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# A Framework for Estimating Uncertainty in Insurance Claims Cost

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## Abstract

This document discusses alternative approaches to the estimation of uncertainty in insurance claims costs and application in the determination of risk margins for insurance liabilities under current Australian prudential regulation. In determining the distributional form of current estimates of future insurance claims liabilities, we discuss the difficulties of a purely quantitative approach and the strong role of actuarial judgement in deciding appropriate assumptions.

The approach currently in most common usage contains internal limitations, which in practice may not be recognised unless actuarial judgement is tempered by sound analytical techniques. In particular we note the inherent unsoundness of estimating central estimates and variances through separate processes, and correlations (and hence covariances) separately again.

We conclude that the role of judgment needs to be more appropriately formalised and to proceed from estimating the uncertainty originating from the actuarial models and data (model specification error), the risk of unforeseen trends or shifts in business performance (future systemic risk) and the ordinary insurance process uncertainty (independent risk). This implies that the approach must be **specific to the modelling techniques being used**, and be applicable to the **current insurance risk environment** (internal and external).

A suitable approach blending qualitative and quantitative risk assessment methods is proposed and an appropriate framework developed for the purposes of practical application. We develop a methodology for both product group distribution estimation and inter-product group risk aggregation which proceeds from a uniform view of the risks.

In the authors' view, the approach satisfies the criteria of being forward-looking, transparent, and specific to the current risk environment and the techniques used. It has the desirable qualities of, firstly, promoting alignment in the methodologies used for central estimates and risk margins; secondly, of providing through repeated application a consistency of view in changing risk environments; and, thirdly, promoting the use of a control cycle by incentivising improvements in modelling and in the accuracy and accountability of business risk evaluation.


*Keywords: insurance liabilities; valuation; risk; uncertainty; risk quantification*

# 1 Introduction

This paper is about estimating the distribution of outcomes for a portfolio of insurance liabilities. It is not concerned purely with the regulatory and financial reporting of those liabilities. Nevertheless, in Australia at least, there can be no doubt that the progress of actuarial science in this difficult area has been propelled by the regulatory reforms of 2002, and by subsequent changes to Australian actuarial professional standards, and are being given a further fillip by forthcoming changes to accounting standards for financial reporting of general insurance liabilities.

We begin with a quote from a paper presented by one of the authors to the 10th General Insurance Seminar, 10 years ago:

> "..there is nothing particularly special about the central estimate [of insurance liabilities]… Any actuary who derives a central estimate is making implicit assumptions about the underlying [claims] distribution, whether he appreciates this or not. Any factor which shifts the distribution or changes its shape affects the central estimate just as much as the 75% or 90% sufficiency points… because all depend on the same phenomenon – the underlying distribution." O'Dowd (1995)

Recent changes to actuarial, regulatory and accounting practice reinforce the need to be consistent in the treatment of first and later moments of claim costs. Accounting concepts relate to determining the *value* of assets and liabilities. IAS39 has recently reaffirmed "fair value" as the basis (in principle) for insurance liability valuation, and its Draft Statement of Principles (DSoP) requires this to reflect risk and uncertainty, in the form of a "market value margin"[1]. The UK GIRO Working Party on IAS39 recently discussed the issues facing actuaries in developing appropriate actuarial approaches to meet IAS39 requirements:

> "Traditional actuarial valuation techniques are also found wanting in providing a method to meet the requirements of the DSoP. These techniques do not readily allow for objective assessment of margins in reserves. …Whatever approach is used, transparency and the ease with which a method may be audited will be key criteria. Any approach that constitutes feeding results into a black box, understood only by the originator, and taking the results produced, is unlikely to be suitable for statutory reporting purposes." Clark et al (2004).

Actuarial approaches to distribution estimation have been documented for some considerable time, not least by many Australian actuaries, and this paper owes a debt to those actuaries, most notably Dr. Greg Taylor, Ben Zehnwirth and Robert Buchanan. Ultimately, however, we have not opted for a purely quantitative approach to the problem, for the simple reason that the most significant causes of model error are essentially unquantifiable. Instead we have supplemented the available *quantitative* arsenal with *qualitative* approaches to risk assessment which have developed strongly in recent years, generally outside of insurance.

In this paper, we examine current actuarial approaches and reach the view that, due to the slowly evolving nature of actuarial thinking in this area, commonly-used approaches represent a "grab bag" of inconsistent development and piecemeal thinking.  The result is a fragmented "bottom-up" approach which risks losing sight of the ultimate aim – to estimate the **aggregate** loss distribution of a licensed insurance entity.

If we were to apply the "man from Mars" test to current methodologies, how could we reasonably explain that means, variances and covariances are all estimated using entirely separate methodologies, some almost entirely subjective, and internally inconsistent with each other?  Could we, for instance, demonstrate consistency and mathematical orthodoxy in our treatment of possible skewness in the distribution as it affects our central estimates, risk margins and adopted correlations between classes?  And why do our professional standards become increasingly prescriptive in terms of single-product loss estimation, while remaining silent about their aggregation into a portfolio estimate?

Against these considerations our profession applies an armoury consisting largely of our actuarial judgement, supplemented with quantitative approaches which provide little illumination on underlying past risks, let alone their relevance for the future.

A framework to bring greater consistency and transparency of methodology to bear is entirely appropriate.  It is our hope that this paper is a significant step in the right direction.

# 2 Commonly-used Risk Margin Methodologies

A "risk margin" in general represents the difference between the "best estimate" of an insurance liability and the "value" at which that estimate is reserved or otherwise reported. More precisely, in the Australian environment, the risk margin is a value, higher than the mean, selected as a percentile of the underlying claims distribution. Australia is somewhat ahead of overseas actuarial practice, which is currently also being propelled to consider the same issues by proposed reform of international accounting standards. This is because Australian practice has been aligned closely with the general nature of these reforms since the early 1990s.

This paper started out as a potential survey of risk margin approaches used in Australia. After an informal internal survey within our actuarial firm, it transpired that only a narrow range of methods are used in any actuarial work we have sighted through our actuarial or audit work. These current approaches can be generalised as follows:

1. Decide upon appropriate "product groups" for which risk margins will be individually determined;

2. Determine the "coefficient of variation" (CoV)[2] for each product group, and assume the shape of the distribution to derive an ultimate outstanding claims cost distribution;

3. Determine the "diversification benefit" between product groups, applied through a product group correlation matrix[3].

4. Repeat steps (2) and (3) for Premiums Liability, establishing further assumptions about correlations between Claims Liability and Premiums Liability.

The earliest application of this approach has been traced to 1994, though its origins have never been formally presented and discussed by the actuarial profession. Instead it seems to have spread by a form of osmosis. It is fair to say it is still a robust methodology if its limits are appreciated and if practical application adheres to certain constraints imposed by those limits.

Some of the limiting assumptions are obvious, for example that all product groups have distributions of similar shapes, that these shapes are those that are tractable mathematically (eg. all normal or lognormal, the latter being far more common) and that inter-product interactions can de described through a simple linear correlation. Other limiting assumptions, which we discuss later, are not so apparent and are frequently ignored in practice.

The difficulty in calibrating this model, not the limits of the model itself, results in actuarial judgement playing a large role in deciding the risk margins that are adopted. We believe it is also the reason the model has not been developed beyond its current limited horizons.

The calibration of this model depends substantially on two papers commissioned by APRA and the Institute of Actuaries of Australia (IAAust) in late 2001. These papers were in response to new regulatory requirements effective from 1 July 2002 with specific reference to risk margins. The benchmarks established in these papers – in particular Bateup and Reed – continue to be significant in industry determination of appropriate assumptions for CoVs and correlations.

Application of this methodology – and in particular the calibration of the assumptions – is now described in more detail.

## 2.1 Determination of Common Product Groups

The determination of ultimate claims cost distributions and diversification benefits needs to be done using consistent product groupings. The two most common approaches are:

- Use many relatively homogenous groups, such as individual valuation classes.
- Use major lines of business that may incorporate different legislative regimes and other portfolio characteristics. For example all workers compensation business may be grouped together and this may incorporate different State legislative regimes.

In theory the two approaches should of course provide the same risk margins both by product group and in aggregate.

- The former approach (many groups) should entail higher levels of claims cost variation within groups (as measured by higher CoVs) and higher diversification benefits (measured by lower correlation coefficients).
- The latter approach (fewer groups) implies lower levels of claims cost variation within groups and lower diversification benefits (higher correlation coefficients) between groups.

In practice, limitations in quantification techniques and in risk aggregation approaches mean that differences and inconsistencies emerge. The practice of benchmarking CoVs across broad class groups and the general difficulties surrounding correlation estimation, both undertaken without taking the granularity of the group definitions into account, means that the final risk margin can vary unacceptably because of the groupings used[4].

In short, determining a product grouping involves marrying the conflicting objectives of homogeneity in selection and ease of parameterisation. It might be thought that actuarial methodologies would have evolved to assist with the problem of classifying products into groups by virtue of their inherent risk characteristics, to derive an optimal number of groups and differentiation of risk characteristics. Instead more approximate approaches are universally adopted. It is a subject that has received little actuarial attention.

## 2.2 Determination of Product Group Outstanding Claim Cost Distribution

Coefficients of variation (along with an assumed shape of the distribution and the mean or central estimate) allow the assumed claim cost distribution by class to be determined. It should not be forgotten that these assumptions are merely conveniences and the desired end result is the underlying distribution of claim cost outcomes.

There has been some investigation of the benefits of separating each product group into systemic and independent CoVs. This has considerable virtue as (by definition) correlations should only occur between systemic components of risk. However the calibration problem is made more complex using this approach since many of the accepted quantitative methodologies do not clearly separate systemic and independent sources of error.

There are typically many inputs into the process of determining ultimate claims cost distributions. Some of the inputs into the process may include:

- **Quantitative Techniques**

  Analysis of company data using commonly accepted methods such as Bootstrapping or the Mack method[5].

- **Measurement of past loss reserving variability.**

  This is intuitively appealing, as it has the virtue of measuring past instances of the future phenomenon we are trying to estimate. It is especially useful for shorter tail classes of business where multiple near-independent observations can be used for statistical analysis. However companies typically have poor data history in this regard, not helped by significant industry consolidation in recent years.

- **Benchmarking against industry analysis.**

  Bateup & Reed recommend a formula to determine a CoV based on the size of a portfolio and the class of business, and Collings & White recommend ranges of CoVs based on the size of a portfolio.

  Care is generally required in relating these back to individual company experience. For example, the workers compensation benchmarks in Bateup & Reed include data from NSW WorkCover and the VWA. These workers compensation schemes have different claim characteristics to a typical commercial insurer portfolio and the benchmarks should therefore be treated with caution.

  There is also the difficulty that the benchmarks were determined using the quantitative techniques set out above, which means that they not surprisingly produce very similar results, and have the same limitations.

None of the above techniques have been applied completely successfully in practice. Shortfalls to existing quantitative techniques can be summarised as follows:

1. Bootstrapping is technically complex and the technique fails, as with any other methods, if assumptions are not satisfied. For example, the residuals are not independent and identically distributed or the assumed underlying process is different from the actual process. These violations arise if the chosen reserving model does not fit the data well.

2. Because of the complexity involved, bootstrapping is commonly applied to simple reserving models where lack of goodness-of-fit can almost be taken as a given. This results in poor or wild estimates of CoV and, in general, it can be expected the CoV will be overstated.

3. The bootstrap technique also does not capture all *potential* risk factors as it only incorporates risks that have eventuated in the past. Hence it is not necessarily a good guide for the future.

4. Similar comments to (1) to (3) can be made in relation to the Mack method. For Mack, it is difficult to determine an appropriate distribution. Most implementations use simple models such as chain ladder which would not be used in practice in setting reserves.

5. Logically the model to be used in any quantitative analysis should be the actual reserving model. Even the earliest papers setting out quantitative techniques stress that both the first and second moment should be investigated using the same reserving model, since results are model-dependent[6]. It is possible to bootstrap any model given time and effort – however the economic cost of bootstrapping the complex models used in practice would be prohibitive.

6. Assuming that the reserving model is bootstrapped, these quantitative techniques only give information on 'ordinary' levels of claim variability, as they only model residuals from the model fitted values. A good model fit should explain all past systemic influences, leaving residuals that are independent (appear random) in nature. The model does not provide any information on the probability that the model may be systematically incorrect either due to incorrect model specification or the 'future being different from the past'[7] For most long-tail classes these systemic factors may be far more significant than normal independent variation.

## 2.3 Calculation of Diversification Benefit

### *2.3.1 Inter-product group correlations*

The allowance for diversification benefits across different product groups remains an area of continuing development. The general approach is to create a correlation matrix between product groups. The formation of a correlation matrix between different classes of business is difficult to calibrate because it is difficult to measure with limited information. This is one reason why some companies keep the approach reasonably simple and use high level product groupings.

In determining an inter-class correlation matrix consideration is usually given to:

(a) The proportion of independent risks (which are fully diversifiable) versus systemic risks (which may or may not be diversifiable).

(b) First principles reasoning, giving consideration to both direct causes of correlations (such as catastrophe events, legislative environment, and economic inflation) and indirect causes of correlations (such as reliance on company data systems, company management practices, use of similar actuarial modelling techniques).

(c) Benchmark correlation matrices. Two views on correlations between major classes of business are given in Bateup & Reed (2001) and Collings & White (2001). Bateup & Reed (2001) have created a formula for the expected diversification discount based on size of portfolio, the number of lines of business, and the coefficient of concentration of liabilities. This can be used as a broad check on the results.

One common practice in the industry is to separate correlations into "High/Medium/Low" classifications using the above analysis as a guide. Standard coefficients (eg. 75%, 50%, 25%) are attached to high, medium and low categories respectively. In others, coefficients for the most important correlations are determined uniquely.

Over the past few years correlation coefficients have been increased by many insurers. It is becoming unusual for zero correlations to be adopted for the majority of classes (ie. those largely unrelated to each other). This is generally justified on the grounds that some risks, for example economic inflation link most classes of business indirectly. Importantly, however, when deriving correlations from first-principles reasoning we have found very little *analytical* sense-testing of the derived correlations.

Correlations adopted tend to be higher than can be observed in the loss data. This is often rationalised as the historic record not containing enough observations, or as an allowance for tail correlations (eg. extreme loss scenarios, catastrophes etc.). Not enough work has been done on determining whether these differences are reasonable.

### *2.3.2 Inter-entity correlations*

No standard approach exists regarding whether the risk margin established at group level should make allowance for diversification benefit arising between licensed entities of the Group. Similarly, where this **is** allowed for, there is no common approach on whether this inter-entity diversification benefit should be allocated to Group, individual entity or individual class level.

## 2.4 Application to Premiums Liability

### *2.4.1 CoVs for Premiums Liability*

Both the 2001 papers establish general multipliers between the CoVs adopted for outstanding claims and those adopted for Premiums Liability. These multipliers vary by class between 1.25 and 1.75 (Bateup and Reed) or 1.3 to 1.5 (Collings and White). In practice, the use of such multipliers is common, and very little analytical work on premium liabilities has been carried out.

In general terms the use of a multiplier can be justified as a practical means of allowing for the 'expanding funnel of doubt', whereby many risks associated with the liabilities are perceived to carry a time dimension, and thus vary directly or indirectly with the time to run-off. For example, superimposed inflation (and claims inflation in general) is clearly directly time-dependent.

However this 'funnel of doubt' is appropriate to homogeneous units of risk separated only by time – for example the claims incurred in two accident periods. Allowance needs to be made for the different aggregation of these units implicit in the outstanding claims and premiums liabilities. For a long tail class, outstanding claims may aggregate the bulk of claims over many accident periods, whereas premiums liabilities for annual premium business is restricted to four accident quarters. There is no 'rule of thumb' that we can readily discern that allows multipliers to have much validity without independent validation, and our testing has shown the multiplier to be very sensitive to the payment pattern of the outstanding claims run-off, even between similar classes of business.

The use of a multiplier is even less defensible where the Premium Liability contains additional sources of uncertainty, such as for example the risk of natural catastrophes, not present in the outstanding claims liability. In the presence of such risks the distributional forms of the Premiums and Claims liabilities may of course be entirely different.

### *2.4.2 Correlations for Premiums Liability*

While practice varies, the inter-product group correlation matrix for Premiums Liability is generally assumed to be similar or identical to that for Claims Liability. This is inconsistent with the different risk aggregations represented by the run-off pattern of the claims liability and the exposure pattern of the Premiums liability.

It is also necessary to adopt a correlation between Premiums and Claims Liabilities for each product group. This is generally assumed to be very high, even 100%. Clearly such correlation assumptions represent further simplification of the problem of substantiating the distributional form of the liabilities.

## 2.5 Sensitivity and Consistency Testing

### *2.5.1 Sensitivity analysis*

It is common practice to apply sensitivity analysis to key assumptions which underlie the risk margin calculations, including:

- Assume CoV's are increased or reduced by a fixed percentage amount or ratio.
- Test against the benchmark CoVs and correlation coefficients in aggregate.

- Assume a multiple of the current correlations across the product groups.
- Assuming a minimum correlation across product groups.
- Test diversification benefit sensitivities by eg. stepwise including or excluding classes of business (or entities) and altering correlation coefficients.

This allows the key assumptions of the overall risk margin to be determined. Quantitative techniques can then be focused on these areas.

An interesting topic not often pursued is how to apply sensitivity analysis below the level of simply flexing the model assumptions. Product-level sensitivity analysis is often undertaken (as required by professional standards) but only rarely is this properly meshed with the approach to risk margins. More often it is used to inform generally on the potential variability of individual product group central estimates, and hence on the CoV. The major difficulty is the lack of any probability estimates to associate with individual estimate sensitivities.

### *2.5.2 Use of Benchmarks*

We have referred above to the widespread use of the benchmarks in the Bateup and Reed and Collings and White 2001 papers as reasonableness tests for the adopted CoVs and correlation assumptions. There is a tendency to regard the estimates in these papers as minimum rather than (as their authors intended) best estimate assumptions. This is perhaps one of the inevitable dangers of benchmark use, rather than a conscious preference.

In addition we have seen a number of cases in practice where there has been a misapplication of the benchmarks. To provide two examples:

1. The Bateup and Reed "multipliers" (ratio of Premiums Liability CoV to outstanding claims CoV) are based on the "independent and systemic variances determined for the net outstanding claims liability, but based on the size of the net premium liability". We have seen many insurers base their multipliers on the size of their outstanding claims liability. This can have the effect of overestimating variability, compared to the benchmarks, for very short tail business (where premium liabilities can be much greater than outstanding claims) and underestimating variability for the longer tail business (where premium liabilities can be much smaller than outstanding claims).

2. We have seen CoV comparisons between portfolios being made in raw terms, ie. without appropriate adjustment for the size of the portfolio being compared. Bateup and Reed provide a mechanism for the combination of systemic and independent CoVs, with the latter dependent on portfolio size.[8]

In short, even with due care in application, we consider benchmarking to be best used to prioritise areas for further investigation or explanation, and do not regard it as appropriate to use as the primary determinant of risk margins.

### 2.5.3 *Historic claims reserving variability*

Notably lacking in the 'accepted' approach is any concerted attempt to measure past variability in loss reserves. This absence is quite startling, given the general modelling principle that one should measure past instances of that which one is trying to estimate.

The quantitative approaches outlined earlier generally do not use a past history of claim reserving variability. In fact, most use current data only, and so lose much of the history of reserving instability as well as evidence of past data errors which contribute to the reserving problem. As such there is a risk of mis-statement of the CoVs as well as method-bias in the 'bottom up' CoVs and correlations.

This is perhaps an illustration of how much of the past record of loss reserving has been lost through recent industry consolidation; alternatively perhaps it is deemed irrelevant on the grounds of continual change in actuarial and other reserving practices. However it is difficult to justify the observed absence of any current attempts to rectify the situation going forward. The reserving history, and the data on which it is based, continue in many cases to be archived and lost (to all intents) for useful analysis.

Our investigations for this paper have found the analysis of historic claims reserving variability to be informative, particularly for short tail classes, where successive valuations are based on near independent cohorts of outstanding claims[9]. For long tail classes, successive valuations deal with strongly correlated cohorts of outstanding claims and the reserving processes may contain similar judgmental bias. Even so, the past reserving error – and analysis of the reasons therefore – form the starting point for future considerations.

### 2.5.4 *Integrity of covariances*

We note that there is scope under current approaches for CoV and correlation assumptions to be mutually inconsistent. This arises primarily because central estimates, CoVs and correlation coefficients are pursued through separate and inconsistent methodologies, with successively higher levels of subjective judgement being applied. Instead, the process needs to be regarded as steps toward a single set of covariances[10].

Secondary considerations relate to the common assumption of non-normality of the distribution. Embrechts et al (1999) demonstrates that joint risk distributions cannot be properly described through two CoVs and a correlation coefficient, and correlations between -1 and +1 are not achievable once non-normality is assumed. Overleaf is an illustration from that paper. "Sigma" denotes, in our terms, the ratio of the two CoVs, assuming a lognormal distribution. For example if the CoV of one risk is double that of another, the maximum correlation possible is about 0.6, and the minimum -0.1. Thus the range of acceptable correlations is greatly constrained.

The problem, illustrated with regard to two lognormal risks, becomes far more profound when applied to the joint distribution resulting from 20 (or more) distributions.

In addition, Embrechts points out that, as the correlation approaches the maximum, the two lognormal functions become increasingly closely mapped such that, at the maximum, one is a simple, though not necessarily linear, function of the other. It requires considerable bending of the mind to see how insurance run-offs could be made to satisfy this condition. For example, classes with greatly different run-off patterns would be highly improbable candidates for their distributions being functionally related, since much insurance risk is accepted to be time-dependent.

Figure 1 Applicable range of correlations for two lognormal distributions

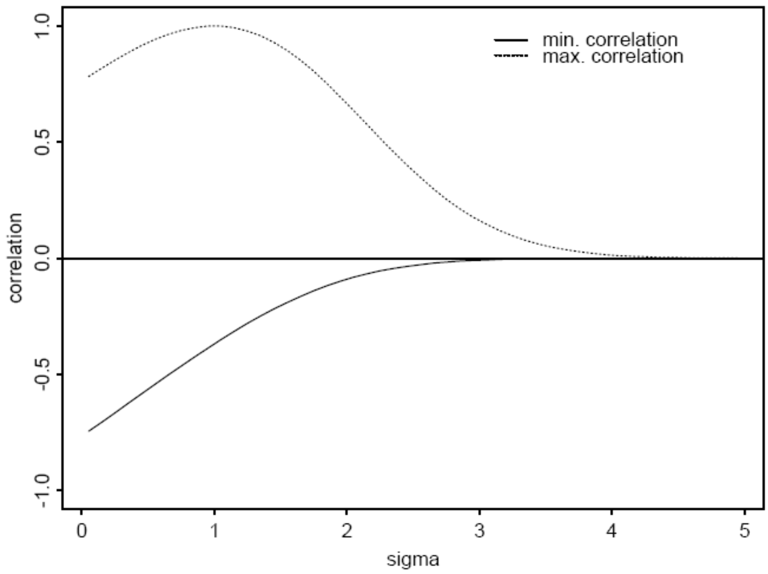



Figure 2: Maximum and minimum attainable correlations for lognormal risks $X_1$ and $X_2$, where $\log(X_1)$ is standard normal and $\log(X_2)$ has mean zero and variance $\sigma$.

While this provides strong ammunition to argue that correlations should be very modest, Embrechts points out “we would, however, be very wrong in leaping to the conclusion that this means the dependence is very weak”. Actuaries may leap on this as justification for their approach (ie. that the correlation matrix paradigm is a substitute for a more complex approach involving assumptions of tail dependence). This however is not necessarily how the paradigm came about, or how it is generally presented.

### *2.5.5 ‘Top-down’ reasonableness checks*

To control the problems illustrated in the last two sections, it would be instructive to measure CoVs for higher level product and entity groupings, and carry out quantification methods on these higher level groupings as a form of check on the bottom-up methodology. Otherwise there is a strong risk of cumulative bias through the bottom-up methodology.

One simple approach would be to measure historic variability in claims reserves on a bottom up and top down basis, as a broad check on the risk aggregation methodology. However this sort of approach is not in common use. This could be for the simple reason that the individual ‘bottom-up’ distributions are not themselves derived from or calibrated to the historic record, so it is unlikely that the aggregation of multiple such classes can be successfully benchmarked using the same record.

This seems to be a shame. We believe that any proposed measure of future claims experience should ideally be reconciled to the historical record. Even if we can legitimately assume that "the future does not equal the past", and even though prediction error may allowably exceed the historically recorded reserving error, we contend that these assumptions should be explicit – as is common practice for other actuarial basis assumptions like superimposed inflation. Otherwise it is very difficult to demonstrate the reasonableness of the actuarial basis.

## 2.6 Summary of Problems with Current Approaches

The determination of risk margins has historically been an area of tremendous subjectivity. Little consistency has been achieved because attempts at a rigorous quantitative approach result in subjectivity in interpretation of results, and the results cannot be replicated at a later date when additional loss data is added. Actuaries may, as often we do, have hit upon a reasonable result by a mix of a little science and a lot of judgement. However, we are concerned that the science, as commonly expressed, would not withstand outside scrutiny.

The following list summarises the issues we have identified with the standard approach – ie. estimating CoVs for each product group and then combining these using a correlation matrix:

- The use of a CoV and correlations approach necessarily limits the distributional forms that can be modelled.
- The limitations of quantitative techniques for estimating CoVs, set out in Section 2.2 above, mean these can only reliably measure independent causes of error.
- There is no suitable method for estimation of dependence without impractically large quantities of hard data.
- Separate approaches to the determination of means, variances and covariances leads to the absence of any over-arching framework describing how insurance losses can relate to each other, for example how catastrophes can affect the results.
- With reference to Figure 2 above, the CoVs and correlations adopted may result in a non-attainable distributional form for the aggregate risks.
- There is limited analytic rigour applied to measuring uncertainties and the resulting CoVs with respect to premium liabilities (Section 2.4).
- There is a lack of consistency in the treatment of diversification benefit within complex corporate structures (Section 2.3).
- There is a lack of elementary controls in the approach to ensure consistency in assumptions over time, due to the judgemental nature of the assumptions. This may lead to either undue volatility in risk margins over time, or more plausibly to the lack of responsiveness to emerging experience.

- There is a general lack of transparency and accountability, leading to the impression that risk margins are derived through ‘black box’ approaches that bear little resemblance to reality.

- Independent review of risk margins is not readily achievable with any intellectual rigour, since so much of their basis is either unexposed or is expressed in terms of flawed science.

These are serious and substantial issues. We have therefore sought out an approach which allows the framework to be more transparent and defensible.

## 2.7 Alternative Technical Approaches

In this section we briefly consider methodologies which have developed outside of the insurance space, mainly in the fields of capital management and risk quantification in industrial companies and in banking. We discuss these in terms of risk aggregation.

### *2.7.1 Risk identification and quantification*

Under the Basel II Operational Risk Advanced Measurement Approach (AMA), banks are adopting approaches to model operational risk, with scenarios and subjective risk assessment being employed, that is broadly similar to our proposed risk margin approach discussed later in this paper. Insurance risk has a much better basis for quantification than operational risk. Nevertheless, operational risks make a major contribution to insurance reserving risk (model risk is itself an operational risk), and some insurance risks do not have good quantitative foundations – for example, most of the risks we gather under the collective label of ‘superimposed inflation’.

For that reason it is interesting to note the different paths down which risk quantification for insurance risk and operational risk have proceeded, despite the following similarities:

- A combination of high-frequency, low-severity and low-frequency high-severity losses.
- Available data on low-severity losses, but little data on high severity losses.
- The uncertainty disproportionately resulting from low-frequency, high-severity events.
- Quantification requiring the combination of a multitude of risk categories and business entities.
- Complex and little-understood inter-dependencies, especially in tail losses.
- Rapid change in the risk environment.

There are also of course many differences between insurance and operational losses. Insurance covers defined losses whereas operational losses can spring from anywhere and are not constrained in terms and conditions. In the current context operational risk probably represents an extreme case of the types of problems commonly grappled with in the insurance risk context.

Actuaries have persisted with the ideal of full quantification, essentially brushing aside the essentially non-quantifiable nature of large low-frequency losses, the role of internal and external systems and processes and so forth. Operational Risk modellers have pursued an approach firmly fixed on qualitative techniques using risk diagnostics of the processes under examination. In the banks, this is now being more firmly embedded in an over-arching quantitative framework through development of the methodology required for Basel II AMA accreditation.

To constrain the magnitude of the task, banks have concentrated on assessing their key risks only, taking a top down approach, and building in controls to the risk identification process to ensure that no risks are missed, and that risks are ranked appropriately. Again, this contrasts with the bottom-up approach to insurance risk margins, where the risk aggregation model is 'bolted-on' to a line-by-line valuation process.

Approaches to quantify operational risk must deal with the very limited use that can be made of the historic record. As such, a clear delineation emerges between risks that can be regarded as within the historic experience and those that lie outside this experience. By excluding the latter risks from scope, the former can be quantified and assessed against the historic loss range. This allows limited sense-checks to be performed against the historic record. We have hitherto noted that such checks are not commonly performed in determining insurance risk margins.

As a final note of contrast, we note a fundamental diagnostic used by operational risk models - the "Key Risk Indicator" (KRI) - which is used to try to bring some measure of accountability and continuity to the risks introduced by the processes being examined. An essential piece of the puzzle (and one still to be satisfactorily solved by operational risk modellers) is the link between KRIs and the top-down quantification of risk. Early work on KRIs has been less than convincing, at least to the eyes of actuaries. However, much current work is focusing on improving the granularity and the predictive ability of KRIs.[11]

Actuaries, on the other hand concentrate on statistical models in which independent variables form the predictors of outcomes. These models are very high-level – for example the Payment per Claim Incurred (PPCI) model predicts claim payments using numbers of claims notified and claim payments from earlier periods. While these allow broad estimates of expected outcomes to be derived, they do not "attach to the process close to the risk". Closer examination of the processes underlying the risks is required to develop KRIs for insurance liabilities.

### *2.7.2 Risk aggregation*

Our experience, and our understanding of current literature, suggests two approaches are being taken to addressing the main problems of risk-based capital models.

1. The first, which we might describe as "measure risks singly, then aggregate," retains the same basic modus operandi of the correlation matrix approach, but seeks to employ more advanced techniques. For example, rather than using correlation matrices to combine risks, leading banks are adopting methods based on copulas[12]. Such methods can be and are applied in insurance also, and there is some literature on the topic. The

main difficulty with the technique lies not in adopting a copula-based framework, but in estimating the relationships precisely enough for a particular copula to be adopted with any degree of certainty. The calibration problem is not therefore improved by the simple abandonment of the correlation framework in favour of an even more difficult alternative.

To assist with this difficulty, the basic technique is improved by employing better techniques to develop the underlying loss distributions. For example, in credit risk various analytical and simulation-based approaches are used to develop loss distributions that better reflect the non-normal nature of credit portfolio losses. Fundamental to these is a characterisation of the dependency within the portfolio – for example the Basel II capital standards are based on a single-factor model. We consider that these methods might helpfully be applied in improving insurance loss distributions for particular product groups, but are not sure they would help in combining distributions across classes unless an appropriately descriptive risk framework can be found.

2. The second method we have seen might be described as "identify systematic risk factors, and simulate collectively". This approach accommodates both subjectively-assessed risks like that described above and macroeconomic risks factors such as interest rates, unemployment, etc.We have applied an approach where the underlying causes of potential cash flow variations are identified, and the relationships between them mapped and modelled. For example, a particular risk (economic, social, environmental etc.) may impact two business units. Rather than incorporating this risk factor into the distributions developed separately for each business unit, and then seeking to combine them by estimating a correlation, it is more sensible to simulate the aggregate distribution, in which case the dependency induced by the common risk factor is automatically correctly captured. In an example like this the dependency may not be linear, and correlation will thus be a poor way of describing it. For actuaries, the concept of producing the shape of the dependence relationship from an underlying model is intuitively appealing, and we consider this type of situation as likely to arise in the insurance context.

Examples of methodologies which reduce the need for correlation assumptions includes the following:

(a) Using higher-level product groupings (eg. all Workers' Compensation classes), effectively making correlations between sub-classes implicit in the results.

(b) Where common causes of uncertainty exist – for example, economic inflation, or catastrophe risk – these could be explicitly modelled in the framework across all affected portfolios. This would require a portfolio-wide approach to generating distribution assumptions.

(c) Searching for and isolating possible causes of correlation and attempting analytically to assess their contribution to the aggregate risk margin (as the approach described in Section 2.3 ((b) above attempts to do judgementally).

# 3 Ten Guidelines for Risk Assessment and Aggregation

This leads us to propose 10 guidelines in the construction of risk quantification and aggregation frameworks.

## 3.1 General Guidelines

1. Methodology for consideration of the moments of the claims cost distribution should be consistent.

2. Methodology should be consistent across product groups, transparent and replicable.

3. Changes in methodology over time should be motivated by and result in improvements in terms of these guidelines.

## 3.2 Risk Assessment

4. All the appropriate risks should be included – for our purposes that is any source of variation in the underlying claims run-off compared with the actuarial reserving model.

5. The approach should be forward looking, but controlled through analysis of past risk events.

6. It is acceptable to concentrate on quantifying major contributors of risk only, scaling the results to accommodate the contribution of minor risks. As a corollary, while it is important that all contributors of risk be identified, it is less important that they should all be quantified.

7. The methodology should use a range of techniques to provide some verification of results and reduce subjectivity where possible. Quantitative and qualitative methodologies should both be used where they have strengths, but the methodology should be consistent across classes.

8. Changes in results over time (eg. in CoVs) should be related to changes in observable risk phenomena, either internal to the model risk or in external business risks.

## 3.3 Risk Aggregation

9. The framework should give analytic justification and explanation for dependency assumptions.

10. There needs to be top-down reconciliation of the results of bottom-up risk aggregation.

# 4 A Proposed Risk Margin Framework

Our proposed framework combines statistical analysis with qualitative information on individual portfolios, and derives relationships between portfolios, through a risk identification and evaluation process.

We believe that by making the ***process*** rigorous and consistent, the analysis, though subjective in terms of assessment, will yield results that will be reproducible and change over time consistent with the risks of each portfolio. The aim is not to replace actuarial judgement so much as to make it transparent and accountable.

In addition we note that these objectives are entirely consistent with:

1. the requirements of the draft Independent Peer Review standard,

2. the direction taken by the Draft Statement of Principles of IAS39, and

3. the requirements of risk-based Financial Condition Reporting.

## 4.1 Overall Risk Framework

We require a rigorous framework to identify and quantify all risks which contribute to variability in insurance liability reserves. Our framework consists of separate components for the **quantification of risk** for product groups (Section 4.3 to 8), and **risk aggregation** across product groups (Section 9). Both components, however, use the same information provided on risk identification and assessment.

## 4.2 Past work on risk quantification

Past work has concentrated on quantitative approaches to measuring the prediction error of single actuarial models. A risk quantification framework is represented by the work described in a number of papers in the 1980s by Dr. G.C. Taylor and others. In Taylor (1988) the model prediction error is considered to originate from components termed specification, selection, estimation and statistical error. This framework is well represented in current use, though the terms have changed somewhat – specification, parameter and process error being common.

The concept of risk as being divided into “systemic” and “independent” components is also common, but has seen relatively little development, and is not well integrated with the above quantification approaches.

Although quantitative development has continued through to the present, little work has been done on the error structure and, in particular, the roles of subjective judgement and future systematic departures from past experience.

Subjectivity is present in all actuarial models. For the quantitative approaches described above, subjectivity is restricted to the choice of an appropriate model structure and the choice of parameters, and various methods can be used to reduce (but not eliminate) this subjectivity. "Traditional" methods (ie. simple triangulation methods such as PPCI or Payments per Claim Finalised [PPCF]) take less stringent approaches to both of these areas and include greater subjectivity.

Further error is however introduced (for all models) by the future insurance process, including the possibility of both systemic and random variation from model predictions. Actuaries use subjective approaches – such as "superimposed inflation" SI) to allow for future systemic risk.

We have uncovered very little research into the possible systemic sources of variation – past (in the form of model selection and parameterisation) or future (in the form of systemic process risk), which we consider surprising in view of its importance.

In a well-fitted model, the prediction error estimated by the quantitative approaches described above will relate to:

1. ***independent parameter risk*** and

2. ***independent process risk*** – ie. normal past and future random variability, and

3. ***systemic parameter risk*** **-** an element of specification error introduced by past systemic factors which have not been recognised in the model selection and parameterisation steps. However this element of specification error will not be correctly treated (it may appear to be random as the model fitting process is designed to produce error terms which are independent and unbiased and have an appropriate distributional form).

The following sources of error will not be quantified by standard approaches:

4. ***model specification risk*** resulting from subjectivity in model selection and parameterisation, and

5. ***future systemic process risk*** resulting from future claim trends being essentially unpredictable.

With this reconciliation of the quantification framework into systemic and independent categories, we proceed in the next section to a simplified framework.

## 4.3 Product Group Risk Quantification

Our risk framework within product groups breaks risks down into independent and systemic components:

Table 1presents a summary of the framework:

Table 1: Components of Future Claims Cost Estimate Variability

| Source of risk | Description | Effect on Claim Cost Estimates | Proposed Measurement approach(es) |
|---|---|---|---|
| ***Independent risk*** | | | |
| **Parameter risk** | The model construction is an appropriate representation of reality. However independent variability in the past data results in volatility in calibrating the model. | Volatility in past data results in "up and down" movements in liability between valuations, even though the inherent process may not be changing. | Formal quantification approaches (eg. bootstrap)<br><br>Informal analysis (eg. sensitivity analysis)<br><br>Examination of historic reserving error (during stable times) |
| **Process risk** | The model construction and calibration is a perfect representation of expected outcomes. However the future insurance process will result in volatility relative to these perfect expected outcomes. | Insurance will always result in variable outcomes, no matter how accurate our models[13]. | |
| ***Systemic risk*** | | | |
| **Model specification risk** | The model is an imperfect representation of a complex real-life process, introducing unknown bias into the model | An actuarial model assumes the level of claim payments is related to a relatively simple set of predictors. In reality the process is considerably more complex. | Qualitative assessment of risk of the actuarial estimation process |
| **Future Systemic risk** | Assume a perfect model representation of reality, as it exists today. Trends in loss outcomes may result in outcomes moving systematically away from current realistic outcomes. | Trends in claim frequency, trends in levels of claim settlement (superimposed inflation), changes in accessibility of common law benefits in statutory schemes. | Qualitative risk identification, assessment and quantification<br><br>In certain cases, informal analysis (eg. sensitivity analysis) |

The simplifications introduced in this framework are as follows:

1. independent parameter and process risk can be measured together (separate measurement is also possible, but not generally informative),

2. systemic parameter risk, which is in any case mistreated by current quantification approaches, is included in model specification risk.

This framework admits of a certain elegance, with systemic risks intrinsic and extrinsic to the actuarial modelling process being quantified through separate qualitative approaches, while independent risk (with some simplification as discussed above) can be quantified using existing actuarial quantification approaches.

It is of course necessary to combine the estimates of systemic and independent risk into a single aggregate risk estimate for each product group. This can be achieved in a number of ways. We describe one approach – using simulation, in Section 8.

Simulation allows this aggregation (by risk type within product group) to be carried out simultaneously with the aggregation across product groups, retaining maximum information regarding the risk distributions. The risk aggregation framework across product groups is described in more detail in Section 9.

Central to this structure is the tenet that **the systemic risk categories contain all potential causes of inter-dependence between product groups**. The use of a qualitative risk identification and evaluation already implies this – we are not restricted to measuring the risks which we can observe in past data. A risk which may (or may not) materially add to the volatility of the estimates within each class, but which creates inter-dependency, can and should be included as systemic in nature and included in the identification and assessment process. An example might be risks associated with a data system which provides actuarial data for multiple product groups.

The next sections of this paper (Section 5 to 7) describe possible quantification approaches to independent risk, model specification risk and future systemic risk respectively.

# 5 Independent risk

The preceding discussion on existing quantification approaches noted that a well-fitting actuarial model will "factor out" past systemic risk events through, for example, the addition of suitable terms to a regression model. Any measurement techniques based on the residuals of such models will adequately measure independent parameter and process error.

We consider the inclusion of the distorting factor resulting from systemic parameter error to be bearable in this context. We reason that actuarial techniques have progressed to the point where systemic factors will be missed from our models generally where they are currently developing, in other words, will be prevalent along the later diagonals. The error so introduced will be spread over all observations (for example if bootstrap is used, residual sampling occurs randomly over all observations). This understates the prediction error associated with systemic parameter risk.

Statistical procedures to estimate parameter and process error are well documented in Taylor and Ashe (1983) and Taylor (1988). More recent examples using more generalised modelling approaches are England and Verrall (2001) using GLMMs and Taylor and MacGuire (2004) using GLMs. Where blends of models are used, further calculation is required since the model weights will in most cases further reduce parameter variance (see Taylor (1985)).

Application of these techniques to modern reserving models is complex, because modern reserving models are complex. The cost-benefit may be questionable however, since independent risk is readily diversifiable across portfolios, and in the presence of significant systemic risks, its *marginal* contribution to the overall CoV is greatly reduced[14].

Independent risk can be reliably modelled by a combination of the following approaches:

1. **Formal modelling** as above eg. by bootstrapping *the actual reserving models*.

2. **Informal modelling,** through sensitivity analysis and simple time series analysis of variation in claim costs.

3. Measurement of **historic reserving variance**, excluding periods affected by past systemic risk 'episodes'.

The relative sophistication of the techniques used should depend on:

- the significance of the product group in terms of its contribution to the overall risk margin,

- the robustness of the actuarial modelling techniques used, in terms of the availability of unbiased estimators of loss,

- the relative significance of model specification and systemic risk, and

- the cost of applying formal quantitative techniques.

It is to be hoped that the cost of formal quantification techniques, now quite expensive, will reduce as familiarity increases and technology progresses. In the meantime, for the general case where independent risk is not a major contributor to aggregate risk levels, we briefly describe two techniques, both requiring judgement, for assessing parameter and process error respectively:

(a) Independent parameter error can be assessed by **weighted sensitivity analysis**, taking advantage of the fact that such analysis is routinely carried out as one of the requirements of Australian professional standards. Determination of the key assumptions, the sensitivity bands and the weights used to combine these assumptions into a single estimate depend on the class of business and the model used. Generally it is a straightforward exercise in analysing the actual reserving model used and applying actuarial judgement, remembering that we are concerned only with 'normal' volatility and can ignore any uncertainty resulting from uncertain future trends. Judgement is required to produce sensible combinations of sensitivity assumptions to assess overall model sensitivity to random variation.[15]

    For example, for a PPCI model the claims reporting pattern, payment pattern and average claim size can be flexed between normal boundaries to examine the combined effect on the liability. The absence of any probabilistic framework for the sensitivities requires judgement to be used in adopting a CoV.

(b) Independent process error can be measured by **accident period time series analysis**, in which historic levels of cost volatility for each accident period are examined, using actual outcomes as far as possible (so discarding more recent accident periods which depend largely on the actuarial model projections). Variations around general trends can be described, for example, using simple random walk models. Applying run-off payment patterns to the resulting time series model can provide an estimate of process error close to those produced by more formal modelling. In addition this process can be used regardless of the formality of the model adopted.

    The major simplifying assumption made is that process error is non-heteroscedastic, especially in the tail.

    By way of example, the actual random volatility in past accident year average claim frequency and claim size can be used to develop a useful proxy for the process error in a PPCI model. It should be noted that systemic risk needs to be removed either by selecting the past period carefully, or by fitting a trend line including the influence of past systemic effects. The 'random walk' described by variation in past accident period average claim frequency and size is then applied to the claims reporting and run-off pattern to produce the estimate of process error for the run-off.

# 6 Model specification risk

We have considered three major causes of model specification error, namely:

- **A Mis-specified Model**: how close is the model to actuarial best practice, given the data available.
- **Extent of business knowledge**: how well does the model respond to ongoing changes within the business, and how well informed is the actuarial process about these changes.
- **Data Quality**: the influence of poor data quality or the lack of availability of desired data.

For model specification risk a partly qualitative approach is proposed, informed by metrics developed around risk indicators. A number of diagnostic and quantitative tools need to be developed to properly implement the process. In applying these we:

1. Examine risk indicators for each risk category in the table below,
2. develop a balanced scorecard, and
3. apply a scaling factor to the total balanced score to derive an estimate of model specification error.

Table 2: Model Specification Risk Qualitative Assessment

| Risk | Risk category | Potential Risk Indicators |
|---|---|---|
| **Mis-specified Model** | General Modelling Approach | • Number of independent models used<br>• The range of results produced by the models<br>• Checks made on reasonableness of results<br>• Confidence in assessment of model 'goodness of fit'<br>• The number and importance of subjective adjustment factors in the models<br>• Extent of monitoring and review of subjective assumptions |
| | Availability of predictors of claim cost | • Best predictors have been identified through data investigation even if they cannot be used in model<br>• Best predictors are the same over time / change due to claims process change<br>• Time taken for best predictors to stabilise/ develop to maturity |
| | Value of predictors used | • The predictors used are close to the best predictors<br>• The predictors used lead rather than lag claim costs<br>• Development of the predictors is modelled rather than subjectively allowed for |

| Risk | Risk category | Potential Risk Indicators |
|---|---|---|
| | | • The predictors used have been subject to systemic shifts or trends in the past |
| | Detection of trends | • Performance of the models in detecting development of trends in key cost indicators (exposure, claim numbers, claim mix, claim costs)<br>• Stability, sophistication, performance of superimposed inflation (SI) diagnostics<br>• Uncertainty in SI (or other future trend) assumptions |
| | Ability to re-model | • Availability of unit record data<br>• Perceived value of unit record data<br>• Flexibility of data specification to change |
| **Inadequate business knowledge** | Dependence on business stability | • Reliance of predictors on stability in internal processes (eg. claim closure rates)<br>• Extent of 'invariant see-saw' effects and behaviour of model in response |
| | Extent of business knowledge | • Level of stability or instability in past business processes affecting the predictors<br>• Extent, timeliness, consistency and reliability of information obtained from the business |
| **Data errors and limitations** | Data quality and controls | • Data is subject to assessment and quality control<br>• Data processes are robust and replicable<br>• Incidence and severity of past mis-estimation caused by data revision<br>• Assessment of severity of current data issues on key predictors |

## 6.1 Risk Indicators

The exact risk indicators used depend on the results of the diagnostics, and can probably not be generalised. Central to the evaluation is the concept that the actuarial model is a predictive model of future experience, and that an important part of the model function is early detection of trends in that experience, as well as the ability to see through movements in the predictors which are caused by ordinary variations in business processes.

Standard actuarial models (ie. those that use triangulated data and broad fitting methodologies) do not generally perform well in the presence of possible trends. The predictors used are commonly payments, numbers reported and finalised and case estimates, which share one or both of two difficulties: either they are so general as not to greatly predict claims cost stresses, or they do not lead the independent variable (claim payments) being modelled. In addition the broadness of the analysis means that predicted values are thrown out by even slight changes in management processes (for example a slowdown in claim finalisations).

Models can be developed using lead indicators which may be qualitative indicators of claims progression (for example, qualitative assessments of claims potential carried out by claims managers). While these are generally preferable to crude high-level predictors, the qualitative nature of the indicators, the need to regularly update them (since they tend to be progressive in nature over the life of a claim), and the complexity they introduce to the models tends to make assessing the potential improvement to the process a challenge.

## 6.2 Balanced scorecard and scaling factors

In applying this framework we have opted for a simple “balanced scorecard” which rates the existing techniques against an idealised best practice. To convert this to a CoV, scaling factors (upper and lower limits on the CoV) are required. These factors require care in development. Firstly, balanced scorecards are notorious for minimising the range of results produced across different portfolios (for example, a scorecard based on scores ranging from 1 to 5 may only produce a range of 2.5 to 3.5). Secondly, there is no obvious way to separate observed past variability into that intrinsic to the actuarial process and that caused by systemic influences external to that process, and the two may well be correlated. Acceptable scaling factors can only be developed with experience.

We applied a number of analyses, across a range of portfolios (we grouped these into long-tail and short-tail) as past circumstances vary so widely across lines of business. These included:

- The variance estimated from the broad quantitative techniques of Section 2.2 above, for example Mack and bootstrap. Though we eschew these models for quantification of risk, their very broadness, and the confusion of systemic risk effects and independent risk effects introduced, means that the measures calculated may represent a close-to-worst case result. Further information can be gleaned from applying these models over successive periods and studying the variability in the CoVs produced. Independent risk (which can be measured from better-fitting approaches) can be ‘backed out’ of the measures produced.

- The standard deviation of independent model sub-estimates (for example separate PPCI, PPCF and Projected Case Estimate [PCE] estimates). This provides an estimate of prediction error if an actuary applies only one of these methods rather than a blend of the three. Especially when produced using simple ‘black-box’ methodologies, this may also represent a reasonable worst case result.

- Measuring ‘hindsight’ error of broad black-box models calculated at past valuation dates.

The actuaries’ own past experience and judgement is essential to the process. Past systemic events will distort the record but their effect is generally known in hindsight and with some care they can be backed out from the reserving error detected.

# 7 Future systemic risk

As noted above, the existence of systemic effects in the past data makes the modelling process more difficult. Once observed and rationalised, however, sophisticated modelling techniques can readily exclude these effects from forward estimates. However, there is no accepted approach to estimating the quantum of future trends which could emerge, or even the extent to which a presently observed trend may continue.

Actuaries allow for this, in central estimate estimation, through interviewing business experts, conducting ad-hoc analyses on metrics other than the predictors used by their models and so forth. In most cases, a logical rationale for their assumptions can de derived and the uncertainty caused by reliance on this rationale ascertained in very broad terms (for example through developing and estimating alternative scenarios). In some cases, the model predictors can be directly stressed to produce an expected future outcome (for example, participation in common law for workers compensation claims). In most cases, however, a large part of the allowance is usually wrapped up in very general assumptions such as ‘superimposed inflation’, which can be regarded as a general catch-all for systemic effects.

This allowance in the actuarial estimate is an aggregation of systemic influences which:

(i) are occurring but cannot be detected (due to one or more risks associated with model specification error);

(ii) are occurring and have been detected, but whose future extent cannot be readily predicted;

(iii) may occur in the future but cannot yet be foreseen, though general causes may perhaps be surmised.

As will be readily noted, the first of these sources of uncertainty has been addressed in model specification error, inter alia through assessing the value of the predictors used in the model and making an allowance for the potential failure of the model to detect trends.

The other sources of systemic risk need to be firstly identified, then quantified. We follow a three stage process:

1. ***Risk identification*** is performed by mapping future business processes and interviewing business experts on potential internal and external influences.

2. Before quantification is attempted we interpose an intermediate stage of ***risk categorisation***, to simplify the quantification process and to allow correlations between classes to be more readily assessed at a later stage.

3. **Quantification** uses qualitative assessment techniques and scenario development, followed by simulation.

## 7.1 Systemic Risk Identification

For risk identification, it is useful to consider a framework in a form which mirrors the business functions, from pricing through to claim incidence, settlement and recovery. In estimating the extent and likelihood of future trends under each heading, it is important to keep in mind that it is the significance of the risk factor to the actuarial process, and not to the business, that is being assessed. Nevertheless coverage needs to be exhaustive, in order to ensure that all candidates for quantification are identified.

We adopt a framework which follows the insurance process, from pricing through to settlement and recovery. These headings can be used to identify the main risks applying to the business.

Table 3: Systemic Risk Identification Framework

| Risk | Description | Potential Risk Diagnostics |
|---|---|---|
| **Pricing** | Accuracy of Pricing | How often rates are reviewed<br>Risk of anti selection / extent of cross-subsidies in rates by class |
| | Pricing strategy | Any deliberate pricing strategies<br>Competitor actions |
| **Underwriting** | Delegated Authority | Appropriateness of authority levels given to underwriting staff<br>Extent to which agencies bind business on behalf of the insurer |
| | Policy terms | Changes in policy terms and conditions |
| | Distribution channels | Changes in distribution arrangements / mix<br>Effectiveness of monitoring and reporting by distribution channel |
| | Control Processes | Extent and effectiveness of controls to ensure adherence to underwriting guidelines<br>Staff turnover impact on underwriting decisions |
| **Claim Incidence** | Exposure monitoring | Extent and effectiveness of monitoring of exposure mix |
| | Claim frequency | Level of understanding and consensus regarding current outlook for claim numbers.<br>Extent to which current trends are monitored and explained.<br>Significance of external factors such as weather patterns (home, motor, CTP), OH&S trends (Workers Comp) etc. on recent and future experience |

| Risk | Description | Potential Risk Diagnostics |
|---|---|---|
| **Claim Reporting** | Claim Notification Processes | Changes in claim notification process and flow-on effect to uncertainty in reporting patterns (eg. change in call centre operations).<br>Causes of / effectiveness of resolution for any backlog in the processing of claims notified<br>Claim cancellation – stability and effectiveness of process<br>Effectiveness of monitoring around claim notification and cancellation. |
| **Claims Settlement** | Case Reserve Estimation | Changes in case estimation philosophy or processes |
| | Authority Levels | Effectiveness of monitoring the appropriateness of authority levels given to staff and use made thereof |
| | Staff Turnover | Effect of staff turnover on the efficiency of the claims management process |
| | Internal Management Processes | Have there been any changes in the claims management process that may impact the speed of payment, the quantum of claims, the numbers finalised, reopening activity etc |
| | Settlement processes | Effectiveness of and trends in judicial awards, medical assessments, external claim settlement mechanisms |
| | External parties | Changes in contractual arrangements or cost trends in external contractors (eg. smash repairers, legal costs) |
| | External costs | Trends in direct claim costs eg. spare parts, building materials, medical costs |
| **Recovery** | Third Party | Changes in third party contractual arrangements (eg. salvage) |
| | Reinsurance | Level of understanding of operation of contract<br>Monitoring processes around recoveries<br>Counterparty risk |

We assume knowledgeable experts in the business are available and co-operative. A systemic risk assessment questionnaire and subsequent discussions with business experts can provide a good foundation for identification of product group risks and are also a useful tool to better understand current (and future) business processes.

Discussions with business subject matter experts need to follow appropriate qualitative assessment techniques, to identify "red herrings" and to prevent too much focus on business risks which do not significantly affect the actuarial process. It should also focus on the separate effects on outstanding claims and premium liabilities, where these may be different.

These discussions with the business should focus on identifying and quantifying significant *external* risk influences that may include (but are not limited to):

1. Experience arising from legislative change that is different to expectations as well as new legislative changes.

2. New sources of potential claims, including latent diseases.

3. Changes to regulation that may have an impact on ultimate claim outcomes.

4. Changes to the economic environment. For example changes to interest rates, inflation rates and exchange rates directly impact valuation results. Other indicators such as the unemployment rate, car accident rates, and tax changes may impact on the volume and quantum of claims.

5. Legal precedents or decisions that may significantly impact claims outcomes.

In addition a range of *internal* factors will need consideration – for example issues emerging from the internal claims management process. Process Key Performance Indicators (KPI's - not to be confused with KRI's) may need to be examined and performance issues discussed.

Not surprisingly most of the uncertainty in the claims liability estimates is likely to manifest itself in the claims settlement phase. The following figure shows our experience of where the risks are generally sourced, split by outstanding claims and premium liabilities.

Figure 2 Insurance Process and Sensitivity Assessment


| Process | Sensitivity of Outstanding Claims Liability | Sensitivity of Premiums Liability |
|---|---|---|
| Pricing | Generally low | Low unless loss ratio methods used |
| Underwriting | Low, unless exposure mix changed in last year | |
| Claims Incidence | Low (IBNR only) | Moderate |
| Claims reporting | Moderate – distortions in patterns due to process change | |
| Claims Settlement | High | |
| Recovery | Generally low, unless comprising a large portion of the liability. | |

## 7.2 Systemic Risk Categorisation

We have found the methodology is assisted if highly correlated risks are combined together for estimation purposes. Another way of saying this is that risks are classified into different generic risk classifications that are then assumed to be independent of each other. Table 4 has a listing and explanation of some of the categories of risk that we have encountered.

Table 4 Future Systemic Risk Categories

| Category | Description | General comments |
|---|---|---|
| **Economic, Social and Environmental causes** | Inflation and other social and environmental trends. | Risks are generally long-term in nature and of moderate influence on liability risk. |
| **Legislative and Political risks** | Effect of known (actual or potential) change and unknown or unforeseeable change. | Varies depending on level of known change in product group. Unknown future change is generally a low risk. |
| **Process Change risk** | Relating mainly to the claim reporting process (including cost estimation) and finalisation processes | Generally a low contributor except for shorter tail classes, where process change is expected but overall effect on costs is difficult to evaluate. |
| **Claims Inflation risk** | Causes of shifts or trends in overall levels of claim settlements (superimposed inflation in average claim size). | The biggest contributor to risk for long-tail classes. |
| **Claims Expense risk** | Relating to claim handling expense only. | A very small contributor to overall risk. |
| **Event risk** | Risks relating to future and very recent past events (severe storms, catastrophes) | Relevant to premium liability for short-tail classes, particularly Home. Occasionally relevant to outstanding claims liability. |
| **Latent Claim risk** | The risk of claims resulting from risks not currently deemed to be covered by the policies written. | Relevant for some accident compensation schemes (especially Workers' Compensation and public liability) Not considered very likely for other classes. |
| **Recovery risk** | Reinsurer default and or risks to non-reinsurance recoveries. | Generally considered to be low likelihood, though (for reinsurance) potentially high severity if it occurs. |

The risk categories in Table 4 are intended to be largely independent of each other, although we note that there are circumstances where this independence may be breached. In these circumstances we have found it useful to combine risk categories for measurement purposes.

## 7.3 Quantification of Systemic Risk

The overall contribution of systemic risk events in the past can of course be determined, and used as information or as a control on the techniques described below. However, the approach we describe is 'forward-looking', whereas formal quantification can only ever be backward-looking. We consider professional and regulatory standards require a forward looking approach. Actuaries routinely make judgements about the future, at least implicitly, in determining some aspects of the deterministic central estimate basis. Our framework helps to provide transparency in the use of this judgement.

### *7.3.1 Qualitative assessment and rank-order*

It is likely that a long list of possible causes of future systemic uncertainty can be drawn up, many of which are potential future possibilities and not known and identified current concerns. It should be recognised that any distributional assumptions for the former are far more approximate than for those where concerns already exist. At a certain point the marginal contribution of the smaller risks becomes inconsequential, and further quantification is of little value, given the overall level of uncertainty in the process. To control the process around this 'stopping point' it may be appropriate to first attempt an informal ranking of risks by perceived severity.

This is in fact a useful technique at the end of the risk identification workshop discussions, and serves to marry the informal business knowledge with the need for a more formalised actuarial approach to quantification.

### *7.3.2 Formal Quantification*

As a general rule, only a small number of risks identified are suitable for quantitative modelling. Examples are:

- Economic risks such as inflation, interest rates
- Event risk
- Some social risks which may relate to long-term trends in claims costs (eg. trends in motor vehicle usage)

For most classes of general insurance, these risks explain only a small part of the total contribution for systemic risks. For specialist classes, quantitative techniques may be of greater overall usefulness[16].

Events that give rise to extreme variation in claims outcomes can be expected to fall outside of the probability of adequacy either required by APRA or booked in the insurer's accounts[17]. These events cannot however be ignored in building an understanding of the entire distribution of claims outcomes, on which the central estimate relies.

### 7.3.3 *'Fuzzy quant' approaches*

For the general run of systemic risks we apply qualitative measurement using controlled scenario analysis. It is already common for actuaries to construct scenarios around the severity and duration of a particular trend or event. Examples could be of potential outcomes for a very recent weather event, a recent change in legislation or more prosaically simple shifts or trends in claims reported or in payment patterns. However to allow for appropriate treatment of these scenarios in the assessment of risk margins it is necessary to apply them inside a probabilistic framework.

We derive the probabilistic framework from the qualitative assessments conducted with business subject-matter experts. This paper does not present in depth the means used to derive this framework, which is amply covered elsewhere (for example, in approaches to KRI identification in Basle II AMA). However we consider there is ample scope for actuarial skills to contribute. For example, to illustrate the effect of a claim settlement mechanism breaking down, alternative severity outcomes can first be addressed with claims management personnel, then by building pictures of key business metrics under these alternatives, a qualitative probabilistic context can be derived. Generally, discussion centres not on "doomsday scenarios" but on how quickly remedial action could be applied, and how effective it could be.

Views of business management on the effectiveness of risk controls need to be rigorously tested through appropriate discussion, and aligned with outcomes of internal risk management reviews. This will generally involve bringing in skills outside of the actuarial profession.

Where immediate potential for uncertainty in future claim trends cannot be identified, there is still the need to allow for the effect on the distribution of claims outcomes. Examples could include management intentions to change future claims management procedures or proposed new legislation that can affect claim outcomes. Another example may be in asbestos portfolios where a wide range of future systemic uncertainties need careful consideration from medical and other subject matter experts.

Timing of risk incidence may need to be considered as it plays a critical role in determining the contribution of each risk to the overall systemic risk variance. For example, recent legislative changes often go through a 'honeymoon period' and uncertainty about how long this might last (and not just what the final outcome in settlement levels might be) can be critical to the overall systemic risk.

# 8 Aggregate Product Group Distribution

A standard approach for aggregation would be to assume each risk is distributed according to a standard distribution (such as a lognormal or normal) and aggregate upwards using standard statistical techniques based on the properties of the chosen distribution.

We chose an alternative method - stochastic simulation. This has the advantage of not requiring any restrictions on specific probability distribution to be used for any risk factor. It allows for many of the risks to have non-specific or even non-continuous forms. It allows the effects of reinsurance to be modelled more precisely, or alternatively, discrete distributions may be used to capture important extreme outcomes (eg. incidence of catastrophe events). Stochastic simulation techniques also have the advantage of allowing you to explicitly model correlations *between* product groups, as detailed in Section 9.2.

A key advantage to this approach is that it retains all the distributional information. Accepting that the result is only indicative in view of the judgement applied in the framework, the distributional shape is still useful in assessing the validity of the aggregation methodology applied.

As noted earlier, the resulting aggregate product group distribution needs to be examined for overall reasonability. We found it productive to regard past systemic events as examples of changes in internal and external processes and use them as a guide for where weaknesses may arise and with what severity. Sensitivity testing (for example assessing the reasonableness of the marginal contribution of each risk component) is also an important tool in assessing the final result.

# 9 Diversification benefit

## 9.1 Sources of Inter-product Group Relationships

For proper understanding and consistent treatment of relationships between product groups it is important (in our view) for the rationale for pre-supposing correlations be properly determined, even if attempts at formal measurement are unlikely to be successful. The following construct is used to formalise the problem:

Table 5 Sources of Product Group Inter-dependencies

| Cause of Product Group Inter-relationship | Description | Potential modelling approach |
|---|---|---|
| **Economic, social and environmental causes** | General economic inflation<br><br>Economic growth or general social trends (eg. litigiousness)<br><br>Class-specific trends eg. growth in vehicle numbers, passenger numbers, property values etc.<br><br>Long-term weather trends or cycles | Include as future systemic risk factors (or model spec. risk factors) in product group calculations but quantify across all classes at once.<br><br>This stratified modelling approach would typically use a layered stochastic simulation approach whereby the layers would include the risk factors identified (including a root dependency variable for each risk factor), the product groups modelled and the type of liability valued (outstanding claims or premium liability).<br><br>This approach is technologically more complex since it implies risk margins have to be evaluated simultaneously across all product groups.<br><br>However, the benefits are that correlation and/or diversification benefits can be explicitly identified and measured as a direct output to the process. |
| **Extreme events** | Catastrophes | |
| **Specific systemic risks** | Though generally rare, examples might be judicial precedent affecting multiple common law schemes | |
| **Coincident systemic risks** | Coincidence in claims cycle caused by eg. recent tort reform affecting multiple states, but with different timing/effect | |
| **Modelling risks** | Using actuarial valuation models with similar characteristics | |
| **Data risk** | Using data with similar defects, eg. from a shared IT system | |

In short, it appears to us that the root cause of major inter-relationships between product groups can be expected to be identified by the qualitative analysis of model specification and future systemic risks set out in preceding Sections of this paper. Hence the similarity of the left hand column of the above table to the risk categories in Table 2 and Table 4. Between these two latter tables there are 11 sub-components of systemic risk. The approach used to identify and model potential dependence between product groups is described in the remainder of this section.

## 9.2 A Stochastic Approach to Modelling Diversification Benefits

At first sight it seems unpromising to start with 11 sub-categories of systemic risk for each product group. If we have 10 product groups, that provides 12,100 potential correlations. This hardly seems in line with out stated intention of controlling and reducing explicit correlation assumptions.

Recall, however, that:

1. The 11 sub-categories have been determined as being reasonably independent of each other. (In applying this framework we identified potential dependence in two cases. Combining the relevant categories reduced the number of categories to 9)[18].

2. Model Specification Risk has been calibrated by reference to past worst case performance, removing the contribution of future systemic risk. Consequently, correlation between Model Specification Risk and Future Systemic Risk is already implicitly allowed for.

We consider that this renders inter-risk category dependence relatively insignificant, and for calculation purposes it is ignored. This assumption needs to be tested for relevance in each application of the framework. For 10 product groups, it reduces the number of potential correlations to 900.

### *9.2.1 Correlations within individual risk categories*

The framework described in Sections 6 to 7 above enables us to identify potential risk dependence for systemic risk categories between product groups. For example, a single claims management team may manage claims across multiple product groups. This may cause correlation in a number of systemic risk categories associated with the "claim reporting" and "claim settlement" stages of the insurance life cycle. As always, study of appropriately constructed scenarios can assist in illustrating the potential effect of this correlation, compared with the assumption of independence. This obviously coincides with the scenario analysis already conducted for quantification of Future Systemic Risk.

Given the unlimited number of potential risks in each risk category, we need a way to control the calculation before it becomes too unwieldy and "black box"-like. Since 900 correlations is still a lot to consider, our approach categorised correlations between categories into High/Medium/Low buckets, based on:

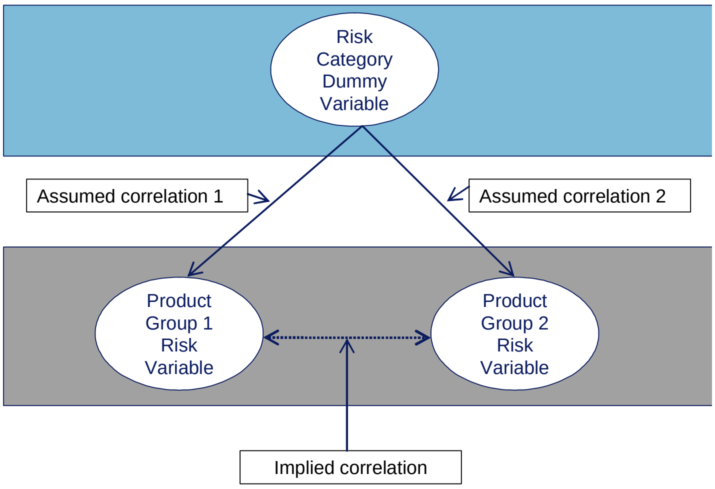
1. In-depth quantification of the individual risks, where the cell is (potentially) a significant contributor to diversification benefit, and

2. Qualitative judgement otherwise.

We have found it is usually clear which of these techniques to apply in individual cases, with quantification required in only a small minority (< 1%) of possible inter-relationships.

The way we choose to model these relationships uses a framework of one-way correlations and stochastic simulation. An example of such a correlation method is shown below.

Figure 3 Schematic Representation of Correlation Method




A "dummy variable" (per Figure 3) is set up for each risk category. Conceptually, the dummy variable can be thought of as the root source of correlations within the risk category concerned. For example, for Economic Risk, it may be the result of general economic inflationary pressures. For Event Risk, it is the frequency and severity of events, which affect more than one product group. These however will not be perfectly apparent in the claim costs for individual product groups, where (for example) the effect of economic inflation will be filtered through a combination of geographic, social, structural and other relationships. For example, inflation in a Western Australian Workers Compensation portfolio will differ from that in a Queensland Compulsory Third Party portfolio due to the influence of wage outcomes in each state, the different benefit structures and settlement mechanisms of the two schemes and so forth.

A random outcome for each risk category dummy variable is generated for simulation. Random outcomes for that risk category are then generated for each product group, where the outcome is correlated with the appropriate risk category dummy variable. This results in an "implied correlation" (terminology as per Figure 3) between product groups.

We recognise that the adoption of specific values for the High/Medium/Low correlation groupings is a subjective process. However, it does enable correlations to be directly modelled and attributed back to their root source. As such this is a distinct step in the direction of accountability and transparency, compared with current practice (which frequently requires a High/Medium/Low assumption for the two product groups as a whole). Sensitivity analysis on these assumed correlations can be used to determine "reasonable" ranges of ultimate correlation.

We believe that this methodology gives a more robust framework for calculating diversification benefits, because:

1. It reduces the sensitivity of the results to a single correlation assumption.

2. It allows correlations to affect the distribution directly at relevant probabilities (for example, event Risk correlation only affects the tails of the aggregate distributions).

3. It allows general reasoning for correlation existence to be supplemented by quantitative analysis of its potential magnitude.

Our experience with this structure has shown that it is very difficult to achieve correlations as high as those commonly adopted in practice between different product groups. The principal reason for this is that systemic impacts are likely to affect different classes to different extents and even then at different points in the future run-off, unless there is an underlying shared process. **Significant correlations between product groups as a whole are associated with shared systems and processes.** This is of course exactly as implied by Embrechts et al (1999) – refer to Section 2.5.4 and Figure 1.

Time dependence is also a mitigant, especially for long-tail and short-tail interrelationships. With 90% of a typical short-tail class paid within about 12 months, even a short timing delay in the incidence of a shared risk will greatly reduce the potential correlation.

# 10 Premium and Claims Liabilities

## 10.1 Within Product Groups

We have noted the common use – purely on intuitive grounds – of a 'CoV multiplier' to convert CoVs established for the Claims Liability for application to the Premiums Liability. In addition, the correlation between Claim and Premium Liabilities within product group is assumed to be very high, even 100%.

It is important, to ensure reasonableness and consistency, that some rationale be established as a replacement for purely subjective intuition. The latter is based on conceptions around:

- the almost identical risks to which both components of the technical liabilities are subject (a major exception being catastrophe risks, which do not affect the Claims Liability),
- the extended timeframe of the Premiums Liability making it inherently more uncertain due to the 'expanding funnel of doubt', ie. the time value of risk , (a major exception being latent claim risk, which affects Claims Liability to a greater extent than Premiums Liability),
- the additional risks to the valuation result for Premiums liability, being a dependence on additional data (eg. exposure data) and in many cases on the pricing function of the business,
- the more approximate modelling approaches commonly taken to Premiums Liability, in many cases being based on extrapolating output (such as claim frequencies or loss ratios) of the Claims Liability, and
- a relatively consistent assumption concerning the ratio of premium liabilities to outstanding claims liabilities.

In our view, there is nothing in this list that is not addressed – at least better than is currently the case – by the qualitative approaches to model specification and future systemic risk outlined earlier. For the latter it is informative to consider whether a particular risk 'attaches' in the context of all business already written or in the context of future exposure only.

Accordingly we encompass the linkage between Claim and Premium Liabilities within product group using the framework developed for model specification and future systemic risk. These allow an appropriate multiplier and correlation assumption to be determined.

## 10.2 Inter-product Group Correlations

In terms of inter-product group correlations, the typical current approach is to assume similar or identical correlation matrices for inter-product group correlations under both Claims and Premiums Liabilities.

This can cause technical difficulties – for example, since it is reasonable to assume that the Premiums Liabilities are more volatile than Claims Liabilities, it would be unusual for them to exhibit identical correlations. This would imply a higher level of systemic risk for Premiums Liabilities, all else being equal.

It must be appreciated that many of the causes of a higher CoV for the Premium Liability – for example more approximate modelling techniques, or the existence of catastrophe risk – predispose the Premiums Liability to ***lower*** correlations than equivalent correlations for the Claims Liability.

Only where there is a common cause – for example simultaneous underpricing across multiple product groups, combined with dependence on a loss ratio methodology – can equal or higher correlations be justified intuitively.

# 11 Summary of the Framework

The purpose of this section is to recap the framework and discuss the outputs of the process.

## 11.1 Recap of Framework

Recall in Section 4 that the framework breaks product group risk down into its component parts. The major risk "buckets" that we have defined include independent risk, model specification risk and future systemic risk. Sections 5 to 7 then outlines methods that can be used to quantify these components of risk using a mix of quantitative and qualitative analysis.

Independent risk is discussed in Section 5 and recommends that existing quantitative techniques be used. The analysis needs to be suitably adjusted to ensure that systemic components of risk are excluded from the analysis.

A largely qualitative-based approach is proposed in Section 6 to help quantify model specification risk. The use of a balanced scorecard approach is recommended with one of the key elements being consistency of approach across the groups of products being assessed.

Section 7 recommends that future systemic risk uses a forward looking method to identify, categorise and measure risk. Our recommended approach is to firstly identify key risks via a mapping of business processes and interviews with business experts. Risks for each product group are then categorised into a number of reasonably independent risk categories. Finally a quantification of the uncertainty using a mixture of qualitative and quantitative techniques is recommended.

There is no fundamental reason why any of the sub-components of risk need follow any specific distribution. Indeed, there are some risks that are well suited to discrete parameterisation such as latent claims, event risk and reinsurance recovery risk. Section 8 presents an alternative approach to aggregate product group risk using stochastic simulation to firstly enable the full distributional information to be retained and secondly to enable correlations to be explicitly modelled.

Correlations and diversification benefits are discussed in Section 9 using a bottom-up approach. We firstly discuss possible root causes of correlations with reference to the systemic risk groupings identified earlier. We then discuss a potential method of quantifying the correlations by use of stochastic simulation techniques.

Section 10 provides commentary on the use of multipliers in determining premium liability uncertainty. We then propose that the framework we have developed can be extended relatively easily to a premium liability context.

## 11.2 Outputs of the Framework Process

Once the framework process has been completed a clear picture can be developed on the underlying risks of a portfolio. Importantly there is visibility of key underlying assumptions that have been used in the process. The outputs of this approach would include, among other things:

- **A discrete distribution of ultimate claim outcomes for each product group.**
  This distribution is not limited to any distributional form, through the use of stochastic simulation of random outcomes. Risks can be assigned continuous or discrete distributions, and combine quantitative modelling (where appropriate, such as for Event Risk) with more approximate model forms.

- **A discrete distribution of ultimate claim outcomes for the entire entity.**
  As for the product group distribution, there are no distributional limitations on the outcomes if a stochastic simulation method is used. We can calculate percentiles of the distribution by ranking simulated outcomes from highest to lowest. The more extreme outcomes generated from the process can be investigated in greater detail. In fact any single observation can be analysed in order to give more information on the root cause of the result. This may then prompt further refinement of model inputs or be used as a useful storyline for explanation of results. It is also possible to combine any part(s) of the entity that may be required for further business reporting. It is a relatively simple process to aggregate upwards from the individual product groupings.

- **Stochastic valuation information**
  It is easy to calculate percentiles of the distribution by ranking simulated outcomes from highest to lowest. However it is also possible to combine the distribution of outcomes with stochastic valuation techniques. For example, the dependence framework results in both an outcome distribution and information on its dependence on economic outcomes. This has implications for future development of true valuation principles, rather than using 'value-at-risk' measures such as percentiles[19].

- **Dependence matrices are a direct output of the process:**
  The use of a bottom-up approach to model dependence between product groups enables correlations (and better dependence measures) to be a direct output of the process. Additionally, the root causes of dependence are identifiable and measurable. Sensitivity analysis of risk-category inter-relationships can be used to help measure maximum and minimum potential correlations between product groups.

- **Premium liabilities:**
  By modelling risks for outstanding claims and premium liabilities together, much more useful information is available on their close dependence.

# 12 An Illustrative Example

## 12.1 Application of the framework

Over the past 6 months we have applied this framework in a number of circumstances, some deliberately experimental in nature. Their diversity can be shown from the following examples:

- IAG sponsored an initial framework application on a diverse range of short-tail and long-tail classes.
- We applied the framework to a large mono-line insurer that has numerous sources of variability not captured by quantitative analysis alone.
- St George sponsored the development of a model for their Lenders' Mortgage Insurance captive, where formal quantitative modelling of economic and other causal relationships explain the vast majority of the variability – this is documented further in a paper by Kelly and Smith (2005).
- We applied the framework to an asbestos portfolio, where almost all the variability was in the form of systemic risk requiring a qualitative assessment approach.

These diversity has been valuable in learning some lessons, with some exercises being highly quantification oriented and some being almost entirely subjective in nature.

## 12.2 An Illustrative Example

The following example is purely illustrative, drawn from 'realistic but not real' data, including qualitative data. It is used purely to highlight some lessons learnt in applying the proposed risk margin framework in practice. The results shown in this example do not derive from our actual investigations above, which have convinced us that each portfolio has to be assessed separately based on its own risk profile. **These results carry the warning that they should not be used as benchmarks applying to actual insurance portfolios!**

For the purposes of our example, we have assumed 3 classes of business being Home, Motor and Workers Compensation. We have run 4 scenarios as follows:

- a small insurer writing small volumes of business in each class;
- a large insurer writing large volumes of business in each class;
- a short-tail insurer writing predominately home and motor business but with a small volume of workers compensation business; and

- a long-tail insurer writing small volumes of home and motor business but with a large portfolio of workers compensation business.

Using the framework and applying the quantitative and qualitative measurement approaches outlined earlier, we derive:

(i) independent risk measures that not surprisingly vary depending on the size of the portfolio; and

(ii) model specification risk and future systemic risk measures derived for one portfolio that are assumed to apply unchanged for others (this is a simplifying assumption to better illustrate the differences in results).

The independent risk assumptions used in this example are as follows:

| | Outstanding Claims Liability | | | Premium Liability | | |
|---|---|---|---|---|---|---|
| **Independent Risk CoVs** | **Home** | **Motor** | **Workers** | **Home** | **Motor** | **Workers** |
| Small Insurer | 25% | 25% | 25% | 25% | 25% | 40% |
| Large Insurer | 10% | 10% | 10% | 9% | 9% | 18% |
| Short Tail Insurer | 10% | 10% | 25% | 10% | 10% | 40% |
| Long Tail Insurer | 25% | 25% | 10% | 25% | 25% | 18% |

The model specification risk assumptions are as follows:

| | Outstanding Claims Liability | | | Premium Liability | | |
|---|---|---|---|---|---|---|
| **Risk Category** | **Home** | **Motor** | **Workers** | **Home** | **Motor** | **Workers** |
| Model Specification Risk | 8% | 9% | 13% | 9% | 10% | 14% |

The future systemic risk assumptions are as follows:

| | Outstanding Claims Liability | | | Premium Liability | | |
|---|---|---|---|---|---|---|
| **Future Systemic Risk Bucket** | **Home** | **Motor** | **Workers** | **Home** | **Motor** | **Workers** |
| Economic / Social Risk | 1% | 1% | 5% | 2% | 2% | 7% |
| Data Integrity | 2% | 2% | 3% | 3% | 3% | 4% |
| Legislative / Claims Inflation Risk | 1% | 1% | 10% | 2% | 2% | 11% |
| Process Change Risk | 2% | 2% | 5% | 3% | 3% | 6% |
| Claims Expense Risk | 1% | 1% | 2% | 2% | 2% | 3% |
| Event Risk | 0% | 0% | 0% | 20% | 8% | 1% |
| Latent Claim Risk | 0% | 0% | 7% | 0% | 0% | 0% |
| Recovery Risk | 1% | 2% | 1% | 2% | 3% | 2% |
| Future Systemic Risk | 3% | 3% | 15% | 21% | 10% | 15% |

The following points are noteworthy:

- In the example, there were no major future systemic risk drivers for the short-tail portfolios (except event risk), whereas long tail is affected to a much greater extent, particularly due to claims inflation and the effect of recent legislative amendments.

- Event risk is a major driver of uncertainty for premium liabilities, particularly in the home portfolio noting that motor is particularly sensitive to hail events whereas home is not only impacted by hail but also windstorm and earthquake. (Note that presenting the empirically calculated CoV is a very approximate risk measure for this risk category.)

- Latent risk is important for workers compensation outstanding claims due primarily (in this case) to asbestos liabilities. However premium liabilities are not heavily influenced by latent claim potential.

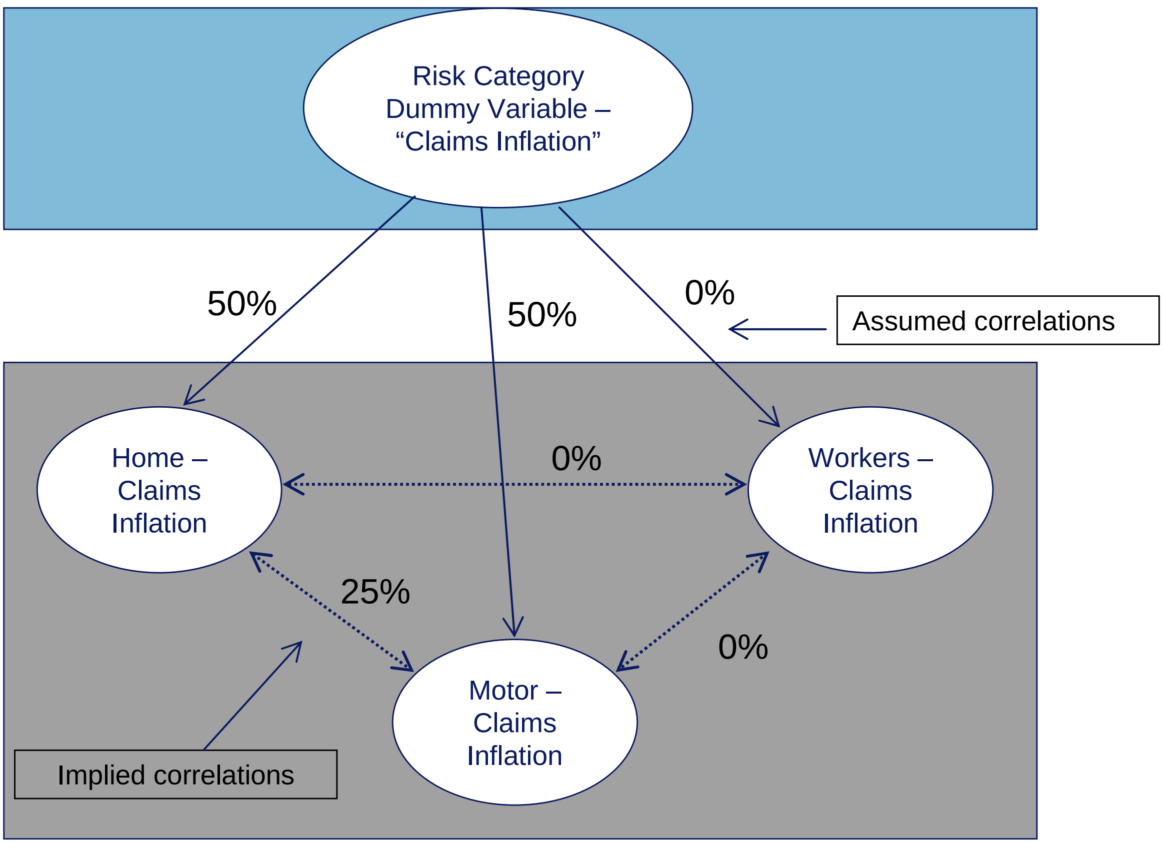
The main point is that two of the three largest systemic risks, as measured using the framework, are not related between premium liabilities and outstanding claims liabilities in any way that can be readily surmised from judgement alone.

## 12.3 Correlation assumptions

Before discussing the outcomes within each scenario, we first discuss the application of correlations through the use of an example.

The following diagram illustrates the application of correlation assumptions as discussed in Section 9.2.1. We have chosen legislative/claims inflation risk to demonstrate our methodology however a similar diagram could be constructed for each of the future systemic risk buckets shown in the table above as well as for model specification risk.

Correlation Method Schematic




After considering the drivers of uncertainty within the legislative/claims inflation risk category, informed judgement can be applied to assess the correlations between each class of business. For example, the factors that may drive up repair costs in motor may be only weakly related, if at all, to benefit reform in workers compensation (implied correlations).

The risk identification and assessment process allows us to rationalise "implied" correlations over the run-off period, and from this deduce "assumed" correlations that more elegantly capture the relationships.

In the above example the zero correlation assumed between workers' compensation and motor and home costs is probably an exaggeration (wage costs might cause some correlation to be expected). However the assumption can be tested by constructing past cost indices (perhaps wage costs for Workers' Compensation and a mixture of wage, price and exchange rate indexes in Home and Motor), and examining past correlation between the two.

The following table shows the extent to which the example uses "assumed" correlations between the dummy variable and the product group. From these it is possible to establish the "implied" correlations in the same way as described in the diagram above. In terms of quantum, High = 75% correlation, Medium = 50% correlation, Low = 25% correlation and Minimal = 0% correlation.

| Risk Bucket | Home | Motor | Workers Comp |
|---|---|---|---|
| Model Specification Risk | High | High | High |
| Economic / Social Risk | Medium | Medium | Low |
| Data Integrity | High | High | High |
| Legislative / Claims Inflation Risk | Medium | Medium | Minimal |
| Process Change Risk | High | High | Medium |
| Claims Expense Risk | High | High | Low |
| Event Risk | High | High | Minimal |
| Latent Claim Risk | High | Low | High |
| Recovery Risk | High | High | High |

## 12.4 Product Group Results

The first of the following two tables shows the size of the outstanding claims and premiums liability for each of the 4 scenarios whilst the second shows the results of our example for each product group before allowances for diversification.

| | Outstanding Claims Liability | | | Premium Liability | | |
|---|---|---|---|---|---|---|
| **Size of Liability ($m)** | **Home** | **Motor** | **Workers** | **Home** | **Motor** | **Workers** |
| Small Insurer | 10.0 | 8.0 | 25.0 | 10.0 | 8.0 | 10.0 |
| Large Insurer | 60.0 | 50.0 | 160.0 | 60.0 | 50.0 | 64.0 |
| Short Tail Insurer | 60.0 | 50.0 | 25.0 | 60.0 | 50.0 | 10.0 |
| Long Tail Insurer | 10.0 | 8.0 | 160.0 | 10.0 | 8.0 | 64.0 |

| | Outstanding Claims Liability | | | Premium Liability | | |
|---|---|---|---|---|---|---|
| **Portfolio Results** | **Home** | **Motor** | **Workers** | **Home** | **Motor** | **Workers** |
| Small Insurer | 27% | 27% | 33% | 34% | 29% | 46% |
| Large Insurer | 13% | 14% | 23% | 25% | 17% | 28% |
| Short Tail Insurer | 13% | 14% | 33% | 25% | 17% | 46% |
| Long Tail Insurer | 27% | 27% | 23% | 34% | 29% | 28% |

The following observations can be made regarding these results:

- The CoVs for the small portfolios are dominated by the contribution of independent risk.

- As the portfolios increase in size, systemic risks become increasingly important in the determination of a portfolio CoV.

- The relativity of the premium liability CoV to the outstanding claims liability CoV is dependent on the relative size of each liability.

- Event risk is a major contributor to the CoV for home premium liabilities and this is evident in the relativity to outstanding claims, particularly once the portfolio size becomes larger and independent risk becomes of lesser importance.

## 12.5 Correlation Results

The following tables show the resulting correlations for the outstanding claims (no suffix) and premiums liability (PL suffix) both between classes of business and between the components of technical liabilities within a class of business.

| Class - Small Insurer | Home | Motor | Workers | Home_PL | Motor_PL | Workers_PL |
|---|---|---|---|---|---|---|
| Home | 100% | 8% | 5% | 8% | 6% | 3% |
| Motor | | 100% | 7% | 4% | 10% | 2% |
| Workers | | | 100% | 4% | 6% | 18% |
| Home_PL | | | | 100% | 10% | 1% |
| Motor_PL | | | | | 100% | 4% |
| Workers_PL | | | | | | 100% |

| Class - Large Insurer | Home | Motor | Workers | Home_PL | Motor_PL | Workers_PL |
|---|---|---|---|---|---|---|
| Home | 100% | 26% | 14% | 21% | 19% | 10% |
| Motor | | 100% | 16% | 13% | 36% | 10% |
| Workers | | | 100% | 7% | 11% | 45% |
| Home_PL | | | | 100% | 23% | 3% |
| Motor_PL | | | | | 100% | 9% |
| Workers_PL | | | | | | 100% |

| Class - Short Tail Insurer | Home | Motor | Workers | Home_PL | Motor_PL | Workers_PL |
|---|---|---|---|---|---|---|
| Home | 100% | 26% | 9% | 21% | 18% | 6% |
| Motor | | 100% | 11% | 13% | 35% | 5% |
| Workers | | | 100% | 5% | 8% | 18% |
| Home_PL | | | | 100% | 22% | 2% |
| Motor_PL | | | | | 100% | 6% |
| Workers_PL | | | | | | 100% |

| Class - Long Tail Insurer | Home | Motor | Workers | Home_PL | Motor_PL | Workers_PL |
|---|---|---|---|---|---|---|
| Home | 100% | 8% | 6% | 8% | 5% | 5% |
| Motor | | 100% | 9% | 4% | 11% | 4% |
| Workers | | | 100% | 5% | 7% | 45% |
| Home_PL | | | | 100% | 10% | 2% |
| Motor_PL | | | | | 100% | 6% |
| Workers_PL | | | | | | 100% |

The following observations can be made:

- the correlations are very low in nearly all cases. Although some drivers of uncertainty are highly correlated between classes, such as economic risk via inflation, the combination of all ‘risk buckets’ dampens the impact of correlations to levels lower than are typically adopted in practice.

- the correlations for the short tail classes are smaller when independent risk is larger (reflecting the diversification effect).

- the correlations between the outstanding claims liability and the premiums liability is much lower than the 100% that is often assumed in practice.

- it is difficult, and potentially misleading, to generalise correlation matrices between entities because the correlations are heavily linked to the contribution of independent risk to each product group.

# 13 Insights from our use of the Framework

The previous sections of the paper have presented a framework that can be used to calculate and manage uncertainty with respect to insurance claims cost. We have used this framework on a number of occasions and in all cases it has provided greater insights into the products we have been valuing.

## 13.1 Insights from Use of the Framework

Some of the major lessons learned and insights from using this framework have included:

- **Risk aggregation principles make a top-down approach very powerful.**
  We have found that the identification of the top 3 risks generally contributes over 90% of the coefficient of variation for a given product group using our framework methodology. This has significant ramifications for some portfolios. For example independent risk will not be a significant contributor for large portfolios, so little time should be spent trying to quantify this component. This is particularly chastening given how much actuarial research has been devoted to quantifying it.

- **Bringing in the business information is half the work.**
  The application of business expertise in assessing risk margin requirements is in its infancy, and the workshops we conducted were useful indicators of progress, but by no means the last word. Approved actuaries will need to consider carefully how best to bring qualitative information to bear without the accountability that results from an actuarial Code of Conduct. We believe the framework can be a valuable control in this regard.

- **Model specification risk is a significant challenge requiring further work.**
  There has been little work to date in actuarial literature on the quantification of model specification risk. We have found quantifying this component of risk challenging. Our methodology really calibrates this as the balancing item after independent and past systemic effects are removed from past history. Our view is that this comprises a significant element of risk in most claim valuations. The qualitative approach outlined in this paper at least enables consistency to be achieved between product groups, and over time. It also identifies some possible approaches to measuring the level of this uncertainty.

- **We cannot justify the use of high correlations between product groups.**
  Our framework has confirmed the mathematical impossibility of highly variable liabilities being highly correlated except where there are high levels of functional correlation. We believe that this methodology gives a more robust framework for calculating diversification benefits by explicitly allowing for this functional correlation.

- **The 'multiplier' approach to premiums liabilities is inherently flawed.**
  We believe that the use of multipliers in the calculation of CoVs for premium liabilities

is fundamentally flawed. This approach used without modelling will give spurious results. Even small differences in payment patterns can be enough to produce very different multipliers between otherwise identical classes. For example, personal motor and personal home react very differently to event risk and hence standard multiples are not appropriate to use. Similarly the existence of latent claims in some accident compensation classes of business means that standard multiples are not appropriate to use.

- **Conceptual models are often useful guides to risk relationships.**
  Conceptual approaches can work well in informing on key relationships. As part of our work on premium liabilities, we constructed a "conceptual model" which allowed multipliers to be examined first on the assumption that every accident quarter carried inherently the same risks, then conducted sensitivity analysis on varying the levels and types of risks included. This allows links to be established between premium liabilities and outstanding claims for various components of risk, such as independent risk. It is especially useful where a portfolio is not in a stable state (a recently acquired start-up for example), as most other approaches fall down in such circumstances.

## 13.2 Advantages of Proposed Framework

Finally, our work has convinced us that this approach has the following significant advantages over current approaches:

- **A robust framework in thinking about insurance liability risk**
  This approach provides a framework to justify changes in risk margins from valuation to valuation by isolating the reasons for the change in uncertainty. It is relatively easy under this framework to quantify the effect of any changes in assumptions of risk factors.

- **A consistent approach to moment estimation**
  The approach provides consistency between the actual valuation models used and the estimation of uncertainty implicit in those models. For example, the information provided allows the actuary to explicitly estimate the effect of skewed distributions on the central estimate.

- **Consistency across product classes.**
  The framework allows consistency in calculation of risk margins between risk product groups within an entity. The consistency is achieved by giving visibility and commonality of approach for concepts such as model specification risk, systemic risk factors (such as economic uncertainty), type of liability (outstanding claims versus premium liabilities versus future business) and correlation estimation.

- **Consistency but evolutionary over time.**
  A real advantage is that the approach allows consistency of application over time, while recognising the changing nature of the risks faced.

- **Transparency and accountability of all stakeholders.**
  This approach gives greater transparency in the determination of risk margins with

greater visibility and understanding of the root causes of uncertainty. This is an advantage in explaining the results to Board and management. Just as importantly, for the actuary, is that his reliance on non-quantitative information provided by the business is rendered explicit, workshopped with appropriate business experts and can be quantified. This makes management more responsible and accountable especially over time) for the accuracy and completeness of these disclosures.

- **Subjectivity is controlled.**
  Subjectivity in the actuarial basis is the mother of delusion, whether this derives from the views of the actuary or the business experts. Transparency and accountability over the subjective elements of the basis results in better risk management control.

- **Correlations emerge naturally from dependency relationships.**
  Correlations and diversification benefits are a direct output of the framework, and the reasons for them are clear. The framework allows for explicit modelling of correlations for both outstanding claims and premium liabilities (which may be very different). The approach gives transparency and justification for any diversification benefits that are ultimately adopted.

- **A forward-looking approach.**
  Needless to say it is a puzzle that actuaries will take a forward looking approach to some assumptions in their central estimate, while searching for a ‘pure quant’ solution to risk margins which can only ever be backward-looking in nature. The approach is forward looking and recognises the limitations of using purely historic quantitative analysis, while providing for its contribution where appropriate.

- **Premium liabilities are no longer a poor relation**
  Premium liabilities and outstanding claims liabilities are closely related, but not to the point that the relationships are obvious. The framework allows them to be seen as a risk continuum for some risks while very different for others, providing consistency between underlying coefficient of variation assumptions of premium liabilities and outstanding claims.

- **Direct distribution estimation opens the door for further developments in actuarial valuation approaches**
  There are no limiting distributional assumptions to this methodology. Stochastic valuation approaches become possible, potentially removing the “half-way house” of using quantile-based risk margins. Perhaps in future our valuations can produce values and not mere estimates!

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## End Notes

1 The DSoP also provide for this margin to include allowance for diversifiable as well as undiversifiable risk, and came down (somewhat guardedly) in favour of stochastic valuation approaches.

2 CoV = ratio of the standard deviation to the mean. In addition some assumption must be made on the 'shape' of the distribution, for example either normal or lognormal.

3 The covariance matrix which determines the aggregate loss distribution actually relies on the vectors of central estimates and CoVs and correlation coefficient matrix.

4 As noted in the next section both Bateup and Reed and Collings and White attempt to overcome this difficulty by modifying CoVs to take into account the size of the individual product group.

5 **Bootstrapping** derives estimates of the probability distribution of a statistic by repeated recalculation of it, using random samples drawn with replacement from the original data. In practice, it is the residuals rather than the actual data that are 'bootstrapped' where the residuals are assumed to be identically distributed across accident and development years. The repeated re-sampling of the observed residuals around the underlying process captures information about variability characteristics.

The **Mack method** requires specifying a distributional function assumption to be made, supplemented to the mean and standard error of prediction, whereas bootstrapping estimates the full predictive distribution directly. In return the application of Mack is simpler than for bootstrapping.

For details on the stochastic chaim ladder see Mack (1993), Mack (1994) or Renshaw and Verrall (1994).

6 For example, Taylor and Ashe (1983).

7 Ill-fitting models will not correctly explain past systemic factors, and this will be incorporated into the second moments, but not in any ordered way.

8 Even with this adjustment, however our work on this paper makes us averse to "translating" CoVs across different portfolios, however superficially similar.

9 As a general rule, over 90% of a typical Motor or Home book will be paid off within 12 months. A simple history of 12-month 'hindsight' estimates represents a time series with limited correlation in reserving error between observations.

10 That is, if the standard approach of using correlations is accepted.

11 For example, it has been suggested, somewhat weakly, that staff satisfaction surveys be used as a KRI for incidence of internal fraud. More powerful KRIs are emerging from monitoring weaknesses in front-office transaction systems, using back office analytical tools to identify

process breakdowns and areas of potential weakness. Aside from the obvious business use of such a tool, the number of exceptions identified by the analytical tool provides an intuitively appealing KRI because it attaches to the process much closer to the risk.

12 The function of a copula is to combine known marginal distributions and the dependency structure between them into a joint distribution (or in the case at hand into the distribution of the sum of component risks). The correlation-matrix approach arises as a special case when a Gaussian (i.e. Normal) copula is assumed.

13 Best considered by a simple example: If you toss an unbiased coin 100 times, you expect to get 50 heads and 50 tails (a perfect "central estimate" of the outcome), yet this outcome is almost never observed due to the inherent randomness of the process.

14 For example, if the systemic components of risk comprise a CoV of 15%, and the independent components 10%, the combined CoV will be 18%. If the CoV of the systemic risk is 20% and independent risk is 5%, the total is only 20.6%. (All figures assume normal distributions).

15 The *sensitivity analysis* described is widely used, but also easily confused with *scenario analysis*, a useful tool for assessing systemic risk potential.

16 See Kelly and Smith (2005) which applies the framework of this paper to Lenders' Mortgage Insurance. Quantitative modelling of the economic aspects of credit risk contributes the vast majority of the overall CoV. In addition valuable information is provided on the shape of the distribution in the tail.

17 By their nature, as the very worst scenarios possible, they must apply to the top of the claims distribution. Since they have a very small probability of occurrence during the exposure run-off, inclusion or exclusion of catastrophe risk would hardly affect the $75^{th}$ percentile of the distribution. Nevertheless we note it is common for the GPS 210 Premiums Liability to include an allowance for the future incidence of catastrophic events.

18 The cases were "Mis-specified model" and "Inadequate business knowledge", within Model Specification Risk, and "Claims Inflation Risk" and "Legislative and Political Risk" within Future Systemic Risk. The latter comprised "honeymoon effect" risk for long-tail classes which had been subject to recent reform. It proved impossible to separate the mechanisms of this reform from "normal" super-inflationary risks.

19 A value is influenced by the entire distribution of outcomes. A value-at-risk is a percentile of the distribution and can be uninfluenced by changes in some outcomes – for example a change in estimated severity of catastrophes may not affect a $75^{th}$ percentile estimated outcome.