IAA Risk Book

Chapter 17—Risk and Uncertainty

Quantification, Communication and Management

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1. Executive Summary

The recognition and management of the distinctive features of risk and uncertainty underlie both the purpose of insurance[1] and steer management's actions, affecting all its stakeholders. The management of risk and uncertainty is a central function of an insurance company. As such, the issues addressed in this chapter are important to its many stakeholders, including boards, insurance supervisors and rating agencies, as well as to its Chief Risk Officer, the actuarial function and other insurance management.

Sound application of risk and uncertainty management concepts will lead to more effective governance of an insurance company and its business, including their identification, quantification, management and communication.

To highlight their differences, this chapter uses the following definitions:

- Risk is the effect of variation that results from the random nature of the outcomes being studied (i.e., a quantity susceptible of measurement).
- Uncertainty involves the degree of confidence in understanding the effect of perils or hazards not easily susceptible to measurement.

Key messages of this chapter include:

1. Consideration of risk and uncertainty on an updated basis is needed to effectively assess and manage the current and future responsibilities and performance of the insurer. This includes:
    a. the valuation and testing of the adequacy of assets and liabilities;
    b. the determination of required (or target) capital;
    c. the roles that risk and uncertainty play in stress testing; and
    d. the most appropriate ways to manage insurance in a sustainable manner.
2. Risk and uncertainty as reflected in required capital calculations address only adverse consequences, while provision for uncertainty in the valuation of liabilities or in premiums generally consider both positive and negative effects. Expectations

[1] To reduce adverse financial consequences of insured risks by reducing the uncertainty of financial fluctuations of its purchasers

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regarding future cash flows will in practice always represent a combination of risk and uncertainty.

3. Effective communication of the extent and possible effects of the risks and uncertainties involved is important for all stakeholders, although the form and content of such communication may differ by type of stakeholder. Its content may be numerical or visual displays of a range of metrics, the enumeration of alternative outcomes or scenarios, or a set of management implications and choices. Alternative scenario assessment may provide useful and understandable illustrations, especially through graphical displays of the range of performance and possible future scenarios.
4. Although assessment of risk and uncertainty regarding individual assumptions has value, enhanced value may be derived from the study of the validity of actuarial models on an aggregate basis through a comprehensive set of assumptions, including their inter-relationships.
5. Metrics, such as actual-to-expected indices, provide insightful comparative information for the operation of an insurer, including trends, planning/budgeting and liability/capital/pricing adequacy.
6. The sense of false precision when presenting single number results can be addressed by clarifying the basis of results and using ranges and scenario analysis.

2. Introduction / Background

Insurance provides financial security against unlikely losses related to specific events which may occur to a policyholder. It is a complex, yet adaptive system. Through the principle of the law of large numbers and risk pooling, insurance spreads the adverse financial effects of such losses over a pool of similar risks and over time.

Since the future is uncertain, there remains the possibility of loss both to the insured (to the extent the risk is not insured) and to the insurer. This possibility of loss is due to both risk and uncertainty. Note that in many cases, "risk" is used as shorthand for both risk and uncertainty, although the distinction between them as discussed in this chapter is quite important.

The modern distinction between economic risk and uncertainty was presented by the economist Frank Knight. His 1921 book, *Risk, Uncertainty, and Profit*, distinguished between situations under risk where the outcomes were unknown but governed by probability distributions known at the onset (such as tossing a fair coin), in contrast to uncertainty situations where the outcomes, although likewise random in nature, are governed by an unknown probability distribution or model. "The essential fact is that 'risk' means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomena depending on which of the two is really present and operating. It will appear that a measurable uncertainty, or 'risk' proper is so far different from an unmeasurable one that it is not in effect an uncertainty at all."[2]

[2] F. H. Knight. (1921) 19-20

Knightian uncertainty is often referred to as "uncertainty" about the extent to which the expected mean (a key parameter) of the probability distribution is incorrect.

Some examples include:

1. Aspects of the future that are not considered by the parameters or the model structure. There is always uncertainty regarding the "true" value of parameters regarding the future, no matter the historical data available. In some cases, the volume of available and relevant data may not be sufficient to develop a model structure or reliable estimates of its parameters, while in others, conditions will differ between the past and the future.
2. A particularly adverse future may be the result of what has been referred to as an unknown-unknown (also called a paradigm shift or black swan). Such uncertainty can affect what is being estimated/projected. Some examples include:
    a. Changes in mortality that can result from either a medical breakthrough that affects the level of mortality in all future periods or a pandemic that is a one-time occurrence;
    b. A novel court decision that can change the liability of an insurer;
    c. New information gathered during the claims process; or
    d. An event (e.g., the 2008 financial crash and asset bubbles) that affects one or more economic assumptions such as inflation or credit risk.

When there is limited relevant and reliable data, there can be a great deal of uncertainty about the actual nature of the underlying probability distributions. This uncertainty due to ambiguous data can lead to indecision, precluding effective responsibility, impeding learning, inaccurate forecasts and incorrect decisions. This highlights the possible effect of a lack of sufficient understanding of the past or the drivers of future scenarios. Professional judgement and effective quantitative techniques can provide insight into the issue and the nature of those distributions.

Almost all actuarial applications involve looking ahead to the future and therefore are affected by both risk and uncertainty. There are limited circumstances in which a controlled experiment can be conducted that provides findings that can be reproduced or validated based on underlying exposure changes in volume and characteristics. But in many cases, the incidence rate is so small that reliable experience cannot be obtained and judgment has to be applied.

In summary, questions that need to be addressed to assess whether risk or uncertainty are more dominant include (1) can accurate and reliable historical information (data) be obtained, (2) can a model/set of assumptions be developed consistent with the historical information and (3) can the model/set of assumptions be applied or adjusted to characterize a reasonable representation of the future?

The purpose of risk management is to quantify risks and identify the actions needed to eliminate or reduce the adverse effects of their consequences. Just because something is uncertain doesn't mean that it can't be managed – it may be able to be avoided, controlled or its adverse consequences minimized.

3. The nature of and distinction between uncertainty and risk[3]

Since contingencies covered by insurance policies are exposed to significant risks and uncertainties, margins are included in the premiums for these policies. Margins are also included in prices charged by a third party if the risks are transferred to that party through reinsurance, business combinations (i.e., mergers or acquisitions), or portfolio transfers. Methods chosen to set and release those margins will affect reported earnings timing and volatility. Earnings volatility that is not understood or is a surprise – the result of emerging risks or uncertainty – may result in decreased market valuations of the company.

Determining how much reliance should be placed on observed experience is a significant challenge. To do so, experience should be decomposed where possible to help distinguish how much volatility is due to risk or uncertainty. Analysis and comparison of trends and patterns observed between actual and expected experience can help distinguish between risk and uncertainty. Significant one-off or systematic deviations in the same direction can also help provide insight. In many cases, however, it can be difficult to distinguish between the two – nevertheless, the determination of whether to modify prior expected probability distributions and other estimates is a necessary step in revising expectations (a feedback loop) and developing risk plans to help avoid or reduce the effects of an adverse future.

Volatility in an insurer's financial results generally reflects the results of a combination of the risks and uncertainties involved in its operations, although the reported volatility can either be smoothed over time or be exacerbated by the method of accounting used. It is important to distinguish the effect of a deviation from expected performance and the effect of the financial reporting framework[3]. The disentanglement of performance reporting is especially challenging in product lines whose results tend to evolve over a lengthy period and that are expected to experience volatile results. Interpreting deviations from expected is difficult enough, let alone determining whether these deviations will continue over the long-term life of the business or claims. An effective insurance risk management process thus applies feedback loops and dynamic risk mitigation/control techniques to address this issue. Favorable results may lead to taking on new risks and opportunities in applying a risk and reward trade-off approach, which may facilitate obtaining a competitive advantage while maintaining financial sustainability.

The risks and uncertainties associated with insurance follow the life-cycles of insurance coverage and claims. For example, prior to business being sold and claims incurred, there is uncertainty associated with the future or emerging mix of insureds covered or the types of claims that will be made. As more information is gathered, e.g., as the portfolio of life insurance policies matures or information regarding new claims is reported, the uncertainties diminish and resulting risks become dominant as they become more estimable/measurable.

[3] Therefore, a deep understanding of the effects of the accounting system is necessary for actuarial assessment and financial planning and review.

Sound application of risk and uncertainty management concepts will lead to more effective governance embedded into the corporate culture of an insurance company and its business – that is, the identification, quantification, management and communication of risk and uncertainty.[4]

Premiums and other considerations incorporate the aggregate effect of bearing both risk and uncertainty, which reflect the overall expected sources of volatility that economically justify an inherent reward for conducting an insurance business. Capital provides for a level of risk and uncertainty greater than moderately adverse. In reality, a perfectly competitive market (where, according to economic theory, excess profits would be driven down to a minimal level) does not exist. Arguably, because insurance policies, with few exceptions, have not been bought and sold in a perfect market, such profits can be assumed to arise, but are usually difficult to isolate and quantify.

Knight's distinction between uncertainty and risk, mentioned previously, has been used by some commentators to differentiate between measurability and immeasurability, objective and subjective probabilities, and insurable and uninsurable probabilities of probabilistic outcomes. Knight went on to indicate that "'judgment', 'common sense', or 'intuition'"[5] is used for business decision-making relating to those items that are immeasurable through formal processes of logic and model-building. A more practical and useful distinction may be drawn between process risk and parameter/model risks (see section II for a discussion of these concepts) that does not attempt to deal with whether uncertainty is measurable.

According to Langlois and Cosgel (1993), one interpretation of Knight represents an understanding that an agent can form subjective probability assessments of any situation, so that the distinction that Knight intended to make was between situations in which insurance markets can operate smoothly (where risk exists) and situations in which insurance markets become unsustainable because of moral hazard and adverse selection (with associated uncertainty and internal imbalances).

Except in unusual and laboratory situations (e.g., tossing a coin) rarely encountered in the real world, partial information or suppositions will always exist; thus the expectations regarding future cash flows will in practice always be a combination of risk and uncertainty. In addition, since future conditions will always be at least partially different than those of the past, a distinction between objective/subjective probabilities is rarely distinguishable, and as a result judgment will always be needed.

Consistent with this distinction, Karl Popper noted that outcomes of physical experiments are produced by a set of "generating conditions". When an experiment is repeated, it is independent with a similar set of generating conditions. Such conditions with a propensity *p* of producing the outcome *E* means that those exact conditions, if repeated indefinitely, would produce a sequence in which *E* occurs with limiting relative frequency *p*. However, this only occurs if future conditions are identical to those in an earlier experiment. Therefore, because of differing

[4] This doesn't mean total avoidance of risk and uncertainty (as that is impossible), but it does point to the importance of understanding and management of the risks and uncertainties involved.
[5] F. H. Knight. (1921) 211

conditions, conclusions reached based on past events cannot be automatically assumed to be applicable in the future.

Differences from a base set of expectations can emerge as a result of many factors, including (1) a lack of proper understanding of the underlying coverage or insureds and (2) changes in conditions, especially discontinuities in experience or performance, some of which are referred to as "black swans" (deemed highly improbable on an individual basis and outside the range of preconceived notions, but as a group happen far more often than expected – although often thought of as negative or adverse, they can also be beneficial). The most obvious of these black swans are catastrophic events not previously envisioned as being possible such as an earthquake occurring along a previously unknown fault line, either of natural causes or man-made.

Less obvious, but of greater likelihood and cumulative importance in some long-term insurance policies than one-time discontinuities in experience, are significant but gradual differences in trend in one or more underlying factors. A "grey swan" event (also referred to as "grey rhinos" – the obvious, predictable, risks that are consistently neglected) is something that could be anticipated, but is considered at the time to be unlikely to occur; if it does occur, its effect is difficult to quantify. But not all discontinuities in experience are due to black swan-type sources—for example, expected changes can manifest themselves quickly, result from changes in the interrelationship between factors such as lapse and mortality because of changed or temporarily stressed conditions, or be simply the result of statistical fluctuations either prior to or after the point of discontinuity.

In some insurance coverages, both gradual (trend) and sudden (discontinuity) changes in conditions can be difficult to identify, predict, and distinguish from a process (statistical fluctuation) risk. Examples of these changes include broader environmental changes as a sudden advancement in medical technology or in social attitude toward utilization of some insurance benefits, applicable regulation, and change in the nature of the services provided or service providers.

Donald Rumsfeld, a former U.S. Secretary of Defense, distinguished[6] between known knowns, known unknowns (grey swans), and unknown unknowns (black swan) risks. Of course, little if anything about the future is certain – nevertheless, the first category refers to circumstances with estimable outcomes. The sources of volatility can be (1) inherent in past or current conditions, but not yet quantified or understood or (2) did not exist in the past, such as a disease that had never before been identified or a reinterpretation of an existing law/regulation that is applied retroactively. Both black and grey swan events can be categorized as uncertainties, with grey swan events likely not to be quite as catastrophic, but possibly more frequent. Swan-type situations may be a one-off change in conditions or a permanent discontinuity.

The concept of risk as used in finance is primarily concerned with process risk (see section 4.I.A) for a discussion). In contrast, actuaries are more concerned with processes that are relatively long-term in nature, with shorter term fluctuations not especially significant relative to overall adequacy or appropriateness. As the period observed lengthens and the number of independent

[6] D.H. Rumsfeld (2002). Speech at a U.S. Department of Defense New Briefing, February 2002

insured exposures increase, perceived process risk tends to decrease with the reduction in effect of short-term fluctuations. Nevertheless, both risk and uncertainty are of concern, because management, regulators, and investors need to make decisions based on understanding reported performance that reflects longer-term volatility and the value of an insurer's future obligations.

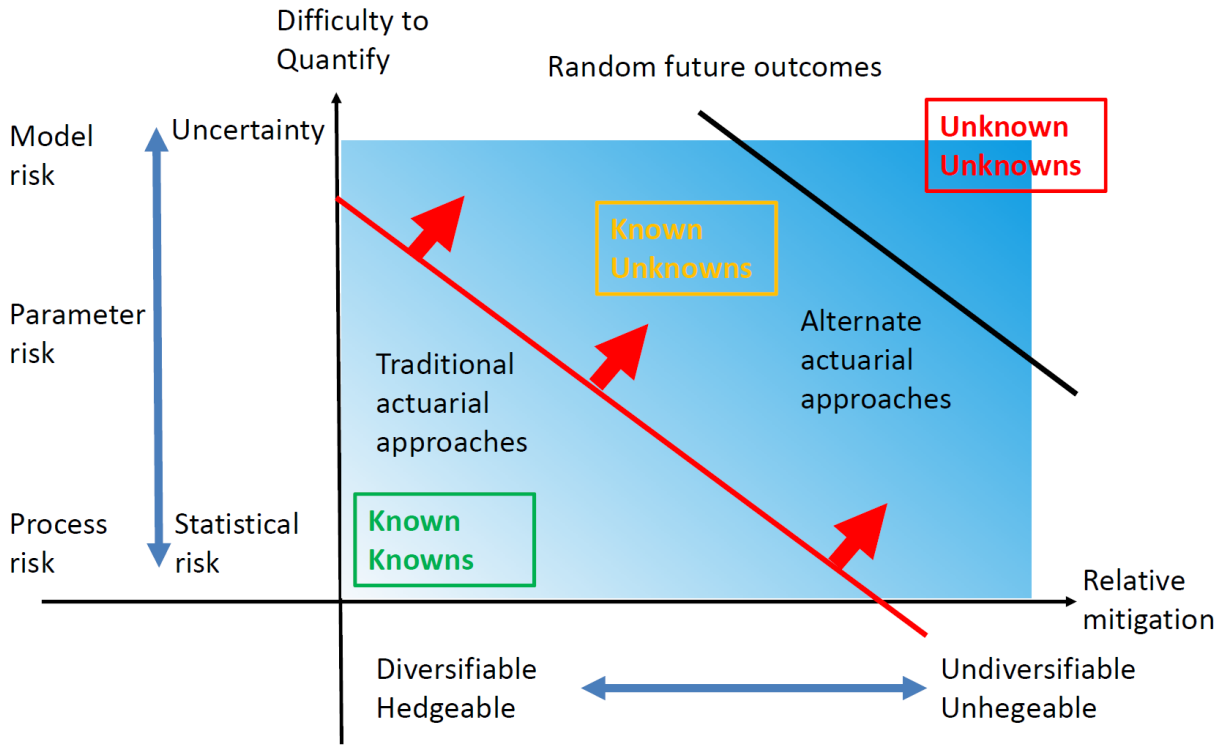
It is important to attempt to distinguish between the effects of risk and uncertainty. Methods that have been used to test for the existence of uncertainty include:

- Statistical significance testing, which determines whether observed differences in predicted experience are statistically significant.
- Confidence intervals that provide a measure of limits within which the actual outcomes are expected to lie with a certain degree of confidence.
- Use of the formula: variance (actual – expected) = variance (actual) + variance (expected) – 2 x covariance (actual, expected). This relationship describes the effect of the correlation between actual and expected experience; when actual and expected experience are independent, then the variance is the sum of the two variances, while if actual and expected are perfectly correlated, then naturally there is no uncertainty.
- Pervasiveness and consistency of differences between actual and expected experience. For example, if these differences arise in all significant categories (e.g., geographical regions, period of issue, risk classifications) it is more likely to be due to a period effect, although analysis may be needed to ensure it is not due to unrecognized changes in claims management or data coding.
- Smoothed results over time (using rolling periods of, say, one or three years, depending on the amount of experience) rather than monthly reporting periods that often contain a significant amount of statistical noise. Outliers or discontinuities may be the result of changes in conditions and past uncertainties, which may or may not lead to subsequent changes.
- Expert knowledge. This can help to identify drivers of future outliers or discontinuities and changes in the existence or significance of underlying drivers of experience that would not be expected based on simple extrapolation from the past.

Possibly a more pragmatic distinction of use to actuaries is between the ability to quantitatively model or estimate future events or conditions based on relevant and reliable experience data and in turn validate the results based on actual experience. Future results or their drivers that cannot be so derived with a given level of confidence would fall into the uncertainty area. In some cases, actuaries have been known to attempt to measure everything to the extent possible and to incorporate the effects of risk and uncertainty into their estimates. As can be seen, boundaries may not be perfectly distinct in some cases as some risks can be difficult to cubbyhole – whether resulting in discontinuities or unexpected results. An example of how these factors can be illustrated in Figure 1, including the degree of actuarial risk aversion inherent in actuarial

approaches. As experience is gained in an area of uncertainty, the applicable aspect of the future can move downward, if not to the left, in the chart[7].

Figure 1 –Risk/uncertainty continuum



Between the issuance of some long-duration insurance policies and the recognized emergence of adverse experience, one of the major concerns is whether volatility, that is, divergence between actual and expected experience, is due to temporary (i.e., involving risk) or permanent (i.e., involving uncertainty) conditions expected to continue or evolve that should be reflected in changes to future premium rates. Rigorous analysis of emerging experience will help identify leading indicators of adverse experience and provide better criteria to assist both insurers and insurance supervisors to evaluate rate increase requests and inforce management decisions such as policyholder dividends/bonuses/profit participation.

4. Characteristics of risk and uncertainty

The following are several key characteristics and elements of risk and uncertainty.

I. Process, parameter and model risks

Classical actuarial decomposition of risk and uncertainty is based on the following three categories: process risk (due to stochastic processes), parameter risk (if the variables chosen in a

[7] An example of a future condition that was not contemplated is the emergence of negative interest rates, which up until the 2010s was almost unthinkable and was widely discounted in most financial models, which just a few years later was common, even in corporate bonds in certain countries.

model don't have the right values) and model risk (if the model structure is appropriate and the variables in it have been selected and whose relationships are recognized properly). This decomposition is performed from the perspective of the user of a particular model, given the model and risks being assessed. This decomposition can change from time-to-time as understanding and experience is enhanced, conditions change, or differing stakeholder views are taken. These three aspects are all subject to differing degrees of risk and uncertainty.

A. **Process risk**.

Process risk, sometimes referred to as statistical risk, is the risk of unavoidable random statistical fluctuations that occur in any stochastic process. It will occur even if the insurer has chosen a model that is totally accurate and has accurately estimated the parameters of the distribution under that model.

Insurance risks often cover many relatively homogeneous but independent risks. The aggregate process risk of a portfolio of insurance policies (measured on a per policy basis) can be reduced by increasing the number of policies in an insurance portfolio or the period over which observations are made, since the process risk decreases as the square root of the number of policies exposed increases.

However, the extent to which pooling (i.e., aggregating many policies) reduces insurance risk can be limited by not only the uncertainty regarding the true expected values and shapes of the applicable probability distributions, but also because of the uncertain relationship between factors that affect experience. For example, a trend or discontinuity (e.g., whether referred to as structural, black swans, non-linearity, tipping point, unknown-unknowns or systemic condition) affecting the incidence or severity of benefits/claims potentially affects all insureds, but more likely only affects certain subgroups of policies, insureds or claimants.

One view is that it is inappropriate to reflect homogeneous and independent risks in a provision for risk and uncertainty because the risk and uncertainty involved could effectively be eliminated by insuring a sufficiently large number of independent insured risks. This view is similar to the concept of not requiring a provision for diversifiable risk (see section 4II). Despite this, conditions sometimes exist for which an insurance risk is not sufficiently stable, nor is an insurance market sufficiently efficient and independent[8], to eliminate the need for a provision for risks and uncertainties.

B. **Parameter risk.**

Parameter risk arises because information regarding an underlying probability distribution is, by necessity, incomplete, with the resulting distribution being inadequate or incorrect. It is the risk that the parameter estimates in the model are incorrect. It has also been referred to as measurement risk and can be viewed as the uncertainty that the expectation (mean) is accurately estimated (the range of uncertainty involved is not necessarily the same as that of the process risk involved).

[8] There have been numerous situations where independence was assumed but did not exist. For example, the recent financial crisis where mortgage risks were not independent and residual value insurance on car leases where resale values were at times highly correlated.

Mis-estimation and data risks. Historical data represent necessarily incomplete information, since it is obtained from conditions different from the period for which the estimates will be applied to. However, most actuaries take a Bayesian approach with respect to the parameters used as input to their models; that is, they develop an initial set of assumptions that they modify as better experience and enhanced understanding are obtained, thus gradually reducing parameter risk in the case where the underlying environment is stable. Generally, a set of observations constitute only one realization out of an infinite range of "might have been" scenarios.

As a result, it is subject to random sampling error. Other reasons include inaccurately reported or otherwise available data, and variations between insurance risks that are not intuitively obvious until appropriately distinguished experience data becomes available.

Many variables that require estimation, e.g., mortality rates or claim development, involve several components. Take mortality rates – several factors can contribute to mis-estimation of the current level of a portfolio, such as using population mortality when a lower-income market is involved, new claims management has just been installed so old loss development factors are not relevant, in general that future exposure or conditions being different than the future or that the portfolio of an insurer is a new line of business. In addition, long-term mortality improvement or long-term health care or automobile damage costs may be mis-estimated or the possibility of a one-time pandemic, sudden increase in antimicrobial resistance or the effect of a sudden increase in self-driving cars or other new car models.

Aggregation and inter-action. It is common to aggregate the effects of multiple variables into a major component of a model – an advantage of this process is to reduce the model's complexity. Despite this advantage, such aggregation can reduce the reliability and accuracy of the model. In any event, it is important to understand and recognize the inter-action, correlation and patterns between the variables, especially if there is a cause-and-effect relation. For example, for a variable/unit-linked annuity a sudden shift in the economic or political environment may induce significant policyholder behavior such as lapsation of the better annuity risks from the insurer's perspective. The more that the correlation is due to cause-and-effect, the better the model will tend to perform and the extent of uncertainty tempered. In contrast, if it assumed to be due to cause-and-effect and it isn't, the level of uncertainty can increase.

Exposure mix. Not only experience can change, but also the composition of insureds covered may change or become different than what the pricing assumptions were based on. This risk can be due to different characteristics or behavior between cohorts or generations, different market segments from which insureds are drawn for an insurer, different choices made by insureds or insurers, or different underwriting rules or risk classification categories applied. The cost of insurance can be significantly affected by selection (due to the markets targeted and underwriting procedures followed) and anti-selection (on the part of applicants at the time of and after application), which in some cases have arisen from inadequate market penetration. These factors have led to a deviation of industry mortality or morbidity experience from that of the general population. Prior to a book of business being written, the distribution of exposure characteristics is not known, thus resulting in potential moral hazard and anti-selection risk, although usually reasonably estimable based on prior writings or on expected target market penetration. This mix can subsequently change to reflect subsequent terminations

Change in conditions. Future experience will differ from that of the past, in part because future conditions will be different. Some of these changes arise due to a gradual or sudden change in conditions (of a temporary or permanent nature), which can be due to a paradigm shift, such as when legislative, business model, and social attitudes change. Examples of paradigm shifts that have arisen in the past have been when (1) the business model for the subjective nature of certain health coverages change and (2) society realized that second-hand smoke was dangerous, which resulted in changes in smoking prevalence and restrictions in locations where people could smoke. Both examples were unforeseen and not reflected in available experience as input to the basis of insurance premiums.

Other examples of changed conditions that have resulted in actual experience being different from that previously expected have included: more robust economic growth, lower market interest or equity growth rates, onset of climate change, better health conditions and more stringent safety rules. Other examples of possible sources of uncertainties include a cure for all cancers, impact of self-driving cars, new government programs or court rulings, and delayed adverse effect of increased obesity prevalence.

C. **Model risk.**

Models by definition are simplified representations of reality. There are two types of model risk: (1) the identification of the proper variables (parameters) in a given model and (2) the structure of the model, i.e., whether the correct model has been selected. Model risk arises when an incorrect representation of the future is reflected in the model, improper parameters (variables) are used or the wrong model structure is applied. This can arise from under- or over-specification of the variables (specification risk) used in the model. Under-specification occurs when a model is over-simplified, in an extreme example, mortality rates that are independent of age. Over-specification (or over-fitting) occurs when there is too much concern about fitting parameters to non-statistically credible or irrelevant data, incorrect variables are applied, over-extrapolation (e.g., linear extrapolation when not appropriate), or an incorrect underlying structure has been applied. Either problem can result in inaccurate or biased projections.

Unless a pre-determined factor or formula-based model is used, uncertainty models can be quite complicated. Models should be subject to proper governance and controls, as described in chapter 15 *Governance of Models*. They should also be validated, and subjected to sensitivity and stress testing, where practical.

There is no single accepted model for any aspect of the insurance business, although adaptation and refinement of the model used should occur as more information and insight becomes available. The use of multiple models can often be useful – especially recognizing that they are representations of reality, which may be refined or modified over time, and that primary reliance on a single model should only be made when it is determined that the model is sufficiently useful and good enough to move outcomes from known unknowns to known known risks. Nevertheless, it has to be realized that any model has strengths and weaknesses.

Multiple risks

The period observed can change the mix between process and parameter risks. For example, if reporting or experience is measured on a daily, weekly or even monthly basis, the volatility due

to process risk for those short periods should be expected to dominate. The longer the period studied, the more the underlying reality would be expected to be revealed, in which case parameter risk will likely dominate. In addition, to study whether a trend is occurring may require an even longer observation period. Nevertheless, the use of a long observation period can raise the possibility that the earliest experience is no longer relevant, which may lead to a misleading trend. One approach to determining whether a trend exists is to study experience on a rolling basis, which tends to smooth the contribution of process risk to volatility. Understanding the conditions over the period study is necessary to determine whether the trend is trustworthy.

Some believe that even though it is conceptually preferable to reflect parameter risk and model risk, it is not necessary to include an adjustment for the sources of these risks until persuasive evidence is available to enable an insurer to quantify their effects by reference to observable data. Nonetheless, as long as these risks are estimable, it is appropriate and indeed necessary to include them. In fact, not including a provision for parameter and model risks (i.e., only including a provision for process risk) is tantamount to unsound pricing by ignoring economic reality, which may lead to inappropriate business decisions (in the extreme case, capital inadequacy). Thus, it is appropriate to consider all the relevant process, parameter and model risks in pricing, valuation, capital assessment and management decision-making.

Actuarial practice dictates that a sound and sustainable process should be followed with respect to the consideration of applicable risks and uncertainties. This may involve the inclusion of appropriate margins (e.g., risk adjustments or in required/economic capital calculations) or testing relative to the objectives of the application. Actuarial work in these areas is covered by applicable actuarial standards of practice and codes of professional conduct, supplemented where applicable with appropriate peer review procedures. Consistent with such standards, an understanding of the context of risks and uncertainties involved goes beyond the application of applicable formulas, but to the application of actuarial analysis and judgment regarding the overall soundness of the entity.

II. Diversifiable and non-diversifiable (or insurable and uninsurable) risks

Risks may also be characterized as being either diversifiable or non-diversifiable. For example, market risk for stocks (shares) can be diversified by aggregating stocks (shares) from different industry sectors, as in most cases they are unlikely to all move in the same direction. In fact, the risk of any stock has a diversifiable and a non-diversifiable (or systemic) component. The non-diversifiable component can be characterized by the trend line in the relationship between that stock and the market, representing risks shared with all elements in the market. The diversifiable component is the variation around that trend line. Similar analysis can in many cases be applied to each risk factor that affects an insurance premium.

There is a limit to the diversification benefit, beyond which the marginal benefit of risk reduction is smaller than the loss of potential returns. Some risk factors impact nearly all insurance policies or stocks, as applicable, and are non-diversifiable. Factors unique to a particular stock are largely diversifiable. Most risk factors fall between these extremes.

Risks may be described as either market-based or independent of market (also known as "orthogonal"). In the context of investment risks, market risk can be understood by considering

risky assets such as stocks. In capital asset pricing model (CAPM) terms, the return from each stock has a (positive or negative) correlation with the return from every other stock. The regression coefficient between the individual stock and the market is called the "beta" of the stock. Risks that are uncorrelated with a market are independent of that market and have a beta of zero, although if a stock is included in what is measured as "the market", it likely has at least some (albeit quite likely small) correlation to the market by virtue of its inclusion as part of the market.

Similar to the above capital markets example, morbidity and mortality rates of individuals in a pool are usually considered independent of the corresponding rates of the others in the pool. They may, however, not be independent, as they may be subject to similar environmental and provider conditions, as well as similar habitational attitudes and insurer's claims management processes, some of which may be correlated to changes in market, economic or demographic conditions. An assessment of the mix of risks involved may be needed to confirm such an assumption.

While some believe that diversifiable risk should not impact the amount of provision for risk and uncertainty, others believe that since no market is perfect, all investors require some risk premia for all risks, whether diversifiable or non-diversifiable. Since insurance markets are not perfectly efficient and complete diversification of many relevant risks is not practical, a provision would be correspondingly appropriate for all insurance risk. Market prices reflect both diversifiable and non-diversifiable risks as both types of risk are always present and can be estimated. Thus, both types of risk should be considered.

III. Hedgeable and non-hedgeable risks

The discussion so far has assumed that all relevant risks and uncertainties are reflected or considered in the development of applicable risk distributions. For the purpose of a provision for risk and uncertainty, risks reflected in the risk distribution include all their non-hedgeable aspects. A risk is hedgeable if an active market exists in which the risk can be traded, such as via derivatives. Hedgeability derives from the existence of a relevant market and not directly from the characteristics of the risk. Insurance-related risks normally considered to be non-hedgeable, include the risk of variability in the amount of settlement obligations, operational risk, the risks associated with the runoff of claims/satisfaction of policy obligations and reinsurer counter-party credit risk (although this could theoretically be hedged by means of a financial instrument of the applicable reinsurer). Risks normally determined to be hedgeable include market or credit risk of invested assets.

Risks that are not completely hedgeable are considered in the determination of liabilities and required (or desired) capital. For example, these also may include interest rate risk for very long durations or market and currency risk in thinly traded markets, such as those in developing economies.

IV. Time it takes risks to emerge and be recognized

Many insurance policies and claim provisions provide for benefits or claim payments over a lengthy period. The timeframes involved can range from the extremely short (e.g., dental or most property insurance) to the extremely long (e.g., long-term care insurance or annuities offered to

the young, which can last fifty or more years). In most cases, the longer the period of coverage, the larger the uncertainty. Dynamic influences over time represent second and third order parameter risk. While over a short period their effects may not be significant, they may represent a significant source of uncertainty over a longer-term horizon, especially where the effects accumulate over time. They thus "fatten" the probability tails involved.

Even without these dynamic changes, the forces affecting the sources of uncertainty may be time-dependent. In other words, certain ongoing trends such as mortality improvement or inflationary effects on certain claims/benefits and expenses may continue and accumulate over time in a serial manner, without necessarily reverting to an earlier expected mean, as might be expected for some economic variables, such as, arguably, interest rates.

Many risks take a complex form – in these cases, the composition and interaction among the risks can take an extra period to become observable, as deviations from expected may offset each other. For example, in the early policy years a portfolio of life insurance may in the aggregate appear to be consistent with initial expectations, while the ultimate level of mortality might be misestimated, the absolute and timing effect of underwriting or market selection might be misestimated and anti-selection resulting from policyholder behavior might be misestimated. In addition, in this example the number of deaths in these early policy years may be too small to represent statistically reliable data to draw a conclusion. Thus, the degree of risk aversion is likely to increase as the time horizon increases[9].

However, as more useful information becomes available, the amount of uncertainty will decrease. And, to the extent that effective non-guaranteed elements or other management discretion is available, the risks and uncertainties are shared with the policyholders. In addition, effective asset/liability management techniques will reduce the level of uncertainty.

V. Risk concentration

An elevated level of risk concentration exists when a sizable percentage of an insurer's risks (e.g., coverage, market segment, geographic area of insureds or assets are in a certain category of exposures. For example, although the management of a mono-line insurer or one dealing with a single market can provide focused attention on and specialized expertise, it can simultaneously suffer from a lack of diversification of risks. Even here, caution should be exercised since there have been occasions where an insurer was "forced" or advised, by a rating agency, investors, supervisor or overly aggressive marketing staff to diversify their markets or products. As a result, the company was put at financial risk when there was a downturn in areas where management was not properly prepared.

Achievement of economies of scale (through greater business volumes) can enable spreading overhead or fixed operating expenses over a larger number of units. However, it carries with it a potential increase in the aggregate effect of catastrophe and operational risks to the insurer, thereby at least somewhat offsetting the beneficial effect of risk diversification and risk pooling.

[9] As well as possibly increasing the capital charge.

A significant risk concentration can result in greater volatility, in part due to the potential for large catastrophic losses. More capital may be required to absorb the effect of certain operational risks (events) or catastrophes with low probability and high severity, resulting in a greater degree of financial uncertainty than would be the case had there be less concentration. Nevertheless, the question of how to quantify the degree of concentration or tail risk that would be significant enough to qualify as a catastrophe remains an issue for continuing study and debate. This also depends upon the size of the insurer and its capital resources.

The aggregate effect of concentration of risks is one example for which the expected experience of a group of insureds may not be independent and can be inter-related. Concentration of exposures usually affects the volatility of results, as a result of an increase in severity of loss in a portfolio (as a result of a significant increase in the number of claims). While the resulting loss to the insurer would usually be categorized as risk, it might also be thought of as uncertainty if, for example, the cause was sufficiently unrecognized.

5. Basis for assumptions/expectations

To the extent that a perfect market is available, a calibration of the amount of risk and uncertainty could be performed with respect to market prices. However, such a deep and liquid market never seems to exist in insurance risk applications. Valuation techniques need to be applied in almost all cases. The following is one categorization of the types of input that form the basis for assumptions or expectations of risk and uncertainty involved in modeling. The risk criteria applied are based on the valuation basis / quantification applied.

- Market observations. This approach estimates the economic value of risk implied by market prices, the credibility of which may depend upon the size and robustness of the market. A given degree of risk can have different values to different individuals, depending on the extent of their risk aversion. Prices of risk and uncertainty in the market reflect a consensus of (or negotiation between) the views of market participants, including aggregate amount of risk aversion.

  Of course, just because risk exists and market participants charge for the risks undertaken does not by itself mean that the resulting prices are "correct", as they are influenced by such factors as the current market risk aversion, misinformation, and herd mentality.

- Model/estimations. Examples include a margin over current estimates (MOCE) in regulatory accounting and in the revisions to insurance accounting of insurance policies (IFRS 17), which provide for expected outcomes reflecting estimates of risk and uncertainty that are based on non-market based factors. A MOCE is usually based on probability distributions relating to the risks undertaken, using confidence intervals, cost of capital or similar measures. The extent of the provision may differ between pricing, valuation of liabilities or capital, as each has a different purpose.

  The most relevant and reliable observable experience should form the basis for the experience assumptions, although it is uncommon to observe enough sufficiently relevant data to base a full probability distribution, especially extreme (tail) probabilities. Under

normal circumstances, the best source would be derived from policies and claims from the same product and insurer, for which experience and volatility of this experience are most relevant (i.e., including where available the same market segment, underwriting screens, policy features and claims management). However, in some cases, such as if the coverage offered by an insurer is a new or immature line of business or if the frequency of the event is sufficiently small, external data[10] or professional judgment will be needed either as a substitute for, or a supplement to, the insurer's experience data.

The blend of experience used as inputs depend on the amount of data with characteristics similar to the business being assessed or the reliance that can be placed on either external or other internal sources. For example, for a new line of business, no internal data would be available. Data from the central portion of the probability distributions may have to be used as a base to estimate complete probability distributions. Unadjusted industry data or public data without any selection or insurance-affected constraints may not be relevant to the business being studied.

Just as there can be a herd risk inherent in market-based measures, there is a consensus risk in non-market based measures. That is, when there appears to be an overwhelming consensus of a given area of uncertainty or trend the risk of everyone being wrong, when ignoring either a black swan event or condition or an event or condition that is not recognized because there is a consensus. Examples might be mortality risk, where a consensus has been reached that the current level of mortality improvement will continue forever and it doesn't, and interest rate risk where the consensus is that interest rates continue forever at historically low levels, where it turns out that a reversion to the long-term historical mean is ultimately experienced.

The use of historical experience requires an understanding of the conditions under which that historical information was obtained and estimates of the expected effect of changes in those conditions. Historical experience is, at best, a sampling from the underlying actual experience, which is not known for certain and will probably change over time.

Expected experience is generally driven by a set of variables (parameters), in some cases determined with respect to the policy features and demographics of the insureds and their environment and behavior, as well as characteristics of the portfolio of claims, where applicable. A common approach is to analyze the characteristics either one at a time or in aggregate. Newer techniques, including predictive analytics, can be used to study the drivers simultaneously, reducing the uncertainty with respect to the interaction, correlation and patterns between the variables. An easy trap to fall into is to assume that the characteristics are independent—an example is where it is assumed that a specific cause of death or morbidity is cured—this elimination usually in turn affects the size of the parameters or even introduces additional variables into the model of mortality being used.

[10] For example, aggregate insurance industry experience or general population data, although caution needs to be applied if not adjusted to be consistent with the insurer's product features, underwriting, market segment, and effects of the existence of insurance.

The level of aversion to risk reflected may differ by the stakeholder and application. For example, for IFRS 17, the aversion inherent in the risk adjustment is taken from the viewpoint of the insurer. For fair values the aversion is based on the implied values derived from observed prices or estimated views of market participants. And, for required capital or stress tests, levels may be based upon the perspective of the supervisor or the insurer.

6. Sources of exposure to risk and timing of its management

Risk and uncertainty associated with a portfolio of policies or a company/group can arise from multiple sources. These sources may or may not be related or inter-dependent. Their relationships create dependency uncertainty, which may differ depending on the situation (e.g., the correlation between sources in situations such as asset credit default and policyholder lapse rates can increase significantly under adverse conditions such as a recession).

These sources of risk and uncertainty differ by coverage, market, distribution system, and jurisdiction. Some may vary every year as external conditions or internal decisions may change quickly; other tend to change slowly, such as mortality or inflation trends. Examples are described in Appendix 1.

The permanence and severity of risk and uncertain conditions differs widely by coverage and situation. It may be a one-time shock, a part of cyclical experience or a permanent change in conditions. Although usually obvious in hindsight, during volatile conditions, it can be difficult to differentiate them. Inferences can be drawn from historical experience, for example from a violent storm, heat surge or epidemic. However, there are other situations where definitive identification is not possible, e.g., during the second year of especially low or high interest rates (e.g., Japan over the past two decades) or if mortality has deteriorated in two consecutive years with no obvious direct cause. Although stochastic/probabilistic modeling can be useful in estimating one-off or even cyclical changes in conditions, scenario testing might be a better approach to develop contingency plans in preparation for the future.

In conducting experience studies, the selection of longer study periods increases the data points and hence the credibility of the study (unless conditions or the mix of exposures change during the period). In contrast, it can include experience generated under conditions different than that expected to exist in the future. Inclusion of earlier periods can mask underlying trends or changes in fundamental conditions. Actuaries often deal with the trade-off between reliability (the accuracy and statistical credibility of the data) and relevance to the period of concern, supported where possible with analysis of drivers of experience and relevant trends.[11]

Timing of the emergence and severity of risks can therefore be important to recognize. Although risks can be characterized in many ways, one approach to risk management is to categorize them in terms of their short-, medium- and long-term natures. Different types of supervisory action relate to the immediacy or severity of these adverse effects, as they impact the sustainability of an insurer and the time needed to rectify them. The applicable period will depend on the risk structure of the insurer, types of insurance involved and supervisory tool chosen:

[11] This is particularly relevant when setting parameters for equity returns and volatility.

- 3-90 days. The primary concern regarding an extreme condition during this short period is a lack of adequate liquidity and cash. In contrast to some banks, such liquidity risk will rarely be of concern to most insurers. Nevertheless, exceptions may exist if there is improper short-term risk management, if asset-liability matching is not maintained or where a significant concentration or pricing or policyholder behavior risk emerges quickly, especially if extreme economic conditions arise suddenly. Rapid management and supervisory action may be needed in such a case. This might affect an insurer's investments, e.g., margin calls on financial instruments or precipice conditions on external debt that trigger immediate repayment. An example of mitigation against such risks include a constraint on accessing policyholders' accounts that during normal circumstances would not be called for.
- 90 days-3 years. Risks likely to arise during this timeframe may result from operational (e.g., significant underpricing, mismanagement, economic or catastrophic shocks). A one-year period is often used as a benchmark timeframe over which a supervisor can attempt to take remedial action (which could include beginning a run-off or sale or merger of a troubled insurer with a stronger one). This period can also allow for the re-pricing or re-underwriting of policies with one year. Even catastrophic insured events will often even take more than one year to fully pay claims.
- 3 years+. An insurer may become unsustainable over this longer period due to several conditions, including slow-developing actual or expected experience significantly worse than expectations, or significant adverse trends that lead to sustainability concerns. It is also the likely timeframe for failure due to mismanagement, as it usually takes some time for its effects to become material.

  This is also be the timeframe for a decline due to a paradigm shift, e.g., delayed use of big data for competitive pricing that an insurer is unable to achieve because of insufficient investment in resources or staff. Another example is political risk – a government takeover of a key line of business of the insurer that takes away their main competitive advantage, thus leaving them with business they can't manage well.

Although a significant issue can lead to sustainability concerns over any of these time categories, the assignment to a shorter time category can be caused by either the type of the problem, who is affected, the severity of the problem, the availability of and ability to apply relevant and available mitigation tools such as reinsurance, or the extent of the insurer's adequacy of capital.

The time frame over which stressed conditions apply is an important assumption in many important calculations, such as the determination of minimum required capital. Two general approaches have been taken:

- One year stress (uncertainty) assumptions, followed for subsequent periods by risk assumptions that would be expected to be relevant over the lifetime of the liabilities. This has, for example, been the approach taken by Solvency II. The use of this timeframe assumes that, subsequent to the occurrence or emergence of an adverse risk situation, a supervisor will take no longer than one year to manage the insurer's

condition, e.g., exiting from an insurance market or implementing rate increases, or in the extreme through selling it to or merging with another insurer or putting into a runoff mode. This presumption may not always be achievable, depending on factors that include the extent of the problem, the risk event that generated the problem and whether the risk event affects only that insurer or its entire industry. A one-year time horizon has usually been applied on the presumption that this aligns with supervisory action in dealing with a troubled insurer, such as arranged reinsurance, resolution or liquidation. However, such an approach should not ignore continuing provision needed for future risk and uncertainty at the end of the one year shock horizon.

- Lifetime stress assumptions (for the life of the inforce policies or claims) relating to a structural change. This approach is often taken for liability (MOCE) determination. It also may be more applicable if the adverse condition is an ongoing one, e.g., mortality improvement trend which is often of a much longer-term nature or is a one-time problem that cannot be easily addressed in a short-term period. In addition, it is highly likely that a purchasing/merging insurer who has been encouraged to take part in a rescue would demand to be compensated for the probable effects of continuing risk and uncertainty conditions.

There is a range of processes and actions that an insurer can take to effectively manage adverse cash flows and associated risks and uncertainties. Some techniques are automatically generated, while others result from management action. In some cases, the application of management action (e.g., reduction in excess interest or management-based bonus/dividend/profit participation policy) may be constrained by competition, especially if the insurer is the only entity within the industry that has to make such a change, e.g., anti-selection as a result of policyholder behavior can result from an impairment of the insurer's brand, which may be accompanied by further adverse financial effects.

To the extent that such mitigation (e.g., automatic based on policy features or through management discretionary) is available and can be expected to be applied under adverse conditions, both the expected adverse consequences and the effects of corresponding mitigation actions that can be realistically taken should be reflected. If the mitigation actions rely on third party (i.e., supervisory) actions, its likelihood (and uncertainty) might also be considered.

7. Application and uses based on the viewpoint taken

The purpose of the analysis and stakeholder viewpoint taken can influence the basis (methodology and considerations) of recognizing uncertainty.

Although insurance accounting systems can differ significantly around the world, most incorporate either explicit or implicit provision for uncertainty. General purpose accounting tends to stress transparency or explicit provision for disclosure purposes. Such a system can combine a reflection of risk in a general margin that aggregates the effect of risk, uncertainty and profit, or can be presented as an implicit offset in the situation where the time value of money is not explicitly reflected (discounting).

Inclusion of provision[12] for risk and uncertainty serves multiple purposes, including the avoidance of premature reporting of income in light of the risks and uncertainties involved, an incentive to avoid over-optimistic-reporting of new business, and a metric that can facilitate the communication of the degree of risk and uncertainty involved with the fulfillment of the insurance obligations.

Especially in the case of long-term obligations, the adjustment for the value of time and for risk and uncertainty can be entangled. It is important to avoid double-counting or ignoring provision for risk and uncertainty.

The approach taken may be based on a set of historical parameter averages or be limited to only the most currently observed values of the parameter(s). While market values reflect currently observed costs of trading, they do not reflect the effect of implementing trades on the subsequent values available in the market place.[13]

Risk tolerance reflects the risk appetite of the stakeholder for different levels of loss (e.g., by management or the supervisor or the market, depending on the application), which can differ depending on types and levels of risks and uncertainty. For example, a supervisor may focus primary attention on different degrees of adequacy of capital. As a result, the supervisor may be more risk averse than management or the market, although in some cases management may be even more conservative to maintain their employment. Actuaries tend to be aware of risk, in large part due to their concern with the sustainability of the applicable block of business and the entity as a whole.

I. One-sided or two-sided risk

Conceptually, a decision has to be made regarding whether to consider favorable, as well as adverse developments. Although risk is two-sided, in many cases insurance stakeholders are only concerned with the effect of downside deviations and in the risk tolerance of adverse deviations.

Whether to reflect favorable experience developments in the assessment, valuation and communication of uncertainty depends on the application and perspective of the application and stakeholder. For example, an insurance supervisor is concerned with adverse developments. As a result, supervisory emphasis is based upon a one-sided uncertainty, the adverse implications of future events.

In contrast, it is usually more appropriate in pricing or in valuing a policy or claim to consider both sides of an insurance risk. However, because (1) loss aversion is usually stronger than risk

[12] In some regulatory systems an explicit recognition is referred to as a margin over current estimate (MOCE); in international financial reporting it is referred to as a risk adjustment.

[13] For example, prior to 1991 Executive Life (U.S.) had invested in a significant amount of junk bonds whose market value, where there was one, and interest rates earned were sufficient for it to offer competitive prices and remain a going concern. However, when the value of these bonds dropped as a result of defaults emanating from a deteriorating economy, their value plummeted, with the result that it was unable to continue as a going concern. Prior to this time, the company had relied upon the favorable credit history of these bonds and their then market value achieved during good economic times. But, the decision to sell all those bonds after being taken over by supervisors, further depressed this security market so that the values obtained by selling the bonds were less than the reported value at the time of the company's takeover. In other words, the decision to sell due to their lower prices meant they had to be sold at even lower prices.

aversion and (2) most consequences of insurance risk are asymmetric, that is the right tail of cost or loss functions are generally thicker than the left tail outcomes, the value of a liability or premium may over-emphasize the possibility of an adverse development, especially if it might impair sustainability or generate a loss, rather than a profitable development. A provision for risk and uncertainty in a liability, asset or premium that considers both favorable and unfavorable situations may be relatively smaller than for such a provision for required capital, which may only consider unfavorable effects. Required capital is as a metric used to assess the likelihood that an insurer will be able to fulfil the promises it has made and in some cases survive as a going concern. Note that, especially for a life insurer, effective asset/liability management maintained in a dynamic manner can reduce or even eliminate the risk and uncertainty and therefore the need for such a provision.

8. Quantification of risk and uncertainty

An essential element in risk and uncertainty management is the assessment and, where possible, estimation of the effect of risk and uncertainty involved in an insurer's operations and decision-making. In some cases, such an assessment can be as crude as rank ordering the sources of risk and uncertainty, e.g., asset credit risk, mortality improvement and policyholder behavior. In others, e.g., for establishing a minimum or target level of capital, a quantification of the effects of individual circumstances is needed.

Risk and uncertainty can conceptually be included or be expressed in terms of either expected cash flows, discount (or cost of capital) rates or a combination. The approach taken is usually inherent in the method used. For example, for the valuation of liabilities, it may be appropriate to directly relate risk and uncertainty to what is at risk, i.e., risks and uncertainties associated with the insurance obligations based on the expected cash flows and those associated with investment risks based on the discount rate (e.g., use of a risk-adjusted discount rate). However, when assessing an insurer as a whole, e.g., for company / group level capital assessment, an aggregate measure such as a cost of capital may be appropriate.

A description of some of the primary approaches to measure risk are included in Appendix 2. They include the quantile, explicit assumptions, cost of capital and discount rate related methods. Each quantification method requires certain parameters that are also described in general in Appendix 2.

With respect to the applicable parameters,

- They need to be reassessed on a regular basis. This does not mean that they must be revised, but periodic monitoring is appropriate to ensure that they are reasonable, both regarding whether the parameters applied are up-to-date and responsive to underlying conditions and business, but also whether the parameters, and indeed the models used remain reasonable. Expectations should be dynamic in nature, just as the risks and uncertainties change over time.
- Both disclosure of and supervisory or professional guidance regarding methods, assumptions, and the resulting valuation tend to produce more consistency between

insurers over time. Although outliers may continue due to different management or circumstances, peer or external pressures may contribute to convergence in practice over time.

- For all approaches, calibration to market-based values (i.e., actual transfer values) is problematic, as there are few, if any, transfers with observable prices that provide reliable calibration benchmarks. Even if such cases were to occur, such prices are not usually publicly available, involve special circumstances, or refer to such complex accumulations of transferred business that it is not practical to derive prices for specific relevant components.
- Because stochastic methods or use of probability distributions normally focus on process risk, increased confidence may be required to reflect uncertainty, that is, the effect of parameter and model risks, although moderated somewhat due to the extent of the inter-relationships as evidenced by the correlation between the factors. In certain cases, a flatter/wider distribution might be developed through a regime switching model, which assumes that there is a random switch between the "dual" statistical means. The level of confidence used is normally at least in part set by regulators, rating agencies or the insurer (as designated in regulation, professional standards, or professional judgment) through use of judgment, in part because of the difficulty in validating or calibrating the probability distribution(s) used against historical experience or market prices. Validation of a particular distribution(s) is often challenging, in part because historical volatility is not necessarily relevant to the perception of risk and uncertainty related to future conditions.

It is sometimes assumed that the only way by which probability or stochastic methods can be applied is by means of Monte Carlo simulation (i.e., a method that applies many randomly generated parameters that are applied in an actuarial model). That is not necessarily the case – for example, if the probability distribution is symmetrical and risk aversion is not incorporated, such an approach may not add much value. Even if asymmetric distributions are involved, a sufficient number of discretely determined parameters may be used, if they capture the general shape of the distribution, i.e., capture scenarios in the tail of the distribution.

Various practical methods have also been used, including:

- Factors applied to one or more assumptions. For example, a percentage factor based on a confidence interval for the claim incidence rate distribution might be applied to the expected number of new claims assumption.
- Scenario testing (viewed as being either sensitivity or stress tests), possibly using a weighted set of deterministic scenarios selected to be representative of stochastically generated scenarios. A stress test is the result of a scenario of significant size. This approach is especially useful for asymmetric risks, options, guarantees, or policyholder behavior.
- Percentages, depending on the class of business and/or other characteristics, based on perceived riskiness applied to the expected value or loss ratio, determined by sub-models.

- The use of a wider range of confidence than if just process risk was involved, to reflect the impact of parameter and model risks.

With respect to these methods, it has to be remembered that no model is perfect, and is limited by the availability of relevant assumptions and parameters, especially with respect to the many unknowns involved in the specific identification of sources of and quantification of uncertainty. As a result, some humility in applying quantitative methods is needed, with actuarial judgment applied at critical junctures in any such quantification.

In some cases in which even crude probabilities or scenarios cannot be reasonably constructed, a qualitative description of the uncertainty involved may be the only approach that can provide useful information.

9. Communication of uncertainty and metrics

Clear communication of expected and actual deviations from the insurer's objectives/expectations and their causes/drivers is crucial to effective governance, proper assessment of the effects of human behavior and incentives, and the objective setting process (including how compensation incentivizes management). The term risk can also be used in the sense of not achieving an objective, such as a given degree of profitability or financial soundness. A decision regarding how to respond to a deviation or an expected deviation will depend upon the situation and the financial significance of the deviation as well as a determination of whether it is just a random statistical deviation or a realization of a condition/event that was not anticipated and is actionable.

Successful communication entails an effective connection between stakeholders (and the business decisions they make) to experts in risk and uncertainty (such as actuaries). An important consideration in this communication is its purpose and users. The primary purposes considered in this chapter include management decision-making, supervisory action and investor decisions.

Risk is often measured by means of stochastic models or an assessment of a range of representative scenarios that capture a reasonable range of experience in the context of an objective or subjective probability distribution. Uncertainty is often assessed by means of a study of the possible effect of alternative scenarios.

With respect to risk, comparisons to both the mean and the mean plus or minus one (or multiple) standard deviation(s). Alternatively, performance outside a specified benchmark consisting of a pre-specified band around expected performance may be useful where performance outside that band would be intensively study to enable better insight into its sources (e.g., for a very large portfolio, a smaller band would typically be used because of limited expected statistical fluctuation).

Charts showing actual-to-expected values, together with probable ranges, possibly based on a specified percentage of a standard deviation of expected experience, recent experience or informed judgment, can provide a better understanding of whether a deviation from expected represents a cause for concern or further investigation. A regular report on the key variables

(sometimes referred to as key performance indicators that drive profitability and risk) is important, especially to top management and board members.

A good question is how uncertainty be communicated if the parameters/variables/alternative model cannot be identified. Emerging risk/uncertainty scanning can useful to help identify areas of possible future change – approaches such as development of a watch list or contingency planning can prove helpful. In those areas, a model and/or scenarios that consider historical variations and informed judgment need to be developed, as well as reflect expected deviations based on the resulting distributions. Although detailed documentation is necessary for external review and continuity of the risk management process (especially important when staff turns over), effective communication involves an understanding of the users' attitude toward detail – information provided will likely focus on key indicators, focusing on the extent of deviations from benchmarks and emerging patterns.

There is a danger when an uncertain risk seems to have an exact number representation. Results of models are not "sure things" and their estimates will be wrong because of the uncertain nature of the future. Due to the refinements involved in many models, those involved can easily be persuaded by the accuracy of the models and their embedded parameters – the risks, uncertainties and messiness of the real world should be recognized in their derivation and the communication of their results. An unthinking focus on predictive accuracy runs the risk of over-fitting the past, while ignoring past sampling errors and overlooking the conditions that may affect the future. Users must be able to understand the basis of results and a range or probability statements since a single number/result can give a sense of false precision.

Nevertheless, it is often difficult to assess whether a short-term deviation from expectation represents a random fluctuation, a paradigm shift or an indication that initial expectations were incorrect. In some cases, additional experience is needed to come up with an answer, while in others drilling down into the data or further research may help.

The choice and regular communication of metrics sensitive to significant elements of corporate performance provides an indication of the historical volatility and risks inherent in the operation. Often a set of key performance indicators (KPIs) are developed to communicate this performance—but they also can provide an indicator of the uncertainty involved. Outliers, often ignored, may be able to provide useful insight into possible uncertainties involved. They can either be ignored, monitored for repeated occurrence or analyzed to understand their significance.

The most useful method of communication is determined by the needs of the user and user preferences, including the level of detail and form provided. Typical actuarial assessments/validations may consist of actual-to-expected analysis over time. This can be used to determine the extent an observed deviation represents a one-time blip or an early warning of a structural change to a new level or a new trend. This can help modify current expected assumptions, improve assessments of future possible deviations or uncertainties and lead to a better decision-making process. Transparent and interpretable disclosures of future expectations and outstanding risks and uncertainties is valuable to all stakeholders.

As indicated above, uncertainty is not the random deviation around a set of expected values. Although it can extend to a less-than rigorous understanding of current conditions and underlying trends, it is more often associated with a change in conditions and enhanced understanding of the drivers of future experience. Such changes may be difficult to easily grasp, as it is human nature to think that everything will, at least in expected value terms, remain the same, can be linearly extrapolated or revert to an historical mean. Here, a variety of approaches may be useful. They include:

- Pictures or charts. It has been said that a picture may be worth a thousand words; for many it is more understandable than a huge table filled with numbers. Heat maps, fan charts or similar clear visual techniques that provide insight into experience patterns and deviations from expectations are examples of tools that can be used.

- Scenarios. In some cases, a quantitative assessment may not sufficiently convey a sense of the potential uncertainties involved. As a result, one or more scenarios, representing a story of possible deviations could be developed. The story can focus on a single condition or assumption (e.g., mortality improvement or deterioration, epidemic or natural catastrophe) or alternatively represent a comprehensive story reflecting all major assumptions and their interrelationships.

  As discussed in Chapter 20 on stress testing, the use of scenario analysis can help assess appropriate levels of required capital and provide useful disclosure to assess the sustainability of the insurer or adequacy of liabilities. The use of scenarios can add value in any analysis in which a quantification of and distinction between risk and uncertainty is called for. The quantification of risk is usually most reliable when estimating its mean, but becomes more uncertain when quantifying/targeting the level of tail risk, which is the focus of management and regulatory required capital. Since the degree of stress considered in stress testing and in levels of required capital are necessarily linked to supervisory and management actions, the triggers for, and the actions themselves should be structured based on the relative blend of risk and uncertainty contained in the assessment/measurements. Thus, the assessments themselves will be a blend of a quantitative and qualitative review. The conclusions will need well thought out communication of how the metrics clarify the needed management awareness and any corresponding recommendations, as further explained in the immediately following section on metrics.

- Metrics. There is a wide variety of effective performance metrics to measure volatility of experience. For example, actual-to-expected indices related to key drivers of performance or evidence of the existence or size of historical deviations from expectations can be developed. They can be applied to budgets, long-term plans, prices, liability or capital valuation, with baselines set based on changes from prior history and trends, industry averages or stakeholder expectations.

  Setting the expected (baseline) amount can be quite important to trigger the right type of action. They could be directly based on pricing or liability assumptions or industry

benchmarks, where available and applicable. Depending on the indicator, they can also be based on budgeted or trended values.

It is important to select a relevant set of metrics – both short-term and long-term indicators can be useful (e.g., using monthly or rolling-average data), not only to assess performance, but also to use them to better understand the reasons for deviation in the context of historical volatility.

They can be used as an early warning tool to trigger further study and if appropriate to take preventive actions and for incentive compensation purposes. No action might – for instance, especially if the metric is not controllable by management only a limited deviation (cap) might be used for compensation purposes.

Metrics that are overly complex should generally be avoided, as they can deliver mixed messages to management, although they might be useful for analytical purposes.

- Outliers. Based on the metrics used, it may be necessary to assess outliers, especially if not a single one-off. As indicated above, it is important to understand whether it should have been anticipated or indicate a possibility of a change in internal or external conditions that might reoccur.
- Assumption trends. Changes in expected conditions often arise, especially over a lengthy period. A look-back of change in assumptions over time can provide some perspective into changes into possible future changes in conditions/expectations.

The most appropriate level of aggregation of results will depend upon the experience being analyzed (e.g., mortality might be assessed with underwriting type and era categorized while market segment and product might be appropriate for policy lapsation) and the application. To assess the overall extent of adequacy of capital of a company / group, higher levels of aggregation may be appropriate.

11. Conclusion

Risk and uncertainty are fundamental to the operation of insurance. Their sources need to be understood and recognized to properly perform the risk management function of an insurer. It is important to distinguish between the concepts of risk and uncertainty, with risk being the effect of actual results differing from expected results due to the stochastic nature of outcomes, whereas uncertainty represents unmeasurable or unknowable variation in outcomes.

The aim is not to eliminate risks and uncertainties, as they are inherent in the insurance business – it is to manage them in a financially sound manner, through mitigation techniques such as risk sharing, benefit and product design (such as participating, unit-linked and experience-rating features), reinsurance, required capital targets, and asset/liability management. Assessment of deviations from expectations in a balanced and timely manner demands a focus on the credibility and drivers of these deviations. A decision regarding how to respond to a deviation will usually depend upon the situation and the financial significance of the deviation as well as a

determination of whether it is just a result of stochastic randomness (process risk) or a realization of a condition/event that was not anticipated and is actionable.

Risk and uncertainty should be considered when determining the appropriateness of the value of an insurer's liabilities, assets and required capital, as well as the most appropriate manner to manage an insurer and its business in a sustainable manner. They play a role in developing appropriate scenarios used in stress testing and in communicating the appropriate level of premiums, liabilities and capital. Uncertainty as reflected in required capital reflects only adverse consequences, while provision for uncertainty in the valuation of liabilities or in prices generally considers both positive and negative effects.

Communication of the extent and effects of the risks and uncertainties involved are important for all stakeholders, although the form of such communication may differ by type of stakeholder. Its content may be a number, a range of numbers, or a set of management implications and choices. Alternative scenario assessment may provide useful and understandable illustrations, especially graphical ones of the range of possible scenarios.

These concepts and their models are central to the practice and management of the business of insurance.

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Appendix 1

The insurance business is subject to general risks and uncertainties, including governance, brand, operational (see chapter 4 *Operational Risk*), distribution (see chapter 9 *Distribution Risks*), competition and other third-party risks. In addition, an insurer is subject to insurance and investment related risks, which can differ depending on the coverages and the company involved, may include some of the following:

1. Pricing/underwriting risk. If overly-aggressive pricing or underwriting strategy is implemented in which over-optimistic assumptions are applied, financial distress can emerge relatively quickly (usually expressed in terms of years).
2. Mortality/morbidity claims and benefits. These are payments associated with adverse perils insured against. These risks can take the form of the deviations from expectations relating to the current level, the trend, and sudden favorable or unfavorable permanent or temporary spikes in experience. They can result from changes in marketing, underwriting or program/policy features, environmental effects, policyholder behavior and the tension between possible selection of risks by the insurer and anti-selection by the policyholder. The risk and uncertainty may consist of their frequency (incidence of claims/benefits, sometimes involving multiple claims/benefits of varying size, even within the same insurance policy) and financial amount (if not of an indemnity basis, i.e., if the policy's exposure to loss is a fixed amount).
3. Catastrophe (calamity) risk. The possible very large loss that can jeopardize the future soundness of a company, involving a catastrophic amount of losses in a specific geographic of demographic exposures, such as epidemics, natural disasters. One source of this risk is over-concentration in exposures in a particular business segment or weak corporate governance. The longer the period covered, the more likely it is that such an unexpected set of conditions could arise.
4. Policyholder behavior (see chapter 18 *Policyholder Behaviour and Management Actions*). The resulting risks include voluntary lapse and mortality/morbidity/claim anti-selection/policy mix, which may affect the amount of claim/benefits and degree of continuance of insurance policies, due to anti-selection or moral hazard. They usually are a result of options provided to the policyholder through various policy provisions, such policy termination or filing a health claim. Rate spirals, where premium rate increases cannot catch up with corresponding increase in average costs, can get out of the insurer's control and cause serious financial damage to the insurer.
5. Changes in economic / legal conditions. These can affect the ultimate payout of claims or benefits.
6. Mis-estimation, e.g., of level, trend or frequency and severity of any parameter. The object of the estimate could be the number or amount of claims incurred, to be incurred during the remaining coverage period or the development of those losses (i.e.,

claim liability estimates). To the extent an insurer does not recognize the uncertainty underlying the insurance or investment perils, the premiums may be under-estimated. Although this may be the result of process, parameter or model risk or uncertainty, it could also be the result of such factors as inaccurate data or inappropriate data sample used as a basis for assumptions, incorrect models or change in conditions from the time the data was obtained.

7. Investment and counterparty risks. All insurers have investments of various sorts (e.g., financial instruments or real estate). These are associated with classic financial risk, including market, credit and interest rate risks. Because of the long time frame of many insurance coverages and claims, reinvestment risk can also be significant. Counterparty risk can include such situations as the bankruptcy of a reinsurer, fraud committed by a third-party administrator or inadequate security resulting in computer hacking of policyholder records.
8. Regulatory, legal or political risks. These risks can include unanticipated adverse effects of changes in regulation, imposed supervisory action or retrospective application of changes in law or taxes.
9. Asset / liability mismanagement. Examples or asset / liability management tools include derivatives, reinsurance and other hedging techniques. Cash flow projections under a range of scenarios can provide relevant information, as can such metrics as key rate durations. Since not all such techniques are "perfect", the extent of lack of hedge effectiveness remains a risk. (see chapters 13 *Asset / Liability Management Risk* and 19 *Dynamic Derivatives*)
10. Expenses. Operating or acquisition costs can be in excess of those expected. This might arise from conditions such as a lower number of units (e.g., sold or inforce) over which to spread fixed costs or higher cost inflation than anticipated or that fixed costs are treated as if they were variable.
11. A combination of risks. Although it is tempting to place a risk in a silo, their effects can become more severe when they are interrelated. Variable annuities with guarantees is an example of policy features that created a large bubble of risk exposure for several insurers[14].
12. The ability of an insurer to provide sufficient funds to pay benefits. This could include illiquidity risk in periods of unusually concentrated cash outflow demands relative to assets on hand, over-leverage in the case it has an over-reliance on much debt, and asset/liability mismatch where an investment loss arises during periods in which invested assets would have to be liquidated at a value that would be lower than their reported value.

[14] This rose to near-crisis proportions over the last decade. Dynamic hedging has been used to help mitigate some of these risks, although it can exchange one type of risk for another to the extent that the hedge used is not perfect. This highlights the distinction (and combinatorial effects) of non-diversifiable risks partially mitigated by dynamic hedging with short term contracts.

13. Uncertainty as to the actual operation of the larger financial system in times of stress. Markets may shut down, governments may change rules or intervene or policyholders may change their behavior. These may result in a breakdown of normal pricing and liquidity expectations and risks. These are examples of the uncertainty associated with changes in correlations between drivers or inter-relationships between key risks that change unexpectedly under extreme conditions.

These examples may be mitigated by one or more techniques, some automatically called upon, while others might be evoked under a set of conditions by management action. Examples of the former include (1) risk transfer techniques such as ceded reinsurance or catastrophe bonds, (2) hedges such as derivatives, (3) risk sharing such as policyholder sharing of risks in applicable types of certain participating, variable/unit-linked or experience-rated policies, or (4) negatively correlated obligations (e.g., having a book of annuity payout risks that also contain life insurance risks on the same lives). Examples of the latter include amounts of policyholder dividends/bonuses/non-guaranteed amounts that are determined through management discretion and situations where management can reduce operating expenses or enhance investment income levels.

Appendix 2

Major categories of methods that have been used to quantify insurance-related risks and uncertainties include:

1. **Quantile**. Quantile methods are expressed in terms of a degree of confidence that the liability or capital is sufficient to provide for a designated amount of adverse experience. Each variation applies a model to determine applicable risk distributions, so that the level of margins (or amount of assets if assessing reserves) required to achieve the desired level of confidence in meeting policy obligations can be determined. The techniques within this family include:

    a. Confidence levels (Value at Risk, VaR). A given probability of sufficiency leads to a value at risk.

    b. Conditional tail expectation (CTE or Tail-Value at Risk (T-VaR or Tail-VaR)). This is equivalent to the expected present value of the cost of claims or benefits greater than a threshold value.

    c. Moment methods. A multiple of standard deviation, variance, semi-variance, or higher moment(s). These require the entire shape of the probability distribution (statistical or empirically derived) to be estimated, either based on a model, on observed data or other related experience.

2. **Explicit assumptions**. Although not a totally separate approach, this variation of a quantile method used for long-duration policies separately assesses each major assumption separately, including a reflection of interactions. It usually applies professional actuarial standards that specify ranges within which the liability lies.

    Canadian actuarial standards currently require the actuary to add an explicit margin for each assumption. The minimum level of the Canadian ranges provides for a minimal amount of conservatism, while the maximum is at a level that still is not so conservative as to distort income. Although not explicitly based on a quantile method, these ranges have been developed based on practice, with the expectation that actuarial judgment will be applied in the context of applicable actuarial standards about the business being valued. It applies the correlations among the assumptions, as they may be inter-related.

    For example, (1) mortality and policyholder behavior, (2) policyholder behavior and economic conditions or (3) frequency and severity of claims, may or may not be related or trends may or may not offset each other. Although they are not likely to all go sour at the same time, for certain extreme scenarios, it may be appropriate to assume that they do. In contrast, aggregate methods usually reflect correlation implicitly, as they usually treat all the individual experience assumptions on a combined or aggregated basis.

3. **Cost of capital**. The cost of capital approach expresses risk as a function of both the passage of time and costs associated with assessments against capital made on a

continuous basis. Evidence regarding the cost of holding this capital is provided by prices in a market. It refers to the amount of return demanded by the marketplace on an investment of capital that enables an insurer to fulfill its policy obligations after payment of income tax.

4. **Discount rate**. A discount rate approach focuses on the effects of risk and uncertainty as they occur over time. Unless constrained by rules associated with financial reporting rules, actuarial practice may consider the extent of uncertainty through an adjustment to the expected cash flows or through the discount rate – the approach used depends upon the type of application and common practice. The important consideration is to reflect uncertainty in one of the two and to not double-count it. Although there is no unique accepted method for determining the discount rate adjustment, the following techniques have been used in various applications:

    a. Risk adjusted discount rate. Usually a level but subjectively selected margin applied to the discount rate for risk.

    b. Deflator adjusted cash flows. Deflators are usually applied to asset values, constructed using market price information. As such, there are currently no practical examples in the literature on how to apply them to non-hedgeable risks where there is no relevant market information available.

    c. Capital asset pricing model (CAPM). Although CAPM was developed for the analysis of asset values, it has also been used to allocate capital. It has been used as a method for determining the "cost" in a rate of return method. It may be more appropriate to apply in determining parameters for other methods, rather than as a method itself.

Each method requires parameters, possibly directly considering regulatory requirements, re-engineering, scenario analysis including stress or sensitivity testing, stochastic modeling, judgment or a combination. The parameters needed differ for each method, including:

- The cost and amount of capital (including its runoff pattern) in the cost of capital method;
- Confidence level or other quantile level for quantile methods;
- Multiple of higher moments;
- A basis point adjustment in the risk adjusted discount methods; and
- Margins for each or selected explicit assumption.

The parameters used may incorporate several possible elements, including, for example:

- The characteristics of the product being priced, the liability being estimated or the company whose required capital is being assessed.
- The actuary's interpretation of the regulatory or financial reporting requirement, which may be stated differently, for example for liability measurement, "moderately adverse experience";

- The actuary's degree of confidence in the underlying assumptions;
- The sensitivity of results to variations in the assumptions;
- The actuary's judgment as to the effect of combinations of various assumptions, their degree, and the likelihood of them being adverse;
- The severity of the issue and the timing of resolution of the amount;
- The insurer's tolerance of adverse financial results before considering an increase of inforce premiums; and
- Subject to approval or specification by a regulator, if applicable.