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Reflections on the 2015 Solvency II internal model approval process

The second half of 2015 was a busy period for the PRA, with the simultaneous approval of 19 internal models for use by insurance firms under Solvency II from 1 January 2016. Throughout this process and the preparatory phase that preceded it we have aimed to shed as much light as we can on our approach to taking model approval decisions. Informed by the experience of making decisions in 2015, this letter aims to provide further insights into the process.

The letter focuses on the use by the PRA of a 'Quantitative Framework' as one tool to assist with decision-making, because this has been the subject of some debate with firms. In addition, for the benefit of firms and market participants I set out how the PRA views the Solvency Capital Requirement under Solvency II, whether it results from the use of an internal model or the standard formula.

The Quantitative Framework

As part of our work reviewing firms' internal models, we have used a set of yardsticks collectively known as the 'Quantitative Framework'. This framework covers risks such as credit and longevity, and dependencies between risks. We used the framework as one input when considering whether or not a firm's model met the tests and standards set by Solvency II.

Some details of this framework were set out in an Executive Director's letter in March 2015, and the annex and appendices to this letter provide further information, including how the framework was operated in practice through the model review process in 2015. In addition, I would like to explain the philosophy we have adopted in the use of this framework:

1. The Solvency II Directive requires us to ensure that firms are capitalised to withstand a 1-in-200 year shock. Projecting what a 1-in-200 year shock would be is inherently a difficult and uncertain undertaking, which involves a significant degree of judgement. Inevitably, reasonable and well-informed people can reach different views about this. However, it does not follow from this that the PRA should have no views on the calibration of important inputs to firms' models. It is true that our job is to decide whether or not an internal model meets the tests and standards set by the Directive, not to set the capital requirement itself. This is one of the major changes from the previous individual capital adequacy standards (ICAS) regime, and we have followed the new approach assiduously. But in order credibly to form a view on whether a model meets those standards, we must make an assessment of the strength of the calibration of important inputs to that model. We have developed the Quantitative Framework to help us formulate those assessments.

2. Bearing in mind the inherent difficulties of projecting a 1-in-200 year shock, it would be wrong for the PRA, in its Quantitative Framework, to claim a monopoly of wisdom, adopt a position at odds with the evidence, or take a black-and-white approach. We have instead aimed to take a balanced and proportionate approach and we have in no area aimed to use the arrival of Solvency II to increase capital requirements. This does not mean that the PRA will agree with all firms all of the time about the calibration of key inputs to internal models. It does mean that:

- Our views take appropriate account of industry views and expertise, and our views will evolve in response to new evidence as it becomes available.
- We take a flexible approach, for instance by expressing our view as a range in the case of some risks.
- We make use of peer analysis, but also allow for the specificities of individual firms' risk profiles rather than taking a blanket approach.
- We focus on material issues and apply our judgement, rather than taking a tick-box approach.

3. It is clear that in some respects the new regime is materially different from the ICAS regime, for instance through the introduction of the risk margin, and that this different regime may have some impact on firms' capital positions (positive and negative), even though the underlying 1-in-200 calibration is the same in both regimes. However:

    - This should not be confused with the PRA hardening its view of key risks, which we have not done as part of the introduction of Solvency II.
    - The transitional measures allowed for under the Directive exist to cushion the impact of moving from one regime to another. As a safeguard, the benefit from the transitional measure on technical provisions (TMTP) is generally limited to make sure financial resources of UK firms cannot drop below those required under the ICAS regime as a result of using the transitional. The PRA will allow full use of transitional measures by those firms that qualify to use them, and when we consider whether or not firms are in a position to pay dividends, one of the main quantitative yardsticks we will use is capital levels after the benefit of transitionals.

Please note that while the general philosophy set out in the letter has applied to our use of quantitative metrics across all model reviews, the focus of the annex and the detailed commentary within it is on life issues.

The Solvency Capital Requirement (SCR)

Solvency II is clear that firms must hold sufficient capital to meet their Solvency Capital Requirement (SCR). I consider that we have done a thorough and robust job in making sure that for UK firms that requirement represents a 1-in-200 year standard, as set down in the legislation (partly informed, for internal model firms, by the use of our Quantitative Framework as set out in this letter, and informed by an assessment of standard formula appropriateness for firms without an internal model). It follows from this that we will hold firms to their SCR.

As we did under the ICAS regime, we will of course monitor capital more closely, and expect to discuss contingency plans, as a firm approaches its SCR. In doing so we will take into account the volatility of each firm's capital position, the nature of its business model and the risks to which it is exposed as set out in its Own Risk and Solvency Assessment (ORSA). These factors will clearly differ from one firm to another, just as there are elements of the new regime such as the Ultimate Forward Rate which work differently for firms operating in different countries. It is also worth noting that for an insurance group's solvency position the Solvency II SCR, as an economic measure, is much more similar to the ICAS regime than to the Insurance Groups Directive (IGD) regime, and therefore any simplistic read-across from groups' previous IGD positions to their new Solvency II positions is unlikely to have much information value. Given this, I would like to be clear that we will not deploy a single ratio, somewhere above the SCR, as a formal intervention point across the insurance sector. That would be incompatible with the intention of legislators to deliver a 1-in-200 level of solvency across Europe, and would not take into account the different risks different firms run. Instead, we have developed monitoring tools which we will use in the operation of our judgement-based approach to prudential supervision.

Using Solvency II to compare capital positions across countries

The aim of Solvency II has been to create a more robust regulatory standard (in particular relative to the unadjusted and now very dated standard of Solvency I) and thereby establish a benchmark standard. We have commented in recent months that considerable caution is required in making comparative judgements on the basis of Solvency II capital positions. A good example of this issue is the different application of the Ultimate Forward Rate under Solvency II, which leads to different outcomes. There are other areas where we consider that further work will be required to improve the comparability of Solvency II positions; these include the differing approaches being taken to the implementation of the Volatility Adjustment, which will need to be ironed out. This is to be expected with such a far-reaching and complex measure, but in the meantime we would further emphasise that great care is required when attempting to draw comparisons on relative capital levels.

Next steps

To conclude, I would like to thank everyone who has been involved over the last decade in the UK's preparations for the arrival of Solvency II, and in particular those within the Bank, firms and trade bodies who have put a huge amount of effort into getting us to this point. These efforts will need to continue, particularly in relation to internal models where, following discussions with us over the last 18 months, a significant number of firms decided to take more time in developing their models and are likely to bring them to us for approval during 2016 and 2017. We will apply the same standard of rigour to any further approvals sought – and to any model change requests for models already approved – that we applied in the model reviews we undertook during the second half of last year. I hope that this letter and any further communications we issue will help firms in those preparations.

Yours sincerely

Annex: the PRA's use of a 'Quantitative Framework' during internal model reviews

1. On 1 January 2016 Solvency II came into force as the regulatory regime for UK insurance firms. Among the many changes introduced by Solvency II is the ability for firms to calculate regulatory capital requirements based on their own internal models, subject to supervisory approval. On 5 December 2015 the PRA announced that 19 UK firms had received approval to use partial or full internal models for this purpose.

2. Model approval has been a significant undertaking for firms and for the PRA, involving many man-years of work in the internal model approval process (IMAP). But of course model review activity has not come to an end: several more firms are expected to apply for model approval in 2016 and the PRA will have to monitor the ongoing appropriateness and assess major model change applications for those firms that already have approved models.

3. Throughout the IMAP the PRA has aimed to provide insight into the PRA's internal processes for model reviews and feedback on specific topics or risks. It has provided this transparency through a variety of means such as workshops, speeches or letters. The PRA will continue to do this, and as part of this sets out here more information about the operation of the PRA's quantitative framework for model reviews. This was already the subject of a letter on 9 March 2015 ('the March 2015 ED letter') but given the recent approval of the first batch of internal models this is a good time to share more details on how the framework has operated in practice and how it has aided model reviews. However, for ease of reference this annex builds on the March 2015 ED letter and reiterates the messages already communicated there, providing more detail on insights gained about practical implementation issues during the final stages of the IMAP (particularly in the life insurance sector).

4. In this annex the PRA's objectives are to provide additional detail regarding how:

   a) the PRA has used quantitative analyses as part of model approval;

   b) the PRA has developed its quantitative framework for model assessment; and

   c) model reviews have benefitted from the use of the quantitative framework.

5. In addition this annex includes a technical appendix where the PRA provides an expanded overview (supplementing the March 2015 ED letter) of the development and use of its quantitative indicators ('QIs') for longevity risk, credit risk and dependency structures within the quantitative framework.

6. Please note that while the general philosophy set out in the letter has been applied to the PRA's use of quantitative metrics across all model reviews, the focus of this annex and the detailed commentary within it is on life issues.

How the PRA has used quantitative analyses as part of model approval

7. It is important to place the quantitative framework within the context of the overall model review process. The PRA's model reviews are structured around the requirements for internal model approval set out in Regulation 48 of the Solvency II Regulations 2015 (the 'tests and standards' or 'T&S'). The internal toolkit the PRA uses in its assessments is framed around those requirements such that the PRA is able to satisfy itself that the model meets the T&S. Within this structure the PRA applies a series of qualitative and quantitative tools to help guide areas that are in need of greater review focus. One of those tools is the quantitative framework for model reviews, which includes the use of specific quantitative indicators ('QIs') where risks are sufficiently homogeneous.

8. The PRA's decision-making process is built around assessing the T&S, building from a granular assessment of each of the criteria into broader requirement categories (eg 'documentation') through to a final approval or rejection decision. As part of this overall assessment the PRA has used its risk-based approach to supervision to focus additional scrutiny on a firm-by-firm basis. In this assessment process the PRA uses a series of indicators to determine the focus of review scrutiny; these are both qualitative (eg a view on the embedding of the model from previous supervisory engagement) and quantitative.

9. One of the T&S categories relates to the calibration standards, which are set out in 'Solvency Capital Requirement – General Provisions 3' and 'Solvency Capital Requirement – Internal Models 12' of the PRA Rulebook. An assessment of these requirements is geared towards ensuring that the Solvency Capital Requirement (SCR) produced by the model corresponds to the 99.5% confidence level over one year standard set out in 'Solvency Capital Requirement – General Provisions 3.4'.

10. The PRA has used its quantitative framework as:

a) a diagnostic tool to help assess model rigour and capital adequacy and hence highlight areas of potential concern;

b) a prioritisation tool, to help inform where review teams should direct their attention, eg by identifying risks or correlations which may be under-calibrated; and

c) one contributor to decision making as to whether a firm has met the T&S, and therefore whether its model should be approved.

11. Internal models are required to be calibrated to the standard specified in 'Solvency Capital Requirement – General Provisions 3.4' of the PRA Rulebook. Where risks are homogeneous, a PRA quantitative assessment of the calibration of individual risks and their dependency structures can give an efficient diagnosis of whether there are areas of potential concern where the model has not been calibrated adequately to meet the Directive requirements. Where the risks are largely (but not totally) homogeneous, the PRA has tailored its quantitative assessments to reflect a firm's specific risk profile.

12. Quantitative tools are important too in helping review teams prioritise areas for early review where firms may not have calibrated their risks or correlations adequately. However, they are not determinative of the PRA's final view of a model or model component. It is also worth noting that the PRA looks at the calibration of any model as a whole as well in its constituent parts, with particular consideration being given to whether the model remains appropriate in a range of conditions and over time when the balance of risks may change.

13. Finally, the outputs of this quantitative analysis constitute one of the many indicators that are taken into account by the PRA in concluding whether the model meets the T&S. Specifically, while the PRA's quantitative analysis assists in verifying that the calibration standard in 'Solvency Capital Requirement – General Provisions 3' of the PRA Rulebook has been met it does not negate the need for other aspects of the model to be reviewed including Statistical Quality Standards in 'Solvency Capital Requirement – Internal Models 11'.

14. As is apparent from the description above, the operation of the quantitative framework does not yield a mechanistic 'pass / fail' decision. It is worth highlighting once more that model approval does not hinge on meeting any particular quantitative criterion, but on meeting the T&S. It must also be emphasised that the use of the tools underlying the PRA's quantitative framework is always tailored having regard to a firm's own risk profile.

How the PRA has developed its quantitative framework

15. The PRA has tailored the quantitative framework for model reviews to best fit its intended uses, as specified above. The PRA has paid particular care to the following areas:

a) **Use in homogeneous risks assessments**. Many of the risks that life insurers are exposed to are largely homogeneous. Where this is the case, it is useful to employ a homogeneous quantitative assessment as part of the PRA's evaluation of the model. This quantitative assessment comprises both comparisons against generally accepted market practice as well as comparison against QIs which the PRA believes are representative of models likely to meet the calibration standard. Where risks are not sufficiently homogeneous the PRA has not used this quantitative framework as part of the PRA's assessment.

b) **Alignment to firm's risk profile**. When using the quantitative framework the PRA has ensured that any cross-firm comparisons are made with firms that have similar risk profiles. Likewise, when compared against the QIs mentioned in the previous paragraph, the PRA has tailored the assessment to reflect firms' respective risk profiles.

c) **Alignment to Solvency II requirements**. The PRA has ensured that the development of its QIs reflects the requirements of Solvency II (eg such as using a consistent definition of the risk-free rate).

16. In order to provide more clarity on the underpinnings of the PRA's approach specific details are provided below on how the PRA has derived the QIs for three important areas (longevity risk, credit risk, and dependency structures).

How model reviews have benefited from the use of the quantitative framework

17. The March 2015 ED letter highlighted three expected benefits for IMAP reviews:

a) enhanced consistency and efficiency of model reviews;

b) increased effectiveness in the PRA's assessment of firms' justifications and application of an appropriate level of challenge; and

c) improved assessment of compliance with the calibration standard of Solvency II.

18. The PRA believes that the use of this quantitative framework as part of model assessments has helped ensure that similar risks are assessed consistently across firms, and has resulted in an efficient approach to model reviews.

19. The T&S are principles based and require supervisory judgement to come to a view on whether specific standards are in fact met. The quantitative framework has been an important part of this structure and has allowed the PRA to apply consistency in its reviews, for example by assessing model outputs to ensure that more complex models can be assessed and compared in a consistent manner.

20. The development of QIs has served to identify critical assumptions that need to be made in order to calibrate risks for homogeneous risk categories. Where firms have been identified as weak against these indicators the PRA has followed through to the judgements that firms have made so as to allow a thorough assessment of those assumptions. For example, in applying the framework the PRA has been able to identify and challenge firms which were using data misaligned to their exposures or which had inconsistencies in their modelling.

21. In other circumstances, however, firms have been able to justify their assumptions based on their specific risk profile. As noted above, the quantitative framework is not a 'pass/fail' test: some firms have been able to justify their calibration based on their specific risk profile or on the overall quality of their model judged against the T&S. In other cases the review activity has led to an update to the QI where the PRA has recognised a better way to reflect the relevant risk data.

22. In particular, when applying the QIs during model reviews the PRA has taken into account the fact that firms' models may use a different definition of risks, as well as reflect their specific exposures. Moreover the approach explicitly recognises that there is a range of reasonable judgements that can be made when modelling risks for capital purposes that the PRA needs to consider when concluding whether it is satisfied that the T&S have been met.

23. Internal models must be calibrated to the standard set out in 'Solvency Capital Requirement – General Provisions 3.4' of the PRA Rulebook. The T&S recognise the need for supervisors to assess the calibration of the internal model against this standard as part of the model assessment, which the PRA has sought to do through the quantitative framework. This has allowed the assessment of firms' calibrations against peers as well as the reference point of the QIs, which has provided further assurance that the approved models meet the calibration standard of Solvency II in 'Solvency Capital Requirement – General Provisions 3.4' of the PRA Rulebook.

24. Peer group analysis plays an important role in the PRA's use of the quantitative framework and the construction of the framework itself has been informed by views and expertise from the industry. However, the PRA does not consider that in itself the fact that firms may have calibrations for key risks that are consistent with those of some of their peers means that the calibration requirements have necessarily been met.

25. The appendices which follow provide more information about the approach the PRA has taken for its quantitative framework for three areas; longevity risk, credit risk (including the Matching Adjustment in stress) and dependency structures.

Appendix A: technical overview of the PRA's longevity risk QIs

Background

1. Internal models must capture longevity risk where a firm is exposed to such risk. In developing its QIs, the PRA has defined longevity risk as the risk that policyholders or pension scheme members, in aggregate, live longer than expected. The main life insurance products exposed to this risk are immediate and deferred annuities although there will be some exposure to longevity risk in an insurer's own pension scheme (if defined benefit), in respect of certain health contracts and possibly within with-profits funds. There is also growing exposure within general insurance in relation to Periodic Payment Orders (PPOs).

2. As there is not currently a deep and liquid market for longevity risk, firms are required to derive their longevity assumptions from first principles for two purposes:

   a) the valuation assumption: to value their annuity (and other longevity-dependent) liabilities; and

   b) the capital assumption: to quantify the level of capital that has to be held to cover longevity risk.

Decomposition of longevity risk into component parts

3. In line with industry practice, the PRA considers that longevity risk includes at least two sub-risks which effectively mirror the main components of the valuation assumption; namely, base mis-estimation risk and future improvement risk:

   a) **base mis-estimation risk** represents the risk that the actual current mortality experience differs from the assumption about current mortality rates used in the best estimate assumption; and

   b) **future improvement risk (or trend) risk** represents the risk that future improvements differ from future improvements assumed in the best estimate assumption.

4. In terms of risk decomposition, the PRA notes that most firms have used this broad split of longevity risk although some firms include more risks under the longevity risk banner than the PRA has done (eg other risks such as proportion married risk are included) or define the risks slightly differently (eg split what the PRA calls 'event risk' – see below - into more granular components).

Determining the sub-components of longevity risk for which a QI is appropriate

5. Although the concept of setting and potentially mis-estimating the current level of mortality is well understood, quantifications are likely to vary markedly by firm due to the heterogeneity of exposure. For this reason the PRA decided not to develop QIs for current mortality rates and base mis-estimation risk in valuation and capital assumptions respectively.

6. The allowance for future improvements in mortality tends to be less heterogeneous across firms. The PRA therefore considers it is appropriate to derive a QI for future improvement risk in both valuation and capital assumptions.

Modelling time horizon

7. Under Solvency II, the calibration standard for the Solvency Capital Requirement (SCR) is set out in 'Solvency Capital Requirement – General Provisions 3.4' of the PRA Rulebook. However, for internal models, the risk measure or time period used may be different from this provided it can be demonstrated that there is an equivalent level of policyholder protection ('Solvency Capital Requirement – Internal Models 12.1' of the PRA Rulebook).

8. While some firms have opted to model longevity risk over a time period that is greater than one year, for the purposes of setting its QIs the PRA has modelled longevity risk directly over a one year time horizon.

9. For the direct one-year approach the PRA has modelled future improvement risk by considering how much the best estimate future improvement assumptions could change over one year. This has been split into data-driven changes in the best estimate assumptions ('data risk', ie the impact of introducing an additional year of mortality data) and event-driven changes ('event risk', ie the impact of new information emerging that is not contained in the data).

Construction of the QIs for future improvements

10. The QIs for future improvements have been developed using the following steps:

Step 1 – The PRA modelled future improvement risk using Office of National Statistics data. The specific choices of data period and age range used are supported by a desire to focus on data of sufficient credibility and relevance to annuity business.

Step 2 – One model was selected from each of four commonly used families of stochastic longevity risk models for investigation. These models are all industry-recognised and have been subject to extensive challenge. None of the models are cause of death models due to their greater complexity, data requirements and the need for a greater level of judgement to be exercised. In particular the PRA was concerned that the correlations between causes of death were not easily measured and would not be stable over time.

Step 3 – The PRA ran the selected models to obtain the valuation assumption (taken to be the 50th percentile output). It also made a judgement that the future improvements would reduce to nil between the highest age modelled and age 100. The range of valuation assumptions implied by the different models was wide and so the PRA used judgement to derive a reasonable range for the best estimate. This was informed by the assumptions firms are currently making and judgements the PRA had made around the expected shape of future longevity improvements.

Step 4 - The PRA split the modelling of future improvement risk into data risk and event risk.

Step 5 – Data risk was modelled by simulating an additional one-year's worth of longevity data and re-fitting the models. The PRA repeated this a number of times and then selected the empirical 99.5th percentile change in the 50th percentile simulation as a result of the additional year's worth of data. All models gave similar calibrations for this risk.

Step 6 – There is no statistically robust method for calibrating event risk. The PRA has therefore done this by looking at the variation in the valuation assumptions implied by each of the models (Step 3 above). It considers a change in model to be a good proxy for this risk as the PRA considers that a 1-in-200 longevity risk event is likely to lead firms to change their modelling approaches.

Step 7 - The strength of the calibration obtained was validated by comparing the resulting calibration to the results in published papers on longevity risk modelling, other published projections and the impact of historic events (most notably the introduction of the cohort improvement factors).

Step 8 – A full PDF was derived by fitting a lognormal distribution to the 50th percentile from step 3 and the 99.5th percentile from step 6.

11. Further detail on these steps is provided below.

Steps 1 – 3: QI calibration at the 50th percentile

12. The QI is based on output from the four families of stochastic models that are considered under the PRA's methodology. In setting the actual QI, the PRA made the following judgements:

    a) **Model families used**: The four model families used are all stochastic or pseudo-stochastic model families. They are: Lee Carter, p-spline, Age-period-cohort (APC) and Cairns, Blake and Dowd (CBD).

    b) **Shape of improvements over time**: The high improvements that have been seen in recent decades in the age range 50 to 80 will reduce to the historical average over the next 10 to 20 years. This judgement reflects the changing mix of causes of death. The high improvements in recent years have arisen mainly as a result of significant improvements in mortality from cardiovascular disease. During this time period, cardiovascular disease was the dominant cause of death particularly for men: dramatic reductions in deaths from this cause were therefore a key driver in overall population longevity improvements. However, due to these improvements, cardiovascular disease is now being replaced by cancer as the leading cause of mortality between ages 50 and 80. As cancer covers a diffuse range of diseases, it is much more difficult to develop treatments applicable to all cancers and so the PRA considers that the pace of improvements can be expected to reduce over the medium to longer term.

    c) **Ages at which improvements occur**: Historically, the ages seeing the largest reductions in mortality rates have increased over time. This reflects shifting medical research priorities and diminishing impact of medical improvements as mortality rates at younger ages are reduced. Based on this, the PRA has made a judgement that it will see increasing reductions in mortality rates at ages 80 to 90 over the next 10 to 20 years.

13. The PRA recognises that in recent years UK population mortality experience has exhibited lower mortality improvements than were the case previously. When calibrating QIs for longevity trend it has used the most up-to-date data available. Therefore, as part of its regular review of QIs these changes

to population experience are considered and incorporated into both the modelling approach and associated judgements as appropriate.

Steps 4 – 7: QI calibration at the 99.5th percentile

14. The calibration of data risk is a natural output of the statistical models used in the PRA's methodology. The PRA has followed the industry standard approach to doing this which effectively involves repeatedly simulating an additional year's worth of data and then re-fitting the model.

15. However, as event risk relates to information not in the data, this is by definition not captured directly in any of the model outputs. The nature of this risk therefore means that judgement is essential to its calibration. In reviewing firms' models the PRA has seen a number of different approaches taken to allowing for this risk: the PRA welcomes this and has no desire to impose a preferred approach on firms in this area.

16. However, for its QIs, the key judgement the PRA has made, in order to calibrate event risk, is that if event risk were to crystallise then firms are likely to have to change the model(s) used to calibrate their best estimate assumptions. This is supported by historic evidence where the PRA has generally seen firms change models following a major change in longevity risk drivers (eg introduction of the cohort effect). Hence, it has used differences between the 50th percentile calibrations implied by the four models it investigated as a proxy for the impact of event risk.

17. The PRA recognises that this approach could be argued to include some model risk as well as event risk. The intention of the framework is for event risk to be relatively widely defined and so where some firms have split event risk and model risk into separate components the PRA effectively combines them.

18. Validation of a 99.5th percentile one-year stress calibration for changing perceptions of future longevity improvements can be challenging due to lack of data and consistency of available data over time. In validating the strength of its QI calibration at the 99.5th percentile the PRA has considered information from a range of sources including:

    a) in circa 2001, the Continuous Mortality Investigation (CMI) published a new analysis of historic longevity improvements and a revised projection of future improvements in longevity. This implied materially higher future improvements than had been recognised previously. The PRA considers this to be an extreme longevity event along the lines that it would be expecting an internal model to capture. The PRA's QIs give a broadly similar impact to the introduction of these cohort improvements; and

    b) a number of other historic changes to longevity assumptions over the past 60 years (generally driven by the publication of new longevity improvement projections) gave rise to impacts that are consistent with the PRA's QIs.

19. That said, in terms of the overall calibration of the QI at the 99.5th percentile, the changes in population mortality experience in recent years discussed above may also have an impact and this will again be a factor the PRA will take into account when updating the QIs. However, any experience data emerging, particularly where changes have only been seen over a relatively short timescale, are likely to have a lower impact on the stress calibration than on the calibration for the best estimate (ie 50th percentile).

Step 8: The QI distribution

20. The PRA has calibrated at the 50th and 99.5th percentiles of the distribution directly and then fitted a parametric distribution (the lognormal) around these two calibration points – this distribution has been chosen so as to reflect the key characteristics of the risk (as described below). This approach is generally consistent with firms' approaches where firms have also tended to calibrate only one or two percentiles and then fit a distribution to this. The 50th percentile calibration is used for the calculation of firms' best estimate liabilities.

21. The PRA considers that there are a range of reasonable underlying judgements that could be made in calibrating at both the 50th and 99.5th percentiles. For this reason, the PRA calibrated a QI range at both percentiles and hence effectively calibrated a range for the whole QI distribution for trend risk.

22. When selecting an appropriate distribution to fit around the two calibration points, the PRA made a judgement that a fat tailed distribution is appropriate as, in reality, longevity risk only tends to become particularly onerous in the most extreme events.

23. The PRA has also made a further judgement that the shape of the trend risk distribution should not allow future improvements in longevity to be negative in order to ensure that in scenarios with weak longevity improvements the impact of other risks is not distorted.

24. These two preceding points are the PRA's key justifications for the choice of a lognormal distribution although it recognises that some other distributions may be appropriate and some firms have indeed used these instead.

Appendix B: technical overview of the PRA's credit risk QIs

1. Life insurers invest in a range of assets whose market value reflects the likelihood of the asset owner receiving the contractual payments in full and on time; the PRA refers to such assets as 'credit risky assets'. In the context of Solvency II SCR calculations, life insurers need to consider two sources of exposure to credit risky assets:

   a) **asset side credit risk:** the risk of changes in the market value of credit risky assets; and

   b) **liability side credit risk:** the risk of changes in the discount rate used to value annuity liabilities by those firms that have received permission to apply a 'Matching Adjustment'.

Asset side credit risk

2. Within the universe of all credit risky assets, corporate bonds constitute the largest single asset class to which life insurers are exposed and the PRA has developed QIs to assist in its reviews of firms' models of these assets. The PRA has not developed specific QIs for other credit risky assets; however, it has applied the same underlying principles (as for corporate bonds) when considering IMAP firms' calibrations of credit risk for these other asset classes.

3. The PRA notes that firms' exposure to other credit risky asset classes, such as infrastructure investments and commercial real estate, is increasing and the PRA expects firms to increase the sophistication of their internal models for these assets accordingly.

4. Firms generally model the change in corporate bond prices via changes in corporate bond spreads. Spread models have increased greatly in complexity during the internal model development process and the calibrations for these models involve a significant number of material judgements. This has increased the importance for the PRA of having QIs for corporate bond credit risk, in order to provide an overall view of firms' calibrations on a consistent basis.

5. The PRA's QIs have, in its view, provided an effective basis for challenging firms' credit risk modelling, and improving the quality and robustness of firms' calibration approaches. For example, the PRA relied mainly on GBP denominated bond data series in building its QIs while many firms were allocating material weight in their overall calibration to US credit risk data from many decades ago. The PRA considered this weighting to be inappropriately strong, particularly as these data were unlikely to be reflective of firms' actual asset holdings, and as a result firms have reassessed their approach.

6. Regarding the term structure of credit risk, firms developed a wide range of practices. The PRA considers that there is evidence for a term structure of credit spread changes for corporate bonds (ie there is evidence that spread widening varies by term of the bond). This view is based on the PRA's analysis of historical credit risk index data, allowing for adjustments made by data providers for the treatment of callable bonds during 2008-9. During the IMAP review the PRA challenged firms that did not vary credit risk calibrations by term and has seen general acceptance of the need to model the term structure of credit spreads.

7. In deriving its QIs the PRA has not assumed different levels of spread change for bonds of different sectors. In the PRA's view, the spread-widening experienced by financial sector bonds in 2008-2009 is an example of a single-sector event that could reasonably be indicative of a future shock to another (non-financial) sector in the future. The PRA considers that non-financial bonds could stress to such levels in the future.

8. The PRA found that some firms used overly data-driven approaches that did not adequately distinguish between data sources of varying relevance and credibility. In finalising its QIs, the PRA has applied judgment to the raw results of its analysis to ensure that the final QIs make economic sense and do not unduly reflect any less credible features of the calibration data, and it has encouraged firms to do the same. In particular, the PRA used judgement to produce consistent (smoothed) distributions across ratings and terms. The PRA informed its judgement in this area by considering the implied percentage change in bond prices, comparing against the changes expected for other asset classes, both more and less risky. The PRA considers that the percentage fall in credit risky asset prices is a useful additional QI metric, because the balance sheet impact of spread changes is dependent on the precise model used to revalue assets.

9. Although the PRA's asset side credit risk QIs were initially developed at the 99.5th percentile, the PRA has expanded them to a full risk distribution, for consistency with Solvency II internal model requirements. In line with firms, the PRA considers this distribution to be fatter-tailed than a normal

distribution, although the PRA has challenged firms with distributions that it considered excessively fat-tailed.

Liability side credit risk

10. The PRA has seen a wide variation in firms' approaches to modelling liability side credit risk for their Matching Adjustment (MA) portfolios. The PRA has not sought to impose a single approach, but it has challenged firms and asked them to justify their methodology in the context of the PRA's proposed five-step framework, which was set out in the March 2015 ED letter and which is discussed in more detail below. Firms have responded well to this challenge and the PRA has seen significant improvements in firms' methodologies and calibrations as a result. Where firms assume that the value of their liabilities in stress scenarios would benefit from use of a MA, they need to consider both whether they would continue to qualify for MA in stress and what might be the MA that would apply. On the former point, the PRA expects firms to verify that their portfolios still qualify for MA, and to consider all risks that arise in respect of the use of the MA. On the latter point, the PRA does not consider it would be appropriate simply to re-calculate the fundamental spreads using the methods and assumptions prescribed by EIOPA for the purposes of calculating technical provisions in the base balance sheet (ie a purely 'mechanistic approach'), and its QI has been developed accordingly.

11. As already noted, the PRA has seen a wide variety of modelling approaches and methodologies for liability side credit risk, and therefore it felt it was appropriate to consider a simple overall QI. The PRA considers that 'matching adjustment or fundamental spread, expressed as a percentage of spread' is a useful metric to enable comparisons with the Solvency II calibration standard and between firms. The PRA has developed its QI as a range based on this metric, and has challenged firms whose calibrations were below this range. In many cases a calibration approach that the PRA considered overly 'mechanistic' (ie which simply applied EIOPA's methods and assumptions for the purposes of calculating technical provisions in stress without adjustment) caused firms' calibrations to fall below this range. Such approaches gave insufficient consideration to wider possible economic scenarios, such as a material increase in expected future defaults in excess of the default rates seen in the period used by EIOPA to calibrate fundamental spreads. On this latter point in particular, the PRA expected that firms would incorporate their existing credit default analysis work into their liability side credit risk calibrations, as the PRA does not consider that the underlying risk has fundamentally changed.

12. The PRA also considers it appropriate to assess the capital held in respect of credit risk (post any allowance for increase MA in stress) against the reduction in value of the credit risky assets in response to a stressed environment (ie the capital relating to the asset side credit stress). For many firms, the complexity of their credit risk modelling has meant that it has been more appropriate to assess the calibration against this capital output-based QI, in addition to the input-based liability side modelling approach outlined below.

The PRA's framework for considering the risks in matching adjustment portfolios

13. As part of its quantitative framework for assessing internal models, in addition to the QIs, the PRA also developed a five-step framework for assessing how firms have reflected the risks arising from the use of an MA in their internal models. The PRA did not expect firms to follow this framework exactly but it did expect firms to capture all the relevant issues that apply to each step. The following paragraphs provide further observations on the liability side credit risk approaches used by internal model firms, with reference to the PRA's five-step framework.

Step 1: re-value the MA portfolio assets under a one year stress

14. The primary output of this step is the change in total asset portfolio value over one year, ie the calculation of asset side credit risk. As such, the PRA developed a QI for corporate bonds that assesses the change in asset values compared to the starting value of the credit risky assets, noting that this is dependent on the characteristics of the actual corporate bond portfolio held by individual firms. The liability side impact of a credit stress is directly related to the asset side behaviour and so should not be viewed in isolation, hence the development of a QI for both the asset and liability side of credit risk.

Step 2: calculate updated fundamental spread values, reflecting the stressed modelled economic environment

15. The PRA has seen many firms calculate stressed fundamental spreads via a number of different approaches and then apply the maximum. These approaches include (among others): updating the long-term average spread with one year of stressed spreads; applying a separate non-mechanistic calculation (following the five-step framework); considering a deterministic (stressed) run-off

approach; and applying the 'EIOPA in a box' approach which involves a firm building its own version of what it considers EIOPA would do to recalculate the fundamental spread in a stressed environment.

16. The non-mechanistic approaches tend to consider the impact of stressed probability of default and cost of downgrade assumptions, as well as taking into account the increased transaction costs that might be incurred when attempting to rebalance the matching adjustment portfolio under stressed conditions. The PRA has also seen firms developing their views on the relationship between increased probability of default and cost of downgrade, through the correlation assumptions between these two risks. Many approaches reflect that stressed conditions do not immediately revert to long-term averages, and as such stressed conditions persist for a number of years, decaying to a long-term average over that period.

17. The PRA expects the non-mechanistic approach developed by each firm to reflect the nature of the risks faced by the individual firm in the context of MA. Firms have acted on the information in the March 2015 ED letter and have demonstrated that they have considered the applicability of models to the particular risks to which they are exposed and have focussed on the components of the five-step process that are most material to their particular exposure. While the calculation of updated mechanistic figures may provide a minimum underpin, the PRA expects firms to focus on the results of its non-mechanistic approach which should reflect the firm's own view of the risks to which it is exposed.

18. As the PRA expected, a number of firms have leveraged earlier work on recessionary scenarios, such as the 1930s depression, as either a stress event to determine stressed fundamental spreads or as a validation tool. While the PRA believes that such scenarios are very useful in the calibration and validation of the model, the PRA also expects firms to consider potential future events that may differ in the nature, magnitude and duration to events seen previously.

Steps 3 and 4: verify whether the MA qualifying conditions are still met, and if this has failed, then the cost of re-establishing an MA compliant position should be specified, such as considering the cost of re-balancing the asset portfolio

19. It is likely that, following an extreme economic or insurance risk stress, and after making a suitable estimate of the revised pattern of liability cash-flows, firms might conclude that the MA qualifying conditions are no longer met. Assuming that the conclusion is that the qualifying conditions would no longer be met, firms would need to determine the actions required to re-establish a qualifying portfolio and the cost of doing so. For example, additional assets might need to be inserted into the MA portfolio for a number of reasons, including in order to:

    a) deliver additional risk-adjusted cash-flows following the downgrade of some assets and/or a change in expectations for the probability of default, and consequent reduction in the default-adjusted cash-flows of those assets; or

    b) meet new expected long-term cash-flows following a longevity stress.

20. Whatever the reason for needing additional assets, firms should also consider whether under the range of scenarios in their internal models they would be able to source additional assets of at least the same or equivalent credit risk characteristics as the existing assets. Firms should consider whether, under extreme conditions and within the year of consideration in the internal model, they might be forced to buy assets that are more liquid and/or of higher credit quality than existing assets, particularly if their portfolios contain large exposure to illiquid and/or untraded assets. As a result, firms should not simply assume that they could maintain the pre-stress risk characteristics of their asset portfolios, ie they should not simply scale up their existing credit portfolios to deliver the additional cash-flows required without investigating and justifying the plausibility of this assumption.

21. Typically, the costs of rebalancing the matching adjustment portfolio include the costs associated with asset disposal and acquisition, along with other frictional costs, all within the stressed environment. Sourcing appropriate assets that are eligible for use in the matching adjustment portfolio may not be a straightforward task and could involve further costs, as could reinvestment or sourcing longer-dated assets under a longevity stress. Firms may also need to consider implementing hedges or other risk mitigation. Given the variety of approaches implemented by firms, and the different types of assets held, for some firms the stressed fundamental spreads are the most material component of the framework, while for others the cost of rebalancing dominates the capital calculation.

Step 5: Re-calculate the MA. Note that based on the analysis in the previous steps this may need to be based on a re-balanced MA asset portfolio

22. Following a stress, the efficiency of assets in terms of matching adjustment benefit gained may be impaired (due to downgrade below investment-grade, for example). Firms should consider the need to address this reduced efficiency by having appropriate levels of eligible assets available outside the matching adjustment portfolio that could be injected, or sufficient liquid assets to purchase eligible assets.

23. Firms may find it useful to apply some high-level 'sense checks' such as verifying that matching adjustment expressed as a percentage of spread is consistent with their own view of the inherent level of credit risk for such assets.

Appendix C: technical overview of the PRA's dependency QIs

How diversification effects feature in a firm's internal model SCR

1. A firm's SCR must capture all of the material risks to which the firm is exposed. While those risks may be inter-related, it is recognised that an extreme event affecting one risk will not always simultaneously coincide with extreme events affecting other risks. This absence of automatic coincidence gives rise to diversification effects, which is a key economic reality of insurance activity. More precisely, Solvency II (as set out in the Glossary of the PRA Rulebook) defines diversification effects as:

   "The reduction in the risk exposure of UK Solvency II firms related to the diversification of their business, resulting from the fact that the adverse outcome from one risk can be offset by a more favourable outcome from another risk, where those risks are not fully correlated."

2. Diversification refers to the concept that incidences of different risks are generally partly or fully unconnected with each other and the financial impact of this can be modelled using a dependency structure that captures the extent to which different risks are correlated with each other. In general the PRA expects models to specify both the individual distributions of risks as well as their dependency relationship. The dependency relationship may be imposed (eg set as a parameterised copula) or set structurally (eg captured in the equations that drive the output of a scenario generator).

Developing QIs for dependency

3. The PRA has based its QIs for dependency on the analysis of the relations between standardised risk categories. These correspond to the most common homogeneous risks that life insurance firms are exposed to.

4. The PRA has developed its QIs on the basis of a simple dependency structure based on the use of a Gaussian copula parameterised via the analysis of correlations between risks. In this parameterisation the PRA has considered various market and other publicly available information. The PRA has focused on its technical analysis based on its investigation of the relevant historic data (where available) as well as its application of judgement as described below. It has also considered and taken into account the calibration views of firms and other parties, particularly as part of its internal validation and challenge process.

5. The PRA's approach should not be seen as an endorsement of a particular methodology; in practice it has reviewed and approved models that use a variety of dependency structures. The extensive modelling freedom afforded by Solvency II allows the choice of simple models of dependency provided that appropriate adjustments are made such that the ultimate capital requirement corresponds to the standard set out in 'Solvency Capital Requirement – General Provisions 3.4' of the PRA Rulebook. Given the difficulty in specifying the dependency relations between multiple risks across the whole distribution the PRA has viewed all dependency structures as pragmatic approximations valid for modelling in specific contexts, provided firms can demonstrate that they understand the limitations and, where appropriate, mitigate them.

6. For example, simple symmetric copulas such as the Gaussian may be too limited to describe the actual dependency relationship between risks whose joint behaviour may vary in different parts of their joint distribution. However, the PRA has accepted that most parsimonious dependency structures, which contain simplifications or approximations, can meet the Solvency II requirements, and has derived its QIs accordingly. Two particular areas where the Gaussian copula was deemed to be too simplistic and requiring adjustments were:

   a) Allowance for lack of diversification in stressed conditions (also known as 'tail dependency' allowance). For example, where data analysis is used in the QI derivation, the QI calibration is generally stronger than would simply be obtained by calculating the mathematical rank correlation between two historical data series. The PRA's overall data analysis has involved considering the results of a number of statistical tools such as time series plots, scatter plots, rolling correlations over the data period, historic correlation, confidence intervals, goodness of fit tests and the coefficient of finite tail dependence observed in the data.

   b) Asymmetric relations: the real-world dependency relation between two risks will not generally depend on the exposure of an individual insurer to those risks. However, where simplifications are adopted to describe a complex dependency relation by means of simple dependency structures (eg a Gaussian copula) it may be necessary to adjust the correlations depending on exposures to ensure the system used to measure diversification benefits captures the right

dependency characteristics (eg reduced diversification in extreme scenarios compared to benign scenarios).

7. The PRA has also applied judgement in the development of the QIs between all risk pairs, particularly for those pairs where relevant data is scarce or absent.

8. In applying its judgement the PRA has sought to identify not only direct links, but also non-intuitive links between variables and common drivers of variables. This is because it is well known that correlation is not equivalent to causation, and that in fact correlations between variables can be counterintuitive. In particular variables that might superficially appear to be independent (because neither directly causes the other) can in fact be related by common drivers that result in a non-zero correlation between them even in the absence of a direct causal link. These common drivers are often hard to identify, especially in benign conditions; the role of judgement in this area is to consider all of the routes by which changes in one variable could be reflective of conditions that might affect the other variable.

Application of the dependency QIs

9. Where firms have other means of allowing for the features referred to in the previous section (eg a more sophisticated copula structure) the PRA has considered this when comparing calibrations against the QIs.

10. When assessing firms' calibrations compared to its QIs the PRA has emphasised a qualitative review to ensure that correlations are set with an overlay of expert judgement, as it has done in the derivation of its QIs. That qualitative review has been based on the relevant EIOPA guidelines[1] regarding the application of expert judgement in internal models.

11. As an illustration of the general approach taken in the derivation and application of the PRA's QIs, consider the important correlation between longevity trend and credit spreads:

    a) Generally there is not enough relevant data to set this correlation, and therefore this must be done using judgement. In applying its judgement the PRA has sought to identify not just direct links between these variables but also non-intuitive links and common drivers between them. However, the PRA has also recognised that there is a range of reasonable judgements that may be made in setting this correlation.

    b) The PRA has used this QI to identify firms that may have under-calibrated the assumption in this area, and has applied additional scrutiny to the justification provided by the firms. The PRA has challenged firms which had for example derived this correlation based on an application of expert judgement that fell short of Solvency II standards, assessed following the EIOPA guidelines noted above.

12. In summary, the PRA's QIs in this area have helped to identify firms that had, in the PRA's view, insufficiently strong assumptions, and helped to focus the PRA's reviews on establishing the quality of the evidence provided and assessing whether their models meet the tests and standards.

[1] https://eiopa.europa.eu/Publications/Guidelines/IM_Final_document_EN.pdf.