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# Economic Capital Modeling: Practical Considerations

**MILLIMAN INC.**
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# Executive Summary

"Economic capital" is an emerging concept that should be on the minds of decision-makers at various financial institutions, particularly insurers and banks. Economic capital means different things to different people, but the term generally has two meanings:

- "Required economic capital," which typically applies to the realistic amount a business believes it needs to meet future risks.
- "Available economic capital," which typically indicates the realistic or market-consistent amount the business actually has available.

A company that properly employs economic capital analysis will strike a balance between:

- Too much capital—which can lead to an excessive cost of insurance.
- Not enough capital—which can lead to an unacceptable risk of insolvency.

The move toward economic capital is driven by the recognition that companies need to make strategic decisions based on a realistic assessment of the capital that is required or available. Other important drivers include Solvency II and the emerging global solvency framework proposed by the International Association of Insurance Supervisors (IAIS).

In this new paradigm, regulatory solvency is determined in terms of economic capital, reflecting each insurer's specific financial condition. Risks are held more realistically than they are in conventional formulaic approaches, many of which merely focus on the difference between the value of assets and liabilities on a statutory balance sheet. Such formulaic approaches are either incapable of dealing with all types of risk, or they are not adaptable to changing market conditions.

There is no single approach to developing economic capital models, and calculation methods are still emerging. Many companies have yet to adopt economic capital calculations, and even those that have adopted calculations may still be interested in other methods. This explains why economic capital is of such primary concern to insurance executives, shareholders, and regulators.

Decision-makers looking to develop an organizational approach to economic capital have several questions to ask themselves:

- What type and scope of risks should their company consider? (see p. 14)
- How should these risks be measured and what probability of ruin is the company ready to accept? (see p. 18)
- What kind of decisions should underpin the development of economic capital models? (see p. 24)

This report endeavors to answer these questions as well as to look at a few illustrative cases of how economic capital can be practically applied. The report will help decision-makers formulate an approach to economic capital that will align with their larger corporate strategies.

**FINANCIAL AND REGULATORY FORCES CONTRIBUTING TO THE ECONOMIC CAPITAL MOVEMENT**

- The Chief Financial Officer (CFO) Forum and the Chief Risk Officer (CRO) Forum in Europe, which strive to achieve a degree of standardization.
- The International Accounting Standards Board (IASB), which is driving the move towards "fair value."
- The International Association of Insurance Supervisors (IAIS) and the International Actuarial Association (IAA), which are developing a common structure and common standards for the assessment of insurer solvency.
- Solvency II, which is part of a convergence between economic and regulatory management of insurance companies in the EU.
- Basel II, a regulatory standard for internationally active banks.
- Individual Capital Assessment (ICA) in the UK and the Financial Assessment Framework (FTK) in Holland, which have introduced solvency regimes ahead of Solvency II.
- A long-standing move toward Principles Based Valuation in the US.

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# 1. Introduction

Economic capital means different things to different people. The concept is widely used in the management of a company's resources. The word "economic" is generally interpreted as referring to either a realistic or market-consistent valuation, while the word "capital" refers to the discounted present (capital) value of future cash flows, or to the resources within the company's balance sheet more generally. Thus the concept can be used either to measure and optimize the capital resources already existing within a business, or to determine the amount of capital required by a business to meet the risks inherent in its liabilities and business operations. In this context it may be useful to distinguish between the amount of economic capital a business believes it needs—"Required Economic Capital"—and the amount of economic capital the business actually has—"Available Economic Capital."

In short, economic capital can be used as part of the valuation of the business, or as part of the risk management of the business.

IN SHORT, ECONOMIC CAPITAL CAN BE USED AS PART OF THE VALUATION OF THE BUSINESS, OR AS PART OF THE RISK MANAGEMENT OF THE BUSINESS.

Increasingly, more and more companies employ economic capital analysis, as it is being recognised as a useful measure/tool for facilitating strategic management decisions. Hayes and Monet (2005) report in their paper, "ECONOMIC CAPITAL: IMPLEMENTATION PRACTICES AND METHODOLOGIES," that the increasing adoption of economic capital within the banking community has in part been hastened by the pressures of Basel, though its use as an everyday instrument is based on a deeper need. Milliman's own report, "ANALYSIS OF EUROPEAN EMBEDDED VALUE DEVELOPMENTS," published early in 2006, found that many life insurance companies use economic capital as part of both their vocabulary and their set of metrics for managing risk across the entire enterprise. For example, economic capital was found to be widely used to calculate cost of capital for embedded value calculations.

That said, regulatory pressure is another important driver for accelerating the use of economic capital analyses. The drivers include both Basel II (which is a new regulatory standard for internationally active banks) and Solvency II (a similar standard for insurers in the EU). In addition, the International Association of Insurance Supervisors (IAIS) is also in the process of developing a common structure and common standards for the assessment of insurer solvency. It is currently expected that insurers should have an adequate risk

REGULATORY PRESSURE IS AN IMPORTANT DRIVER FOR ACCELERATING THE USE OF ECONOMIC CAPITAL ANALYSES.

management process established and have an adequate internal model to calculate economic capital that can capture all material risks the insurer is exposed to; such a process should be used for making decisions in the risk management process. At the same time, the way to calculate economic capital is still emerging. Different companies use different approaches. Thus, one needs to make various judgments. Potential questions include:

THE WAY TO CALCULATE ECONOMIC CAPITAL VARIES, SO ONE NEEDS TO MAKE VARIOUS JUDGMENTS.

- What type and scope of risks should their company consider? (see p. 14)
- How should these risks be measured and what probability of ruin is the company ready to accept? (see p. 18)
- What kind of decisions should underpin the development of economic capital models? (see p. 24)

Within the insurance industry, where embedded value measures are widely used (and despite the efforts of the CFO (Chief Financial Officer) and CRO (Chief Risk Officer) Forums), there are still widely varying approaches to calculate embedded value.

There are still many companies that have not adopted the economic capital calculation, and many companies that have already developed an economic capital model may still be interested in other methods. The purpose of this report is to overview various issues that insurers encounter when they develop an economic capital model and to provide useful information that can aid decision making.

Sections 1-4 provide an overview of economic capital and examine the benefits and applications of economic capital analysis. Sections 5-7 point to examples of how economic capital (whether required or compared against the available capital) can be managed to take into account the risks inherent in the business. Section 8 provides three illustrative examples that are widely used by leading insurers.

# 2. What is economic capital?

As explained above, various definitions of economic capital are possible. We will focus on the following two definitions (while keeping in mind that other definitions are possible).

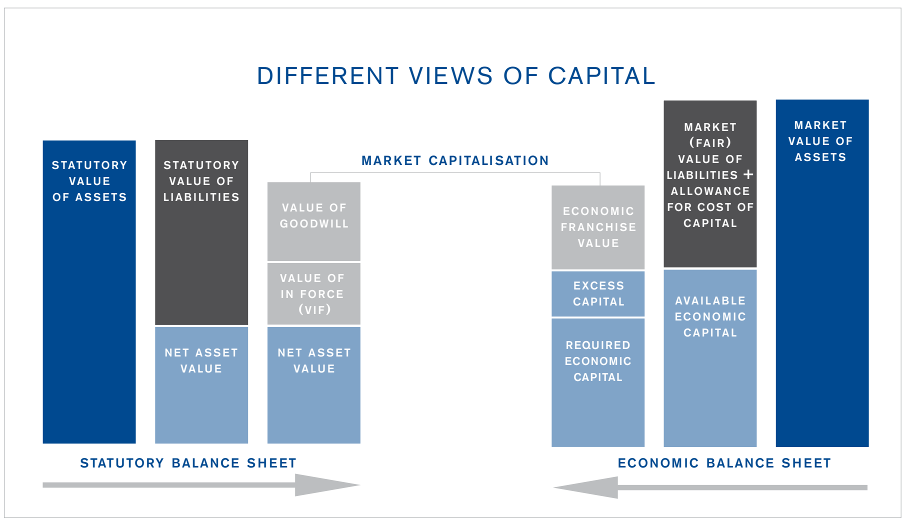
"REQUIRED ECONOMIC CAPITAL" CAN BE DEFINED AS THE CAPITAL REQUIRED TO SUPPORT A BUSINESS WITH A CERTAIN PROBABILITY OF DEFAULT.

"Required Economic Capital" can be defined as the capital required to support a business with a certain probability of default. It should be noted that this capital is "required" from an economic point of view rather than from a regulatory point of view. While regulatory capital requirements are moving towards economic capital-type definitions in many countries, these requirements are certainly not identical.

"AVAILABLE ECONOMIC CAPITAL" CAN BE DEFINED AS THE EXCESS OF THE VALUE OF THE COMPANY'S ASSETS OVER THE VALUE OF ITS LIABILITIES ON A REALISTIC BASIS.

"Available Economic Capital" can be defined as the excess of the value of the company's assets over the value of its liabilities on a realistic or market-consistent basis. This definition is closely related to the European Embedded Value (EEV) standard, which is discussed further in section 4 (p. 8) of this report.

The following diagram illustrates the relation between these concepts and between the statutory and the economic balance sheet.



Clearly, a number of parameters and questions will arise in a formal definition of economic capital. These include:

- What is the scope of risks under consideration? Ideally, this scope would include all material risks to which the company is exposed.
- What is the probability of ruin to be accepted? This probability could, for example, be equivalent to a certain credit rating.
- What is the time period over which the probability of ruin is to be assessed? E.g., are we looking at the capital needed to have a 1 in 200 chance of not meeting liabilities over a one-year time period? A multi-year time horizon could involve projecting the balance sheet over a long period (e.g., 20 years) or even until all the liabilities have run-off.
- Should the company look only at the current in force business or should it also look to view the business on a going concern basis, which includes the impact of future new business?

These issues are discussed in more detail in the following sections.

It is widely recognised that the true level of financial strength for a life insurer depends not just on the difference between the value of the assets and the liabilities, but also on the basis on which these are valued. Existing supervisory systems have tended to rely, in theory at least, on a combination of prudence in both the asset and liability valuation bases; these systems look to simple formulae to define the required minimum level of solvency. Although it is not always certain that the combined impact of the asset and liability valuation bases will be prudent, it is most normally the case.

**THE TRUE LEVEL OF FINANCIAL STRENGTH ALSO DEPENDS ON THE BASIS ON WHICH THE VALUE OF THE ASSETS AND THE LIABILITIES ARE VALUED.**

The International Accounting Standards Board (IASB) is among the many regulatory bodies involved with moving towards "fair value" (i.e., financial reporting standards that give a true and fair picture of the company's business—for an example of this, see IFRS (2006)(b)). Fair value generally equates to market-consistent valuation, although there are some qualifications to this. Whereas the use of market values for assets is generally uncontroversial (although far from universally in use today), the correct method for liability valuation has been the subject of considerable debate. Among other things, it needs to be decided whether future discretionary bonuses are to be considered, not considered, or partially considered as a liability.

THE ISSUE IS WHETHER TO ASSESS THE AMOUNT OF CAPITAL REQUIRED BASED ON A STATUTORY VIEW OF SOLVENCY, OR ON AN "ECONOMIC" VIEW OF SOLVENCY.

The issue is therefore whether to assess the amount of capital required based on a statutory view of solvency, or on an "economic" (or fair value) view of solvency. A few companies using economic capital models currently have to look at the results on a statutory accounting view of solvency (i.e., on the current rules), but it seems clear that in the future all companies will move toward an economic view of solvency. This approach recognises prudence in existing technical provisions and is sometimes referred to as a total balance sheet approach[1].

Economic capital models have been increasingly used by leading insurers as a key tool to manage their risks and capital and to measure their performance. Several leading insurers have developed such models and publicized the results.

[1] THE INTERNATIONAL ACTUARIAL ASSOCIATION (IAA) REFERRED TO AND RECOMMENDED "TOTAL BALANCE SHEET APPROACH" IN THE REPORT "A GLOBAL FRAMEWORK FOR INSURER SOLVENCY ASSESSMENT" (2004). IAIS HAS ADOPTED THE TOTAL BALANCE SHEET APPROACH TO ITS VENTURE TO DEVELOP A COMMON FRAMEWORK FOR INSURERS' SOLVENCY ASSESSMENT. THE ASSESSMENT IS CURRENTLY UNDERWAY.

# 3. What are the benefits of economic capital analysis?

One of the underlying principles of a private insurance market is that insurance companies hold capital in order to take on risks and absorb the inevitable fluctuations in experience. They do so in a way that will maintain a high probability of having the financial resources needed to meet obligations to their customers. The providers of this capital (e.g., shareholders in an insurance company) want to earn an adequate return, and the cost of this return on capital needs to be allowed for in the pricing of the insurance. Therefore, there is an interest in establishing what is a "correct" level of capital under given parameters so that:

- The capital on which the providers of capital are expecting to earn a risk return is not too high, since this leads to an excessive cost of insurance.
- The capital is not too low, since this leads to an unacceptable risk of insolvency.

ESTABLISHING THE "CORRECT" LEVEL OF CAPITAL IS IMPORTANT TO GUARD AGAINST EXCESSIVE COST OF INSURANCE (TOO HIGH) OR A HIGH RISK OF INSOLVENCY (TOO LOW).

For these reasons, economic capital is an extremely useful tool for all constituencies interested in the financial health of an insurance company.

The management of insurance companies needs to better understand the capital requirements of their business. They should be able to explain and justify their views of such capital requirements to rating agencies and other users of company financial statements. Many companies believe that the formulaic approach used by the rating agencies does not appropriately reflect the company's processes and procedures for effectively managing risk; these companies feel confident that their risk management practices would be positively reflected in the determination of economic capital. For example, the companies may want to be able to take credit for the diversification of risks and for the recognition of superior credit management. Insurance company management will also want to measure performance, taking account of the capital that is effectively being employed in different business areas.

Shareholders and other users of insurance company financial statements need to understand whether companies are adequately capitalized or over-capitalized. They should be able to judge the effective return on capital employed in the insurance business.

Regulators will want to understand on as realistic a basis as possible how well capitalized companies are, since one of their primary goals is preventing insurance company failures.

# 4. How can economic capital analysis be applied?

As mentioned above there are wide applications for economic capital analyses. What follows are some details on the background of its applications and the parallel developments in regulations, financial reporting, and financial management.

## International Regulatory Trends

REGULATORS HAVE RECOGNISED MANY WEAKNESSES IN FORMULAIC APPROACHES TO THE ASSESSMENT OF REQUIRED SOLVENCY LEVELS FOR INSURANCE COMPANIES.

Many regulators have recognised a number of weaknesses in formulaic approaches to the assessment of required solvency levels for insurance companies. For example:

- There is no link between the amount of capital required and the effectiveness of a company's risk management and risk mitigation strategies.
- The current formulaic rules cannot deal with all types of risks.
- Mistaking prudent management with capital requirements leads to a lack of transparency over the actual level of solvency of a company.
- Formulaic approaches do not necessarily cope with changes in the financial environment or in insurance markets (e.g., the introduction of new products).
- Such approaches do not generally allow for the benefit of the various forms of diversification.

In 2000 the European Commission started the so-called Solvency II process, which will lead to a major revision of the solvency margin regime for insurers in the European Union. Solvency II is intended to be much more realistic than the current EU solvency basis in assessing the capital requirements for insurers.

The process of developing and agreeing upon the Solvency II system is complex and beyond the scope of this report. As of the writing of this report, a draft outline of the Framework Directive had been published; a consultation process and impact study was underway.

The draft Framework Directive defines two levels of solvency capital, the Solvency Capital Requirement (SCR) and the Minimum Capital Requirement (MCR).

- The SCR is the level of capital required so that there is a 0.5% probability that assets will not be sufficient to meet liabilities during the following year.
- The MCR represents an absolute minimum level of capital, below which urgent action would be required by the regulator. The MCR is calculated according to a simple formula.

The draft Framework Directive envisions a day when regulators permit insurers to calculate the SCR using internal models, provided these have been validated and approved by the regulator. Such models will need to have risk measures, time horizons, and scopes of risk at least as prudent as those underlying the standard approach to calculating the SCR. From the regulators' point of view, internal models have the advantage that they encourage insurers to measure and manage their risks. They are more flexible than industry-standard models and can be updated as financial markets and a company's business evolve. Furthermore internal models should be able to represent the business of an insurer more closely than a rule-based standard approach. Internal models are most likely to be suited to large insurers or to innovative or niche players for whom the standard formulae are least likely to be representative.

**INTERNAL MODELS ARE MORE FLEXIBLE AND CAN BE UPDATED AS FINANCIAL MARKETS AND A COMPANY'S BUSINESS EVOLVE.**

The body driving the development of Solvency II, the Committee of European Insurance and Occupational Pensions Supervisors, has pointed out that the SCR "shares many features with economic capital." The development of such economic capital models can therefore be viewed as a precursor to the use of internal capital models in the regulatory supervision of companies. Solvency II is part of a convergence between economic and regulatory management of insurance companies based on a realisation that, ultimately, companies that are profitable and well managed are those which are most likely to remain solvent.

**SOLVENCY II IS PART OF A CONVERGENCE BETWEEN ECONOMIC AND REGULATORY MANAGEMENT OF INSURANCE COMPANIES BASED ON A REALIZATION THAT, ULTIMATELY, COMPANIES THAT ARE PROFITABLE AND WELL MANAGED ARE THOSE WHICH ARE MOST LIKELY TO REMAIN SOLVENT.**

Since Solvency II is expected to become effective around 2010, some countries have already adopted their own solvency regimes, which are generally consistent with the spirit of Solvency II. Examples include the Individual Capital Assessment (ICA) of the United Kingdom and the Financial Assessment Framework (Financieel toetsingskader/FTK ) of Holland.

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IN THE US, REGULATORS USE RISK-BASED CAPITAL (RBC) AS A MEASURE OF THE SUFFICIENCY OF SURPLUS. RBC IS GENERALLY FORMULAIC AND THE USE OF INTERNAL CAPITAL MODELS IS BEING ADOPTED SLOWLY.

In the United States, regulators use Risk-Based Capital (RBC) as a measure of the sufficiency of surplus. RBC is generally formulaic and the use of internal capital models is being adopted slowly. In one of the first important steps, the National Association of Insurance Commissioners (NAIC) adopted an RBC provision in October 2005 for variable annuity contracts with guaranteed minimum death benefits and living benefits such as guaranteed minimum withdrawal benefits, accumulation benefits, or income benefits. Under this provision companies will:

- Calculate their capital requirements using stochastic projections.
- Use internally developed models that represent the risks assumed.
- Potentially use company-specific assumptions, prudent best-estimate assumptions, and equity and interest return scenarios calibrated to a set of 10,000 scenarios provided by the American Academy of Actuaries.
- Be permitted to use projections that reflect the use of hedges, under certain circumstances, if the company has adopted a clearly defined hedging strategy.

In addition to using internal models and stochastics, RBC must be calculated using a deterministic projection set by the regulators (referred to as the Standard Scenario). The actual RBC is the greater of the amounts produced by the deterministic or stochastic projections. A similar methodology is being considered for the calculation of basic reserves (technical reserves) for the same contracts.

The adoption of internal models for Universal Life (UL) Insurance is also under consideration, yet another part of a move towards Principles-Based Valuation in the US. However, because US regulatory capital and surplus requirements are still formulaic, companies are developing internal capital models to more accurately reflect their risk profiles and risk management practices.

In Canada, principles-based supervision and financial reporting have been in effect for several years. Internal models and company-specific assumptions, with margins, are used.

Switzerland is not a member of the EU; it announced the introduction of the Swiss Solvency Test (SST) in 2006. The SST is based on stochastic modelling and extreme scenarios. It is, to a large extent, formulated in terms of principles and guidelines defined by the supervisory authorities rather than by strict formulas.

The development of a solvency regulation framework is also proceeding on an international basis, much like the International Financial Reporting Standards (IFRS) development by IASB. The IAIS is an association of insurance supervisors from about 180 countries and districts. The IAIS was formed in 1994 and has established various principles and standards that should be followed by local supervisors.

THE DEVELOPMENT OF A SOLVENCY REGULATION FRAMEWORK IS ALSO PROCEEDING ON AN INTERNATIONAL BASIS.

In October 2005, the IAIS adopted a policy paper, "A NEW FRAMEWORK FOR INSURANCE SUPERVISION: TOWARDS A COMMON STRUCTURE AND COMMON STANDARDS FOR THE ASSESSMENT OF INSURER SOLVENCY" (Framework Paper). Since then, the IAIS has published subsequent papers and is steadily proceeding the venture. It will finish publishing most of the major papers by the second quarter of 2007.

The IAIS takes the view of the total balance sheet approach recommended by the IAA. The IAIS has kept a good relationship with the IAA, and it has approached the IASB so that the new solvency standard and the soon-to-be-adopted IFRS will be consistent (or, at a minimum, insurers should be able to reconcile the different standards).

At the time of this writing, the IAIS had completed a draft of its fourth major paper, the Structure Paper, where the IAIS shows its intention in more detail than in prior papers. The details of the IAIS papers are beyond the scope of this report, but generally they are consistent with the spirit of Solvency II. It is expected that solvency regulations in many countries are moving toward being consistent with the IAIS's common solvency framework, which will be completed a few years from now.

## EUROPEAN EMBEDDED VALUE

Over the last 10 years, almost all leading European life insurers and a number of companies outside Europe have disclosed information about embedded value in their financial reporting. This disclosure aimed to provide users of financial statements with additional information about the financial position of the company that could not be derived from statutory accounts. However, limitations of the traditional embedded value approach were exposed following extreme market conditions in recent years, with drops in interest rates and equity markets uncovering guarantees.

In May 2004, the Chief Financial Officer (CFO) Forum (a body formed by the major European insurance companies) launched the European Embedded Value (EEV) principles. EEV takes traditional embedded value techniques and extends them to include explicit valuation of options and guarantees. It also aims to standardise the way in which embedded values are reported, with the goal of having EEV reporting that is more consistent and transparent via the establishment of unified guidelines.

Historically, traditional embedded value approaches have allowed for the cost of holding the minimum regulatory capital by considering the discounted value of future releases of that capital and investment returns theron, and comparing it with the face value of that capital at the valuation date. This does not allow for differences in the appropriate level of capital and the minimum regulatory capital, although some European companies have started to modify this approach in recent years.

One of the EEV principles states that the level of required capital is at least the level of solvency capital required before the regulator can take action, but may also include amounts required internally (e.g., based on an economic capital calculation or on what is required to achieve a target credit rating). This leaves considerable discretion in determining the required capital for a particular company and there has been a wide divergence in the approaches followed.

Some companies have used economic capital as the basis for the cost of capital. This particular approach appeals to advocates of the market-consistent embedded value (MCEV) approach, which generally does not involve any risk margin for non-market (non-financial) risks. By using a cost of capital based on economic capital, which considers all risks to which a company is exposed, companies are able to claim that they have made adequate allowance for all risks without the need to diverge from a market-consistent approach to non-market risk.

BY USING A COST OF CAPITAL BASED ON ECONOMIC CAPITAL, COMPANIES CAN CLAIM THEY HAVE MADE ADEQUATE ALLOWANCE FOR ALL RISKS.

## RISK-ADJUSTED RETURN ON EQUITY OR CAPITAL (RAROE OR RAROC)

Insurance companies typically have various products that involve different levels of risk and hence require different amounts of economic capital. Management should look to measure return on equity in a way that recognises economic capital employed. It would then be reasonable to look for the same return on economic capital for all business. If some other capital measure which does not sufficiently differentiate levels of capital for high-risk and low-risk businesses is used instead (e.g., statutory solvency capital), and if the same return is targeted for all business, there will be a tendency to overprice the less risky business lines and underprice the more risky ones.

MANAGEMENT SHOULD LOOK TO MEASURE RETURN ON EQUITY IN A WAY THAT RECOGNISES ECONOMIC CAPITAL.

Different companies may use different measures of return with European companies, most commonly using the embedded value profit. RAROE or RAROC also have the advantage that they can be compared with the same measures employed in parallel businesses, such as banking, asset management, and non-life insurance within diversified financial services companies.

# 5. What type of risks should be considered?

Risk can be defined differently depending on the context. For example, risk is defined as variability (standard deviation) of investment return under the traditional Capital Asset Pricing Model (CAPM), where better performance than expected is also considered as risk. However, for the purpose of enterprise risk management, economic capital is calculated so that it is sufficient to cover a certain level of possible losses due to holding risks, and thus it focuses only on downside risk.

IT IS IMPORTANT TO ACCOUNT FOR ALL RISKS THAT THE INSURER IS EXPOSED TO FOR THE PURPOSE OF ECONOMIC CAPITAL CALCULATION.

It is important to account for all risks that the insurer is exposed to for the purpose of economic capital calculation—oftentimes one of the most difficult aspects of the economic capital calculation. The definition of insurer risk types and key components are well described by the IAA's paper, "**A GLOBAL FRAMEWORK FOR INSURER SOLVENCY ASSESSMENT**," (Global Solvency Paper) published in 2004; this can be a starting point.

## IAA RISK CATEGORIES

The Global Solvency Paper categorizes risk under the five major risk types: underwriting risk (insurance risk), credit risk, market risk, operational risk, and liquidity risk.

### (1) Underwriting Risk

Underwriting risks are associated with both the perils covered by the specific line of insurance (death, major accident, fire, windstorm, earthquake, etc.) and the specific processes associated with the conduct of the insurance business. The main risk drivers for life insurers are mortality, morbidity, persistency, and lapse risk. Examples include Underwriting Process Risk, Pricing Risk, Product Design Risk, Claims Risk, Economic Environment Risk, Net Retention Risk, Policyholder Behaviour Risk, and Reserving Risk. This is described in more detail in the Appendix (see p. 45 ).

### (2) Credit Risk

Credit risk is the risk of default and change in the credit quality of issuers of securities, including corporate bonds in the insurer's portfolio, counterparties such as on reinsurance contracts, over-the-counter derivative contracts, and intermediates to whom the company has an exposure. Examples of credit risk include Direct Default Risk, Downgrade or Migration Risk, Indirect Credit or Spread Risk, Settlement Risk, Sovereign Risk, Concentration Risk, and Counterparty Risk.

### (3) Market Risk

Market risk results from the volatility and uncertainty inherent in the market value of future cash flow from insurer assets and liabilities. Market risk is thus driven by the exposure to movements in the level of financial variables. The prevalent risk drivers are interest rates, stock prices, exchange rates, real estate prices, and commodity prices. Regarding derivative prices, not only exposure to the movement of underlying asset prices but also the effect of other financial variables such as market-implied volatility are included in market risk. Examples of market risk include Interest Rate Risk, Equity and Property Risk, Currency Risk, Basis Risk, Reinvestment Risk, Concentration Risk, Asset/Liability Management Risk, and Off-Balance Sheet Risk.

### (4) Operational Risk

Operational risk is the risk of loss resulting from inadequate or failed internal process, people, or systems, or from external events. While the operational risk is not a well-defined concept, it is broadly categorized by two components, operational failure risk and operational strategic risk. Operational failure risk arises from the potential for failure in the course of operating the business.

Failure of people, process, and technology used to develop the business plan can be included in this category. Operational strategic risk arises from environmental factors, such as a new competitor that changes the business paradigm, a major political, tax and regulatory regime change, and earthquake or other disasters that are outside the control of the company.

### (5) Liquidity Risk

Liquidity risk is exposed to loss in the event that insufficient liquid assets will be available, from among the assets supporting the policy obligations, to meet the cash flow requirements of the policyholder obligations when they are due or when assets may be available, but only at excessive cost. Loss due to liquidity risk can occur when a company has to borrow unexpectedly or sell assets for an unanticipated low price. The liquidity profile of a company is a function of both its assets and its liabilities. Life insurers often offer policyholders embedded options (such as settlement options) that have the potential to cause liquidity problems. Unexpected demand for liquidity may be triggered by cash calls following major events, a credit rating downgrade, negative publicity, or deterioration of economy. In the case of a large US life insurer that suffered a significant liquidity event, the event was triggered by a downgrade in its credit rating. The contributing factors to liquidity risk were large funding agreement contracts held by relatively few, sophisticated customers.

## THREE KEY COMPONENTS FOR MODELLING

EACH RISK TYPE CAN BE FURTHER DECOMPOSED INTO THREE KEY COMPONENTS: VOLATILITY, UNCERTAINTY, AND EXTREME EVENTS.

In modelling those risks mentioned above, each risk type can be further decomposed into three key components: volatility, uncertainty, and extreme events.

### (1) Volatility Risk

Volatility is the risk of random fluctuations in either the frequency or severity of a contingent event. In fully efficient markets, volatility is not market-valued, since investors can reduce volatility by diversifying their portfolio. However, because of the relatively inefficient markets for valuing insurance risks, the volatility component of risk cannot be ignored. An insurer can go into bankruptcy because of diversifiable risk. For example, even if the distribution of claim payment is modelled accurately (i.e., real claim distribution is the same as modelled), a company's actual claim payment may largely differ from the average of the distribution depending on the size of the business.

One good example is mortality risk for small companies. The law of large numbers works for mortality risk, which means that smaller companies have more volatility risk than larger companies and thus should hold more capital per unit of insurance liabilities for a given probability of ruin.

### (2) Uncertainty Risk

Uncertainty involves the risk of misspecifying the model used to estimate the claims; uncertainty can also originate from misestimating the parameters within the models. Examples include misspecification of models for frequency and severity (model risk), for parameters in selected models (parameter risk), and the use of incorrect or miscalibrated models for market value or interest rate movements. For example, a company's liability may be based on an incorrect assumption of claim distribution (risk of misestimation); even if the current model is appropriate, there may be a trend of parameters that are not considered in the current model (trend risk). Uncertainty risk is nondiversifiable since it cannot be reduced by increasing portfolio size.

As an example, it could be generally said that term insurance has lesser uncertainty risk than medical insurance, since cost of medical insurance would depend not only on pure incidence rates but also on government policy, improvement of medical technology, economic downturn, and other social problems that are difficult to predict.

### (3) Extreme Events (Calamity)

Extreme events include the risk of large common-cause events such as calamities: high-impact, low-frequency risks. Models may not capture all aspects of extreme risk, especially if no extreme events appear in the historical data used to develop models. Examples include catastrophes with multiple claims, market crashes, or extreme interest rate movements.

# 6. How should each of those risks be measured?

TOTAL RISK IS CALCULATED BY MEASURING THE EFFECT OF SPECIFIC RISK(S) TO A COMPANY'S EARNING OR SURPLUS.

Total risk is calculated by measuring the effect of specific (or aggregate) risk(s) to a company's earning or surplus, generally as a function of the probability distribution of losses. Total capital requirements may be based on the aggregate distribution of losses or an indicated capital requirement for a component based on the loss distribution of the component only. The issue of aggregating individual risks is explained in detail in the section "7.4. Diversification effect."

There are several approaches to the measurement of losses: scenario-based model, static-factor model, stochastic-factor model, and covariance model.

A scenario-based model can be deterministic or stochastic. Risk capital is calculated by measuring the impact of specific scenarios to the distribution of loss. These scenarios simultaneously cover multiple risk drivers. The approach is different from stress tests, under which only one shock is given to specific risk drivers. Correlation between risk drivers must be taken into consideration when stochastic scenarios are generated.

A static-factor model is based on a linear combination of a static risk factor multiplied by a company-specific amount, which are typically accounting items such as the amount of a specific asset class or premium income. RBC in the US is an example of such an approach, except C3 phase I and II, where a scenario-based model is used. A stochastic factor model is processed in the following steps:

1. Identify relevant risk drivers.
2. A sensitivity analysis for each risk driver value is conducted to measure Delta (proxy for the first derivative), Gamma (proxy for the second derivative), or a scenario vector (evaluation of several known points for highly non-linear functional dependency).
3. Joint distribution of risk drivers is modelled.
4. The resulting loss is aggregated across all risk types, leading to its stochastic distribution; risk capital is determined by applying a risk measure such as value at risk (VaR) or conditional tail expectation (CTE) to the company's total losses.

A covariance model is a special case of a stochastic factor model with multi-normal distributions, first order sensitivities, and VaR as risk measure. The accuracy of the covariance model may be improved by using the IAA's sub-risk classification, including the risk components volatility, uncertainty, and calamity.

According to "Benchmarking Study of Internal Models," carried out in late 2004, for the CRO Forum,[2] eight out of 13 surveyed use a stochastic factor model and the remaining five participants use a covariance model, although it is not straightforward to classify the modelling approach.

Since there are varieties of risk types, it is beyond the scope of this report to fully describe the risk measurement models for each risk type. Following are some briefly-explained examples of widely used approaches:

### (1) Underwriting Risk

For life insurance, the major drivers of underwriting risk are mortality, morbidity, longevity, lapse, and other policyholder options such as guaranteed annuitization.

Mortality, morbidity, and longevity risks can be further decomposed into a diversifiable component and a systematic component. Diversifiable component (Volatility Risk) decreases as the number of policies increases. The IAA's Global Solvency Paper illustrates that the volatility risk can be measured as the difference of liability amounts between best estimate and the tail value at risk under stochastic simulation of binomial mortality distribution. Here is one way to conduct such a binomial mortality analysis:

MORTALITY, MORBIDITY, AND LONGEVITY RISKS CAN BE FURTHER DECOMPOSED INTO A DIVERSIFIABLE COMPONENT AND A SYSTEMATIC COMPONENT. DIVERSIFIABLE COMPONENT (VOLATILITY RISK) DECREASES AS THE NUMBER OF POLICIES INCREASES.

For each policy in force at the beginning of each period

1. Generate random number s, 0<=s<=1
2. If s<=qd, the policy is terminated by death
3. Otherwise, generate another random number s
4. If s<=qw, the policy is terminated by lapse
   where qd is best estimate mortality rate
   and qw is best estimate lapse rate

Systematic component relates to mortality level risk (Misestimation of the

[2] THE CRO FORUM IS COMPRISED OF THE CHIEF RISK OFFICERS OF THE MAJOR EUROPEAN INSURANCE COMPANIES AND FINANCIAL CONGLOMERATES.

SYSTEMATIC COMPONENT RELATES TO MORTALITY LEVEL RISK (MISESTIMATION OF THE MEAN) AND MORTALITY TREND RISK (DETERIORATION OF THE MEAN). LIFE INSURERS OFTEN ESTIMATE THE MEAN (BEST ESTIMATE) OF MORTALITY BASED ON COMPANY SPECIFICS OR INDUSTRY EXPERIENCE IN THE PAST.

Mean) and mortality trend risk (Deterioration of the Mean). Life insurers often estimate the mean (best estimate) of mortality based on company specifics or on industry experience in the past. However, there is a risk of uncertainty that actual mortality rates fluctuate around the mean due to the volatile nature of the historical observations. The IAA's Global Solvency Paper introduced a technique to modify the estimate by enhancing the credibility to certain confidence levels as an example. This method tests the case as if observed sample mortality mean were, for example, at the 95th percentile of true probability distribution. Then the true mean based on the true probability distribution can be obtained using an inverse Normal Power approximation. The use of the Normal Power approximation (as outlined by Van Broekhoven, 2002) is just an example, but it has a merit in that it is a closed-form formula and an analytic solution can be found without conducting a time consuming simulation.

Mortality trend risk is the risk that mortality trend differs from what is expected. This may result from medical improvements or new diseases. As mortality rates improve in many countries, the mortality trend is important, especially for products vulnerable to longevity risk such as life annuities.

Catastrophic mortality risk is another risk that should be explicitly considered. There is no established way of estimating catastrophic mortality risk at this point since we have only limited experiences (such as a few pandemic cases and large, infrequent earthquakes in some countries). Life insurers traditionally reduce this risk through traditional reinsurance agreements. Another risk mitigation method recently emerging involves issuing mortality bonds in the capital markets. For example, Swiss Re issued a mortality catastrophe bond in 2004. If more and more insurers issue mortality catastrophe bonds in the future, market-consistent approaches for mortality risk may become feasible.

Surrender and lapse risk can be quantified in a similar way as described for the mortality risk.

RISKS ASSOCIATED WITH A POLICYHOLDER'S OPTIONS ARE OFTEN DEPENDENT ON ECONOMIC CONDITIONS AND CAN BE MORE PROPERLY MEASURED WITH STOCHASTIC ANALYSIS OR A STRESS TEST.

Risks associated with a policyholder's options are often dependent on economic conditions and can be more properly measured with stochastic analysis or a stress test. Examples are:

- Policyholders' right to surrender policies to receive predetermined cash value.
- Policyholder's right to annuitize policies to receive predetermined annuity amount.
- Profit sharing mechanism where negative profit cannot be shared.

Once an interaction formula between economic assumptions and policyholder's option execution assumptions is defined, the risk can be quantified by conducting simulations under a number of economic scenarios. The interaction formula can be developed by calibrating to past company-specific or industry experiences. However, policyholder behaviour is difficult to formulate, as it is affected by other factors than economic conditions such as downgrade of a major player in the industry and changes in tax policies. While a number of interaction formulae are introduced in reading materials, one would need to make judgments to come up with the formula that is reasonably adequate for economic capital calculation purposes.

### (2) Credit Risk

Credit risk is modelled in a way consistent with the banking standards. Default, credit mitigation, spread, and spread volatility risks are considered.

**CREDIT RISK IS MODELLED IN WAY A CONSISTENT WITH THE BANKING STANDARDS. DEFAULT, CREDIT MITIGATION, SPREAD, AND SPREAD VOLATILITY RISKS ARE CONSIDERED.**

CreditRisk+, CreditMetrics, and KMV are industry-standard credit models in use. Often, the economic scenario generator for market risks is also used for measuring credit risk.

A general approach of default model is to explicitly model the rates of default and recovery. "CreditRisk+," developed by Credit Suisse Financial Products, is one of the default models. It assumes that the probability distribution for the number of defaults over any period of time follows a Poisson distribution with the parameters estimated by historical statistical data of default experience by credit class.

Credit migration models consider not only the risk of default, but also the risk that an investment will lose or gain value due to changes in the corporation's credit rating. "Transition Matrix," containing the probability that a bond will change from its current credit rating to another, is used by credit migration model. An example of credit migration models is "Credit Metrics" developed by JP Morgan.

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Consultants and Actuaries

Another type of credit model is the asset model developed by Merton in the 1970s. The general concept is that a firm's default can be modelled as an option against its asset because the firm will go into default if the value of its assets becomes less than the value of its debt. KMV, developed by KMV Corporation, is one of the widely used credit risk models.

The reinsurance default risk is also quantitatively assessed. For the quantitative modelling, stochastic factor models implemented by the Monte Carlo method are in use. It is desired that the dependencies between reinsurance defaults, market risks, and catastrophic losses are taken into account. A way to introduce risk dependency is described in section "7.4. Diversification effect."

MARKET RISK CAN BE MODELLED IN A WAY CONSISTENT WITH THOSE USED IN THE BANKING INDUSTRY AND OTHER FINANCIAL INSTITUTIONS, BUT OFTENTIMES IT IS NOT MEANINGFUL FOR INSURERS WITHOUT EVALUATING THE MARKET RISK IN CONJUNCTION WITH LIABILITY, WHICH IS SOMETIMES CALLED "ALM RISK."

### (3) Market Risk

Market risk can be modelled in a way consistent with those used in the banking industry and other financial institutions, but oftentimes it is not meaningful for insurers without evaluating the market risk in conjunction with liability, which is sometimes called "ALM risk." The volatility of market price (market risk) of course affects the net market value of insurer's assets, but at the same time insurers should be aware of its impact on liabilities:

- Changing asset yields could affect the market value of liabilities through the discount rate that is implicitly or explicitly derived.
- Changing asset yields could affect the amount and/or timing of future liability cash flows. Performance-linked bonus is one of the examples.
- Changes in asset returns in the competing market may affect the amount and/or timing of future liability cash flows through changes in policyholder behaviour such as excessive surrenders due to higher return in the competing market or additional premium payment to the existing products guaranteeing higher return compared to the competing market.

DUE TO THE LACK OF REAL MARKET FOR INSURANCE LIABILITIES, MARKET/FAIR VALUE OF LIABILITIES NEEDS TO BE TECHNICALLY DERIVED.

Market value of insurance liabilities is not so straightforward as that of assets, which can generally be obtained from market price. Due to the lack of real market for insurance liabilities, market/fair value of liabilities needs to be

[3] FOR THE ASSET VALUATION, IT IS OFTEN EXPRESSED AS A "MARK-TO-MARKET" APPROACH, WHICH MEANS THAT THE VALUE CAN BE DERIVED FROM THE MARKET PRICE. FOR LIABILITIES, THERE ARE VERY FEW TRADES AND THE MARKET IS MUCH SMALLER; AS A RESULT, LIABILITY VALUATION HAS RECENTLY EMPLOYED A "MARK-TO-MODEL" APPROACH, IN WHICH THE ACTUARY USES A MARKET-CONSISTENT MODEL TO CALCULATE MARKET-CONSISTENT VALUE OF THE LIABILITY.

technically derived.[3] Replicating portfolio is one of the approaches to measure the market value of insurance liabilities. A general approach of measuring market risk is to project future asset and liability cash flows with reflecting the nature of embedded options by using possible future economic scenarios and then discounting the cash flow. There is a debate that the valuation should be done by either risk-neutral valuation or real-world valuation. This issue is covered in section "7.3. Real World vs. Risk Neutral."

### (4) Operational Risk

For insurers, operational risk is the area where methodology on risk measurement is least developed. Operational risks are either quantitatively modelled or qualitatively assessed, and may or may not lead to a capital charge. Modelling approaches currently in use are classified as follows:

#### (A) SIMPLE ADD-ON MODEL

The model aggregates operational risk by combining the anticipated costs for the various identified operational risks. In order to apply an aggregation method to these risks, one must assume a certain degree of correlation and a certain confidence level.

#### (B) STOCHASTIC FREQUENCY-SEVERITY MODEL

The main operational risks are captured in each business unit through scenario analysis with experienced staffs and risk managers. The scenario analysis process includes defining the story behind each risk scenario and determining frequency and severity parameters. These processes require a wide range of experience and information, including the company's existing risk reporting and relevant external sources.

According to the "Benchmarking Study of Internal Models" carried out in late 2004 for the CRO Forum, seven out of 13 surveyed use a simple add-on model, three use a stochastic model, and three use other methods or qualitative analysis.

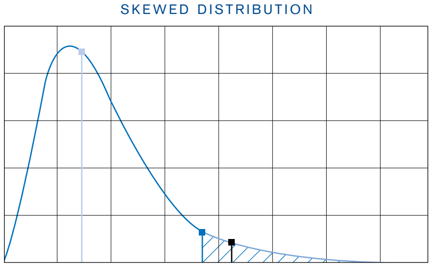
# 7. What modeling decisions should inform the analysis?

THERE ARE A VARIETY OF MODELS TO CALCULATE ECONOMIC CAPITAL.

As seen in the previous section, there are a variety of models to calculate economic capital and it is necessary to make a number of decisions for what type of models, techniques, and parameters should be adopted. This section goes through some of those issues typically relevant for economic capital calculation.

## 7.1. VAR VS. TAIL-VAR

SKEWED DISTRIBUTION




MEAN

VALUE AT RISK (XTH PERCENTILE)

TAIL $\text{VAR}_X$ (AVERAGE VAR IN SHADED AREA)

The two risk measures that have generally been viewed as most suitable are VaR (Value at Risk) and TailVaR (Tail Value at Risk). Other measures are also possible such as the standard deviation of the losses that a company may suffer. All these measures are based on a view of the possible outcomes for the future level of solvency as a probability distribution (this is true even under a stress test approach because the stress test will be calibrated to represent a certain point on the distribution).

VaR assesses the probability of ruin at a given quantile of the probability distribution. TailVaR considers both the probability and severity of losses that exceed a given quantile and is defined as the arithmetic average of losses exceeding a given quantile.

NOTE THAT THE DEFINITION OF ECONOMIC CAPITAL CAN BE BASED ON VAR OR TAILVAR

Note that the definition of required economic capital provided in the opening section was effectively based on VaR. However TailVaR is also discussed as a possible measure for solvency capital and is used by some companies as the measure to assess economic capital.

FROM A SHAREHOLDER PERSPECTIVE, VAR CAN BE CONSIDERED ADEQUATE BECAUSE ONCE THE NET WORTH HAS BEEN EXHAUSTED, SHAREHOLDERS HAVE LOST THE VALUE OF THEIR SHARES AND ARE NOT, IN THEORY AT LEAST, INTERESTED IN THE SEVERITY OF FURTHER LOSSES.

From a shareholder perspective, VaR can be considered adequate because once the net worth has been exhausted, shareholders have lost the value of their shares and are not, in theory at least, interested in the severity of further losses. From a regulatory point of view, however, the magnitude of losses is significant because it will determine the losses to policyholder and hence influence the damage to the reputation of the insurance industry and the regulator.

TailVaR is generally considered to deal better with low-frequency high-severity events because it takes more account of the shape of the tail of the distribution. For this reason, the IAA has expressed a preference for TailVaR over VaR. Although VaR is commonly used in banking, insurance more commonly involves skewed risk distributions. On the other hand, it is often hard to find data to accurately model the tail of the probability distribution.

TAILVAR IS GENERALLY CONSIDERED TO DEAL BETTER WITH LOW-FREQUENCY HIGH-SEVERITY EVENTS BECAUSE IT TAKES MORE ACCOUNT OF THE SHAPE OF THE TAIL OF THE DISTRIBUTION.

At present, the majority of companies' economic capital models are using a VaR approach. Some local regulators who have implemented this type of solvency system have favoured one approach and some the other.

An alternative measure is a conditional tail expectation set at the x% level, denoted CTE(x), which is the average cost of the highest (100-x)% of the results. It should be noted that CTE(x) is generally greater than a (x + ½(100-x)) percentile coverage (i.e., CTE(90) is generally greater than the 95th percentile). Conceptually CTE is quite similar to TailVaR and is used in US regulation.[4]

## 7.2. STOCHASTIC ANALYSIS VS. STRESS TEST

Both stochastic analysis and stress test are commonly used to see an impact of extreme events where you want to know how much capital you need, but they have different characteristics and one may be more suitable than the other for quantification of particular risks. For the purpose of this report, we define stochastic analysis and stress test as follows:

### Stochastic Analysis

Stochastic analysis can be defined as an analysis done by projecting future cash flow based on multiple scenarios of which probability distribution is defined. An example is a Monte Carlo simulation based on 10,000 economic scenarios where probability of occurrence of a particular scenario is typically assumed evenly (1/10,000). You can also assume a certain probability distribution such as Log-Normal or Exponential and use particular scenarios for which occurrence probability is calculated from the assumed probability distribution. For example, if you assume experience mortality for the next year is normally distributed, you can project cash flow by using, say, a 99 percentile

STOCHASTIC ANALYSIS CAN BE DEFINED AS AN ANALYSIS DONE BY PROJECTING FUTURE CASH FLOW BASED ON MULTIPLE SCENARIOS FOR WHICH A PROBABILITY DISTRIBUTION IS DEFINED.

[4] ACCORDING TO THE IAA'S DEFINITION, TAILVAR IS THE QUANTILE VAR PLUS THE AVERAGE EXCEEDENCE OF THAT QUANTILE IF SUCH EXCEEDENCE OCCURS. ALTERNATIVELY, TVAR AT LEVEL P IS THE ARITHMETIC AVERAGE OF ALL VAR'S FROM LEVEL P AND ABOVE. TVAR AND CTE ARE IDENTICAL IF THE DISTRIBUTION FUNCTION IS CONTINUOUS. SEE P. 47 FOR MORE INFORMATION; DHAENE J., S. VANDUFFEL, ET AL.

mortality rate, to quantify the mortality impact on a 99% confidence level. In order to know the impact of extreme scenarios that would occur with x% probability, one needs to project cash flows under a large number of scenarios for the Monte Carlo simulation, but one needs just one scenario to know the probability distribution. However, one needs to do the Monte Carlo simulation for many cases, since the real world is almost always too complex to depict by a simple well-known probability distribution.

### Stress Test

A STRESS TEST CAN BE DEFINED AS AN ANALYSIS DONE BY PROJECTING FUTURE CASH FLOW BASED ON A PARTICULAR SCENARIO THAT COULD OCCUR IN SOME EXTREME ENVIRONMENTS BUT FOR WHICH THE OCCURRENCE PROBABILITY IS NOT SPECIFIED.

A stress test can be defined as an analysis done by projecting future cash flow based on a (set of) particular scenario(s) that could occur in some extreme environments but for which occurrence probability is not specified. The essential difference from stochastic analysis is that the occurrence probability of the stress scenario is not specified, and it is not stochastically meaningful.[5] An example is the Dynamic Capital Adequacy Test (DCAT) of Canada that requires insurers to develop some extreme scenarios in order to evaluate those scenarios.

As seen in another section of this report, it is getting common to calculate economic capital as the amount sufficient to cover losses that can occur over x years with y% confidence probability. To calculate this type of economic capital, stochastic analysis must be used as defined above. However, it is sometimes difficult to assume any meaningful probability distribution for a certain risk. For example, it would be difficult to determine how likely it is that the government might reduce a national health insurance subsidy to half as much as it is now. In this case, it is not a good idea to spend a lot of time and effort to define such a probability distribution, since it is more or less a judgment call. What is important is to identify such stress scenarios that can cause large amounts of losses to the insurer.

In order to calculate economic capital that is defined to cover future losses with a certain percentile of confidence, one should assume an occurrence probability even for such difficult risk by any means. Another important aspect for managers involves understanding that such a probability distribution is determined with actuarial judgment, and the results can differ if such a subjective assumption changes. For the example of a health insurance subsidy reduction, the degree of reduction may be half, one third, or complete elimination at the 95% confidence level. In this case, it is important for the user

[5] THIS DEFINITION IS JUST FOR THE PURPOSE OF THIS REPORT, SINCE OCCURRENCE PROBABILITY IS SOMETIMES ATTACHED TO "STRESS TEST" SCENARIOS AS WELL.

and management to understand the consequences if the impact is different from the base scenario.

MANAGEMENT NEEDS TO UNDERSTAND THE CONSEQUENCES IF THE IMPACT IS DIFFERENT FROM THE BASE SCENARIO.

In summary, it is important to understand the following two points:

- Stochastic analysis, where the occurrence probability is allocated to each scenario, is necessary to calculate economic capital, which is defined as an amount to cover future losses with a certain confidence level.

- For risks for which it is difficult to determine the probability distribution, the occurrence probability is attached just for a technical purpose of economic capital calculation, and thus the user, including management, needs to understand its nature and the sensitivity to change of such subjective judgments.

## 7.3. REAL WORLD VS. RISK NEUTRAL

A risk-neutral technique is a commonly used method to calculate derivative price based on stochastic scenarios. The process of an economic capital calculation is similar to the derivative price calculation in a sense that both involve a present-value calculation of future cash flow based on stochastic scenarios. However, a real-world technique is widely used and is a preferred method to calculate economic capital. We will briefly discuss why the real-world technique is commonly used for the economic capital calculation in this section.

A REAL-WORLD TECHNIQUE IS WIDELY USED AND IS A PREFERRED METHOD TO CALCULATE ECONOMIC CAPITAL.

For the purpose of this report, we define the real-world and the risk-neutral techniques as follows:

### Risk Neutral

A risk-neutral technique is a method to calculate the present value of cash flows by discounting risk-adjusted future cash flow with risk-free rates based on multiple scenarios. The risk-neutral method assumes no arbitrage and a complete market where there is no arbitrage opportunity (no free lunch) and any derivative instruments can be perfectly reproduced by a combination of securities available in the market. If these conditions hold, a mathematical theory ensures that the expected value of the present value of future cash flows based on risk-free discount rates and a transformed probability distribution (Q-measure) is equivalent to the expected value of the present value of future cash flow based on adequate discount rates and a real-world probability distribution (P-measure).

The risk-adjusted cash flow for a particular scenario can be described as cash flow multiplied by a ratio of the occurrence probability of the scenario under the Q-measure to the corresponding probability under the P-measure. The risk-neutral technique is used because it is often difficult to know the "adequate discount rates" under the P-measure, but under the Q-measure, you know risk-free discount rates from the current yield curve and risk-adjusted cash flow can be directly derived by utilizing the risk-free rates and implied volatilities available from the current market price of existing derivative instruments under an adequate modelling of future cash flows.

It is beyond the scope of this report to explain the detail of the risk neutral technique, but important to note that it is the technique to derive "expected value" of future cash flow so that it can be consistent with current observable market prices of derivative instruments.

### Real World

A real-world technique is a method to calculate the present value of cash flows by discounting projected cash flows with risk discount rates based on multiple scenarios. Under this method, projected cash flows are not adjusted for uncertainty risk, which is the risk that future cash flows can be different from those projected. To reflect the "price" of this uncertainty risk, it is common to set the risk-discount rates higher than risk-free rates.

However, as mentioned above, it is often difficult to determine how much the risk- discount rate should be adjusted, and it may need to be set more or less subjectively. If the adjustment is made adequately, the expected present value of future cash flows should be the same under both real-world and risk-neutral techniques.

The risk-neutral technique is superior in that the adjustment for the uncertainty can be consistent with observable market prices of securities. However, there are the following considerations for use of the risk-neutral technique for economic capital calculations:

- Under the risk neutral technique, economic capital needs to be defined as the expected value of cash flows. For example, if economic capital is defined as a loss amount at 95% (VaR definition), the probability distribution should be converted so that the expected value ties to the 95 percentile. It is not straightforward how one can use the market price of securities to construct such a risk-neutral probability distribution.
- Since the loss amount is derived as an expected value under an adequate risk-neutral probability distribution instead of the 95 percentile under a real-world probability distribution, it is often difficult to interpret the meaning of the results.

Because of these shortcomings of the risk-neutral technique for economic capital calculation, the real-world technique is widely used. Particularly relevant to the second point, management people need to have a clear understanding of what the derived economic capital means in order to effectively use it for enterprise risk management.

### 7.4. DIVERSIFICATION EFFECT

It is widely recognised that the total capital requirement could be less than the sum of the capital required for individual risks to the extent that these risks are independent. Mathematical techniques such as linear correlation can be used to analyse risk dependencies. However, it has been pointed out that risk correlations can behave differently in extreme scenarios than they do across most of the probability distribution. For example, a limited movement in mortality may be largely uncorrelated to economic factors driving market risks, but large movements in mortality would seem intuitively to be more likely to be correlated to market risks. A big earthquake or terrorist attack could cause a mortality/morbidity surge and a huge drop in asset market prices simultaneously.

IT IS WIDELY RECOGNISED THAT THE TOTAL CAPITAL REQUIREMENT COULD BE LESS THAN THE SUM OF THE CAPITAL REQUIRED FOR INDIVIDUAL RISKS TO THE EXTENT THAT THESE RISKS ARE INDEPENDENT.

RISK CORRELATIONS CAN BEHAVE DIFFERENTLY IN EXTREME SCENARIOS THAN THEY DO ACROSS MOST OF THE PROBABILITY DISTRIBUTION.

There is a technique called copulas to introduce dependency between risks. Mathematically speaking, a copula is a multivariate probability distribution function with uniform marginal distributions. Although it can be applied to any kind of risk, copula functions are often used in conjunction with default risk modeling, since it is convenient to use copulas to model clear historical evidences that more defaults occur when the market is bear than it is bull. As seen in this default risk case, market and default risk dependency is not a fixed relationship in general, and thus it can not be modelled by a simple multivariate normal distribution with correlation matrix. Copulas are useful to model this risk dependency characteristic.

While a copula function has such an appealing feature, there are sometimes difficulties when applying it to actual practices:

- There is no unique way to determine what kind of copulas should be used.
- There are multiple methods to assess goodness of fit of copulas to sample data points. Those methods include comparisons of likelihood functions, and graphical comparisons of Monte Carlo simulation results with copulas to the sample data points.

SOME PARTIES HAVE BEEN HISTORICALLY SKEPTICAL ABOUT GIVING FULL CREDIT FOR DIVERSIFICATION.

Some parties, such as rating agencies, have been historically skeptical about giving full credit for diversification, and the UK FSA has indicated that it expects that the allowable benefit for diversification of risks across jurisdictions or between life and non-life is likely to be small. The problem of tail dependencies seems to justify this skepticism and suggests that a rigorous approach to understanding risk dependencies is necessary in order to take full credit for aggregation benefits.

Quite a lot of data exists to support the analysis of correlations between various market risks and significant analysis and modelling has been done in this area. Correlation is also supported by well-established economic theory. Whether and why operating factors such as lapse rates are positively or negatively correlated with the stock market is harder to demonstrate and depends on less well-established theories on social trends.

INSURANCE GROUPS WITH DIVERSE BUSINESSES WILL BENEFIT FROM GROUP DIVERSIFICATION BENEFITS BY THE EXTENT TO WHICH THEIR DIFFERENT BUSINESSES HAVE NON-CORRELATED RISKS.

As well as the diversification effect of different independent risks, insurance groups with diverse businesses will benefit from group diversification benefits by the extent to which their different businesses have non-correlated risks.

Leading European insurers are generally large complex groups operating in both life and non-life insurance and have for many years argued that this diversification benefit helped to smooth earnings. From a shareholder perspective this argument relative to earnings seems spurious because investors could achieve the same smoothing by diversifying their investment portfolios without having to invest in diversified businesses. However, the benefits of diversification on capital management seem more concrete since these could not be achieved unless the capital was available to support the different business activities of a company.

It is therefore natural that in presenting their economic capital models, large insurance companies have emphasized the benefits of diversification on the amount of capital calculated as being required. For example, one of Europe's largest insurers calculated diversification benefits of 46% (the reduction in the group capital required compared to the sum of the capital required for the individual operating companies). Of this, 35% was due to geographic diversification and 17% to segmental diversification.

It should be pointed out, however, that from the perspective of local regulators, diversification benefits from a group perspective may not be relevant since they need to ensure the solvency of the individual legal entities that they are supervising. Unless the insurance groups are providing guarantees to provide capital to support potential losses in their operating subsidiaries, then the regulation will require an adequate level of capital for each legal entity.

This has led the CRO Forum to propose that there should be a "Solo Entity Solvency Test" and a "Group Solvency Test" and that the former should be able to take account of capital within the group provided that sufficient capital mobility can be demonstrated, the pledge of capital is backed by appropriate formal legal agreements, and the credit risk associated with such pledges is allowed for. It is worth noting that restrictions on the movement of capital can exist even within different classes of business in the same legal entity as is the case, for example, for UK with-profits business.

## 7.5. TIME HORIZON TO CONSIDER

Generally speaking, insurers that have implemented internal capital models have tended to follow one of two methods in measuring risks and required capital. The first method has a one-year time horizon denoted as a covariance model in the prior section, and the second method involves a multi-year time horizon where the economic balance sheet of the company is projected for a long period such as 30 years or until the liabilities have run-off.

**THERE ARE TWO METHODS IN MEASURING RISKS AND REQUIRED CAPITAL: ONE-YEAR TIME HORIZON AND MULTI-YEAR TIME HORIZON.**

Under the first method, the insurer could involve testing the solvency for a short-term shock such as a sudden movement in equity market or interest rates. The shock is calibrated to represent a certain probability such as a one in every 200 year event. Hence, the amount of capital required to survive the shock is the amount needed to ensure continued solvency with this level of probability. It should be noted that a one-year change in certain risk factors can have an impact on cash flows beyond that one year. An example is the lapse rate. The lapse rate can change due to new information coming in over the year, such as market forecasts, which in turn affects the anticipated future lapse rates that underlie the liability value at the end of that year.

Although this method does not give information about the magnitude of the loss in the tail of the distribution and so could not be used to calculate VaR or CTE, the short-term shock is an attractive approach to those companies wishing to avoid complex and time-consuming stochastic modelling, since if solvency can be adequately estimated by using deterministic methods then no stochastic modelling is required. Another variant of the one-year method could involve projecting stochastically for one year and determining the capital required to have a certain probability of remaining solvent at the end of the current year, for example, by looking at the worst 0.5% of the scenarios.

The second method, which is called a stochastic scenario-based model in the prior section, can either be structured such that there is adequate capital throughout a certain percentage of these scenarios, or only at the end of a certain percentage of these scenarios, which is specifically discussed in the following section "7.6. Whether to allow negative cumulative surplus in the middle of the time horizon." A multi-year time horizon can give deeper understanding of the long-term risk exposures. However, a possible weakness of a multi-year or run-off model is that it may ignore management actions to some extent. Whereas most stochastic models will allow for some dynamic management actions such as investment policy (e.g., asset rebalancing in the event of market falls) and dividend policy, it may be hard to allow realistically for the full range of possible regulatory and management actions on questions such as capital raising and hedging of risks.

The IAA pointed out that there were likely to be various delays between a solvency assessment being established and the regulator taking action due to the need to prepare the reports, regulatory review, and decisions on appropriate actions. However, this delay is unlikely to exceed one year, which could be taken as implying that a one-year horizon for projecting solvency is adequate. Generally, most local regulators and the current economic capital models of leading insurers appear to be in favour of adopting a one-year time horizon. According to the "Benchmarking Study of Internal Models" carried out in late 2004 for the CRO Forum, 10 out of 13 surveyed assess their risks on a one-year time horizon and the remaining three participants use multi-year (5-30 year) time horizon.

## 7.6. WHETHER TO ALLOW NEGATIVE CUMULATIVE SURPLUS IN THE MIDDLE OF THE TIME HORIZON

When economic capital is defined as present value of future losses for a particular adverse scenario, one must decide whether economic capital should be at a level so as not to allow negative cumulative surplus only at the end of time horizon, or at any time in the time horizon.

Definitely more capital is needed if negative cumulative surplus is not allowed in the middle of a time horizon. If it is allowed one may want to assume some borrowings to cover such a shortfall, but it may introduce an issue of what borrowing rate one should use. However, neither one is necessarily superior to the other, and actually both methods are widely used. For example, the current total balance sheet requirement for variable annuities in the US is CTE(90) (not allowing negative cumulative surplus in the middle), but CTE(95) taking into account all future cash flow to the end of projection period in Canada. Since both countries use a different CTE level, it is not apparent which is more conservative for a given set of risks.

## 7.7. WHETHER TO ACCOUNT FOR FUTURE NEW BUSINESS

As a going-concern entity, it is important to confirm that writing new business does not jeopardize the company's economic capital. In fact, one of the CRO Forum's recommendations for the internal model states that "an internal model is more than just stressing the balance sheet—new business must not jeopardize the sufficiency of current assets." If the new business is profitable, which should normally be the case, then including future new business may lower the current value of the insurance liabilities (and thus increase the available economic capital). However, including future new business is also likely to increase the required economic capital. Insurers may therefore want to be certain that there is sufficient capital in each year after taking account of the impact of new business.

According to the "Benchmarking Study of Internal Models" carried out by the CRO Forum, 11 out of 13 surveyed take at most one year of new business into account. The other two participants take two to four years of anticipated new business into account.

# 8. Illustrative Examples

While the definition and the method to calculate economic capital varies largely from company to company, thereby incorporating all material risks that the company is exposed to, this section overviews three examples that are widely used by leading insurers.

1 Measuring the instantaneous capital strain under a deterministic stress test.
2 Measuring the loss from the tail of a P&L distribution using stochastic projections.
3 Measuring the value at risk (VaR) from each source of risk independently, and then combining this for all risks and products allowing for diversification benefits.

## Example 1: Deterministic Stress Test

This approach is based upon determining what the capital strain would be when an instantaneous shock to various risk factors is applied to the economic (or realistic) balance sheet. When the stress scenarios applied are immediate, the approach is seen to be a short-term one, although the impact of the stress on the long-term capital value is taken into account. By using an immediate stress, the approach simulates the impact on the economic balance sheet before management has time to react to it. Consequently it does not include any allowance for possible management actions, such as changes to underwriting practices, or the rebalancing of any hedged positions held.

**THE DETERMINISTIC STRESS TEST IS BASED ON DETERMINING WHAT THE CAPITAL STRAIN WOULD BE WHEN A SHOCK TO VARIOUS RISK FACTORS IS APPLIED TO THE ECONOMIC BALANCE SHEET.**

This approach is a common way of determining capital requirements for companies in the UK (Individual Capital Assesments (ICA) and risk capital margins (RCMS) in Switzerland, under the new Swiss Solvency Test). The choice of stress test does however vary by country and by company. The CRO Forum has recently advocated this approach across Europe.

We consider by way of example a portfolio of unit-linked business with financial guarantees. The stress test illustrated below assumes an instantaneous shock of -20% to equities, +5% nominal to volatility (based on volatility increasing from 20% to 25%), and -1% to short-term interest rates. These are the main sources of market risk, and the amounts selected are generally determined to be equivalent standardised shocks. For example, each shock could represent a three or four standard deviation move on a daily basis. The example below assumes perfect knowledge about other risk factors such as mortality and lapse behaviours, however these factors can be added in.

The following table shows the starting position of the realistic economic balance sheet before any shocks are applied to it.

| STARTING POSITION | TOTAL LIABS | TOTAL ASSETS | EQUITIES | BONDS |
|---|---|---|---|---|
| UNIT RESERVE | 100.0 | 100.0 | 50.0 | 50.0 |
| VALUE OF GUARANTEE | 20.0 | 20.0 | 10.0 | 10.0 |
| CAPITAL | 5.0 | 5.0 | 2.5 | 2.5 |
| TOTAL | 125.0 | 125.0 | 62.5 | 62.5 |

Here unit reserves are taken to be the usual policy reserves held for unit-linked business, typically calculated as the number of units allocated to a policy, multiplied by the price per unit.

Starting unit reserves are 100 and are equally weighted between equities and bonds. The value of guarantees is 20. A starting capital position of five has been hypothesised.

After the application of the above stress test, the realistic economic balance sheet is impacted as follows:

| EQ ↓ 20%; i ⇓ 1.0%; vol BY 5% | TOTAL LIABS | TOTAL ASSETS | EQUITIES | BONDS |
|---|---|---|---|---|
| UNIT RESERVE | 90.0 | 90.0 | 40.0 | 50.0 |
| VALUE OF GUARANTEE | 33.9 | 18.0 | 8.0 | 10.0 |
| CAPITAL | (11.4) | 4.5 | 2.0 | 2.5 |
| TOTAL | 112.5 | 112.5 | 50.0 | 62.5 |

Balances for equities have all fallen by 20%. Note that the impact of the fall in short-term interest rates (e.g., due to monetary policy decision of the central bank) has no impact on long-term interest rates and on the value of bond holdings. The example could however be refined to allow for this additional risk. Under the stress selected, the value of guarantees has risen significantly from 20 to 33.9. Consequently, the capital position of the company has fallen from a small surplus of five to a significant deficit of -11.4. Thus the economic capital required (to absorb the decrease in surplus) is 16.4 (-11.4 – 5). This amount would be sufficient to restore the balance sheet to an equivalent capital position. This is the capital required after the stress scenario has occurred, under post-stress scenario valuation conditions. One normally revalues the underlying assets to obtain the capital value at risk under pre-stress conditions.

As an example to see how the economic capital calculations can be put to good use, consider what would happen if the company put in place a hedging strategy. If the company had implemented a dynamic hedging strategy such that appropriate derivative assets were held to cover the market (delta), volatility (vega), and interest rate (rho) risks, then the starting realistic balance sheet would be as follows.

| STARTING POSITION | TOTAL LIABS | TOTAL ASSETS | EQUITIES | BONDS | RISK-FREE ASSET | OPTION | IR SWAP |
|---|---|---|---|---|---|---|---|
| UNIT RESERVE | 100.0 | 100.0 | 50.0 | 50.0 | | | |
| VALUE OF GUARANTEE | 20.0 | 20.0 | (23.0) | (23.0) | 58.0 | 5.0 | 3.0 |
| CAPITAL | 5.0 | 5.0 | 2.5 | 2.5 | | | |
| **TOTAL** | **125.0** | **125.0** | **29.5** | **29.5** | **58.0** | **5.0** | **3.0** |

An asset position has been established that replicates the risks and value of the guarantee. It includes:

- A short position in equities and bonds, combined with a long position in risk-free assets to hedge the market (delta) risk.
- An equity option to hedge the volatility (vega) risk.
- An interest rate swap to hedge interest rate (rho) risk.

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After the application of the above stress test, the realistic economic balance sheet is affected as follows:

| EQ ⇓ 20%; I ⇓ 1.0%; vol BY 5% | TOTAL LIABS | TOTAL ASSETS | EQUITIES | BONDS | RISK-FREE ASSET | OPTION | IR SWAP |
|---|---|---|---|---|---|---|---|
| UNIT RESERVE | 90.0 | 90.0 | 40.0 | 50.0 | | | |
| VALUE OF GUARANTEE | 33.9 | 33.0 | (18.4) | (23.0) | 58.0 | 11.9 | 4.5 |
| CAPITAL | 3.6 | 4.5 | 2.0 | 2.5 | | | |
| TOTAL | 127.5 | 127.5 | 23.6 | 29.5 | 58.0 | 11.9 | 4.5 |

All positions in equities have fallen by 20%, while the values of the option and interest rate swap have increased. The impact of the stress test reduces the capital from 5 to 3.6. Thus the economic capital required is 1.4. This amount would be sufficient to restore the balance sheet to an equivalent capital position. By hedging the risks with derivative assets, the economic capital required to support this product has been significantly reduced from 16.4 to 1.4.

**NOTE:** As mentioned earlier, while this example only illustrates a stress test on market risks only, in practice, additional stresses to demographic, credit, and other risks are also normally included in the calculations.

## Example 2: P&L Projection

We now illustrate an alternative method for calculating and working with economic capital. To aid comparison, the following analysis is again based upon a unit-linked investment with return of capital accumulated at a guaranteed minimum rate of accumulation, payable on maturity (a GMAB in US parlance). The term to maturity is 25 years and the underlying fund is a diversified mix of approximately 40% equities, 60% bonds.

Following are three main sources of risk underlying the guarantee:

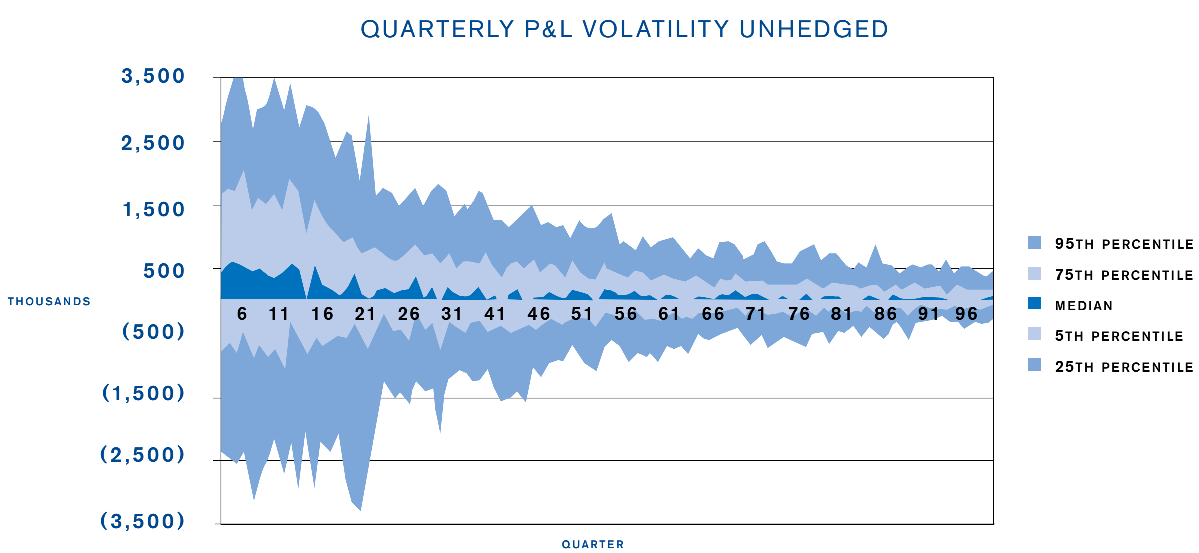
**DELTA**, which is first measure of the risk that the underlying assets fall. When underlying assets fall, the value of the guarantee increases significantly. Delta measures the rate of change of this value with respect to changes in the value of the underlying assets.

**RHO**, which is the primary measure of interest rate risk. If future interest rates fall, the risk-neutral present value of the liabilities increases, due to the lower expected risk-neutral growth rate of the underlying assets and the lower interest rate used to convert future guarantee claims to present values. Rho measures the rate of change of the value of the liability to changes in interest rates.

**VEGA**, which is the primary measure of volatility risk. The greater the volatility, the greater the cost of hedging and the greater the value of the guarantee liabilities. Vega measures the rate of change of the value of the liability to changes in volatility.

In order to quantify these risks it is necessary to undertake a financial projection of the P&L across a wide range of realistic scenarios, and within each one, undertake a series of risk-neutral valuations of the liability guarantee. To the extent that the liability risks are hedged using a derivative asset portfolio, then the asset payoffs at each time step for each scenario need to be calculated and included in the hedged P&L.

The following graph shows 100 projections of the economic P&L on a quarterly basis over the lifetime of the product. It shows stochastically varying market (delta) and interest rate (rho) risks on an unhedged basis.



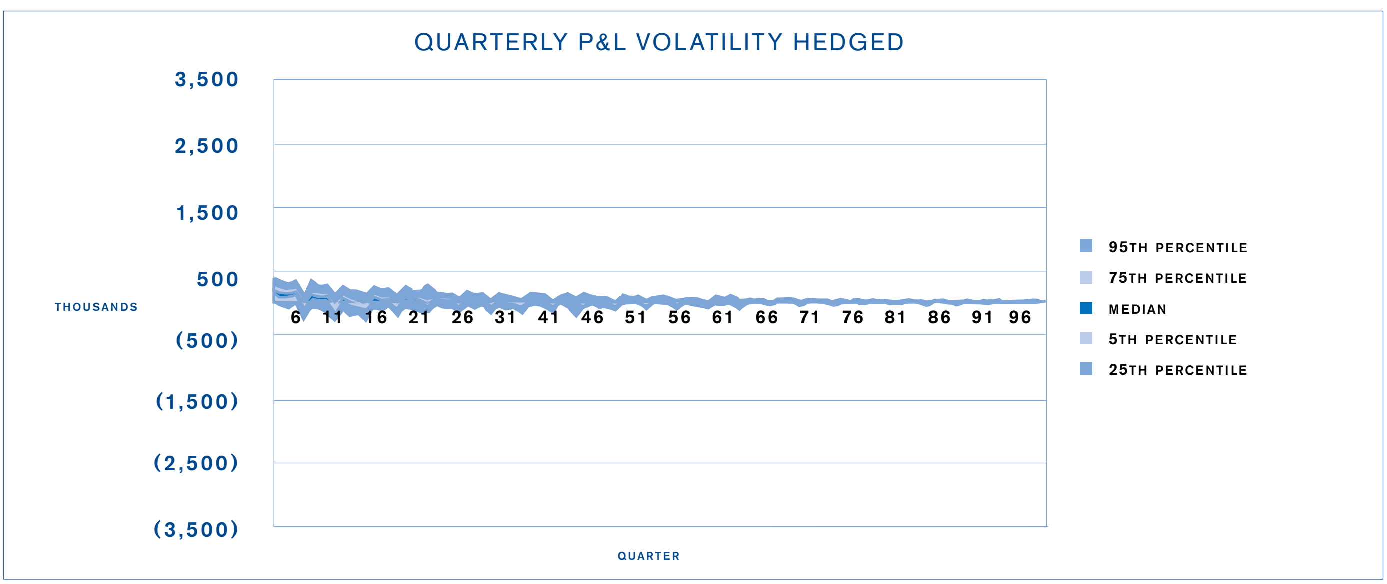
Economic capital supporting these risks can then be calculated using either a Value at Risk (VaR) approach or a Conditional Tail Expectation (CTE) approach. Under a VaR approach economic capital is defined as the capital that would be required to cover the scenario producing the xth worst percentile of potential outcomes. Typical values of x% are 5% and 1%. Under a CTE approach, economic capital is defined as the capital that would be required to support the average loss, for losses in the bottom y% of potential outcomes. Again, typical values of y% are 5% and 1%.

The economic value under these two measures (based upon the analysis in the graph on p. 39) is shown in the following table.

| MEASURE | 5% CONFIDENCE LEVEL | 1% CONFIDENCE LEVEL |
|---|---|---|
| VAR | 2.8 MILLION | 14.5 MILLION |
| CTE | 7.4 MILLION | 14.5 MILLION |

As can be seen, the economic capital measured using a CTE approach is greater than that using a VaR approach for the same confidence level. They are equal at the 1% level simply because the analysis used 100 scenarios, so both measures return the loss made under the worst-case scenario.

The graph below shows the impact upon the net P&L from hedging both delta and rho risks. Note that vega risk has not been stochastically modelled in this example.



As can be seen, the reduction in risk as measured by the volatility or dispersion of P&L results is significant. Likewise, there is a significant reduction in the economic capital required to support the business when the effect of hedging has been taken into account, as shown in the following table.

| MEASURE | 5% CONFIDENCE LEVEL | 1% CONFIDENCE LEVEL |
|---|---|---|
| VaR | 0.01 MILLION | 0.34 MILLION |
| CTE | 0.09 MILLION | 0.34 MILLION |

At the 5% level under a CTE measure, the economic capital required to support these two risks is 0.09 million or 90,000.

The above example illustrates that most risk management strategies do not normally eliminate all risks completely. Rather, they reduce the amount of risk down to much lower levels than would have been the case had the risk management strategies not been in place.

## Example 3: Holistic VaR Aggregation – Towards Enterprise Risk Management (ERM)

The prior methodology showed that it is possible to calculate the economic capital required using the distribution of present value of projected losses resulting from market risk. However it is also possible to repeat this analysis for each source of risk independently. These include:

**MARKET RISK:** the risk that market levels, interest rates, or volatility change, resulting in losses.
**CREDIT RISK:** the risk that an asset held experiences either a default or a significant fall in its credit quality (an increase in its credit spread over risk-free bonds).
**LIQUIDITY RISK:** the risk that reduced liquidity constrains the ability to buy and sell assets, resulting in losses.
**UNDERWRITING/DEMOGRAPHIC RISK:** the risk that actual demographic experience turns out worse than expected. This can further be broken down into:

**MORTALITY/LONGEVITY/MORBIDITY RISK:** which can be further decomposed into a diversifiable component, which reduces as the number of insured lives increases due to the central limit theorem, and a systematic component, which relates to the risk that the mortality basis is incorrect.

**LAPSE RISK:** the risk that policyholders will lapse differently from that expected.

**POLICYHOLDER BEHAVIOUR RISK:** the risk that policyholders will elect various options (annuitisation rates, withdrawal rates, etc.) differently from that expected.

**EXPENSE RISK:** the risk that experienced expenses are higher than those assumed when pricing a product at the outset.

**OPERATIONAL RISK:** the risk that there is a failure in the operational aspects of the business—people, processes, or systems.

**GROUP RISK:** the risk that a loss or failure of a related group entity results in a loss of the entity under consideration.

The economic capital required for each risk category is typically an aggregation of the economic capital required for a series of individual risk types. For example, insurance/demographic risks are further broken down into mortality, longevity, morbidity, lapse, and expense risks. The capital required for each individual risk is calculated using either a deterministic stress test or through stochastic P&L projections as outlined before. These risks are then aggregated through the use of a correlation matrix as outlined in the following example.

| MILLIONS | MORTALITY | LONGEVITY | MORBIDITY | LAPSE | EXPENSE |
|---|---|---|---|---|---|
| MORTALITY | 1.0 | 0.0 | 0.5 | 0.0 | 0.5 |
| LONGEVITY | 0.0 | 1.0 | 0.0 | 0.5 | 0.5 |
| MORBIDITY | 0.5 | 0.0 | 1.0 | 0.0 | 0.5 |
| LAPSE | 0.0 | 0.5 | 0.0 | 1.0 | 0.5 |
| EXPENSE | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 |
| ECONOMIC CAPITAL | 9.0 | 13.0 | 5.0 | 35.0 | 15.0 |
| ECONOMIC CAPITAL WITHOUT DIVERSIFICATION | | | | | **77.0** |
| ECONOMIC CAPITAL WITH DIVERSIFICATION | | | | | **56.0** |

This correlation matrix allows for the fact that the various risk factors are not perfectly correlated; that is, the worst case outcomes do not all occur at the same time. This results in a reduction in the economic capital required from 77 to 56 million. A similar analysis is then undertaken for each risk category.

THIS CORRELATION MATRIX ALLOWS FOR THE FACT THAT THE VARIOUS RISK FACTORS ARE NOT PERFECTLY CORRELATED; THAT IS, THE WORST CASE OUTCOMES DO NOT ALL OCCUR AT THE SAME TIME.

The following table shows the distribution of expected P&L outcomes for a unit linked guaranteed product—the bottom and top 5% as well as the mean outcome. The aggregate result is the sum of all the separate risks.

| MILLIONS | MARKET | CREDIT | LIQUIDITY | INSURANCE | OPERATIONAL | GROUP | AGGREGATE |
|---|---|---|---|---|---|---|---|
| 95% | 754.0 | 842.0 | 1,000.0 | 936.0 | 1,000.0 | 1,000.0 | 532.0 |
| EXPECTED | 1,000.0 | 1,000.0 | 1,000.0 | 1,000.0 | 1,000.0 | 1,000.0 | 1,000.0 |
| 5% | 1,203.0 | 1,173.0 | 1,183.0 | 1,056.0 | 1,356.0 | 1215.0 | 2,186.0 |
| 5% VaR | 203.0 | 173.0 | 183.0 | 56.0 | 356.0 | 215.0 | 1,186.0 |
| 5% VaR WITH DIVERSIFICATION | | | | | | | 816.0 |

In a world of zero risk, the expected value would always be achieved. Risk results from the uncertainty that the actual result will be less than expected. Thus one possible measure of the value at risk is the difference between the expected value and the lower 5th percentile (say) from the distribution of possible outcomes.

In the above example, we have shown the VaR from each source of risk. First, we work with perfect knowledge (i.e., deterministic parameters) for all risk factors except market risks. We see the VaR due to market risks is 203.

Then we work with perfect knowledge for all risk factors except credit risks—and we find the VaR due to credit risks is 173. (This of course depends on the credit worthiness of the bonds held in the portfolio, their term, and the investment strategy involving them—for example, if the bonds are generally held to maturity or rebalanced frequently.)

We proceed on this basis for the other risk sources to compute the VaR from each risk source in isolation. We then see that the aggregate sum of each risk factor VaR is 1,186. However this assumes that each risk factor is perfectly correlated to every other—i.e., the 5% worst scenario for each risk occurs at the same time. Clearly this is unrealistic. Consequently, diversification between the risk factors is accounted for by estimating the pair-wise correlations as shown in the following table.

| | CREDIT | LIQUDITY | MARKET | OPERATIONAL | INSURANCE | GROUP |
|---|---|---|---|---|---|---|
| CREDIT | 1.0 | 0.3 | 0.4 | 0.2 | 0.25 | 0.1 |
| LIQUDITY | 0.3 | 1.0 | 0.5 | 0.25 | 0.1 | 1.0 |
| MARKET | 0.4 | 0.5 | 1.0 | 0.1 | 0.1 | 0.5 |
| OPERATIONAL | 0.2 | 0.25 | 0.1 | 1.0 | 0.1 | 0.5 |
| INSURANCE | 0.25 | 0.1 | 0.1 | 0.1 | 1.0 | 0.4 |
| GROUP | 0.1 | 1.0 | 0.5 | 0.5 | 0.4 | 1.0 |

This enables us to calculate the 5% VaR allowing for diversification benefits. As can be seen, the best estimate of economic capital for this product is 816, a reduction of 31%. It should be noted that the estimate of these correlations is a matter of subjective judgment and debate, although simplified multi-variate models can be used to help derive them. Generally, this is one of the most difficult parts of the ERM process, particularly given the nature of some risks such as operational risk.

Operational risk assessment remains an emerging area. A wide debate over how best to model this risk continues.

The above analysis can then be repeated for each product as shown in the following table.

| MILLIONS | MARKET | CREDIT | LIQUIDITY | INSURANCE | OPERATIONAL | GROUP | AGGREGATE |
|---|---|---|---|---|---|---|---|
| UL GUARANTEE | 203.0 | 173.0 | 183.0 | 56.0 | 356.0 | 215.0 | 1,186.0 |
| EQUITY INDEXED GUARANTEE | 96.0 | 0.0 | 67.0 | 85.0 | 145.0 | 35.0 | 428.0 |
| TERM ASSURANCE | 56.0 | 13.0 | 89.0 | 136.0 | 42.0 | 5.0 | 341.0 |
| UNIT LINKED | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 | 0.0 | 30.0 |
| **TOTAL** | **355.0** | **186.0** | **339.0** | **277.0** | **573.0** | **53.0** | **1,985.0** |
| **5% VAR WITH DIVERSIFICATION** | | | | | | | **1,588.0** |

Summing across all products and risks gives us an estimate of 1,985 for the economic capital assuming perfect correlation between risks. When diversification benefits are taken into account, this reduces to 1,588.

This methodology for determining economic capital is becoming widely used within the UK to set individual capital requirements for the life insurance industry.

# Appendix: Examples of the IAA classification of insurer risk

## (1) Underwriting Risk

**UNDERWRITING PROCESS RISK:** risk from exposure to financial losses related to the selection of risks to be insured.

**PRICING RISK:** risk that the prices charged by the company for insurance contracts will be ultimately inadequate to support the future obligations arising from those contracts.

**PRODUCT DESIGN RISK:** risk that the company faces risk exposure under its insurance contracts that were unanticipated in the design and pricing of the insurance contract.

**CLAIMS RISK:** risk that many more claims occur than expected or that some claims that occur are much larger than expected claims resulting in unexpected losses. This includes both the risk that a claim may occur, as well as the risk that the claim might develop adversely after it occurs.

**ECONOMIC ENVIRONMENT RISK:** risk that social conditions will change in a manner that has an adverse effect on the company.

**NET RETENTION RISK:** risk that higher retention of insurance loss exposures results in losses due to catastrophic or concentrated claims experience.

**POLICYHOLDER BEHAVIOUR RISK:** risk that the insurance company's policyholders will act in ways that are unanticipated and have an adverse effect on the company.

**RESERVE RISK:** risk that the provisions held in the insurer's financial statements for its policyholder obligations will prove to be inadequate.

## (2) Credit Risk

**DIRECT DEFAULT RISK:** risk that a firm will not receive the cash flows or assets to which it is entitled because a party with which the firm has a bilateral contract defaults on one or more obligations.

**DOWNGRADE OR MIGRATION RISK:** risk that changes in the possibility of a future default by an obligor will adversely affect the present value of the contract with the obligator today.

**INDIRECT CREDIT OR SPREAD RISK:** risk due to market perception of increased risk.

**SETTLEMENT RISK:** risk arising from the lag between the value and settlement dates of securities transactions.

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**SOVEREIGN RISK:** risk of exposure to losses due to the decreasing value of foreign assets or increasing value of obligations denominated in foreign currencies.

**CONCENTRATION RISK:** risk of increased exposure to losses due to concentration of investment in a geographical area or other economic sector.

**COUNTERPARTY RISK:** risk of changes in values of reinsurance, contingent assets, and liabilities.

### (3) Market Risk

**INTEREST RATE RISK:** risk of exposure to losses resulting from fluctuations in interest rates.

**EQUITY AND PROPERTY RISK:** risk of exposure to losses resulting from fluctuation of market values of equities and other assets.

**CURRENCY RISK:** risk that the relative changes in currency values decrease value of foreign assets or increase the value of obligations denominated in foreign currencies.

**BASIS RISK:** risk that yields on instrument of varying credit quality, liquidity, and maturity do not move together, thus exposing the company to market value variation that is independent of liability values.

**REINVESTMENT RISK:** risk that the returns on funds to be reinvested will fall below anticipated levels.

**CONCENTRATION RISK:** risk of increased exposure to losses due to concentration of investment in a geographical area or other economic sector.

**ASSET/LIABILITY MISMATCH RISK:** risk in changes to capital levels to the extent that the timing of amount of the cash flows from the assets supporting the liabilities and the liability cash flows are different.

**OFF-BALANCE SHEET RISK:** risk of changes in values of contingent assets and liabilities such as swaps that are not otherwise reflected in the balance sheet.

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