What is a 1-in-200?

Presented at GIRO 2009 by

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The paper starts by looking at the most commonly used definitions in deriving capital requirements at a 1-in-200 level.

Section 2 challenges the limitations of purely considering reasonably foreseeable events or focussing only on return periods of extreme loss events. We note that the definition needs to make an allowance for systematic events that will influence many aspects of an insurer or even the insurance market as a whole.

Section 3 considers a generic ICA model structure and the various risks that need to be considered in a risk based capital analysis. It focuses on the secondary effects of events and how multiple events might impact both sides of the balance sheet at the same time.

Section 4 is an aid to be used alongside the current capital modelling framework. It is not meant to be a technical treatise; it attempts to tie various considerations into a usable framework. It provides a flavour of what aspects need to be allowed for in order to derive a 1-in-200 scenario for various individual risks. Then we identify a number of "common sense" checks to use with model outputs; these will not tell you if your model is correct but they could highlight errors.

Section 5 focuses on how to allow for interrelations and systematic loss events affecting multiple aspects of the business. We start by considering the strengths and weaknesses of using linear correlations and copulas. We propose the use of "cause and effect" models is better at capturing the true nature of risky events influenced by a number of risk drivers. It also focuses the modeller's attention on the true cause of risk and not on the near-impossible task of estimating the outcome of multiple related risks. We extend this idea to a multi-state model where the actual distribution used to model risks changes in light of a significant event or market phenomenon. This final approach has the benefit of capturing extreme outcomes, whilst being a useful tool to aid management, when they are making decisions focussed on shorter time periods.

Finally, sections 6 and 7 consider, respectively, some regulatory best practices and a review of the previous literature pertinent to this paper.

We trust that this paper will stimulate some thought, challenge current mindsets and invite constructive dialogue in formulating your risk based capital assessment.

<u>Please note – the views expressed in this paper should be regarded as being our personal views and in particular, should not necessarily be regarded as being those of our employers.</u>

1. Introduction

The introduction of a risk based capital assessment has been one of the most significant regulatory changes affecting the way General Insurance (GI) companies operate. Formalising the level of acceptable capitalisation in the form of the ICA/ECR (individual capital assessment / enhanced capital requirement) has provided a firm challenge to the soft test or market accepted capital requirement of about three times the MCR (minimum capital requirement), almost irrespective of a company's unique circumstances. Mention the words "1-in-200" and the first thought coming into the mind of the GI actuary would most likely be the ICA or Solvency II.

1-in-200 has almost become synonymous with capital requirements, even in light of the difficulty - clouded by our perceptions, experiences and fears and amplified by the knock-on effect of a global economy - of estimating such extreme probabilities. What has become clear over the course of the last 12 to 18 months is that our view of the world, along with our models of extreme probability, can be turned around in the blink of an eye. This has proved a major flaw in the banking industry's over-reliance on models that do not capture the risk of a major systematic failure of the financial system. So in light of these remarks what does capital adequacy at a 1-in-200 level actually mean for an insurance company? And, importantly, how can we best communicate that message to non-actuaries?

2. Definitions of a '1-in-200' occurrence

One of the major areas of research in behavioural finance is the study of how we misunderstand and misjudge probabilities. The possibility of an event seems to increase the more we hear or talk about that event, and we often overlook the elephant in the room because something has not happened before. Because of the importance of probability theory for the pricing or modelling of insurance contracts and the difficulty we find in deriving the estimates of probability (particularly at the extremes), many attempts have been made to define or describe probabilities in ways such that we can grasp the true magnitude of a specific event. We consider some of the most common definitions below.

2.1. 1-in-200 years

Each company holds enough capital to withstand the events of 199 out of the next 200 years. Underwriters often refer to this as the return period of an event when calculating the risk premium to charge for reinsurance layers. They might believe that an event is likely to occur every 10 years, so they need to charge at least 10% of the limit per year to cover the cost of losses to the layer. A major problem with this approach is that some underwriters might have suffered a major loss in year one and now expect such a loss every five years, whilst others have been fortunate to avoid it and thus revise their frequency estimates downward. Even for reasonably foreseeable events, the return period estimate will be clouded with the bias and experiences of individuals and not uniquely defined.

A further problem with this approach for capital modelling is the extremity of the probabilities we are interested in. In only the past 200 years major events have included the invention of the car and the aeroplane, manned space flight, the downfall of empires, the abolition of slavery, the discovery of penicillin, nuclear reactors and sliced bread…to name but a few. For example, could you have imagined the 9/11 World Trade Center (WTC) attacks, as you stood there watching Napoleon strip the Teutonic Knights of their last holdings in Bad Mergentheim, in 1809? The first aeroplane flight was 100 years later and the World Trade Center was the tallest building when it was opened, a further 65 years after that.

Clearly, it is very difficult or even impossible to look at an output of a capital model and ask a room of experts whether they believe something is likely to occur once every 200 years.

2.2. 1-in-200 companies

Another way of looking at the problem is that 1-in-200 equally well-capitalised companies (relative to their risk) will fail over the next 1 year. The major problem with this definition is that it ignores systemic events that impact entire markets, both locally and globally. As we have seen in the recent banking credit crisis, it is not enough to only consider the fortunes of a single company under 'normal' market conditions. Almost by definition, a 1-in-200 event is likely to change considerably the dependency structure between companies, and should be captured in the risk mitigation strategy and capital setting of individual market participants.

This issue becomes a regulatory/government issue if many companies fail together. If all companies used this definition in setting their risk appetites, how would the FSA look at correlation between insurers? This is especially important when deciding how much additional capital needs to be set aside to deal with such a systematic failure.

2.3. 1-in-200 chance

Each company holds enough capital to withstand the events of the next 1 year with a probability of 199 out of 200. We believe that this is what companies are trying to do and should be doing, as this would allow for the most up-to-date economic, risk and regulatory environment in setting their capital requirements. A good example is the sudden change in the availability of capital in the market and how this would change management's strategy and risk preferences knowing that further capital might not be available.

Using this definition in determining capital requirements, thought would most likely be given to the 1-in-200 Years and Company definitions, but allowing for the shortcomings discussed above. The difficulty in estimating probabilities of extreme events remains, but it is crucial to at least start with this holistic paradigm, including both the return period and the systematic element in your capital setting. We discuss some further definitions below that might be useful in estimating probabilities.

2.4. Further definitions

2.4.1. Reasonably foreseeable adverse event

Another definition commonly used is that a company should hold enough capital to be able to withstand a 'reasonably foreseeable' adverse event, given our knowledge of history and the exposure in their portfolio. In our view, a 1-in-200 likelihood is beyond what is reasonably foreseeable given a 60-80 year living memory and a 20-40 year working memory. It is much more likely to generate a 1-in-20 year event which will be widely different depending on an individual perception of reasonably foreseeable.

2.4.2. Size of loss

This is defined as the biggest loss that is expected to occur with a 0.5% probability. This definition is akin to an exceedance probability as given in the output of cat models. The major limitation of this definition is that it is usually the combination or series of events that gives rise to solvency problems and it is therefore not enough to consider only one such event in isolation. It is, however, a useful check on whether the results generated by a capital model appear reasonable. This method is widely used in stress and scenario tests such as the Lloyd's RDS model.

2.5. Further considerations

No matter which definition is used in setting capital requirements, some problems will persist, such as the actual estimation of events equivalent to these probabilities. One way of modelling these extreme events is to use an extrapolation from 10-20 years using extreme value theory, i.e. use the information available from the recent past and combine it with extreme value theory to extrapolate to a 1-in-200 event. This is the approach that is currently used by many, but serious consideration needs to be given to distribution error, parameter error and simulation error and especially the impact that these can have at the 1-in-200 level.

From a purely practical computational point of view, consideration must be given to the number of iterations needed to be confident of two variables each at 1% confidence, and then being comfortable that the parameters that generated all these simulations are not only reasonable but also inclusive of sufficient degree of variability.

Another question that begs asking is whether it is enough to consider only the 1-in-200 capital events (VaR approach), without considering the magnitude of possible events more extreme than a 1-in-200 (TVaR approach). It is certainly possible for two companies to have the same 1-in-200 but different conditional means given that the event has occurred.

Also, most 1-in-200 scenarios we naturally think of might be centred on natural catastrophe, which are well covered by the catastrophe models, or terrorism events. But could it be easier for ‘black swans’ (see section 7.2.3 below) to appear in markets we do not naturally consider that risky, such as Personal lines (e.g. fraud on motor, home contents and travel insurance, increased claims on payment protection insurance), or which suffer from latent claims such as Casualty lines - particularly if there was a sudden manifestation - or even Financial lines?

It has also become apparent from the banking meltdown that we should be considering correlations or ‘common drivers’ to a much wider extent than is currently best practice. Maybe deriving a modelling method from the world of Operational Research, using networks of interrelated nodes - in which each node is an entity (Insurer, FI, Bank) and different entities have different ‘strengths’ of link - is one solution.

To summarise, there is clearly a very wide range of issues to consider in setting capital at a 1-in-200 level, but it is crucial to start with a proper holistic frame of reference in order to include the widest range of eventualities in an orderly way to avoid under-estimating the 1-in-200 level through omission.

3. Generic ICA Model Structure

This section considers some of the difficulties in creating a robust ICA model given a data set typically limited to less than 20 years data, with a particular focus on dealing with tail dependencies. We consider a generic model structure and discuss a few examples of how each area of risk is linked to others.

The typical approach to developing an ICA model is to develop statistical distributions for as many risk factors as possible and then to model the dependency structure between these elements. There already exist a number of very useful papers on modelling each of the risk elements individually, so we will not focus on these aspects in this paper but will rather consider areas of particular uncertainty including the various interdependencies.

3.1. Data limitations

It is important to consider whether the historic data for the company is appropriate for estimating the extreme adverse results for each area of risk. Take underwriting risk as an example to illustrate this concern; at best a Lloyd's syndicate will have data for 16 underwriting years, including 2008. Even if the business and the claims environment were completely unchanged over this period, 16 sets of observations are statistically not very credible. As a very simple demonstration, consider an attritional loss ratio with true mean 50% and true standard deviation 50%; in a 16 year period the chance of the observed standard deviation being between 40% and 60% is only 1-in-3, with an equal (1-in-3) chance of observing standard deviation values below 30% or in excess of 70%.

This issue is exacerbated by the significant changes we can see in business over a relatively short period; during 16 years there could have been changes in the business mix within a class, coverage, terms and conditions, the underwriting philosophy, the maximum line size, claims handling and the claims environment. The rate index will be approximate, at least for the older underwriting years, and the actuary might be told to exclude events like WTC because "it can never happen again".

Given all these factors, modelling the underwriting risk is immensely subjective. A few examples of the subjective decisions might include:

- How much credibility should be given to a rate index that was put in place retrospectively for older underwriting years?
- Should any losses be excluded? If so, based on what criteria?
- What external "market events" that pre-date the syndicate / company underwriting in that class should be included? How should this be done?
- How should one consider damaging scenarios that could happen, but have not done so as yet?
- What proxy for claims inflation should be used? How will it work for excess layers / treaty business?
- What credibility should be given to exposure data? How does the exposure curve, disaggregated into frequency and severity elements, compare to the experience modelling?

- Should greater weight be given to the largest losses when fitting the distribution to improve the fit in the tail?
- How to allow for trends, e.g. climate change or compensation culture?
- What considerations should be given for changes in legislation and policy terms?

Using an approach that allows for parameter uncertainty given the number of data points modelled is only picking up a small fraction of the uncertainty inherent within this subjective process. For example, simply including market events that pre-date the internal modelling data for a class might increase the values at the extreme of the distribution by a factor of two or three times.

Similar issues apply to other risk areas, where the same paucity of historic data will apply. Consequently we must regard the model as being highly subjective, and at least as much art as science.

There is a temptation to make a model ever more sophisticated in an attempt to compensate for data inadequacies. However there is a risk that the level of reliance placed on a more sophisticated model will be much greater than if a simpler model were used. Given the huge uncertainty in applying past data to the current portfolio / underwriting conditions / economic conditions, we need to ask ourselves whether a more complex model will actually produce more accurate results than a simpler model – or only appear to do so.

3.2. Underwriting risk

This element of insurance risk is often the area on which the actuary will spend most time. Often there will be separate distributions for aggregate attritional losses, large loss severity and frequency plus catastrophe losses; the latter often being represented by catastrophe model output.

If we consider an entity with, say, 20 business lines of which several are vulnerable to natural peril catastrophes such as flood, hurricane or earthquake this approach gives us:

- 20 attritional loss distributions;
- 20 large loss frequency distribution;
- 20 large loss severity distributions; and
- a number of natural peril catastrophe distributions.

Even this does not capture the full range of events, and the underwriting risk model might well be expanded to allow for man-made events such as terrorism or the emergence of latent health hazard claims.

Within the underwriting risk there will be interdependencies within classes, for example between the attritional losses and the frequency of large losses, and between classes, for example between D&O and E&O. Many of these interdependencies will be seen only when the market experiences an extreme event, such as the 9/11 WTC attacks or the financial crisis of 2008/9.

Additionally, there are interdependencies between underwriting risk and the other elements of modelled and unmodelled risk within the insurer. For example a change in legislation could impact both current underwriting and reserves (California property – Montrose judgement) while a major earthquake could cause reinsurer failures and investment market disruption in addition to large underwriting losses. We will return in more detail to such interdependencies later in this and subsequent sections, as we believe these are key to the assessment of the 1-in-200 year loss.

3.3. Reserve risk

This element of insurance risk is often a close second to underwriting risk on the actuarial priority list. We will not attempt to summarise the difficulties in modelling the distribution of reserves here as this is very well covered by the GRIT and ROC working parties. However it is worth noting that any method that is using only the data contained within the paid and incurred claim triangles is likely to understate reserve values at the extremes.

One suggestion made by the ROC working party was that we should use both stochastic methods in addition to scenario and sensitivity testing in assessing the uncertainty in reserves.

Within reserve risk there will be interdependencies between underwriting (or accident) years and also between classes. For example, a reduction in the discount rate used for bodily injury claims could impact both motor and general liability over a number of past years.

Additionally, many factors that could cause adverse reserve run-off could also impact the current underwriting year and the ongoing solvency of reinsurers; one example might be the emergence of a new latent claim arising from the use of a widely distributed product.

3.4. Credit risk

The most significant element of credit risk is typically bad debt in respect of ceded reinsurance. Until recently this was the 'poor relation' for stochastic modelling, with many models simply applying rating agency default rates. The GIRO 2007 paper "Reinsurance Counterparty Credit Risks" described an approach to modelling such risks that made more allowance for the interdependencies between reinsurers and between the insurer's underwriting and reserve risk and the risk of default.

Clearly there is a strong link between claims activity in either the current or prior underwriting years and reinsurer strength – the point at which the cedant most needs its reinsurers is also the point at which those reinsurers may be most likely to fail.

Additionally, there are a number of other areas of credit risk, including brokers, coverholders, third party claims administrators, and investment and bank counterparties. These might show strong interdependencies in certain circumstances, such as extreme economic stress.

3.5. Investment risk

Technically the default risk on assets might more properly lie within the credit risk, but it is more typically modelled within investment risk. General Insurers traditionally had a very conservative investment philosophy, with assets often concentrated in high grade corporate bonds, short term Gilts and US T-Bills, and consequently this area has received far less attention in GI than in Life or Pensions. However in recent years some GI companies have placed an increasing proportion of their investment fund into equities, and corporate bonds have been shown to be anything but low risk assets.

It is important that the investment model selected is one suited to the relatively short term duration of the GI company's assets. For example, the Wilkie model was originally built as a long term model to assist in valuing life insurance guarantees, and is based around inflation rates. Clearly this is not guaranteed to be the most appropriate approach given either the relatively short duration of the GI company's assets or the 1 year time horizon of the ICA.

As recent events have shown, there can be strong interdependencies between the various asset classes, affecting both asset value and investment income expectations. Equally, we anticipate the economic crisis to generate additional losses both directly and indirectly. The reduction in interest rates could lead to a reduction in the discount rate used for bodily injury claims, leading to increases in reserves for lines such as motor and general liability. Finally, the increased claims levels combined with hits to investment portfolios could leave reinsurers more vulnerable – and indeed many reinsurers have been downgraded in the past 12 months as a result of the crisis. This is a useful example of tail dependencies where we might have assumed that none existed.

3.6. Operational risk

Operational risk is typically defined as the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events. An organisation is unlikely to be able to infer very much from its own history of losses due to operational failures, and so must look to general reasoning combined with other data sources to assess the potential impact of operational risk.

One approach suggested by Jim Gustafsson at GIRO 2008 ("Operational Risk: bending the tail of the dragon") is to estimate an industry loss distribution based on reported losses, and then adjust both to allow for under-reporting and the organisation's own internal loss history. One concern with benchmarking allowance for operational risk to peers is that every organisation is likely to believe that its risk management practices are 'better than average'. Moreover, even if its practices were worse than average, a company would perhaps be loathe to admit it to regulators, as this could send an unwanted signal to customers and investors.

Operational risk is often perceived as being separate to other risk elements. However, several scenarios that could cause significant underwriting losses and reinsurance counterparty credit risk could also cause severe operational difficulties, for example a cluster of terrorist attacks in UK cities, a pandemic, or severe flooding in London following Thames barrier failure. Perhaps more difficult to model (and even harder to explain to management and regulators without causing major problems): if senior management is inexperienced or inadequate this could affect control of all aspects of risk.

3.7. Group risk

It is often argued that being part of a broader group of companies provides additional protection against risk, particularly if there are parental guarantees in place. However many scenarios that could give rise to unacceptable levels of risk within the particular company assessing its 1-in-200 adverse result could also cause issues elsewhere in the group. Vice-versa, events elsewhere in the group could impact a single entity’s ability to withstand extreme events.

Additionally, other areas of the group could cause reputational risk, downgrades in the group’s credit ratings, or a change in group strategy that would affect underwriting or reinsurance purchasing.

Finally, if there are any shared support services within a group, such as IT or finance, then failure within another part of the group could cause a significant increase in expenses or a reduction in service quality in a very short period.

4. Aid for arriving at a true 1-in-200 capital position

The previous section identifies some of the key issues involved in attempting to model a 1-in-200 occurrence. This and the following section ("Approaches to Modelling Dependency") attempt to help the actuary address some of these issues.

Whilst there is no simple answer to the question of how to model a 1-in-200 occurrence, this section is an aid to be used alongside the current capital modelling framework. It is not meant to be a technical treatise; it attempts to tie various considerations into a usable framework.

We begin with the actuary's initial expectations. It is important to highlight that the actuary's initial expectations regarding the magnitude of a 1-in-200 loss may be very different to the results of a technical analysis. This is to be expected in many cases and as long as the actuary investigates the reasons behind this mismatch, incorporating any conclusions into his/her model, then this should not be a concern in itself.

4.1. Expectation setting

The actuary should begin their determination of a 1-in-200 loss by firstly becoming comfortable with loss of greater frequency (less extreme), which may be more intuitive to understand. By beginning with and understanding events such as 1-in-10 and 1-in-20, the actuary may be better placed to extrapolate this to less frequent events.

4.1.1. Internal data

As with any modelling exercise, the data need to be selected and grouped appropriately. For these purposes, it is useful to consider both the aggregate book of business across all lines and the following broad risk groupings:

- Motor
- Property
- Casualty including Financial Institutions
- Marine
- Aviation

It is not uncommon for two or more of the above risk groupings to show poor results in a single year, and this should be reflected within the final result.

We have intentionally selected broad groupings but having considered these, it will often be beneficial to divide them into more granular 'line of business' level categories.

The time period should be chosen to include as broad a period as possible. Unlike some other analyses, large claims should not be removed from the data, particularly claims or events which are perceived as being one of a kind, or unable to happen again. By removing such events, the actuary risks introducing bias into the investigation, as many future large losses will inherently be of an unanticipated nature. Similarly, events which would presently be excluded due to updated policy wordings should not be removed from the data.

As a general rule, to avoid the risk of introducing bias, the actuary should keep data adjustments to a minimum. In practice, this means that a simple exposure-adjusted burning cost should be calculated, i.e. adjustments only for exposure, rating changes and inflation. This simple burning cost will give some insight into the characteristics of the risk class.

Using this information and their professional judgement, the actuary can begin by estimating what size of loss he/she would expect for a group of moderate frequency losses.

- Median - this will often lie significantly below the mean, dependent on class
- 1-in-10 - as a rule of thumb, this could be expected to lie at the 95th percentile
- 1-in-20 - similarly, this could be expected to lie at the 97.5th percentile

These opening estimates will act as initial checks for the adequacy of the less frequent losses.

4.1.2. External data

We have already discussed the concerns about the level and availability of data (Section 3.1.). One advantage of investigating large losses however is the relative availability of market information regarding the event in question. The actuary may wish to expand the effective data set by considering how historical events that were not otherwise considered would have impacted the business. This treatment of course needs care, particularly concerning the level of foresight by underwriters at the time. For example, it would be imprudent to assume current-day policy exclusions or a decidedly different coverage focus than the market norm at the time. For example, the actuary for a Lloyd's syndicate with data from 1993 onwards may wish to consider:

- The Savings and Loans crisis in the late 1980s and the subsequent worldwide recession (particularly as a parallel to the Subprime crisis).
- US pollution prior to the introduction of 'absolute' exclusion in the place of 'sudden and accidental' exclusion in 1986 (particularly given the forthcoming EU directive on environmental impairment liability).
- Asbestos prior to the introduction of 'absolute' exclusion clauses in 1986 (particularly given the rise in nanotechnology use).

4.1.3. Understanding the business

Before any further detailed modelling takes place, the actuary should take time to understand the risk structure of the accounts. The aim is to estimate the broad shape of the claim curve. This will be determined by factors such as:

- Layer of account: where it falls on the spectrum from primary insurance to high level excess of loss insurance.
- Type of business: direct, facultative, quota share, excess of loss and stop-loss business will all exhibit different characteristics.
- Concentration of business: geographically and by insured entity type.
- Outwards reinsurance structure: type and quantum (vertical and horizontal limits) of the protection.

- Outwards reinsurance providers: level of diversification, intra-group or external providers.

The risk profile curve may differ significantly between classes, and also between gross and net exposures, with the result that certain classes may be more sensitive to 1-in-200 risks than others. As an example, some classes' 'worst-case scenario' may lie at the 1-in-50 risk level, with very little deterioration past that point. For others, claims may continue to increase significantly to the 1-in-100 or 1-in-200 levels.

This exercise should bring some intuitive reasoning to the process, and provide initial guidance as to the key risk areas to study.

4.1.4. Changes over time

As with all data analysis, the actuary needs to be careful regarding differences between the period from which data was collected, and the period for which the analysis will be used. In particular, within a large event context, the actuary should consider:

- **Exposure –** Historical trends may be particularly noticeable in certain classes, for example commercial property exposures have increased substantially over the past 20 years. A modern-day earthquake on the same scale as one in the 1970s will have a proportionately greater impact today.
- **Information flow –** Some classes will be particularly affected by the increased ease of global communications over the past number of years. It may be argued whether this magnifies the overall losses, or simply accelerates claim reporting. This is particularly noticeable for Casualty type risks, especially those of a financial nature.
- **Socio-economic climate –** For Casualty risks, the increased litigiousness of many societies many lead to an increase in defence costs, if not claims themselves. The economic climate will also have an impact on the level of ultimate costs, with greater litigation and increased moral hazard to be expected during economic downturns.
- **New types of claims –** The actuary may wish to disregard previous events on the basis that they are unlikely to reoccur, for example asbestos claims between the 1950s and 1980s. However, future claims may arise from unexpected sources, such as from mobile phone or nanotechnology uses, and the past events may provide a starting point for analysis.

4.2. Choice of distribution

Through the course of the above and the general capital process, the actuary will often have a good idea of an appropriate claims distribution to be used for the majority of each risk grouping. A common approach is to attempt to fit a single distribution that explains the claims behaviour at all risk frequency levels. This approach is well documented, and despite disadvantages concerning the reliability of tail estimates, continues to be the principal method in practice.

Despite this, there are alternative approaches that can be taken. One of these is a multi-distribution approach, an example of which is discussed in further detail in section 5.4.

The use of a multi distribution approach enables the actuary to estimate claims distribution that are appropriate:

- Under ‘normal’ circumstances, when losses are in line with historic experience; and
- Under ‘extreme’ circumstances, when the claims, economic, regulatory or legal frameworks change significantly.

Both these situations can be modelled so as to be internally consistent, with the remaining subjectivity arising from the frequency of change from the ‘normal’ state to the ‘extreme’ state. While this has arguably a high degree of subjectivity, it must be viewed in comparison to the subjectivity inherent in attempting to fit a single claims distribution that is appropriate in all scenarios.

A useful illustration of when a two-state model may be appropriate is for Property risks. For the first 95 loss percentiles, the most appropriate fit generally appears to be the Weibull. Move past this point, however, and the Weibull proves to be a very poor fit. A two-state model would fit the tail using a second claims distribution, and model the frequency of such a claim falling in the tail.

4.3. Testing expectations

Lloyd’s syndicates are required to carry out Realistic Disaster Scenario (RDS) tests. Given their standardised and public nature, these tests may be able to provide some insight into the rigour of the modelled risk. Although the scenarios described within the RDS suite cannot be directly translated to a 1-in-x framework, the actuary should be aware of where the tests lie within the claims distribution.

A first check would be to compare the largest of the RDS scenarios against the actuary’s expected 1-in-100 loss – it would be unusual for the largest RDS to fall beneath this level. Correspondingly, it would be unusual for the next largest RDS to fall beneath the 1-in-80 risk level.

Companies outside of the Lloyd’s market may not be required to perform the RDS tests, although for many such companies, it may make sense to do so, in order to provide a level of standardised check. This recommendation is subject to the company in question writing a similar type and level of business as would be possible within the Lloyd’s setting.

A similar, although more subjective approach, is for the actuary to first determine what he/she believes a 1-in-100 loss would be in each of the main risk groupings, and to arrive at say 10 such 1-in-100 examples. Each of these could be modelled and compared against the actuary’s risk level curve.

By having 10 separate ‘1-in-100’ events we can make the (admittedly) broad assumption that these 10 events will happen in the next century. The actuary can compare the smallest of these events to the 1-in-10 model output, the next largest to the 1-in-20 output and so on. As a rule of thumb, each model output should be at least as big as the corresponding scenario estimate.

4.4. External Factors

Having performed the first cut analysis, the actuary should then consider whether the 1-in-200 scenarios are realistic in their treatment of the following factors, including the various direct and indirect interactions therein.

4.4.1. Capital

The ‘as at’ capital position will clearly be impacted by an adverse event or set of events but there are secondary effects that also need to be considered, including:

- **Availability –** In many cases there has been an influx of capital to the industry after a major event, although this is not always the case, and the model should allow for this possibility.
- **Premium rates –** A large event will place an upwards pressure on premium rates on numerous classes, not only the affected class.
- **Capital market solutions –** The level of free capital will determine the interaction between the insurance and capital markets via catastrophe bonds and sidecars. The presence of contingent capital agreements may reduce the volatility arising due to this point.

4.4.2. Reinsurance

Like capital, the reinsurance is used to mitigate the impact of adverse events and depending on the impact of those events on reinsurers this protection may or may not respond as intended. Either way, there will again be secondary impacts of (a) large event(s):

- **Cost and availability –** Premium rates in many classes are likely to rise after a major event, and availability in the primary affected class may be expensive to the point of being prohibitive, or coverage may simply be unavailable.
- **Quality –** Even if reinsurance is available, the quality may be reduced. Bad debt allowances on the outstanding existing reinsurance asset may increase due to external auditor and regulator pressure. Defaults can be expected to rise, , payment patterns slow, and consequently profits reduce.
- **Failure –** It is possible that some reinsurers may be declared insolvent. These may be reinsurers with a very tight focus to business (e.g. monoline reinsurers), or may simply suffer from poor management. The structure of the outwards reinsurance protection should be analysed to determine the impact of a reinsurer becoming insolvent, and any knock-on affects that might arise from it.
- **Net exposures –** If the reinsurance programme needed to be changed or reduced as a result of availability concerns, the effect on net exposures and subsequent capital position may be significant. The impact of bad debt may further weaken asset values at a time when they are already under pressure. Solvency may be affected depending on the nature and extent of reinsurance use.

4.4.3. Economic downturn

A slow-down in the economy will have numerous effects on the balance sheet (and income statement) of insurers, including, to a greater or lesser extent some or all of the following:

- **Claim frequency –** Claim frequency can be expected to rise in a downturn across all risk groups. This will affect the claims handling department, and may lead to expense provisions in policies being inadequate.
- **Claim severity –** It is difficult to determine how the claim severity may change in a recession. As a downward pressure, policyholders will tend to claim for smaller amounts, on which they may not have previously have spent the time. As an upward pressure, a greater number of frauds are likely to occur in a downturn, and these can often be sizable in nature.
- **Exposures –** The effect on exposures may vary from risk grouping to risk grouping. Certain market areas may show a decrease in exposure that offsets the otherwise negative claim experience, for example fewer miles travelled by commuters as fewer people travel to work and fewer days at sea for private yachts. Similarly, insureds may elect to increase levels of self-insurance, all of which could have a negative impact on expense loadings.
- **Fraud –** Fraud (especially on yacht insurance but also on other classes) can be expected to rise in a downturn, increasing demands on the claim handling function and raising loss ratios.
- **Sickness rates –** Sickness rates typically rise during a downturn, and so classes with any sort of Accident & Health element will be affected.
- **Emerging markets –** New markets may behave differently to mature markets, in that fraud may be present to a higher degree. The withdrawal of hot money from developing markets may exacerbate other problems discussed here, particularly capital and reinsurance availability.
- **Government intervention –** In extreme cases, key financial entities may be nationalised, which may act to provide a guarantee on their liabilities but which may also lower premiums to very competitive rates. To a lesser extent, it can be expected that a greater level of regulation will be enacted after a major event which results in large failures.
- **Compensation schemes –** Levies can be expected to increase after a number of major financial institution collapses.

4.4.4. Assets

As outlined elsewhere in this and other papers, events that impact insurers can often impact financial markets at the same time, potentially causing the following effects:

- **Impairment –** If the (re)insurer invests in other (re)insurance entities, the level of correlation may be such that asset values fall at the same time as large losses are incurred. If the event coincides with a stock market fall, or rise in interest rates, the (re)insurer may have a significantly decreased solvency position.

- **Volatility –** Investment markets exhibited hyper-volatility in late 2008, leading to a higher chance of insolvency using mark-to-market accounting treatments.
- **Exchange rates –** Volatility in the financial markets can lead to large foreign exchange rate swings. If the business has liabilities in a different currency to capital requirements and insufficient hedging (natural or derivative based) is used, this may lead to balance sheet volatility and be a threat to solvency.
- **Reinsurance bad debt –** There may need to be an increase in bad debt provisions, lowering the effective balance sheet value of the reinsurance protection.
- **Group companies –** Group risk may be a large factor in some reinsurance structures. Although normally small, it may become much larger under a 1-in-200 scenario.
- **Hedging –** Although (re)insurers may enact hedging programmes to protect the value of their assets, there are likely to be scenarios for which such hedging programmes are insufficient. 1-in-200 events may well fall into this category, and so the effectiveness of such programmes cannot be taken for granted.

4.4.5. Business capacity

The ability to write business following an event will clearly be impacted by any loss of capital and reinsurance cover but may also be impacted by:

- **State intervention and premium rates –** Premium rates are likely to rise in numerous areas after a major event as discussed above. Governments may act to limit the rise in these premiums (e.g. 2005 Florida Insurance Code).
- **Exchange rates –** As above, if the business is written in a different currency to capital requirements and insufficient hedging is used, this may lead to profit volatility and also be a threat to solvency.
- **Short term capital –** Any short-term external capital funding may be subject to withdrawal at short notice, e.g. letters of credit, sidecars, overdrafts.
- **Rating agencies –** Rating agencies play a key part in determining the volume and quality of business that a (re)insurer can attract. In the wake of a major event, the actuary's company may find itself downgraded, and an analysis should be carried out to identify the implications of this based on the company's underwriting strategy.

4.4.6. Pandemic

It might appear that a pandemic is an issue just for Life insurers, rather than GIs, but the reality is that many classes of non-life business could be impacted too, for example commercial property classes could experience high business interruption claims as a result of mass evacuations. Other classes potentially impacted could include Contingency, Travel, Employer's Liability, Public Liability and Medical Malpractice.

4.4.7. Macroeconomic factors

The fortunes of insurance companies are clearly impacted by economic factors, some of the more obvious impacts, include:

- **Interest rates –** A sustained rise in interest rates will increase the cost of capital and decrease the value of fixed interest assets. However, this may have an offsetting benefit of reduced valuation of long-tail liabilities.
- **Inflation –** Higher than anticipated inflation will result in higher claim amounts and mispriced products, particularly for longer tailed Casualty risks.
- **Liquidity –** A number of successive large events may place a drain on the (re)insurer's ability to meet its obligations.

4.5. Contagion

The above considerations can be made individually, although it is worth highlighting that many events will result in knock-on effects, with financial casualty type risks in particular being at risk of contagion.

Contagion may take many forms, and while it would be unreasonable for the actuary to second-guess where the next major event arises from, it can be reasonably expected that the actuary takes due notice of the ways in which problems can spread throughout the financial system.

Considerations of note are:

- The secondary effects of the failure of a large reinsurer, bank or other similar entity, including reduced premium levels, increased fraud and increased Trade Credit losses.
- The failure may lead to highly irrational behaviour in the stock markets, resulting in hyper-volatility in asset pricing and large swings in foreign exchange rates.
- The wide reaching implications of recession as noted above

4.6. Sense checks

Whichever modelling approach is adopted, it is essential that the results are "sense checked". There are a number of "sense checks" that can be applied to modelled output, for example:

- **Input vs output –** Suppose the model is based on ten years' data. Make broad adjustments to the historic results to allow for the rate cycle and major changes in business. Does the 1 in 10 result from your model equal / exceed your historic worst result?
- **"As if" or "if only" –** What did you take out of your data in order to model it and why? If you took out WTC because your company has introduced terrorism exclusion clauses you need to think carefully about this. What happens if there is a huge gas build up and explosion taking out the Gherkin, Aviva and Hiscox? Or a plane accidentally crashes into buildings at Canary Wharf. We appreciate these are not very likely scenarios, but neither was WTC before it happened.

- **“Pre-historic” events –** These are events pre-dating your data set. For example, ignoring exclusion clauses subsequently applied what would asbestos do to your company if it emerged tomorrow and not in the 70’s / 80’s? N.B. It is important to ignore post-event exclusions; as mentioned previously, if an event was unexpected at the time it occurred, it is highly unlikely it would have been excluded from policies written at that time. Similarly, what would the Savings & Loan Crisis have done in today’s more global economy? Likewise the Spanish ’flu epidemic, the San Francisco earthquake of 1906, the Great Depression?
- **Scenario testing –** Scenario testing allows you to test out some of the things that might happen but have not happened in the past – for example, suppose that swine flu becomes more infectious and/or develops a higher mortality rate; how might this impact your business? Swiss Re has published a brief paper on the benefits of scenario testing: http://www.swissre.com/resources/bbe421004d1a73a9ad5fed6fbe56bb6a-sigma1_2009_e.pdf
- **Thinking beyond insurance –** Consider events from outside the insurance industry, such as banking crises, and how they might have parallels within the insurance industry. The equivalent to the rogue trader might be the rogue underwriter or team leader who accepts risks far beyond those anticipated by the company. The gradual build-up of the Savings & Loan crisis of the late 1980s could be likened to the emergence of a latent health hazard. The subprime crisis and subsequent contagion of 2008/9 might be compared to a universe in which the 9/11 WTC attacks were closely followed by a spate of further high profile terrorist attacks.
- **Reverse scenario testing –** Think up scenarios that would “break” the company. How likely is it that any one of these scenarios could arise, and how does that compare to your modelled output.
- **How fast does your model tail off? –** What multiple of your 1 in 10 year results is your 1 in 50? And 1 in 100? Does this make sense given what you know about the business? Is there a point at which everything goes wrong together in a terrible cascade, leading to an increased gradient in the result curve?

It must be stressed that passing the above checks does not mean a model is “correct”; however failing them could be a strong indicator that the model is incorrect to an unacceptable level.

4.7. Control cycle

The results arising from this exercise may well be very different to the actuary’s initial expectations, in part due to the complexity of the area and in part because of the unintuitive level of risk under consideration. As with any modelling exercise, care is needed to continue work after the initial result is arrived at, and for that result not to be taken as the final answer.

Sensitivity testing will enable the actuary to determine the key areas of risk within the modelling exercise and subsequently enable them to concentrate their efforts in these areas. Equally, a high degree of sensitivity to a relatively minor assumption may indicate an error or fault in the modelling.

An Actual versus Expected comparison with the actuary's initial expectations can be very insightful. It will allow the actuary to both refine the model by considering key areas for reasonability, but will inform the actuary as to the areas where their intuition may have led to bias of some description.

Beyond the initial modelling and review, the ECM/ICA process is iterative and so the testing and review process needs to be similarly iterative.

5. Approaches to Modelling Dependency

This section follows on from sections 3 & 4; it describes four possible approaches to developing the dependencies within the ICA model, outlining the most significant considerations for each.

We are particularly focussed on the interdependencies both within and between the different risk elements because we believe they are one of the key drivers of the 1-in-200 year value generated by the model. For example, what started out as a sub-prime mortgage issue might now be considered an economic catastrophe.

Aside from direct insurance losses on D&O and E&O policies, we might expect a broad range of classes to be impacted indirectly - household accidental damage and motor fraud, arson, trade credit losses, construction project delays, piracy and kidnap etc. However, there are likely to be secondary effects too, including reduced premium levels over the next couple of years (lower turnover / payroll leads to lower premium on a number of classes), impact on equity markets, downgrading of corporate bonds, reduction in investment rates on government bonds, potential pension funding issues (operational risk), reinsurer downgrades and increased likelihood of bad debt.

Furthermore, if the discount rate used for injury claims is also reduced, this will create a reserve hit on classes such as motor and liability. Clearly, a model that aims to estimate the 1-in-200 year adverse result must find a robust way of dealing with such complex interdependencies.

We have considered four possible approaches to this key issue, each of which is described below. In practice, the ICA model may use two or more of these approaches to best reflect the complex web of interdependencies.

The approaches considered are:

- Linear correlation
- Copulas
- "Cause & effect"
- Multi-state model

5.1. Linear correlation

This model would use simple linear correlations between the various simulated elements within the ICA model to deal with all the interdependencies.

Considerations include:

- **One-way dependency -** dependency may be one-way only, for example a major earthquake might cause a number of reinsurers to fail, causing a bad debt "loss", but a reinsurer failure will never cause an earthquake.
- **Insufficient data –** The level of data required to parameterise a linear correlation coefficient with any level of confidence is likely to be far greater than is available. Examples of this are given in the 2003 GIRO paper "Practical Issues in Dependencies", as outlined in section 3.1..
- **Weak correlation -** correlation matrices generally must be positive definite and if you are trying to correlate a large number of distributions it may be

difficult to include very strong correlations whilst keeping the matrix positive definite. Going back to the portfolio described in the underwriting risk section 3.2 above, we could potentially be trying to correlate 20 attritional loss ratio distributions with 20 large loss distributions and 20 reserving class correlations. Using several smaller matrices gives a work-round to this issue for some circumstances, but does not allow you to deal with the much more extensive correlations at the extremes of the distributions.

- **Tail-only dependencies –** Losses may be correlated at the adverse "tail" but not throughout the rest of the distribution. A small earthquake may cause only moderate property damage losses, a more severe quake might also cause casualty and aviation losses, a very severe quake could cause insured losses to be so high that reinsurers fail, economic problems and massive inflation arise, stock values fall, and local (state) banks experience severe liquidity issues. Generally the dependencies are not linear, and grow stronger at the extremes.
- **1-in-200 vs 1-in-10 –** Given this lack of linearity, the level of correlation required to generate a reasonable 1-in-200 year Own Risk & Solvency Assessment (ORSA – ICA equivalent) value might well be far greater than that suitable for looking at business decisions based on perhaps 1-in-5-year and 1-in-10-year adverse results; this might mean that the model could not easily satisfy the Solvency II "use test".

5.2. Copulas

This model would be similar in structure to the linear correlation model. However, the restriction that cross-element correlations be linear would be slightly relaxed. A copula-based approach to dependency has the potential to mitigate some issues with a linear correlation model (the first, fourth and fifth bullets above), although it accentuates other issues (the second and third bullets above). Copulas are often proposed as an appropriate way of dealing with tail correlations, and can deal with one-way dependency.

Considerations include:

- **Insufficient data –** There may be insufficient data to select even a single parameter for your selected copula. By allowing a non-linear dependency structure, a copula-based approach does allow a statistician to estimate models that fit the data more closely. This is partly due to an increase in the degrees of freedom of the system of equations to be estimated, and partly because dependence relationships are often somewhat non-linear. There are several classes of commonly used copulas including elliptical, Archimedean, extreme value, and other families such as Plackett and Farlie-Gumbel-Morgenstern. However, as described above for the linear correlation, there may be insufficient data to select even a single parameter, let alone determine which family of copulas might be most appropriate.
- **Transparency –** There is a risk that an end-result user without a solid understanding of statistics could place more reliance on estimates of 1-in-200 year events than should be afforded. This is particularly true when an actuary uses complex statistical machinery where the assumptions are difficult to explain or understand. Many end-users of the results would regard this aspect as the actuary's "black box" in which strange and mysterious things happen. If

the model is not transparent, it is very difficult to raise valid challenges; without challenge the model may miss vital points.

- **Loss of focus –** By employing complex statistical procedures, an actuary could distract attention from the methods that could have a much bigger impact on improving the efficiency of estimates. We suspect that the efficiency of 1-in-200 estimates will be largely determined by the skilfulness of the Actuary-As-Empirical-Bayesian, incorporating external data sources into beliefs, particularly relating to extreme events, rather than the Actuary-As-Frequentist, extrapolating 15 data points in an elegant but ultimately arbitrary way.
- **Challenging –** Estimating systems of equations with a non-linear dependency structure is computationally challenging.

5.3. "Cause & Effect" model

The key here is to draw out a number of "common causes" and correlate loss distributions, reserve risk, bad debt etc through these common causes, rather than to one another. One example is where ICA models are built around a core economic scenario generator; loss distribution for selected classes can be correlated to key economic indicators, along with elements such as investment risk and bad debt.

Considerations include:

- **Incorporating qualitative information –** It may be easier to incorporate information and reasoning outside of the portfolio in question than with a linear correlation or copula-based model. If the skill of the actuary in incorporating this information into a 1-in-200 year estimate is the primary driver of the efficiency of estimates then this method might be preferred over the linear correlation or copula-based approaches.
- **Aids thought process –** Using such an approach forces the actuary to think hard to construct expert beliefs about the nature of uncertainty that the portfolio is exposed to. This is likely to help in the decision of how to extrapolate the available internal data.
- **Potential "causes" –** In order to capture a more complete set of "causes" the model would have to include a number of other aspects, for example a "latent health hazard" generator, a "catastrophe model failure" generator, a "pandemic" generator.
- **One-way dependencies –** There are additional complexities as there may also be some one-way dependencies between the economic factors and major catastrophes or pandemics.
- **Efficiency of estimates –** The limited number of data points for the insurance risk causes the same reliability issues in selecting the level of correlation between the external factors and the loss / reserve distributions.
- **More intuitive –** It is more intuitive than linear correlations / copulas so potentially easier to explain to non-actuaries.
- **Loss of focus –** However, such an approach does not necessarily focus on improving estimates of 1-in-200 year events. If the focus is on improving estimates of extreme events then the modeller should focus on causes that

significantly increase the likelihood of extreme events. This provides the motivation for our next model.

5.4. Multi-state model

Here there are two or more sets of distributions and correlation factors for each of the risk elements of the model. Each set of distributions is associated with an external event or "state", for example a set of economic conditions, a major catastrophic loss, or the emergence of a latent health hazard. For each iteration of the model the first aspect simulated would be the state. This would determine which distribution and correlation set would be adopted for that iteration. The majority of the iterations would be based on the "main" (benign) distribution set, with a smaller number being based on the alternative (extreme) distribution sets.

Examples of "states" that might switch the distribution sets might include:

- Emergence of a latent claim on the scale of asbestos – for example suppose that VDUs are found to cause fertility issues in the offspring of users (note that this is a hypothetical example – no such known link exists!). This might generate huge losses on employers' liability / workers compensation, public liability, products liability etc on the scale of asbestos. It could directly impact reserves, the current underwriting year, potentially cause reinsurer insolvency generating more bad debt and could cause falls in equity markets; indirectly it might cause a huge reduction in productivity as VDUs were taken out of use and a suitable alternative sought, which might in turn cause further falls in equity markets, economic instability, trade credit losses, Business Interruption, D&O and E&O claims etc.

- Catastrophe model failure – for example suppose that the severity of property damage arising from earthquakes with Modified Mercalli Intensity (MMI) of IX or greater is significantly understated. This would generate additional property, business interruption and workers compensation claims beyond those suggested by the modelled output. You could create synthetic catastrophe model output with increased losses as a % of the exposed sum insured for more severe events; alternatively if you are using catastrophe model output that allows you to simulate the secondary uncertainty outside the catastrophe model (e.g. RMS, EQECAT) you could require the simulated event values to be sampled only from the top quartile, say, of the event distribution.

- Major economic catastrophe – for example the Great Depression (1929), the Savings & Loan Crisis of the 1980s, the Credit Crisis of 2008. This latter event has been cited as the cause for more frequent and severe Financial Institutions claims, increased fraudulent claims on classes as diverse as motor and yacht, and most recently even for the increased levels of piracy and kidnap.

- Severe pandemic – for example a pandemic with morbidity and mortality rates similar to the Spanish 'Flu pandemic of 1918-20, which is estimated to have killed 4% of the world's total population (see section 4.4.6 for some examples of the potential GI impacts of a pandemic).

Irrespective of which "state" is selected, the outcomes are still simulated; the state simply switches between distributions for selected elements of the model.

The multi-state model could be seen as an evolution of the "cause and effect" model, but where the actuary's thinking is explicitly focused on extreme events.

Considerations include:

- **Highly subjective but transparent** – We have commented above on the level of subjectivity in selecting correlation factors. For the multi-state model the actuary must subjectively select entire distributions, in many cases without any hard data. However, this approach might, in truth, be little more subjective than methods 1-3. Compared to methods 1-2, this subjectivity has the potential to be transparent, as opposed to being hidden within elegant but highly subjective statistical assumptions.
- **Under-estimation –** the potential for under-estimating of the likelihood and impact of the change in state is significant. Throughout the insurance industry, all risk professionals from underwriters to actuaries to CFOs will tend to underestimate the potential downside of a situation. Examples of this were seen as insurers updated their loss estimates in the wake of WTC and hurricane Katrina. Even though there was a broad consensus on the market loss level at a relatively early stage, insurers continued to revise upwards their own estimates for many months. However, this approach may mitigate this problem more than the other three approaches, as the modeller's mind is focused on extreme shocks.
- **ICA acceptable? –** Given the two points above, will regulators be willing to accept a multi-state model for ICA purposes? If a regulator wished to construct the most efficient possible estimate of a 1-in-200 year probability, it would have to incorporate information from diverse sources, as an Empirical Bayesian statistician would. However, Bayesian methods require more application of judgment than frequentist methods, and a regulator may be uncomfortable in affording this degree of judgment to individual actuaries. However, given sufficient guidance from the regulator about accepted general principles for incorporating wider data sources into estimates, the potential gains in terms of the increase in estimate efficiency may well outweigh the potential risks to the regulator.
- **Solvency II acceptable? –** Again given the first two points above, would such an approach pass the "data" test for Solvency II? Even if regulators are sympathetic to the multi-state approach, they might not have the leeway to accept it as the internal model within the ORSA if they feel the various states are not backed by appropriate levels of data.

5.5. Comparison of Approaches

So which dependency structure is best – well, as always the response must be "it depends". The "Cause & Effect" and "Multi-state" approaches still require the use of linear correlations or copulas. However for "Cause & Effect" the risk distributions are related back to the underlying cause, whilst in the "Multi-state" the key drivers of the interdependencies are being explicitly modelled, and the linear correlations / copulas are mopping up the "residual" dependencies.

In practice, the "Multi-state" might appear too subjective to sit comfortably for many companies. However, we consider it may ultimately prove to be the most appropriate framework - if not by itself, then in conjunction with other methods - for a modeller interested in obtaining the most accurate estimate of 1-in-200 year probabilities within a model that can also be used to give useful results for business decisions that are focussed on a much shorter return period.

The “Cause & Effect” is intuitively appealing to underwriters, and has the benefit of being significantly more transparent and easier to explain to the end users of the modelled output compared to alternative approaches. In practice a model may use two or three of the approaches described above to best capture the complex relationships between the different risk sources.

6. Regulatory Best Practices

6.1. Inclusion of events / scenarios beyond the "1-in-200" in internal models and risk management

One of the motivations for setting up a "1-in-200" GIRO WP is that prudential regulation regarding capital requirements for insurance companies is framed in terms of a 99.5% confidence level. This applies for both current FSA regulation (see INSPRU 7.1.42 and 7.1.49) and the EU wide Solvency 2 regulation (see Article 104 para 4) due to be implemented in EU States by 31 October 2012.

It is important to note, from a regulatory best practices viewpoint, that this regulation is framed in terms of "99.5% confidence level" and not "1-in-200". The implication of this, in the opinion of the WP, is that insurers need to consider estimates of the aggregate distribution of changes in financial resources[1]. Consequently insurers' internal models should not ignore an event because, in the insurer's view, it is beyond "1-in-200".

To understand the possible implications of ignoring the "beyond 1-in-200" events, it may help to think of a situation where stochastic simulation is being used to model changes in financial resources from individual risk categories. In this situation it is not difficult to think up an illustration in where, due to risks being aggregated with some allowance for diversification between those risks, the 99.5th percentile of the aggregate distribution includes a contribution from an individual risk category beyond its 99.5th percentile. If changes in financial resources above the 99.5th percentile are ignored for each category of risk, the 99.5th percentile of the aggregate change in financial resources would be underestimated.

Prudential insurance regulation is not just concerned with the financial resources insurers need to meet regulatory requirements. It also has an interest in insurers' risk management and financial resources needed for insurers' own business purposes. This is particularly so under Solvency 2 (see Articles 35 para 1(a), 41 para 3 and Article 44, for instance). In both these areas, it is the WP's understanding that ignoring the "beyond 1-in-200" events would be viewed by supervisory authorities as not best practice risk management and increasing the risk of insurers underestimating the financial resources insurers need for their own business purposes.

6.2. Role of the "1-in-200" in the management of the business and controls around internal models

The concept of events / occurrences at particular return periods (be it "1-in-200" or any other) have an important roll to play in:

- Embedding insurers' internal financial models into the business,
- Parameterisation of internal financial models, and

[1] One could interpret Article 104 para 4 in Solvency 2 as implying that insurers need to consider separate aggregate distributions of changes in financial resources from underwriting [including reserving] risk, health underwriting risk (if this is applicable to general insurance), market risk and counterparty default risk. However, for the purpose of this paper, regulatory best practice is taken to be that insurers should consider estimates of their overall aggregate distribution of changes in financial resources.

- Validation of internal financial models.

Playing back to relevant areas of the business that the implication of a particular parameter selection is that the internal model is assuming that a reduction in the insurers' financial resources of X from a particular risk is a "1 in N" event can be helpful in getting input from the business on the assumptions to be used in the model or to get a sense check on assumptions in the model.

While internal models can be useful for understanding the dynamics of an insurers business and can be a useful aid for managing the business and making decisions about the business, the uncertainties around results coming out of internal models are well understood and much commented on. Therefore it is important that results coming out of internal models are validated against deterministic stressed events. If an internal model produces a result that an insurer needs financial resources of amount X, it is important to understand what types of, and combinations of, events would the amount X absorb.

Regulators want insurers to be able to withstand extreme adverse yet foreseeable scenarios. As discussed in the definition sections of this paper the "1-in-200" concept is difficult to define. Also what might be deemed as foreseeable changes over time? Regulators will generally expect insurers to consider scenarios:

- Which one might reasonably estimate to occur in the region of once in two hundred years;
- For which a reasonable estimate of the likelihood of occurring in a year is in the region of ½%;
- For which a reasonable estimate of the likelihood of occurring in respect of the business the insurer has carried on and plans to carry on in the coming 12 months is in the region of ½%;
- Which one might reasonably estimate to impact 1 in every 200 units exposed to the scenario; or
- Which have a similar degree of 'extremeness'.

When insurers use deterministic stressed events to assess their ability to withstand extreme adverse yet foreseeable scenarios, or to validate results of an internal model, the regulators will generally expect insurers to justify the deterministic stressed events used in terms of them being at an appropriate level of extremeness. However, the WP believes that it might be helpful to insurers, if aiming for regulatory best practice, to keep this "1-in-200" 'ball park' extent of extremeness in mind, when selecting deterministic stressed scenarios to assess their ability to withstand extreme adverse yet foreseeable scenarios.

For further information see: www.fsa.gov.uk/pubs/other/isb_risk_update.pdf (section 5 page 20)

7. Literature Review

7.1. Past Papers

7.1.1. "Estimating the Tails of Loss Severity Distributions Using Extreme Value Theory" (McNeil, 1997)

McNeil's paper provides a good summary on modelling extreme losses and thoughts on extreme events in general, before proposing a number of solutions. It is also referenced in numerous later documents. The paper focuses on severity – frequency is out of scope. Nor does it consider data dependency (i.e. correlations) or trends.

The paper makes the following points:

- Use the Generalised Pareto Distribution (GPD) to model extreme values (rather than, for instance, Lognormal) - Pickands-Balkema-de Haan Theorem.
- The GPD also fits better than other extreme value distributions (e.g. Frechet, Weibull, Gumbel).
- The Fisher-Tippett Theorem is referred to, and compared to Central Limit Theorem.
- The principal practical difficulty is selecting the appropriate threshold.
- Results are sensitive to the highest actual observed value. McNeil suggests using "stress scenarios" such as excluding the largest value or by artificially adding a new largest value.
- Use all the data points and do not presume any are outliers.
- Can fit GPD using the Maximum Likelihood (ML) method, or the method of Probability Weighted Moments (PWM) etc.
- The tail index is the crucial parameter.
- Still have the problem of parameter uncertainty, particularly that for the shape.

7.1.2. "An Actuarial Index of the Right-Tail Risk" (Wang, 1998)

Wang's paper, which also makes reference to "A risk margin based on a theory of ruin" (Philbrick, 1994), provides some alternative thoughts and suggestions to analysing tails:

- The Right-Tail Risk represents low-frequency and large-loss events.
- Observed by (a) Process Deviation (i.e. highly skewed) and (b) Parameter Risk.
- Proposes a new measure of right-tail deviation as a replacement to standard deviation.
- This approach also utilises the Gini index.

7.1.3. "Modelling Extreme Events" (Sanders, 2005)

This presentation – which is based partly on McNeil's 1997 paper – proposes fitting a separate, second tail to the extreme part of the data. It also suggests using the Power Function as an alternative method.

7.2. Current Thinking

7.2.1. "Our Changing Future – ICA" (McDade / Meldrum / Stevenson, 2007)

This paper comments on the scarcity and sometimes irrelevance of available data, which means it is necessary to apply judgements. It also raises issues such as:

- Calibrating the model.
- Dealing with inconsistencies.
- Tackling correlations and aggregations.
- Consideration of non-linearity.

The authors also suggest replacing the '1-in-200' scenario with a combination of more frequent events, such as two '1 in 15's.

7.2.2. "Report of the Benchmarking Stochastic Models Working Party" (Frankland / Smith / Wilkins / Varnell / Holtham / Biffis / Eshun / Dullaway, 2008)

This paper was presented to the Institute of Actuaries in November 2008 and the Faculty of Actuaries this January. Although the authors work in Life Insurance and consider the modelling of extreme market events such as falls in equity markets or changes in interest rates, their comments also apply to GI.

They found that at the 0.5 percentile outcome over one year, prior beliefs play a critical role in determining the outcome of any estimate since there is not sufficient (relevant) historic data for a pure frequentist approach. Such prior beliefs can be obvious, such as the choice of distribution to fit to data, or more subtle, such as the exclusion of a data point as an outlier. A large estimation error arose when looking at a hundred years of equity data – a much longer series than we have for most asset classes.

Results can also be highly dependent on the choice of data used. The decision over what data is and is not relevant is itself a form of prior belief.

7.2.3. "Thoughts on 'The Black Swan'" (Taverner, 2008) (part of the "Behavioural aspects of risk and finance" presentation)

"The Black Swan" was a book written by Nassim Telab in 2007. This provides a lot of 'food for thought', with the main points being:

- Extreme events are totally unexpected.
- They have an extreme impact.
- They become explainable after the event.
- The perception is that such events will never happen again….
- Games - and therefore models! - cannot represent the true randomness of life.

7.2.4. "The fatal error of Solvency II" (Huerta de Soto, 2008)

This was a paper in "The Actuary" in which the author asks "What does it mean for an insurance company to have a 0.5% chance of going bankrupt? That just one company out of every 200 fails each year? That any one firm in 200 years of existence is only in danger in one of those years? What class of *homogenous* phenomena would permit us to make sense of that 'probability' figure?"

He then comments: "Indeed there is none. Every insurance firm is a historically unrepeatable unique event …. Furthermore, any one insurance company varies from year to year …. We conclude that the figure '0.5% probability of ruin' is a simple metaphor which is bereft of objective and scientific meaning, conveys only the idea that the possibility of ruin 'is very slight', and therefore amounts to the mere manifestation of a subjective desire, the meaning of which varies substantially depending on the observer."

His conclusion is that the insurance industry has "over the last 200 years …. overwhelmingly complied with their obligations and survived wars, economic and social crises"; and therefore Solvency II could have the opposite and undesired effect of making firms complacent.

7.2.5. "To VaR or not to VaR?" (Rowe, 2009)

This opinion piece comments on Value at Risk being an element of Solvency II. In the author's view, "VaR created a false sense of security among senior managers and watchdogs. For much too long many were prepared to use the sloppy shorthand of calling VaR the "worst case loss" …. VaR says nothing about what lurks beyond the 1% threshold."

Therefore the author opines that VaR does not adequately measure exposure to extreme events. His proposal is to use the "stress-testing trident"; i.e.:

- Simulate the market's greatest disasters.
- Define and then stress the most serious current vulnerabilities.
- Use imagination based on social, geopolitical and economic inputs to formulate plausible crises for investigation.

7.2.6. "Emerging Risks Agent Survey" (Lloyd's, 2008)

Lloyd's issued a questionnaire that stated the following risks / scenarios should be considered:

- Climate change
- Nanotechnology
- Pandemic
- Genetic modification
- Inland flooding
- Information/digital risks
- Valuing of natural infrastructure
- Global positioning system (GPS) failure

- Carbon sequestration
- Electromagnetic Fields (EMF)
- Political security
- Obesity
- Energy insecurity
- EU Environmental Directive
- Asset value collapse
- Economic uncertainty / recession / depression
- Middle East Instability
- Terrorism