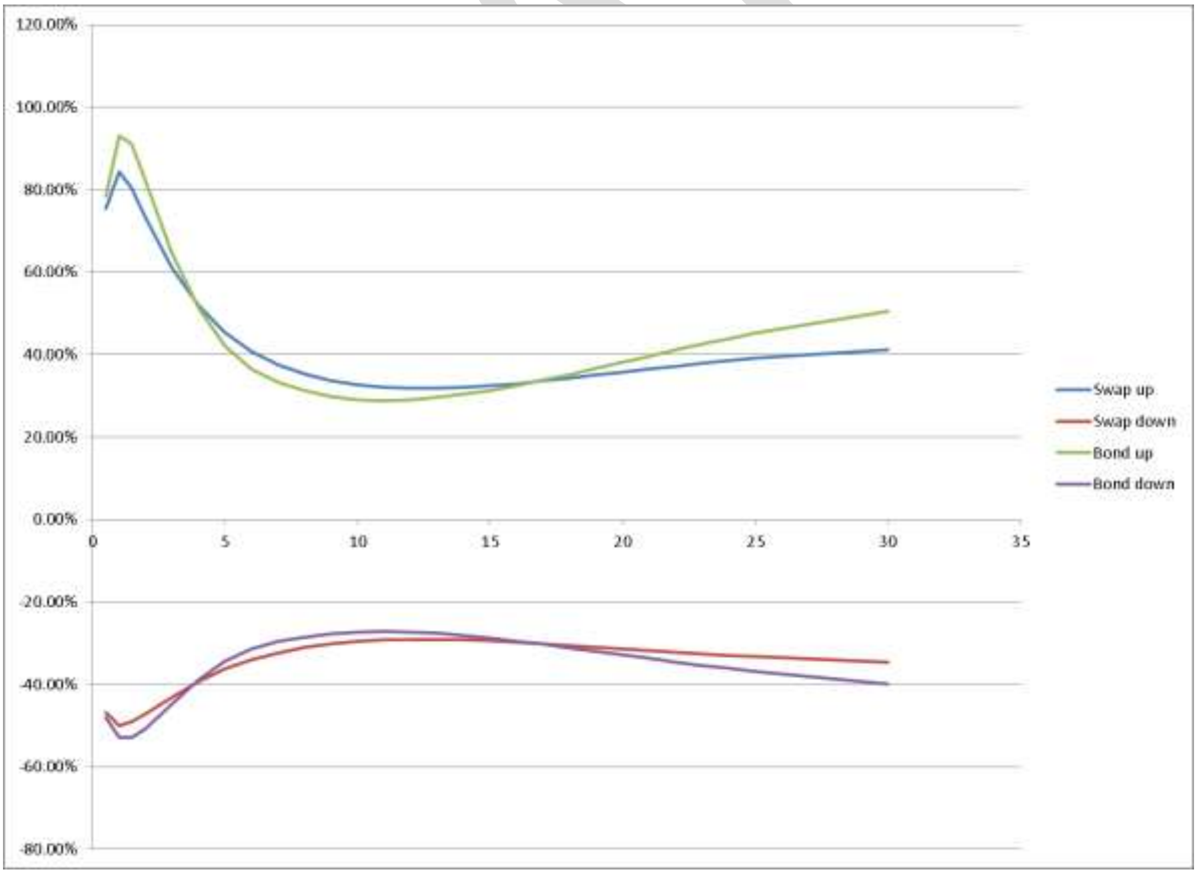

Chart 6.1.6-1: Comparison of nominal interest rate curve stresses based on bond and swap curves.

As can be seen from the chart above, the NACA stresses based on the swap and bond curves are similar. The bond-based stresses are larger at very short and very long terms to maturity. This is because the bond curve is more volatile (i.e. has a larger standard deviation) than the swap curve at those terms.

The final nominal yield curve stresses for SAM are therefore those based on the bond curve.

The forward rates resulting from the stresses determined directly from the bond data were checked for smoothness. A sharp drop in the post-stress forward curve at term 30 was observed. This was a result of the combination of the upward-sloping stress curve just before year 30 and the immediate flattening of the stress curve after year 30. In order to avoid this, a clamped spline was used to determine a smooth interpolation between the calculated stresses at years 25 and 30. The stresses specified in the recommendation were adjusted to include stresses at years 26 to 29.

i) The real yield curve

Ideally a similar exercise should be undertaken for the real yield curve stresses. However, real bond data were not available. Furthermore, the similarity of the nominal swap and bond stresses provided the working group with comfort that any changes to the real yield curve stresses would not be significant.

6.2 Impact of the approaches on EU 3rd country equivalence

In assessing the impact on EU third country equivalence, the document CEIOPS-DOC-94-10 (released on 2010/11/12) was considered. CEIOPS states in ¶1.5 that the document may need to be updated to reflect the European Commission's final proposals.

The overarching principles discussed in section 2 of CEIOPS-DOC-94-10 are presented below, with a brief discussion of the implications for each of the methodologies considered in this discussion document.

- Similarity of the level of policyholder / beneficiary protection
    - It is not felt that any of the recommendations within this discussion document would significantly reduce the level of policyholder / beneficiary protection.
- Supervisory cooperation, professional secrecy and confidentiality requirements
    - Not applicable for this discussion document.
- Use of the proportionality principle
    - The use of the proportionality principle in determining the real yield curve stress methodology should not affect third country equivalence.
    - Furthermore, if it is felt that the proportionality principle should be invoked, say, to reduce complexity, this should not affect third country equivalence.
- Judgement can only be made in respect of an existing regime
    - Not applicable for this discussion document.
- Review of the equivalence assessment
    - Not applicable for this discussion document.

6.3 Comparison of the approaches with the prevailing legislative framework

The allowance for interest rate risk in calculating the Capital Adequacy Requirement (CAR) is stipulated in PGN104. Interest rate risk is considered in:

- Section 6.10.7.2: Resilience Capital Adequacy Requirement; and
- Section 6.10.7.3: Worse investment return Capital Adequacy Requirement.

The Resilience CAR stresses asset values. This includes interest-sensitive instruments, such as bonds. The stress applied is that of an increase or decrease in the (real or nominal) yield to maturity of 25%.

The Worse investment return CAR stresses the valuation interest rates used in the valuation of the assets and liabilities. The stress scenario is a 15% reduction in the (valuation) interest rate.

The CAR stress methodology is significantly different from that of SAM, as is the way in which interest rates are stressed.

The regulator also requires additional stresses to be performed, including a 50% increase and 35% decrease in interest rates (coupled with resilience CAR adjustments).

6.4 Conclusions on preferred approach

The approach recommended by the working group for the SAM standard formula is as follows:

- The nominal and real yield curve stresses are to be split.
- The stresses applied to the nominal yield curve will be the single interest rate stress scenario percentages. This will result in an upward and downward stress.
    - The stresses specified will be relative.
    - An underpin of one percentage point is applied to the stress for the downward scenario.
    - Where the unstressed nominal rate is lower than 1% at any term, the shocked nominal rate under the downward scenario is set to 0% at that term.
- The stresses applied to the real yield curve will be those derived by fitting a Normal distribution to the percentage point changes in the curve.
    - The stresses specified will be relative.
    - An underpin of one percentage point is applied to the stress for both the upward and downward scenarios.
- The capital requirement arising from the nominal and real yield curve stresses will be aggregated using a correlation matrix. The assumed correlation will be 25%.

There was a minority opinion that the stresses applied to the nominal yield curve should be the full set of six PCA-derived stresses, or at least the nominal level and slope stressed separately (i.e. four nominal stresses). Splitting nominal level and slope stresses would help to differentiate between contracts with rand reserves that change sign over the period of the exposure from those that remain positive or negative.

The approach summarised above and discussed in the preceding sections has the following advantages (which have been discussed in the preceding sections as well):

- Splitting the nominal and real interest rate stresses:
    - Avoids making the assumption that nominal and real interest rates move in the same direction;
    - Assesses the capital requirements in respect of nominal and real interest rate risks separately, providing management with more granular risk information; and

    - o Allows for differences in the variability of nominal and real interest rates to be reflected in the stresses used.
- – Combining the separate PCA stresses (vs applying six individual stresses) reduces the complexity of the standard formula relative to the alternative.
- – Deriving the single interest rate stress scenario for the nominal yield curve from the PCA methodology (where a Normal distribution was fitted to the log-changes and a PCA performed):
    - o Results in a relative stress, reflecting the higher variability of the nominal yield curve when it is high;
    - o Still results in stress percentages that vary substantially with term to maturity.
- – Fitting a Normal distribution to the percentage changes of the real yield curve, with an absolute underpin:
    - o Recognises that the real yield curve historic data is of a lower quality than the nominal yield curve;
    - o Results in a relative stress where the real yield curve is high, reflecting its increased variability; and
    - o Results in an absolute (i.e. percentage point) stress where the real yield curve is near zero (or negative), which allows the real yield curve to become negative post-stress and does not break down when portions of the real yield curve are negative pre-stress.

There are also some disadvantages. In particular, combining the separate PCA stresses results in a reduction in the accuracy of the assessed interest rate risk.

For the purposes of the SAM standard formula, the majority opinion was that the advantages of the recommended approach outweigh the disadvantages.

7. RECOMMENDATION

The level two advice of the market risk working group regarding interest rate risk is as follows. It has been determined with reference to the preceding sections, and incorporates elements of the EIOPA-issued technical specifications (e.g. EIOPA-DOC-12/467) where appropriate.

Splitting the nominal interest rate risk sub-module between three principal components (level, slope, and curvature) was considered. Not splitting the three principal components would mean that the standard formula for (re)insurers hedging level risk only would understate their nominal interest rate risk, since it would not cover the slope and inflection risks. The majority of the working group felt this to be an unnecessary increase in the complexity of the standard formula, and that any additional risk not captured in the standard formula would be captured in the Own Risk and Solvency Assessment (ORSA). There was a dissenting minority view. The recommendation of the working group follows the majority view.

The recommendation has also been amended to include all components of the interest rate risk module other than the “volatility” risk component. The reader is referred to discussion document 106 (implied volatility risk) for more detail.

Interest rate risk (Mkt_{int})

<u>Description</u>

Interest rate risk arises when the market-consistent values of assets and liabilities are sensitive to changes in the market yield curves. This includes both the nominal and real yield curves. All assets and liabilities that are sensitive to changes in either yield curve should be considered under the interest rate risk module, whether valued by mark-to-model or mark-to-market techniques.

The above may involve deriving a mark-to-model valuation that is consistent with the mark-to-market valuation. The impact of the change in the yield curve can then be applied to the mark-to-model valuation. Where this is done, (re)insurers should assume that the interest rate stresses are applied to the basic risk-free rate only; any spread in excess of the risk-free return should remain unchanged in the stressed scenarios.

Additional guidance on the application of the interest rate risk module is given below. It does not provide an exhaustive list of assets and liabilities to be considered in the interest rate risk module.

– The discounted value of future cash-flows, in particular in the valuation of technical provisions, will be sensitive to a change in the rate at which those cash-flows are discounted.
– Assets sensitive to interest rate movements will include fixed-income investments, financing instruments (for example loan capital), policy loans, interest rate derivatives and any insurance assets.
– Consideration should be given to the fact that callable bonds and other types of interest rate structures may not be called by the issuer in the event that spreads widen or interest rates increase. This may have an impact on the duration of the asset.
– A repo-seller, having agreed to repurchase collateral at a future date, should take account of any risk associated with that collateral even though the repo-seller is not presently holding it.

- A repo-lender should take account of any concentration, interest, spread or counterparty risk associated with the items exchanged for the collateral, taking into account the credit risk of the repo-seller.
- Interest rate sensitive instruments will include preference shares exhibiting predominantly the features of interest rate risky assets (and which do not substantially exhibit the traits of equity, in which case the preference share should be considered under the equity risk module).

Direct property and equity investments should not be considered to be interest sensitive.

Interest rate risk is an industry-wide (as opposed to company-specific) risk. This is because the events are external to the (re)insurers affected, although the extent to which a particular (re)insurer is affected will be determined by its individual exposures.

The interest rate risk sub-module consists of a "curve" risk component and a "volatility" risk component. More detail is provided below.

<u>Input</u>

The following input information is required:

BOF = Basic Own Funds

<u>Output</u>

The module delivers the following output:

$Mkt_{int,curve,nominal}^{up}$	=	Capital requirement for nominal interest rate risk after an upward shock
$Mkt_{int,curve,nominal}^{down}$	=	Capital requirement for nominal interest rate risk after a downward shock
$Mkt_{int,curve,real}^{up}$	=	Capital requirement for real interest rate risk after an upward shock
$Mkt_{int,curve,real}^{down}$	=	Capital requirement for real interest rate risk after a downward shock
$Mkt_{int,curve,nominal}$	=	Capital requirement for nominal interest rate risk
$Mkt_{int,curve,real}$	=	Capital requirement for real interest rate risk
$Mkt_{int,curve}$	=	Capital requirement for interest rate curve risk
$Mkt_{int,volatility}$	=	Capital requirement for interest rate volatility risk
Mkt_{int}	=	Capital requirement for interest rate risk

<u>Calculation</u>

The capital requirement for interest rate risk is determined as follows:

$$Mkt_{int} = \sqrt{\sum_{i,j} CorrInt_{i,j} \cdot Mkt_{int,i} \cdot Mkt_{int,j}} \,,$$

where *i* and *j* refer to “curve” and “volatility” and the correlation matrix *CorrInt* is given by:

CorrInt	*Curve*	*Volatility*
Curve	1	0.5
Volatility	0.5	1

Interest rate curve risk

The SAM interest rate curve risk module is divided into two sub-modules. These relate to nominal interest rate risk and real interest rate risk. Nominal interest rate risk is the risk that arises from changes in the nominal yield curve; real interest rate risk is that from changes in the real yield curve. Thus only the nominal yield curve is stressed under the nominal interest rate risk sub-module and only the real yield curve is stressed under the real interest rate risk sub-module:

– When applying stresses to the nominal yield curve, the real yield curve is assumed to remain unchanged and inflation is derived as the difference between these curves (as when calculating the base technical provisions).
– When applying stresses to the real yield curve, the nominal yield curve is assumed to remain unchanged and inflation is derived as the difference between these curves.

The following example is provided for clarity:

– Suppose the nominal NACA (Nominal Annual Compounded Annually) rate of interest is 10% and the real NACA rate is 5%. Then the NACA rate of inflation is 4.76%.
– Suppose that the downward nominal stress at the 10-year point is –50% for nominal NACA rates. In this stress scenario, the 10-year nominal NACA rate becomes 5%. The real NACA rate is unchanged at 5% and hence the 10-year NACA inflation rate is derived as 0%.
– Suppose that the downward real stress at the 10-year point is –10% for real NACA rates. In this stress scenario, the 10-year real NACA rate becomes 4.5%. The nominal NACA rate remains at 10%. The NACA inflation rate therefore changes from 4.76% to 5.26%.

The structure of the interest rate risk module therefore includes an allowance for market inflation stresses. Company-specific inflation risk is allowed for under the expense risk module.

The valuation of some assets and liabilities may rely on the interest rate term structure for a currency other than the South African rand. This exposes the (re)insurer to non-South African interest rate risk. Where this is the case, the relevant non-South African term structure should also be stressed in the interest rate risk module. The treatment of non-South African term structures should be the same as the treatment of the South African term structure.

The effect of the interest rate stresses should be determined allowing for any risk-mitigating contracts. It may be appropriate to allow for credit risk on these. Any impairment to risk-mitigating contracts should be done as specified in the relevant SAM credit risk specifications.

The capital requirement for interest rate curve risk is determined as follows:

$$Mkt_{int,curve} = \sqrt{\sum_{i,j} CorrIntCurve_{i,j} \cdot Mkt_{int,curvei} \cdot Mkt_{int,curvej}}$$

where *i* and *j* refer to “nominal” and “real” and the correlation matrix *CorrIntCurve* is given by:

CorrIntCurve	*Nominal*	*Real*
Nominal	1	0.25
Real	0.25	1

All interest rate “curve” stresses described below should be applied to the NACA (Nominal Annual Compounded Annually) rates.

Nominal interest rate curve risk

The capital requirement for nominal interest rate curve risk is determined as the result of two pre-defined scenarios:

$$Mkt_{int,curve,nominal} = \max\left(0, Mkt_{int,curve,nominal}^{up}, Mkt_{int,curve,nominal}^{down}\right)$$

where $Mkt_{int,curve,nominal}^{up} = \Delta BOF\big|_{\text{upwards shock to nominal risk free curve}}$,

$Mkt_{int,curve,nominal}^{down} = \Delta BOF\big|_{\text{downwards shock to nominal risk free curve}}$, and

$\Delta BOF\big|_{\text{upwards shock to nominal risk free curve}}$ and $\Delta BOF\big|_{\text{downwards shock to nominal risk free curve}}$ are the change in Basic Own Funds due to revaluing all nominal interest rate sensitive items using increased and decreased term structures. The stress causing the revaluations is instantaneous.

Where a causal relationship exists between nominal interest rate changes and policyholder behaviour, the policyholder behaviour should be allowed for within the calculation of $Mkt_{int,curve,nominal}$ and its sub-components (up and down).

The altered term structures are derived by multiplying the current nominal spot curve by (1+s^{up}(*t*)) and (1+s^{down}(*t*)), where both the upward stress s^{up}(*t*) and the downward stress s^{down}(*t*) for individual maturities *t* are specified as follows:

Maturity *t* (years)	**Relative change $s^{up}(t)$(%)**	**Relative change $s^{down}(t)$(%)**
0.25	78.55	–48.06
0.5	78.55	–48.06
1	93.08	–52.87
2	82.38	–50.73
3	64.68	–44.65
4	51.24	–38.86
5	42.12	–34.37

Maturity *t* (years)	**Relative change $s^{up}(t)$(%)**	**Relative change $s^{down}(t)$(%)**
6	36.49	–31.37
7	33.19	–29.55
8	31.19	–28.45
9	29.88	–27.74
10	29.08	–27.30
11	28.80	–27.14
12	28.99	–27.26
13	29.55	–27.62
14	30.36	–28.12
15	31.35	–28.74
16	32.51	–29.46
17	33.80	–30.24
18	35.20	–31.09
19	36.66	–31.95
20	38.16	–32.82
21	39.67	–33.68
22	41.15	–34.52
23	42.57	–35.32
24	43.91	–36.07
25	45.18	–36.78
26	46.59	–37.57
27	48.03	–38.38
28	49.31	–39.09
29	50.22	–39.60
30	50.57	–39.79

For example, the "stressed" 15-year nominal interest rate $R_1(15)$ in the upward stress scenario is determined as

$$R_1(15) = R_0(15) \bullet (1 + 0.3135)$$

where $R_0(15)$ is the 15-year NACA nominal spot interest rate based on the current term structure.

Note that for maturities greater than 30 years a stress of +50.57%/–39.79% should be maintained. Where a term to maturity is not specified in the table above, (re)insurers should interpolate between the nearest two specified points.

Irrespective of the above stress factors, the absolute change in interest rates should be at least one percentage point (+100bps for the upward stress and –100bps for the downward stress). Where the unstressed rate is lower than 1%, the shocked rate in the downward scenario should be assumed to be 0%. A floor of 0% applies to both spot and forward nominal rates.

Real interest rate curve risk

The capital requirement for real interest rate curve risk is determined as the result of two pre-defined scenarios:

$$Mkt_{int,curve,real} = \max\left(0, Mkt_{int,curve,real}{}^{up}, Mkt_{int,curve,real}{}^{down}\right)$$

where $Mkt_{int,curve,real}{}^{up} = \Delta BOF\big|_{\text{upwards shock to real risk free curve}}$,

$Mkt_{int,curve,real}{}^{down} = \Delta BOF\big|_{\text{downwards shock to real risk free curve}}$, and

$\Delta BOF\big|_{\text{upwards shock to real risk free curve}}$ and $\Delta BOF\big|_{\text{downwards shock to real risk free curve}}$ are the change in Basic Own Funds due to revaluing all real interest rate sensitive items using increased and decreased term structures. The stress causing the revaluations is instantaneous.

Where a causal relationship exists between real interest rate changes and policyholder behaviour, the policyholder behaviour should be allowed for within the calculation of $Mkt_{int,curve,real}$ and its sub-components (up and down).

The altered term structures are derived by multiplying the current real spot curve by $(1+s^{up}(t))$ and $(1+s^{down}(t))$, where both the upward stress $s^{up}(t)$ and the downward stress $s^{down}(t)$ for individual maturities t are specified as follows:

Maturity *t* (years)	**Relative change $s^{up}(t)$(%)**	**Relative change $s^{down}(t)$(%)**
0.25	75.89	–75.89
0.5	75.89	–75.89
1	75.89	–75.89
2	75.89	–75.89
3	67.36	–67.36
4	65.52	–65.52
5	63.95	–63.95
6	61.17	–61.17
7	58.22	–58.22
8	56.74	–56.74
9	54.07	–54.07
10	54.81	–54.81
11	54.50	–54.50
12	53.56	–53.56

Maturity t (years)	Relative change $s^{up}(t)$(%)	Relative change $s^{down}(t)$(%)
13	53.89	–53.89
14	54.89	–54.89
15	55.33	–55.33
16	54.40	–54.40
17	53.02	–53.02
18	52.27	–52.27
19	52.23	–52.23
20	52.72	–52.72
21	53.60	–53.60
22	54.81	–54.81
23	56.32	–56.32
24	58.10	–58.10
25	60.11	–60.11
26	62.29	–62.29
27	64.42	–64.42
28	66.25	–66.25
29	67.54	–67.54
30	68.02	–68.02

For example, the "stressed" 15-year real interest rate $R_1(15)$ in the upward stress scenario is determined as

$$R_1(15) = R_0(15) \bullet (1 + 0.5533)$$

where $R_0(15)$ is the 15-year NACA real spot interest rate based on the current term structure.

Note that for maturities greater than 30 years a stress of 68.02%/–68.02% should be maintained. Where a term to maturity is not specified in the table above, (re)insurers should interpolate between the nearest two specified points.

Irrespective of the above stress factors, the absolute change in interest rates should at least be one percentage point (+100bps in the upward stress and –100bps in the downward stress). Stressed rates should not be subjected to a minimum of 0.

The above shock factors (whether real or nominal) are applied to the published risk-free curves (for South African Rand denominated instruments), and the relevant risk-free curves for other denominations. It is unlikely that the market value of assets would be derived from exactly the same curve. Define the following:

i_t = NACA spot rate derived from the government bond curve and used in the valuation of the technical provisions;

$i_t + c_t$ = NACA corporate spot rate, where c_t is the credit spread;

r_t = NACA spot rate derived from the swap rate; and

f_t = the relevant interest shock at term *t*.

On the liability side, participants must use the prescribed curve, which is derived from bond rates. The shocked rate will therefore be i_t x (1 + f_t). For liabilities matched with swap-based assets which the (re)insurer values using the swap curve, the absolute change in the discount curve must be maintained. That is, the shocked rate for liabilities matched with swap-based assets is $r_t + i_t \times f_t$.

Similarly, on the asset side participants must add the absolute change in the reference risk free rate determined above ($i_t \times f_t$) to the relevant rate used to value the assets. Therefore:

(a) when revaluing a government bond (re)insurers should revalue the bond at $i_t + i_t \times f_t$;
(b) when revaluing a corporate bond (re)insurers should revalue the bond at $i_t + c_t + i_t \times f_t$; and
(c) when revaluing a swap (re)insurers should revalue the swap at $r_t + i_t \times f_t$.

Additionally, the result of the scenarios should be determined under the condition that the value of future discretionary benefits can change and that the insurer is able to vary its assumptions on future bonus rates in response to the shock being tested.

8. ANNEXURES

8.1 Table comparing past and current stresses – nominal yield curve

The table below compares the stress percentages to apply to the nominal yield curve under the six PCA stresses with those used for SAM QIS1 and Solvency II QIS5:

Duration (Years)	PCA Shocked Curves (UP) % Change			PCA Shocked Curves (DOWN) % Change			SAM QIS1 % Change		Solvency II QIS5 % Change	
	Level	Slope	Curvature	Level	Slope	Curvature	Upward Shock	Downward Shock	Upward Shock	Downward Shock
0.5	12.86	37.03	13.50	−13.40	−28.68	−13.89	88.0	−68.0	70.0	−75.0
1	24.35	39.55	6.23	−21.75	−30.27	−8.40	86.0	−65.0	70.0	−75.0
1.5	32.08	35.59	0.64	−26.43	−28.33	−3.44	NA	NA	NA	NA
2	37.06	30.65	−3.16	−29.13	−25.65	0.31	80.0	−59.0	70.0	−65.0
3	42.70	21.64	−7.18	−31.92	−20.14	4.66	74.0	−53.0	64.0	−56.0
4	45.07	14.58	−8.62	−32.92	−15.07	6.49	68.0	−48.0	59.0	−50.0
5	45.91	9.26	−8.83	−33.21	−10.80	6.90	62.0	−43.0	55.0	−46.0
6	46.05	5.27	−8.44	−33.20	−7.32	6.56	57.0	−39.0	52.0	−42.0
7	45.86	2.22	−7.77	−33.06	−4.49	5.86	53.0	−35.0	49.0	−39.0
8	45.53	−0.12	−6.96	−32.87	−2.19	5.00	50.0	−32.0	47.0	−36.0
9	45.18	−1.95	−6.10	−32.68	−0.33	4.08	48.0	−30.0	44.0	−33.0
10	44.87	−3.39	−5.21	−32.52	1.19	3.14	47.0	−29.0	42.0	−31.0
11	44.61	−4.55	−4.31	−32.38	2.44	2.19	46.0	−28.0	39.0	−30.0
12	44.42	−5.48	−3.41	−32.28	3.47	1.25	46.0	−28.0	37.0	−29.0
13	44.29	−6.25	−2.53	−32.22	4.33	0.34	46.0	−27.0	35.0	−28.0
14	44.23	−6.88	−1.67	−32.19	5.03	−0.53	46.0	−27.0	34.0	−28.0
15	44.25	−7.40	−0.84	−32.21	5.61	−1.37	47.0	−28.0	33.0	−27.0
16	44.35	−7.83	−0.05	−32.26	6.09	−2.17	47.0	−28.0	31.0	−28.0
17	44.48	−8.19	0.71	−32.34	6.48	−2.93	48.0	−28.0	30.0	−28.0
18	44.64	−8.47	1.44	−32.43	6.79	−3.65	48.0	−28.0	29.0	−28.0
19	44.81	−8.70	2.13	−32.52	7.03	−4.32	49.0	−29.0	27.0	−29.0
20	44.97	−8.89	2.78	−32.61	7.21	−4.96	49.0	−29.0	26.0	−29.0
21	45.12	−9.03	3.39	−32.70	7.36	−5.55	50.0	−30.0	26.0	−29.0
22	45.25	−9.14	3.97	−32.78	7.46	−6.09	51.0	−30.0	26.0	−30.0
23	45.36	−9.23	4.50	−32.85	7.54	−6.59	52.0	−31.0	26.0	−30.0
24	45.46	−9.30	4.99	−32.91	7.60	−7.05	53.0	−32.0	26.0	−30.0
25	45.53	−9.37	5.44	−32.96	7.65	−7.47	55.0	−33.0	26.0	−30.0
30	45.77	−9.63	7.23	−33.16	7.81	−9.14	57.0	−34.0	25.0	−30.0

Table 8.1-1: Nominal interest rate stress percentages determined using PCA, with SAM QIS1 and Solvency II QIS5 stresses provided for comparison

8.2 Absolute real interest rate shocks

The table below contains the stress percentages to apply to the real yield curve under each of the relevant stresses if an absolute stress is used:

Term to maturity	rc_lvl_up	rc_lvl_dn
2	2.02%	–2.02%
3	1.90%	–1.90%
4	1.79%	–1.79%
5	1.68%	–1.68%
6	1.60%	–1.60%
7	1.53%	–1.53%
8	1.50%	–1.50%
9	1.44%	–1.44%
10	1.46%	–1.46%
12	1.41%	–1.41%
15	1.39%	–1.39%
17	1.30%	–1.30%
20	1.26%	–1.26%
25	1.39%	–1.39%
30	1.52%	–1.52%

Table 8.2-1: Absolute real interest rate shocks

8.3 Post Stress Forward Rate Behaviour

Define the following notation:

- $\delta(t)$ = NACC spot rate at time *t*;
- $\delta_b(t)$ = base $\delta(t)$;
- $\delta_s(t)$ = post-stress $\delta(t)$;
- $f(t)$ = instantaneous forward rate at time *t*;
- $f_b(t)$ = base $f(t)$;
- $f_s(t)$ = post-stress $f(t)$, derived from $\delta_s(t)$; and
- $s(t)$ = the stress percentage applied at time t.

Thus:

- $f(t) = \delta(t) + t\delta'(t)$; and
- $\delta_s(t) = \delta_b(t)[1 + s(t)]$.

Furthermore, assume that:

- $\delta(t)$ and $s(t)$ are differentiable functions of *t*; and
- $s(t) \geq -1$ for all *t*.

Then we can show that $f_s(t) = f_b(t)[1 + s(t)] + t\delta_b(t)s'(t)$.

We are concerned with the scenario where $f_s(t) < 0$ for some *t*. Using the equation above, it can be shown that this is equivalent to $s'(t) < -\frac{f_b(t)[1 + s(t)]}{t\delta_b(t)}$. Thus, provided the stress curve does not decrease significantly over a small range of *t* (particularly at longer terms to maturity), negative post-stress forward rates can be avoided. Furthermore, this relationship provides guidance as to how the stress curve can be smoothed should this be considered desirable to prevent negative post-stress forward rates.

8.4 Comparison of explanatory power of principal components analyses (PCAs)

As discussed in section 6.1.2, a PCA was performed on data containing yield curves from 2004/01/30 to 2010/12/31. The table below shows the explanatory power of the PCAs on the difference datasets:

Sigma		(%)	Spot	Forward
Swaps	PF	Eigen 1	86.80	58.66
		Eigen 2	10.12	12.34
		Eigen 3	1.50	7.99
		Remainder	1.58	21.01
	BD	Eigen 1	87.57	78.33
		Eigen 2	10.05	8.52
		Eigen 3	1.36	6.27
		Remainder	1.02	6.87
Bonds	PF	Eigen 1	84.86	56.30
		Eigen 2	9.98	13.47
		Eigen 3	2.32	8.29
		Remainder	2.84	21.94
	BD	Eigen 1	86.18	71.81
		Eigen 2	9.87	11.02
		Eigen 3	2.25	7.74
		Remainder	1.69	9.44

As can be seen from the table above, the explanatory power of a PCA is significantly greater when it is applied to spot rates and not forward rates.

8.5 Stress Calibration Methods

This annexure gives a description of various methods that could be used in the analysis of historical market interest rate data to determine the appropriate level of interest rate stresses to apply.

Define the following:

- IR_t is the interest rate for a particular term to maturity at the t^{th} date;
- r_t is the monthly or annual change in interest rates between the $(t-1)^{th}$ and t^{th} date;
- δ_t is the monthly or annual log-change in interest rates between the $(t-1)^{th}$ and t^{th} date;
- σ_i is the sample standard deviation of the monthly or annual returns for the i^{th} term to maturity;
- μ_i is the sample mean of the annual log-changes in interest rates for the i^{th} term to maturity;
- α is the desired confidence level of the stress, i.e. the probability of observing an event less extreme than the stress is α ;
- Φ^{-1} is the inverse cumulative distribution function of the standard Normal distribution;
- F_ν^{-1} is the inverse cumulative distribution function of the student-t distribution with ν degrees of freedom;
- λ_k is the k^{th} eigenvalue for the monthly log-returns; and
- e_{ki} is i^{th} component of the k^{th} eigenvector.

For a given term to maturity $r_t = \left(\frac{IR_t}{IR_{t-1}} - 1 \right)$ and $\delta_t = \ln\left(\frac{IR_t}{IR_{t-1}} \right)$.

8.5.1 The Normal Distribution

When fitting the Normal distribution, the only two parameters to be fitted are the mean and standard deviation. These are taken as the sample mean and standard deviation of the monthly changes in interest rates (r_t).

In order to annualise the distribution, the monthly mean is multiplied by 12 and the monthly standard deviation by $\sqrt{12}$. This methodology implicitly assumes that monthly changes in the level of the yield curve are independently and identically distributed (i.i.d.).

The upward and downward stresses for the interest rate at term to maturity *i* are then:

$$\pm\sqrt{12}\sigma_i \, \Phi^{-1}(\alpha).$$

The advantage of this approach is that it is simple to apply.

The disadvantages of this approach are that:

- independence between different terms to maturity is assumed;
- the changes in interest rate at a particular term to maturity are assumed to be i.i.d.;

- it results in a level stress only, meaning that term-structure mismatches are not tested;
- the upward and downward stresses are symmetrical; and
- the use of the Normal distribution may not be appropriate.

8.5.2 The Log-Normal Distribution

To fit the log-Normal distribution, the mean and standard deviation of the monthly log-changes in interest rates are calculated. A Normal distribution is then fitted to the monthly log-changes, δ_t.

The upward and downward stresses for the interest rate at term to maturity *i* are then:

$$\exp\left\{\pm\sqrt{12}\sigma_i\,\Phi^{-1}(\alpha)-0.5\left(12\sigma_i^2\right)\right\}-1.$$

The $-0.5\left(12\sigma_i^2\right)$ in the exponent adjusts for the mean of the log-Normal distribution.

The advantages of this approach are that:

- it is simple to apply; and
- the upward and downward stresses are asymmetrical.

The disadvantages of this approach are that:

- independence between different terms to maturity is assumed;
- the changes in interest rate at a particular term to maturity are assumed to be i.i.d.;
- it results in a level stress only, meaning that term-structure mismatches are not tested; and
- the use of the log-Normal distribution may not be appropriate.

8.5.3 Student-t Distribution (annual returns)

The student-t distribution is fitted to the standardised values for the annual log-changes in interest rates for each term to maturity. That is, instead of fitting it to $\{\delta_t\}_{t=1,\dots,n}$, it is fitted to:

$$\left\{z_t=\frac{\delta_t-\mu_i}{\sigma_i}\right\}_{t=1,\dots,n}.$$

The only parameter in the student-t distribution that needs to be fitted is ν, the degrees of freedom. ν is determined using the maximum likelihood method.

The upward and downward stresses for the interest rate at term to maturity *i* are then:

$$\exp\left\{\pm\sigma_i\,F_\nu^{-1}(\alpha)-0.5\sigma_i^2\right\}-1.$$

The $-0.5\sigma_i^2$ in the exponent is attempts to adjust for the increase in the mean arising due to the effect of the exponential function on the upper tail of the student-t distribution. It corresponds to the equivalent adjustment for the log-Normal distribution, and therefore likely understates the effect.

The advantages of this approach are that:

- it is relatively simple to apply; and
- the upward and downward stresses are asymmetrical; and
- the use of the student-t distribution provides fatter tails than the Normal distribution.

The disadvantages of this approach are that:

- independence between different terms to maturity is assumed;
- the changes in interest rate at a particular term to maturity are assumed to be i.i.d.;
- it results in a level stress only, meaning that term-structure mismatches are not tested; and
- the number of annual data points is limited, reducing the credibility of the calculation.

8.5.4 Student-t Distribution (monthly bootstrapped returns)

The student-t distribution is fitted to the standardised values for the monthly log-returns. A large number of student-t samples (log-changes) are then simulated from the fitted monthly distribution. These simulated log-changes are combined (adding 12 consecutive monthly log-changes) into a large number of annual log-changes. The appropriate percentile is then read from the annual log-changes, and adjusted to give the stress as a percentage change.

The merits and flaws of this methodology are similar to those for fitting the student-t distribution to annual log-changes. However, the use of monthly rather than annual data through the bootstrap increases the number of data points available.

8.5.5 Bootstrapping

The bootstrapping method involves applying the following algorithm:

- Calculate the historical monthly log-changes in interest rates for each term to maturity.
- Randomly select a set of twelve monthly log-returns from the sample of historical data.
- Combine these 12 monthly log-changes to calculate an annual log-change.
- Repeat the above two steps to create a large sample of annual log-changes.
- Use the generated sample of annual log-changes to read off the annual log-change at the required confidence level.
- Convert the log-change into the interest rate stress that should be applied at the given term to maturity.

The bootstrap methodology assumes that monthly log-changes in interest rates are independently and identically distributed. No assumption regarding the actual distribution of the log-changes is made, however.

The advantages of this approach are that:

- the upward and downward stresses are asymmetrical; and
- no distributional assumptions are made.

The disadvantages of this approach are that:

- independence between different terms to maturity is assumed;
- the changes in interest rate at a particular term to maturity are assumed to be i.i.d.; and
- it results in a level stress only, meaning that term-structure mismatches are not tested.

8.5.6 Principal Components Analysis

A principal components analysis is carried out on the monthly log-changes δ_t. The principal components of the covariance matrix of the monthly δ_t s will explain the majority of the variation of the monthly log-changes (three in this case). For computational reasons, however, the analysis is performed on the correlation matrix and scaled appropriately. (Theoretically the results of the analysis on the correlation matrix can be scaled to be equivalent to those of the covariance matrix; see section 8.6.) A Normal distribution is then fitted to the log-changes. Annual stresses for each term to maturity and for each principal component are then calculated. These have the same allowance for the mean as the equivalent log-Normal formula.

The upward and downward stresses corresponding to principal component k for the interest rate at term to maturity i are then given by:

$$\exp\left\{\pm\sqrt{\lambda_k}\; e_{ki}\sqrt{12}\sigma_i\; \Phi^{-1}(\alpha)-0.5\left(12\sigma_i^2\right)\right\}-1.$$

Note that this method results in three separate stress types in the yield curve. Broadly these can be viewed as level, slope and curvature stresses. A principal components analysis results in orthogonal, i.e. independent, stresses.

The advantages of this approach are that:

- The PCA allows for the interdependence between different terms to maturity of the yield curve.
- The PCA produces a number of stresses which test the insurer's or reinsurer's exposure to different portions of the yield curve. For example, even if an insurer has hedged its interest rate exposure based on the modified duration of its liabilities (in the extreme case, hedging annuity payments with a zero-coupon bond), it may be exposed to changes in the slope of the nominal yield curve. The use of the PCA stresses will therefore lead to a greater understanding of the interest rate risk faced by the company.
- As the PCA is performed on log-changes, it provides asymmetric stresses.

The disadvantages of this approach are that:

- The PCA assumes that the log-change in each month is independently and identically distributed Normal.
- There is additional complexity involved with performing multiple stresses.

8.6 Relationship between PCA results on a correlation matrix vs those on a covariance matrix

Define the following:

- $\mathbf{R}$ is the correlation matrix of the log-returns;
- $\mathbf{C}$ is the covariance matrix of the log-returns;
- $\mathbf{S}$ is the diagonal matrix of the standard deviations of the log-returns;
- $\mathbf{L_R}$ is the matrix of eigenvalue–eigenvector pairs from the PCA on the correlation matrix; and
- $\mathbf{L_C}$ is the matrix of eigenvalue–eigenvector pairs from the PCA on the covariance matrix.

Now,

- $\mathbf{S}$ is such that $s_{ij} = \begin{cases} \sigma_i & \text{where i = j} \\ 0 & \text{otherwise} \end{cases}$,
- $\mathbf{L_M} = \left[\sqrt{\lambda_1}\mathbf{e}_1 \quad \sqrt{\lambda_2}\mathbf{e}_2 \quad \ldots \quad \sqrt{\lambda_n}\mathbf{e}_n\right]$ is a matrix of the eigenvalue–eigenvector pairs arising from the PCA on matrix $\mathbf{M}$, and
- $\mathbf{C} = \mathbf{S}\mathbf{R}\mathbf{S}^T$.

- Assume that all of the components from the PCA are included so that we estimate the matrices exactly. Then:
  - $\mathbf{R} = \mathbf{L_R}(\mathbf{L_R})^T$.
  - $\mathbf{C} = \mathbf{L_C}(\mathbf{L_C})^T$.

Thus:

$$\begin{aligned}\mathbf{C} &= \mathbf{S}\mathbf{R}\mathbf{S}^T \\ &= \mathbf{S}\left(\mathbf{L_R}(\mathbf{L_R})^T\right)\mathbf{S}^T \\ &= (\mathbf{S}\mathbf{L_R})(\mathbf{S}\mathbf{L_R})^T\end{aligned}$$

And so:

$$\mathbf{L_C} = \mathbf{S}\mathbf{L_R}$$

Finally:

$$l_{ik}^c = \sigma_i * l_{ik}^r$$

8.7 Recommendation for SAM QIS2

This annexure reproduces the recommendation for SAM QIS2.

8.7.1 General considerations

- The interest rate stress has been split into two components.
    - One component applies stresses to the nominal yield curve, and the other to the real yield curve.
    - Each component was calibrated specifically to the appropriate yield curve.
    - A correlation assumption between the risks of the two components was determined.
- The restrictions on the interest rate stress in SAM QIS1 should be replaced with the following:
    - Under a downward level stress (i.e. a stress in which all points on the yield curve are made to decrease), the minimum reduction in the nominal interest rate at any point on the yield curve is set to 1pp.
    - Where a post-stress nominal yield curve has any points lying below 0%, those points on the post-stress nominal yield curve are set to 0%.
- For the real yield curve stresses, if the downward stress results in an percentage point decrease of less than 1pp for any term to maturity, the stress should be set to an absolute –1pp at that term to maturity. Similarly, if the upward stress results in a percentage point increase of less than 1pp, the stress should be set to an absolute 1pp increase.
- The proposed interest rate stress for the nominal yield curve will be reviewed in light of the SAM QIS2 results. The results of SAM QIS2 will be used to assess the materiality of the slope and curvature components of the proposed stress.
    - The results required to assess the materiality will be the (relative) diversified and undiversified capital requirements arising under each of the six nominal interest rate stresses. If the slope and curvature components are found to be insignificant across the industry then reverting to a single level stress in each direction will be considered.
    - Specifically, the working group requires the following for all six of the nominal yield curve stresses (using the notation defined in sections 8.7.2, 8.7.3, 8.7.4, and 8.7.6):
        - $\frac{Mkt_i}{Mkt_{int\_nyc\_lv} + Mkt_{int\_nyc\_sp} + Mkt_{int\_nyc\_cv}}$, where *i* refers to the stress in question; and
        - $\frac{Mkt_i}{Mkt_{int\_nom}}$, where *i* refers to the stress in question.
    - Furthermore, the single interest rate stress scenario should be performed to assess the effect on the interest rate capital requirement of using the proposed nominal interest rate stress approach. To this end, the working group requires:
        - the ratio of Mkt_{int_qis1} to Mkt_{int_nom}; and
        - the ratio of Mkt_{int_qis1} to Mkt_{int}.
- Furthermore, the working group would like the following to assess the split between the nominal and real interest rate risks (using similarly-defined notation):
    - $\frac{Mkt_i}{Mkt_{int\_nom} + Mkt_{int\_real}}$, where *i* refers to *int_nom* or *int_real*; and
    - $\frac{Mkt_i}{Mkt_{int}}$ where *i* refers to *int_nom* or *int_real*.
- Finally, the stresses described in the following sub-sections should be performed on both a gross and net basis (regarding allowance for the loss absorbing capacity of technical provisions).

8.7.2 Calculating the nominal yield curve capital requirement

For the nominal yield curve, six stresses are performed:

- nyc_lvl_up: nominal yield curve level up,
- nyc_lvl_dn: nominal yield curve level down,
- nyc_slp_up: nominal yield curve slope up,
- nyc_slp_dn: nominal yield curve slope down,
- nyc_cvt_up: nominal yield curve curvature up, and
- nyc_cvt_dn: nominal yield curve curvature down.

Define $Mkt_{int\_i} = \Delta NAV|\text{shock } i$, where *i* is one of the nominal yield curve stresses. This value should be calculated for each of the six variations of *i*. The stressed nominal yield curve is determined as follows:

$$i_s(t) = i_b(t) * (1 + s(t)),$$

where $i_s(t)$ is the post-stress NACA nominal interest rate at term to maturity *t*;

$i_b(t)$ is the base case NACA nominal interest rate at term to maturity *t*; and

$s(t)$ is the stress percentage to apply to the nominal interest rate at term to maturity *t* under the stress.

Irrespective of the above calculation, the absolute change in nominal interest rates in the nominal yield curve level down scenario should at least be one percentage point. Where the unstressed nominal rate is lower than 1%, the shocked nominal rate in the downward scenario should be assumed to be 0%.

Mkt_{int_nom}, the nominal interest rate risk SCR, is then determined through the following steps:

i. $Mkt_{int\_nyc\_lvl} = \max\{Mkt_{int\_nyc\_lvl\_up}, Mkt_{int\_nyc\_lvl\_dn}, 0\}$;

ii. $Mkt_{int\_nyc\_slp} = \max\{Mkt_{int\_nyc\_slp\_up}, Mkt_{int\_nyc\_slp\_dn}, 0\}$;

iii. $Mkt_{int\_nyc\_cvt} = \max\{Mkt_{int\_nyc\_cvt\_up}, Mkt_{int\_nyc\_cvt\_dn}, 0\}$; and

iv. $Mkt_{int\_nom} = \sqrt{Mkt^2_{int\_nom\_lvl} + Mkt^2_{int\_nom\_slp} + Mkt^2_{int\_nom\_cvt}}$.

Step iv holds since the three principal components are orthogonal, i.e. independent of each other.

8.7.3 Calculating the real yield curve capital requirement

For the real yield curve, two stresses are performed:

- ryc_lvl_up, and
- ryc_lvl_dn.

Define $Mkt_{int\_i} = \Delta NAV|\text{shock } i$, where *i* is one of the real yield curve stresses. This value should be calculated for each of the two variations of *i*. The stressed real yield curve is determined as follows:

$$r_s(t) = r_b(t) * (1 + s(t)),$$

where $r_s(t)$ is the post-stress NACA real interest rate at term to maturity *t*;

$r_b(t)$ is the base case NACA real interest rate at term to maturity *t*; and

$s(t)$ is the stress percentage to apply to the real interest rate at term to maturity *t* under the stress.

The absolute value of the change in the real yield curve is set to a minimum of one percentage point. That is, if $|r_b(t)*s(t)|<1\%$, then $r_s(t)=r_b(t)+sign(s(t))*1\%$.

Mkt_{int_real}, the real interest rate risk SCR, is then calculated as:

$$Mkt_{int\_real}=\max\{Mkt_{int\_ryc\_lvl\_up}, Mkt_{int\_ryc\_lvl\_dn}, 0\}$$

8.7.4 Calculating the total interest rate risk capital requirement

The total interest rate risk capital requirement is calculated by aggregating Mkt_{int_nom} and Mkt_{int_real} using a correlation matrix. Thus:

$$Mkt_{int}=\sqrt{(Mkt_{int\_nom})^2+(Mkt_{int\_real})^2+2*\rho_{nom\_real}*Mkt_{int\_nom}*Mkt_{int\_real}},$$

where Mkt_{int} is the interest rate risk SCR; and

ρ_{nom_real} is the correlation between Mkt_{int_nom} and Mkt_{int_real}.

For the purposes of SAM QIS2, a ρ_{nom_real} of 25% is recommended. This pragmatic parameter choice is to reflect a low level of correlation between nominal and real interest rates. No statistical calibration has been performed in respect of this correlation.

8.7.5 Stress percentages to apply

The table below contains the stress percentages to apply to the nominal yield curve under each of the relevant stresses.

Duration (Years)	nyc_lvl_up (%)	nyc_slp_up (%)	nyc_cvt_up (%)	nyc_lvl_dn (%)	nyc_slp_dn (%)	nyc_cvt_**dn** (%)
0.5	14.0	38.6	14.5	−12.3	−27.9	−12.7
1	25.9	41.4	7.7	−20.6	−29.3	−7.1
1.5	33.9	37.5	2.2	−25.3	−27.3	−2.1
2	38.9	32.5	−1.6	−28.0	−24.5	1.7
3	44.5	23.3	−5.7	−30.8	−18.9	6.1
4	47.0	16.1	−7.3	−32.0	−13.9	7.8
5	47.8	10.7	−7.5	−32.4	−9.7	8.2
6	47.9	6.6	−7.2	−32.4	−6.2	7.8
7	47.7	3.5	−6.6	−32.3	−3.4	7.1
8	47.3	1.1	−5.8	−32.1	−1.1	6.2

9	46.9	−0.8	−5.0	−31.9	0.8	5.3
10	46.5	−2.2	−4.2	−31.7	2.3	4.3
11	46.2	−3.4	−3.3	−31.6	3.5	3.4
12	45.9	−4.4	−2.4	−31.5	4.6	2.4
13	45.8	−5.2	−1.5	−31.4	5.4	1.5
14	45.7	−5.8	−0.6	−31.4	6.2	0.6
15	45.7	−6.3	0.2	−31.4	6.8	−0.2
16	45.8	−6.8	1.0	−31.4	7.3	−1.0
17	45.9	−7.1	1.8	−31.5	7.7	−1.8
18	46.1	−7.4	2.6	−31.5	8.0	−2.5
19	46.2	−7.6	3.3	−31.6	8.3	−3.2
20	46.4	−7.8	4.0	−31.7	8.5	−3.8
21	46.6	−7.9	4.6	−31.8	8.6	−4.4
22	46.7	−8.1	5.2	−31.8	8.8	−4.9
23	46.8	−8.1	5.8	−31.9	8.9	−5.4
24	46.9	−8.2	6.3	−31.9	8.9	−5.9
25	47.0	−8.3	6.8	−32.0	9.0	−6.3
30	47.3	−8.5	8.7	−32.1	9.3	−8.0

Table 8.7.5-1: Nominal interest rate stress percentages determined using PCA, with SAM QIS1 and Solvency II QIS5 stresses provided for comparison

The stress percentages derived above for the level stress are lower at short terms to maturity than at longer terms to maturity. The log-changes for the later terms to maturity are quite highly correlated with each other and have a relatively low correlation with the log-changes for the earlier terms to maturity. (This can be seen by plotting a heat chart of the correlation matrix.) This causes the level stress to be relatively low for the earlier terms to maturity, since their variation is better captured under the slope stress.

The table below contains the stress percentages to apply to the real yield curve under each of the relevant stresses.

Duration (Years)	rc_lvl_up	rc_lvl_dn
2	75.89%	−75.89%
3	67.36%	−67.36%
4	65.52%	−65.52%
5	63.95%	−63.95%
6	61.17%	−61.17%
7	58.22%	−58.22%
8	56.74%	−56.74%
9	54.07%	−54.07%
10	54.81%	−54.81%
12	53.56%	−53.56%
15	55.33%	−55.33%
17	53.02%	−53.02%
20	52.72%	−52.72%
25	60.11%	−60.11%

30	68.02%	–68.02%

Table 8.7.5-2: Real interest rate stress percentages determined by fitting a Normal distribution to percentage changes

Where a term to maturity is not specified in the tables above, (re)insurers should interpolate between the nearest two specified points. Where a term to maturity lies outside the bounds of the tables (e.g. term to maturity one for real interest rates) (re)insurers should use the nearest available stress (e.g. the stress at term to maturity two).

8.7.6 Single interest rate stress scenario

This interest rate scenario is only done for comparison purposes, i.e. the results should not be used in calculating the (re)insurer's final SAM QIS2 capital requirement. It replicates the SAM QIS1 stress methodology using the dataset considered in determining the PCA stresses above (the three up and three down shocks are added to obtain aggregate up and down shocks for each term to maturity). Furthermore, the real yield curve is stressed by the same percentage as the nominal yield curve.

Two stresses are performed:

– int_sis_up: yield curve level up; and
– int_sis_dn: yield curve level down,

Define $Mkt_{int\_i} = \Delta NAV | \text{shock } i$, where *i* is one of the single interest rate stress scenario yield curve stresses. This value should be calculated for each of the two variations of *i*. The stressed yield curves (both nominal and real) are determined as follows:

$$i_s(t) = i_b(t) * (1 + s(t)),$$

where $i_s(t)$ is the post-stress NACA nominal (or real) interest rate at term to maturity *t*;

$i_b(t)$ is the base case NACA nominal (or real) interest rate at term to maturity *t*; and

$s(t)$ is the stress percentage to apply to the interest rate at term to maturity *t* under the stress.

Irrespective of the above calculation, the absolute change of interest rates in the downward scenario should be at least one percentage point. Where the unstressed nominal rate is lower than 1%, the shocked nominal rate in the downward scenario should be assumed to be 0%.

Mkt_{int_sis}, the nominal interest rate risk SCR under the single interest rate stress scenario, is then determined as:

$$Mkt_{int\_sis} = \max\{Mkt_{int\_sis\_up}, Mkt_{int\_sis\_dn}, 0\}.$$

The relevant stress percentages are given in the table below:

Duration (Years)	nyc_sis_up (%)	nyc_sis_dn (%)
0.5	81.1	-44.8
1	91.8	-47.9
1.5	88.0	-46.8
2	81.0	-44.7
3	68.0	-40.5
4	58.3	-36.8
5	51.3	-33.9
6	46.4	-31.7
7	42.8	-30.0
8	40.2	-28.7
9	38.4	-27.8
10	37.3	-27.1
11	36.6	-26.8
12	36.2	-26.6
13	36.2	-26.6
14	36.4	-26.7
15	36.7	-26.9
16	37.3	-27.2
17	38.0	-27.5
18	38.7	-27.9
19	39.5	-28.3
20	40.3	-28.7
21	41.1	-29.1
22	41.9	-29.5
23	42.6	-29.9
24	43.3	-30.2
25	44.0	-30.6
30	46.6	-31.8

Table 8.7.6-1: Interest rate stress percentages determined using the single interest rate stress scenario

8.8 Recommendation for SAM QIS3

This annexure reproduces the recommendation for SAM QIS3.

Interest rate risk

Interest rate risk arises when the market-consistent values of assets and liabilities are sensitive to changes in the market yield curves. This includes both the nominal and real yield curves. All assets and liabilities that are sensitive to changes in either yield curve should be considered under the interest rate risk module, whether valued by mark-to-model or mark-to-market techniques.

The above may involve deriving a mark-to-model valuation that is consistent with the mark-to-market valuation. The impact of the change in the yield curve can then be applied to the mark-to-model valuation. Where this is done, (re)insurers should assume that the interest rate stresses are applied to the basic risk-free rate only; any spread in excess of the risk-free return should remain unchanged in the stressed scenarios.

Additional guidance on the application of the interest rate risk module is provided below. It does not provide an exhaustive list of assets and liabilities to be considered in the interest rate risk module.

- The discounted value of future cash-flows, in particular in the valuation of technical provisions, will be sensitive to a change in the rate at which those cash-flows are discounted.
- Assets sensitive to interest rate movements will include fixed-income investments, financing instruments (for example loan capital), policy loans, interest rate derivatives and any insurance assets.
- Consideration should be given to the fact that callable bonds and other types of interest rate structures may not be called by the issuer in the event that spreads widen or interest rates increase. This may have an impact on the duration of the asset.
- A repo-seller, having agreed to repurchase collateral at a future date, should take account of any risk associated with that collateral even though the repo-seller is not presently holding it.
- A repo-lender should take account of any concentration, interest, spread or counterparty risk associated with the items exchanged for the collateral, taking into account the credit risk of the repo-seller.
- Interest rate sensitive instruments will include preference shares exhibiting predominantly the features of interest rate risky assets (and which do not substantially exhibit the traits of equity, in which case the preference share should be considered under the equity risk module).

Direct property and equity investments should not be considered to be interest sensitive.

The SAM interest rate risk module is divided into two sub-modules. These relate to nominal interest rate risk and real interest rate risk. Nominal interest rate risk is the risk that arises from changes in the nominal yield curve; real interest rate risk that from changes in the real yield curve. Thus only the nominal yield curve is stressed under the nominal interest rate risk sub-module and only the real yield curve is stressed under the real interest rate risk sub-module:

- When applying stresses to the nominal yield curve, the real yield curve is assumed to remain unchanged and inflation is derived as the difference between these curves (as when calculating the base technical provisions). Only nominal cash flows are affected by this stress.
- When applying stresses to the real yield curve, the nominal yield curve is assumed to remain unchanged and inflation is derived as the difference between these curves. Only real cash flows are affected by this stress.

The following example is provided for clarity:

- Suppose the nominal NACC rate of interest is 10% and the real NACC rate is 5%. Then the NACC rate of inflation is 5%.
- Suppose that the downward *nominal* stress at the 10-year point is –50% for nominal NACC rates. In this stress scenario, the 10-year nominal NACC rate becomes 5%. The real NACC rate is unchanged at 5% and hence the 10-year inflation rate is derived as 0%.
- Suppose that the downward *real* stress at the 10-year point is –10% for real NACC rates. In this stress scenario, the 10-year real NACC rate becomes 4.5%. The nominal NACC rate remains at 10%. This would imply a change in inflation from 5% to 5.5%.

The structure of the interest rate risk module therefore includes an allowance for market inflation stresses. Company-specific inflation risk is allowed for under the expense risk module.

The valuation of some assets and liabilities may rely on the interest rate term structure for a currency other than the South African rand. This exposes the (re)insurer to non-South African interest rate risk. Where this is the case, the relevant non-South African term structure should also be stressed in the interest rate risk module. The treatment of non-South African term structures should be the same as the treatment of the South African term structure.

Interest rate risk is an industry-wide (as opposed to company-specific) risk. This is because the events are external to the (re)insurers affected, although the extent to which a particular (re)insurer is affected will be determined by its individual exposures.

The effect of the interest rate stresses should be determined allowing for any risk-mitigating contracts. It may be appropriate to allow for credit risk on these. Any impairment to risk-mitigating contracts should be done as specified in the relevant SAM credit risk specifications.

For sections 8.8.1 and 8.8.2 below, define:

BOF = *Basic Own Funds* (i.e. the excess of assets over liabilities, valued in accordance with SAM rules, plus subordinated liabilities, less any exclusions from Own Funds).

8.8.1 Nominal interest rate risk

For the nominal yield curve, two stresses are performed:

- nyc_up, and
- nyc_dn.

Define $Mkt_{int\_k} = \Delta BOF|\text{shock } k$, where *k* is one of the nominal yield curve stresses. This value should be calculated for each of the two variations of *k*. The stress applied is instantaneous.

The stressed nominal yield curve is determined as follows:

$$i_s(t) = i_b(t) * (1 + s(t)),$$

where $i_s(t)$ is the post-stress NACA nominal interest rate at term to maturity *t*;

$i_b(t)$ is the base case NACA nominal interest rate at term to maturity *t*; and

$s(t)$ is the stress percentage to apply to the nominal interest rate at term to maturity *t* under the stress *k*.

The real yield curve remains unchanged under these stresses. The post-stress market-implied inflation curve should therefore be recalculated using the post-stress nominal yield curve and the base real yield curve.

Irrespective of the above calculation:

– the absolute change in the nominal interest rate at any term in the nyc_dn scenario should be at least one percentage point; but
– where the base nominal interest rate at any term is lower than 1%, the shocked nominal interest rate in the nyc_dn scenario at that term should be assumed to be 0%.

Mkt_{int_nyc}, the nominal interest rate risk SCR, is then calculated as:

$$Mkt_{int\_nyc} = \max\left\{Mkt_{int\_nyc\_up}, Mkt_{int\_nyc\_dn}, 0\right\}$$

Dynamic policyholder behaviour should be allowed for in the calculation of $Mkt_{int\_nyc\_up}$ and $Mkt_{int\_nyc\_dn}$ where a causal relationship exists between changes in nominal interest rates and the behaviour under consideration. This should be applied at an appropriate level of granularity.

8.8.2 Real interest rate risk

For the real yield curve, two stresses are performed:

– ryc_up, and
– ryc_dn.

Define $Mkt_{int\_k} = \Delta BOF | \text{shock } k$, where *k* is one of the real yield curve stresses. This value should be calculated for each of the two variations of *k*. The stress applied is instantaneous.

The stressed real yield curve is determined as follows:

$$r_s(t) = r_b(t) * (1 + s(t)),$$

where $r_s(t)$ is the post-stress NACA real interest rate at term to maturity *t*;

$r_b(t)$ is the base case NACA real interest rate at term to maturity *t*; and

$s(t)$ is the stress percentage to apply to the real interest rate at term to maturity *t* under the stress *k*.

The nominal yield curve remains unchanged under these stresses. The post-stress market-implied inflation curve should therefore be recalculated using the post-stress real yield curve and the base nominal yield curve.

The absolute value of the change in the real yield curve is set to a minimum of one percentage point. That is, if $|r_b(t) * s(t)| < 1\%$, then $r_s(t) = r_b(t) + sign(s(t)) * 1\%$.

Mkt_{int_ryc}, the real interest rate risk SCR, is then calculated as:

$$Mkt_{int\_ryc} = \max\{Mkt_{int\_ryc\_up}, Mkt_{int\_ryc\_dn}, 0\}$$

Dynamic policyholder behaviour should be allowed for in the calculation of $Mkt_{int\_ryc\_up}$ and $Mkt_{int\_ryc\_dn}$ where a causal relationship exists between changes in real interest rates and the behaviour under consideration. This should be applied at an appropriate level of granularity.

8.8.3 Calculating the total interest rate risk capital requirement

The total interest rate risk capital requirement is calculated by aggregating Mkt_{int_nyc} and Mkt_{int_ryc} using a correlation matrix. Thus:

$$Mkt_{int} = \sqrt{(Mkt_{int\_nyc})^2 + (Mkt_{int\_ryc})^2 + 2 * \rho_{nyc\_ryc} * Mkt_{int\_nyc} * Mkt_{int\_ryc}},$$

where Mkt_{int} is the interest rate risk SCR; and

ρ_{nyc_ryc} is the correlation between Mkt_{int_nyc} and Mkt_{int_ryc}, which is set to 25%.

8.8.4 Stress percentages to apply

The table below contains the stress percentages to apply to the nominal yield curve under each of the relevant stresses.

Term (Years)	nyc_up (%)	nyc_dn (%)
0.5	75.54	−46.81
1	84.34	−50.02
1.5	80.24	−49.09
2	73.40	−47.14
3	61.11	−43.10
4	51.90	−39.33
5	45.35	−36.31
6	40.76	−34.03
7	37.52	−32.32
8	35.24	−31.06
9	33.68	−30.17
10	32.67	−29.57
11	32.08	−29.22
12	31.84	−29.05
13	31.85	−29.04
14	32.06	−29.16
15	32.45	−29.38
16	32.97	−29.69
17	33.59	−30.06
18	34.29	−30.47
19	35.02	−30.90
20	35.76	−31.33
21	36.50	−31.76
22	37.21	−32.16
23	37.88	−32.55
24	38.51	−32.90
25	39.08	−33.23
30	41.26	−34.53

Table 8.8.4-1: Nominal interest rate stress percentages

The table below contains the stress percentages to apply to the real yield curve under each of the relevant stresses.

Term (Years)	rc_up (%)	rc_dn (%)
2	75.89	−75.89
3	67.36	−67.36
4	65.52	−65.52
5	63.95	−63.95
6	61.17	−61.17
7	58.22	−58.22
8	56.74	−56.74

9	54.07	–54.07
10	54.81	–54.81
12	53.56	–53.56
15	55.33	–55.33
17	53.02	–53.02
20	52.72	–52.72
25	60.11	–60.11
30	68.02	–68.02

Table 8.8.4-2: Real interest rate stress percentages

Where a term to maturity is not specified in the tables above, (re)insurers should interpolate between the nearest two specified points. Where a term to maturity lies outside the bounds of the tables (e.g. term to maturity one for real interest rates), (re)insurers should use the nearest available stress (e.g. the stress at term to maturity two).

Furthermore, the stress percentages should be applied to the risk-free yield curve. Thus no margins (e.g. for credit risk) should be stressed under the interest rate risk module.

8.9 Comparison of stresses calibrated to the bond and swap curves

As discussed in section 6.1.6, the nominal yield curve stresses were revised after SAM QIS3 such that they were calibrated to the bond curve. The table below compares the result of the calibration to the swap and bond curves.

	SAM QIS3 stresses (%)		Bond curve stresses (%)		Difference (percentage points)	
Duration (Years)	Upward Shock	Downward Shock	Upward Shock	Downward Shock	Upward Shock	Downward Shock
0.5	75.54	−46.81	78.5	−48.1	3.0	−1.2
1	84.34	−50.02	93.1	−52.9	8.7	−2.9
1.5	80.24	−49.09	91.0	−52.9	10.8	−3.9
2	73.40	−47.14	82.4	−50.7	9.0	−3.6
3	61.11	−43.10	64.7	−44.6	3.6	−1.5
4	51.90	−39.33	51.2	−38.9	−0.7	0.5
5	45.35	−36.31	42.1	−34.4	−3.2	1.9
6	40.76	−34.03	36.5	−31.4	−4.3	2.7
7	37.52	−32.32	33.2	−29.6	−4.3	2.8
8	35.24	−31.06	31.2	−28.5	−4.0	2.6
9	33.68	−30.17	29.9	−27.7	−3.8	2.4
10	32.67	−29.57	29.1	−27.3	−3.6	2.3
11	32.08	−29.22	28.8	−27.1	−3.3	2.1
12	31.84	−29.05	29.0	−27.3	−2.8	1.8
13	31.85	−29.04	29.6	−27.6	−2.3	1.4
14	32.06	−29.16	30.4	−28.1	−1.7	1.0
15	32.45	−29.38	31.4	−28.7	−1.1	0.6
16	32.97	−29.69	32.5	−29.5	−0.5	0.2
17	33.59	−30.06	33.8	−30.2	0.2	−0.2
18	34.29	−30.47	35.2	−31.1	0.9	−0.6
19	35.02	−30.90	36.7	−32.0	1.6	−1.0
20	35.76	−31.33	38.2	−32.8	2.4	−1.5
21	36.50	−31.76	39.7	−33.7	3.2	−1.9
22	37.21	−32.16	41.2	−34.5	3.9	−2.4
23	37.88	−32.55	42.6	−35.3	4.7	−2.8
24	38.51	−32.90	43.9	−36.1	5.4	−3.2
25	39.08	−33.23	45.2	−36.8	6.1	−3.6
30	41.26	−34.53	50.6	−39.8	9.3	−5.3

Table 8.9-1: Comparison of swap and bond calibrations