Stress Testing and Scenario Analysis

July 2013

International Actuarial Association | Association Actuarielle Internationale

This paper has been produced by Insurance Regulation Committee of the IAA and has been approved by that committee.

International Actuarial Association
Association Actuarielle Internationale
150 Metcalfe Street, Suite 601
Ottawa, Ontario
Canada K2P 1P1

www.actuaries.org
Tel: 1-613-236-0886 Fax: 1-613-236-1386

Email: secretariat@actuaries.org

Table of Contents

Executive Summary

This paper provides an actuarial perspective on scenario analysis and stress testing. As part of the analysis of risks to the financial condition of a firm, these methods are essential tools for effective risk management and macro prudential oversight. They can enhance the understanding by its stakeholders of the financial vulnerability and viability of the firm.

A scenario describes a consistent future state of the world over time, resulting from a plausible and possibly adverse set of events or sequences of events. A stress test provides an assessment of an extreme scenario, usually with a severe impact on the firm, reflecting the inter-relations between its significant risks.

Together, they complement the use of economic capital models that apply probabilities to possible future scenarios to determine appropriate capital needs of a firm. In contrast to internal models, scenario analysis and stress testing assess the financial effect of the events or sequence of events that lead to specific scenarios in adequate detail so that their causes can be identified and their effects on the firm can be understood. Thus, they can be used to enhance the understanding of if and why a firm is vulnerable to highly uncertain tail risks.

A firm should recognize the value of both approaches, i.e., economic capital models as well as scenario analysis and stress testing, to capture and assess the risks and opportunities of the firm associated with specific sets of scenarios, especially where the likelihood of occurrences are highly uncertain.

The results of scenario analysis and stress testing, including an explicit description of particular scenarios and what might lead to them, can be clearly communicated and understood by senior managers, directors of Boards and other stakeholders. They can also be used to identify the scenarios and the type of adverse risks that would result in a given degree of financial stress. Their use can enhance the risk culture of a firm, as they can alert decision makers to potentially inconvenient truths and provide a framework to enable firms to base their business strategies and risk mitigation activities on a range of forecasts rather than a single best-estimate projected result or an average of stochastic results.

Introduction

The use of internal models is becoming more important for management, regulators and rating agencies in the financial services industry worldwide in order to assess the financial condition and capital needs of its participants. These models are currently used by some regulators to determine regulatory capital requirements[1] and by rating agencies as a sign of competent risk management. Firms have applied their results to develop and refine their corporate strategies.

[1] Reference Solvency II and Basel II for Trading Book, Canada and US RBC

The International Actuarial Association has prepared guidance on the development and use of internal models[2]. They are typically used to project a firm's financial condition, which includes determining its ability to fulfill its obligations to its policyholders over a fixed future period, based on a set of assumptions about the general economy, the environment in which the firm operates and the firm's operating situation. Economic assumptions are often derived from stochastic generators in an internal model using parameters based on either historical experience over a certain period of time or on current or recent conditions. The reliability of these generators depends on the underlying probability distributions chosen and on the data used to fix the parameters of the generator.

Common deficiencies of such models can include a lack of sufficiently "heavy" tails in the probability distributions used (common in many of the most widely used distributions) and calibration of the distribution's parameters from a time period of insufficient length to capture a representative range of conditions. By way of contrast, another deficiency can arise when the modeler does not consider recent conditions in the baseline projections to reflect recent drivers and trends that may be more evident if recent experience is considered.

If the model does not appropriately consider sufficiently extreme (in the "tail" of the probability distribution) conditions that can lead to "severe" stress to the firm, its results may not adequately capture the risks and uncertainties that may arise. Stress to the financial institution may be the result of a complex set of interactions of various risk factors (some of which may not be quantifiable). Although these interactions are often unique and difficult to predict, expected interactions of generic stress conditions may be sufficiently embedded in an internal model to reflect an adequate range of possible futures.

Even if the probability distribution used includes a heavy tail, it is unlikely that every possible stressed environment or every possible contingent event will be considered in a stochastic simulation. Needless to say, especially in light of recent crises, it is important to investigate the effect of a range of possible assumptions about the environments on the firm's financial condition and indeed its solvency and to prepare appropriate risk management strategies for possible use. A limitation of stochastic methods is that since they reflect a weighted average of multiple scenarios as they focus on expected costs, preferences or prices; they do not focus attention on the effect of actual (albeit unlikely before the fact) scenarios, even though some of them represent extreme conditions with potentially disastrous results.

Therefore, to study and plan for the effect of specific types of scenarios, an internal model is applied to assess the effects of the individual scenario and the realistic mitigation approaches used in response. The study of deterministic scenarios can also be useful for other purposes, such as sensitivity testing, development of management strategies and operational plans, product development and financial planning. In addition, regulators can specify particular scenarios to be tested by all firms operating under their authority to gauge possible impacts of systemic risks to both the system as a whole and/or to a range or type of individual firms.

[2] IAA Note on the Use of Internal Models for Risk and Capital Management Purposes by Insurers

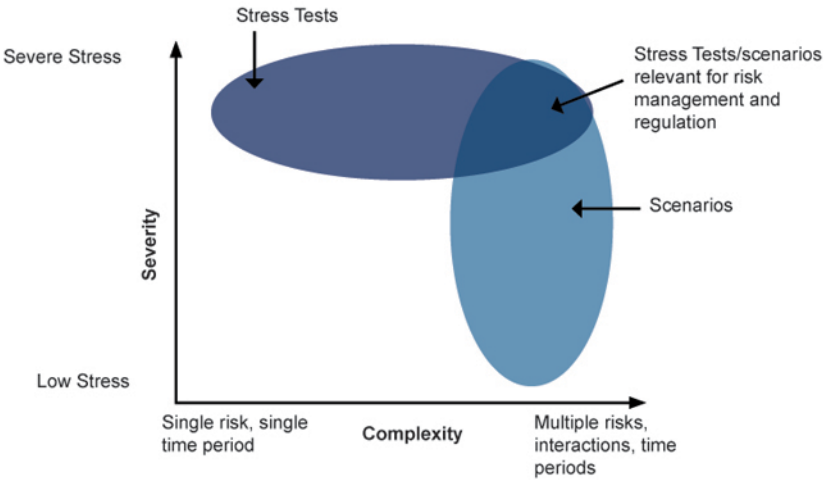
This paper discusses the considerations that may be used to help develop useful deterministic scenarios for insurance companies and other financial institutions for use in sensitivity analysis and stress testing. This paper is principally concerned with the assessment and enhanced understanding of the effects of sensitivities and stresses on a financial services firm or industry through a systematic and rigorous "what if" analysis. It is best read in conjunction with the IAA papers on Internal Models[3] and on Enterprise Risk Management[4].

Definitions

Often the terms scenarios, stress tests and sensitivities are used interchangeably. In this report, the following distinctions are made:

1. A *scenario* is a possible future environment, either at a point in time or over a period of time. A projection of the effects of a scenario over the time period studied can either address a particular firm or an entire industry or national economy. To determine the relevant aspects of this situation to consider, one or more events or changes in circumstances may be forecast, possibly through identification or simulation of several risk factors, often over multiple time periods. The effect of these events or changes in circumstances in a scenario can be generated from a shock to the system resulting from a sudden change in a single variable or risk factor. Scenarios can also be complex, involving changes to and interactions among many factors over time, perhaps generated by a set of cascading events. It can be helpful in scenario analysis to provide a narrative (story) behind the scenario, including the risks (events) that generated the scenario.

Figure 1



Because the future is uncertain, there are many possible scenarios. In addition there may be a range of financial effects on a firm arising from each scenario. The projection

[3] Full reference here
[4] Full reference here

of the financial effects during a selected scenario will likely differ from those seen using the modeler's best expectation of the way the current state of the world is most likely to evolve. Nevertheless, an analysis of alternative scenarios can provide useful information to involved stakeholders.

While the study of the effect of likely scenarios is useful for business planning and for the estimation of expected profits or losses, it is not useful for assessing the impact of rare and/or catastrophic future events, or even moderately adverse scenarios. A scenario with significant or unexpected adverse consequences is referred to as a *stress* scenario.

2. A *sensitivity* is the effect of a set of alternative assumptions regarding a future environment. This alternative scenario can be the result of a single or several alternative risk factors, occurring either over a short or long period of time. A scenario used for sensitivity testing usually represents a relatively small change in these risk factors or their likelihood of occurrence.

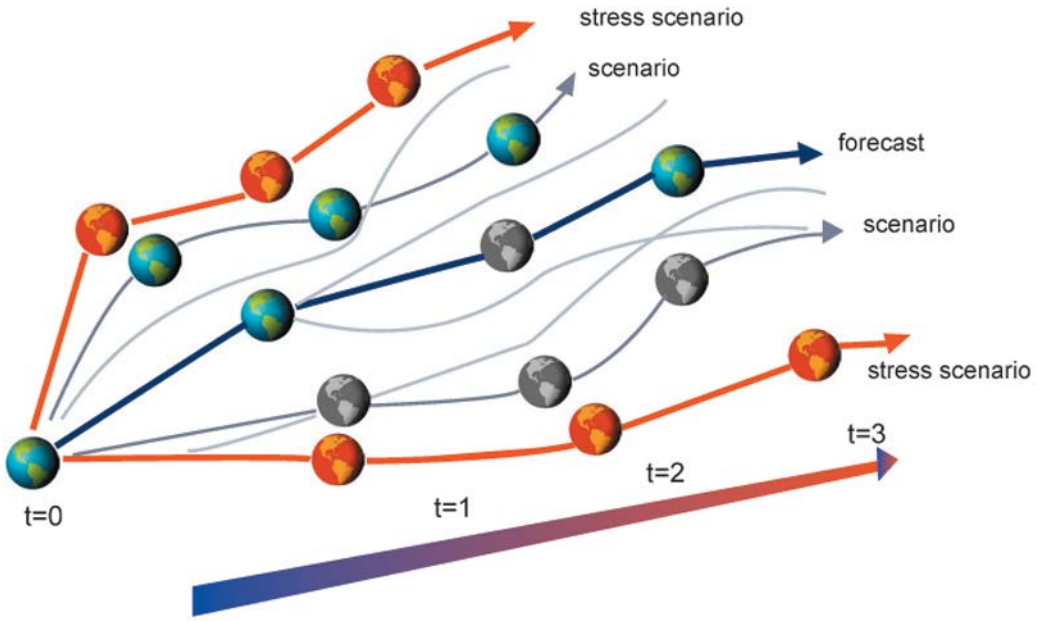
   Since a sensitivity test represents the effect of a scenario, it usually reflects the effect of multiple related factors. The results of a sensitivity test that only varies a single factor without reflecting its inter-relation with other factors needs to be reviewed with caution (although running a model varying one factor at a time may prove useful in validating the reasonableness of the model used). Sensitivity tests are often used as a tool to calculate volatilities and other quantities by the application of further assumptions on the underlying probability distributions, including possibly non-linearity and inter-relationships between the parameters of the model.

3. A *stress test* is a projection of the financial condition of a firm or economy under a specific set of severely adverse conditions that may be the result of several risk factors over several time periods with severe consequences that can extend over months or years. Alternatively, it might be just one risk factor and be short in duration[5]. The likelihood of the scenario underlying a stress test has been referred to as extreme but plausible.

The forecast in the figure below represents the best case projection, deviations from which would constitute the effect of sensitivities and stress scenarios.

[5] In Solvency II, a stress test is defined as the analysis of the impact of single extreme events and scenario analysis is the assessment of the impact of combinations of events. This is consistent with the definitions used in this paper.

Figure 2



Stress testing is a common form of sensitivity testing, particularly useful for regulators as well as internal management. In this paper, we focus on the development of a more complex scenario that is triggered with a single disruptive event that gives rise to a cascade of effects. For example, consider:

- *The financial crisis that began in 2007*. This crisis began with a severe weakening of the U.S. housing market, followed by the seizing up of the market for securitized financial instruments, which in turn led to a general credit crisis, a severe drop in equity markets and a severe economic recession in many countries. Such a multi-effect scenario can play out over months and years due to tight and complex inter-relationships between different participants in the financial market. This example illustrates the possibility that financial stress experienced by one part of the financial market (e.g., subprime lenders) can in turn affect the entire global financial system and affect both related and seemingly unrelated financial institutions, including investment banks, hedge funds and insurers, even though these participants might not have held subprime linked investments. These difficulties can extend well beyond the financial community and have large-scale effects on the general economy.
- *Forced asset sales*. When an event leads to a loss for some market participants, they are forced to sell some of their assets, which in turn lower the market prices of these assets. Firms holding similar assets subsequently may also incur losses even though they may not have been directly exposed to the initial loss. A famous example is the attempt to corner the market for silver by the Hunt brothers during the 1970s; when the price of silver collapsed, the Hunt brothers were forced to sell their holdings in cattle, which also depressed the price of cattle.

- *A series of events*. Major catastrophes expose a firm not only to a contemporaneous financial strain but also to a sequence of effects that can play out over months and years. To only consider the initial event could in such cases vastly underestimate the financial stress the firm would experience. However, it is difficult if not impossible to think up all possible scenarios, let alone estimate their consequential effects. Also, recall that the purpose of using a scenario is less about predicting a future event than to allow a firm to plan in advance about types of events or changes in conditions and to be prepared if a similar (but not necessarily identical) catastrophe were to occur.
- *A single event*. Some catastrophes may be limited to only a single initial event. Although it is unlikely that a bus accident or a hailstorm will lead to an avalanche of further events, either event might be catastrophic for an unlucky individual insurer as well as the individuals affected. Therefore, it may be appropriate for stress testing to include such "simpler" scenarios as well.

Although a particular scenario is often the intermediate or ultimate condition caused by a hypothetical or actual event(s), it can also be the result of the continuation of a trend or change in condition, such as the interest rate associated with a change in monetary policy.

Sensitivities and stress tests are certainly related, in a continuum ranging from simple sensitivities to complex stress scenarios, as shown in the following figure.

Figure 3

Uses of scenarios

Scenarios can be used in a variety of ways to assess the financial vulnerability of the firm and the exposure to failure of both individual financial institutions, such as insurance companies, and entire industries within a regulatory jurisdiction. It also can help evaluate the effectiveness of various mitigating management options available to firms and regulators. Some of these applications are described in the sections below.

Solvency testing and financial condition reporting

The assessment of a firm's financial strength is of fundamental concern in financial analysis to determine whether the firm has or can obtain sufficient financial resources to meet all of its obligations to its policyholders and depositors. Solvency testing examines the severity of the financial effect of scenarios on a firm's solvency.[6] It is a form of stress testing in which the types or level of financial strain a firm can withstand and remain a going concern is assessed. It is often viewed in the context of whether the firm meets regulatory capital requirements that are set to ensure policyholder promises can be paid at some desired level of security

The shareholders' view is usually related to their financial objectives, that is, achievement of a desired level of financial return on their investment and of sufficient, yet not excessive, equity. This emphasizes how effectively the firm is managed for profitable growth, reflecting its business model. Although the risks considered by the shareholder are presumably covered by regulatory capital, they may also include risks directly related to successful growth and profitability. These risks include the ability to obtain new business, the ability to price its products accordingly and manage its inforce, which can demand the assessment of different types or depths of scenarios or metrics. In addition, there is the risk to the overall economy, which takes the form risk exposure to the taxpayer or the general public.

No single quantitative test can provide complete insight into the risks and uncertainties of the financial success of a firm. While internal models driven by economic stochastic generators can provide a great deal of useful information, an adequate assessment of solvency will include sensitivity analysis and stress testing based on scenarios. In many cases, the analytical models (e.g., the economic stochastic generator used), are not calibrated with enough credibility to adequately reflect the effect of rare events and catastrophes that have infrequently or possibly only hypothetically been observed.

The likelihood and financial effect of certain scenarios can be extremely uncertain. In these cases it is almost impossible to precisely estimate their small probabilities. In fact, their effect cannot be estimated and even their identification cannot be easily made through the application of a traditional economic capital model. Consequently, an economic capital requirement cannot usually be assigned to such events in a reliable manner. Yet, such scenarios may lead to the largest financial strain for firms or an entire industry. The use of scenario analysis and stress

[6] Solvency testing is discussed in greater detail in the IAA publication *A Global Framework for Insurer Solvency Assessment*.

testing by decision makers and regulators may prove to be the best approach to prioritize their options, whether to add to capital or to use other approaches to mitigate these risks.

Risk management

The objective of risk management is to identify, quantify and transparently communicate to the appropriate stakeholder(s) the types and extent of risks to which a firm or an industry (in the view of the regulator) is potentially exposed and, where appropriate, to propose methods on how to align exposure to these risks with the risk appetite of the firm.

To accomplish these objectives, a risk manager can

- formulate a range of scenarios, whether stochastically or deterministically determined, that illuminate the risk exposure of the firm to a range of future conditions;
- evaluate the effect of these scenarios on the financial position of the firm;
- discuss the results of these evaluations with senior management and the Board to assess the extent to which they are consistent with the firm's risk appetite; and
- identify and recommend to senior management and the Board, as applicable, realistic management actions or capabilities, including their cost, the firm could apply to manage or mitigate the effects of scenarios that may lead to financial difficulty.

When considering possible mitigating or remedial actions, the risk manager may test the effectiveness of the proposed actions by modifying the identified basic scenarios, incorporating the effect of those management actions and mitigation techniques that may or may not be fully effective in responding to a stress scenario.

For example, suppose a significant portion of the assets supporting a portfolio of participating life insurance business is composed of equities. When a scenario is tested that includes a sharp fall in equity values, a mitigating action might be to reduce policyholder dividends / bonuses. However, when testing the effectiveness and realistic likelihood of success of such an action, the effectiveness may differ if it is the entire industry that is taking a similar action (thus maintaining its competitive position) versus where the firm is the only one applying this investment approach. This is especially important if the finances of the firm or industry are susceptible to stressful or systemic scenarios of this type. The assumptions regarding the extent that management will be willing to take this action, the timing of its action and its consequential effects such as anti-selection effects on mortality, can be important. Scenarios include information related to the development of the scenario that may be helpful in quantifying realistic assumptions regarding the firm's management actions. Factors such as company history and philosophy, actual and desired competitive position and policyholders' reasonable expectations can have a significant effect on the timing of proposed action. The risk manager typically considers such factors and documents the basis for assumptions regarding the effect of the scenario(s) studied.

Risk and uncertainty can be managed in several ways in a financial institution, some methods occur prior to taking on the risk, while other methods are applied after it is retained. The methods used may depend upon the risk involved and the environment either at the time risk is

taken on or when conditions change. These can be implemented through contract terms or by means of management discretion. They include:

- Risk avoidance in the first place;
- Risk elimination, such as by means of fully effective transfers and hedges;
- Risk mitigation or reduction, through less than perfectly effective transfers and hedges, and diversification;
- Future discretionary management actions, for example, policyholder dividend/bonus adjustments and deleveraging product risks;
- Operational measures, such as strengthening of current processes; and
- Raising additional capital or reducing shareholder dividends.

Analysis of non-quantifiable risks

A useful distinction between risk and uncertainty was made in 1921 by the economist Frank H. Knight in *Risk, uncertainty and profit*[7] that

> ... Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated. The term "risk," as loosely used in everyday speech and in economic discussion really covers two things, which in their causal relations to the phenomena of economic organization are categorically different at a functional level. ... The essential fact is that "risk" means in some cases a quantity, susceptible of measurement, whilst in other cases it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomenon depending on which of the two is really present and operating. ... It appears that a measurable uncertainty, or "risk" proper, as we shall use the term, is far different from an unmeasurable one that it is not in effect an uncertainty at all. We ... accordingly restrict the term "uncertainty" to cases of the non-quantitative type.

The study of scenarios is well suited to address uncertainty, especially when the identification or quantification of the effects of relevant scenarios is difficult. In contrast, economic capital models are suitable where relevant historical data and mathematical models of the underlying scenarios are available.

The effect of certain risks that an insurance company faces may not be adequately quantified if the likelihood of occurring is highly uncertain or if there is no supporting scientific insight. Nonetheless, their consequences can have a strong effect on a firm's financial condition.

An example of a risk with highly uncertain probability is reputational risk, which depends on many factors, including the firm's strategy and business model, senior management behavior, and operational risk exposures. While it is almost impossible to calculate an accurate estimate of the probability of such a loss of reputation occurring, the financial consequences when such a reputational loss occurs can be expressed numerically. Such damage may include changes in policyholder behavior (lapse rates), adverse selection (only the worse risks are willing to

[7] Knight, F.H., *Risk, Uncertainty, and Profit*. Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Co.

continue dealing with the firm), new business volume, employee turnover or reduction in productivity, and regulatory actions. To assess the effects of the risk, a scenario could be developed that describes the situation and its effect on various financial elements of the firm's operations. While these consequential financial effects on a firm's reputation often result directly from a specific high risk exposure, they may also arise as a result of the normal operations of the firm or an industry, such as from an ill-conceived offhand comment by a senior executive.

Many consider that operational risk for a financial institution is not quantifiable, since the mathematical applications currently in use are of dubious relevance. In addition, the definition of operational risk used may not be sufficiently clear to assign a loss to an operational risk event, nor be relevant to future operational risk exposures. As a result, capital requirements for operational risk has not been seen as of the same quality or sound basis as those for financial market and insurance risks.

The use of scenarios can thus be a more effective way to understand and plan for the effect of operational risk events relevant to a specific firm, providing the risk manager, senior management and the Board a sense of what could happen and what its effects might be. Use of such scenarios to capture non-quantifiable risks represents an essential complement to economic capital models.

Senior management and Board involvement

It is important that senior management and Board members be involved in this process, not only to emphasize its importance to all areas of the firm, but also to provide insight into the risks of the firm.

Just as senior management and Board members without a strong mathematical background often understand and respond more easily to charts rather than tables of numbers, they may better appreciate risk portrayed in terms of clearly expressed examples or graphics, such as through scenarios, than to statements expressed in terms of confidence intervals or formulas. Of course, users of this information also require some type of estimates of the likelihood that the scenarios could occur, but these estimates usually need not be precise. Scenarios thus become an important tool that the risk manager can use in communicating with those who must understand the results of the manager's work.

Scenarios thus used as a communication tool should be intuitively clear and understandable so that non-specialists can make appropriate decisions based on the drivers of the scenarios and their consequences for the firm. It is important that each scenario be explained by a narrative accessible to readers without a technical background. The narrative provides the rationale for the choice of the scenarios and provides a story explaining what might lead to the scenarios and possible actions that could be taken to reduce the resulting costs, if desired.

Regulators and scenarios

Scenario testing can be used in several ways to meet regulators' needs. For specific risk events a range of scenario results can be analyzed to quantify an individual firm's exposure to those

events. Then the firm can walk through with the regulator how they have planned in advance for needed responses to this range, particularly the most adverse ones. .

To assess systemic risks, the regulator can define the type of risks to be modeled. The regulator might require all firms to test the same scenario (in terms of size and timing and the inter-relationship of risks) and to report the test results in a standard format that could be compiled to give a sector-wide picture. Such a scenario would need to be defined sufficiently narrowly to make the outcomes from different firms directly comparable. If these scenarios are not made sufficiently clear, inconsistent interpretations might be applied by different firms, making the aggregate outcomes less useful for the assessment of systemic risks. Thus, there is a balance needed between specifying an overly detailed scenario that would be irrelevant for many insurers and a general scenario where the evaluation may become arbitrary. In so doing for the major firms within the industry, not only can an individual firm's resilience (or weakness) under those circumstances be assessed, but the aggregate results and systemic risk implications of the industry as a whole in a jurisdiction can be better assessed. In addition, the expected effectiveness (in mitigating or exacerbating a crisis) of alternative regulatory anticipated actions or reactions to the scenarios can be reviewed before their implementation

To the extent that the global economy and inter-connectedness of globally operating financial firms affect firms only operating domestically, it may be appropriate to consider international circumstances even for firms within the jurisdiction of a domestic regulator. Thus, the regulator could consider scenario analysis and stress testing that incorporate the expected effect of global conditions. Because of the complexity of the inter-relations and difficulty in determining the effects of these foreign conditions, studies of systemic risks would likely consider a limited number of parameters capturing key risks relevant to the industry as a whole and the global economy. These might include the probability of a global financial crisis similar to the Great Depression or the recent financial crisis, as well as a severe pandemic event, a large natural catastrophe (e.g., a strong tsunami impacting the eastern seaboard of the U.S. or Tokyo) or a man-made catastrophe (e.g., a terrorist attack using nuclear weapons). They would also consider how different regulatory regimes might respond to preserve their national self-interests. Ten years ago, the regulators in Australia (APRA) conducted a stress test like this, focusing on the domestic exposure of their banks and mortgage insurance companies to a decline in housing prices, leading to an equity shock. Based on the results of this stress test, they were able to implement regulatory safeguards that led them to avoid the issues faced by most jurisdictions in 2008-2009.

To assess the quality of the risk management and the risk culture of a supervised firm, a regulator could also ask a firm to re-formulate sufficiently realistic but extreme company-specific scenarios or review the testing already performed to ensure that its specific risk exposures are assessed properly. Normally, the development and maintenance of company-specific scenarios are managed as a joint effort by different functions within a firm, along with input from senior management and the Board to ensure a higher confidence in the testing results. A badly formulated scenario may be a sign of inadequate communication within the firm, and a lack of interest in or know-how to conduct analysis of the firm's risk exposures.

Assessment of internal models

Internal models incorporate probabilities of alternative outcomes, in some cases, on a stochastic basis. An independent assessment of both the probabilities and scenarios can help validate the reasonableness of these models. A scenario can be used to help validate the reasonableness of a stochastically derived model. For example, the expected cost associated with an extreme scenario can be used to assess whether the internal model assigns reasonable probabilities to such losses. Consistency of assumptions between scenario analysis and internal models can also be tested.

If the likelihood of a particular scenario can be estimated independently and if the probability of that scenario generated by the internal model is significantly different, the possibility that the internal model contains a material error or includes an inappropriate assumption with respect to extreme events can be assessed. For example, if the expected loss for a given scenario is at least US$200m with a probability of 1.0%, but the probability of a corresponding loss generated by the corresponding internal model only 0.01%, the internal model may not adequately consider such outcomes.

This use of scenarios to provide a reality check for a given internal model can be useful even where the probability of the scenario cannot be reliably estimated. In the example above, if the internal model allows for a loss of at least US$200m only once in one thousand years, but such a loss is found to be a result of a reasonably probable scenario, then the estimated losses of the extreme possibility scenarios may not be realistic.

Such reasonableness checks contribute to the trust given to the internal model, because methodologies and mathematical approaches used in these models can break down in extreme situations. These models are often (implicitly or explicitly) calibrated to normal circumstances (e.g., covariance parameters of risk would be based on a historical period without a catastrophe or an assumption of unlimited capital mobility within an insurance group). Since the details of calibration or the technical assumptions used may not be sufficiently clear to the users of the models, scenarios can help identify and communicate the limits of these models.

Defining the firm’s risk appetite

A firm's risk appetite underpins many firms' strategy and implementation of an appropriate governance and risk management framework. The firm’s senior management and Board may desire to develop and periodically confirm the firm's relative preference for potential profit against possible losses. Risk appetite need not be based solely on catastrophic risks or annual profit & loss; rather, additional elements can be considered, including rating down-grade and catastrophic risks.

Management balances these classes of risks. Does it strongly prefer stable income, or is it focused more on minimizing catastrophic risks? There is no unique best choice; rather, it depends on such factors as type of business, business model, its current financial condition and

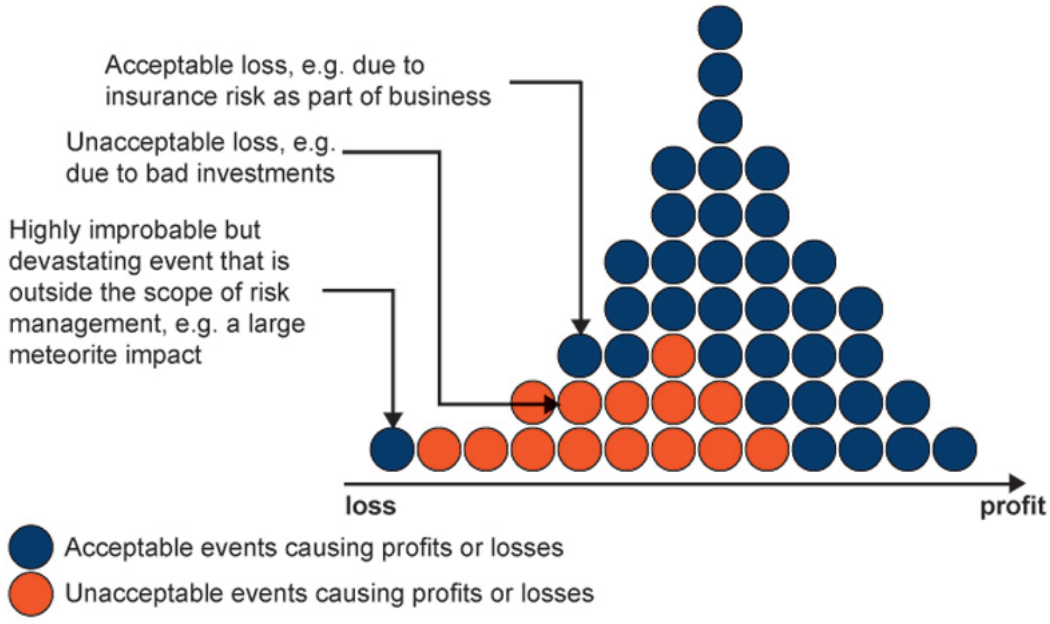
risk tolerance, and its competitive environment. Management needs information not only on expected but also on the range of possible developments.

To assess rating down-grade risk, conditions (or events resulting in such conditions) that occur with a likelihood of, say, once every ten years are relevant. To gain insight into catastrophic risks, costly scenarios expected to occur once in every 50 to 100 or more years and even more extreme events may also be relevant. These scenarios differ not only quantitatively but also qualitatively as well. A rare and extreme scenario is likely to result from larger interdependencies (cascading events and statistical covariances) during extreme conditions than during more normal circumstances, usually resulting in a wider range of losses and different risks than typically used in business planning. For example, a one in 10 year earthquake might lead to limited building damage, whereas a more severe earthquake can lead to severe damage through a tsunami and catastrophic failures of chemical plants and nuclear power-stations.

The type(s) of risks or contributing cause(s) of the scenario are also useful to consider. Different causes will affect the firm in unique ways, even if they result in the same immediate financial loss. For example, a natural catastrophe causing a loss of CHF 1bn for a reinsurer has a different effect from the same amount lost due to bad investments. The former may be seen as a normal business occurrence, while the latter may be due to incompetent governance leading to a loss of reputation.

The following figure illustrates the types of losses that might be considered “acceptable” from a reputational point of view.

Figure 4



The application of scenarios certainly can help define the risk appetite of a firm. An effective presentation covers multiple scenarios, designed to enable an informed Board discussion that focuses on more than the expected frequency of an event or condition, but also to assess the severity of precipitating risks and resulting possible catastrophic losses of different magnitudes and types. Together with an analysis of profit and loss trade-offs and the firm's risk tolerance, this will facilitate the development of a more clearly defined risk appetite that can be applied across the firm.

Developing scenarios

Types of scenarios

There is a wide range in the types of scenarios that can be used with different uses and applications. We discuss below the following:

- Reverse scenarios
- Historical scenarios
- Synthetic scenarios
- Company-specific scenarios
- Single-event scenarios
- Multi-event scenarios
- Global scenarios.

Reverse scenarios

The purpose of a reverse scenario is to identify a scenario (or one or more events that result in a scenario) that is expected to give rise to a particular amount of financial loss. For example, it can be used to determine the level of mortality experience that could result in a life insurer becoming insolvent within the next twenty years. The formulation of a reverse scenario requires a thorough understanding of the potential risks a firm faces and the result of the effects of these risks. A significant challenge in developing such a scenario is to determine the inter-relationships among model parameters that will result in such a scenario. One way to identify such scenarios is to capture the particular circumstances in each simulation run by the economic capital model that resulted in insolvency. Any such commonalities in those simulated "failures" would be an area of focus for reverse scenarios. The identification of a reverse scenario can be a powerful tool to conduct a reasonableness check on the result of internal models, as well to assess and set various risk limits.

Historical scenarios

An historical scenario is based on experience during an observation period, possibly triggered by a certain historical event. For example, a scenario might be developed based on the financial crisis of 2007-2009, on the 1918/1919 Spanish flu pandemic, or on the 1923 Great Kanto earthquake. A major advantage of a scenario based on a historical event is that it can be more easily understood, since the situation actually occurred.

Another advantage is that information concerning the short, medium, and long-term effects of the scenario might be available. In particular, its effect on other risk factors may be observable, such as interest rates, equity markets, and inflation can be studied, as can historical events leading up to the event.

Since the historical circumstances will inevitably be different from the current or future situation, in developing the scenario adjustments will need to be applied. For the Spanish flu for instance, these might include an increase in population density, increased global mobility and improved medical conditions and treatments.

In most scenarios, historical financial values will be adjusted for inflation to make the values more consistent with current values. Care is needed when a historical scenario relates to the financial markets, as their nature and regulatory framework are constantly evolving and an event that had little impact in the past might have a larger or smaller impact in the future.

Examples of factors that may require adjustments to historical scenarios include:

- Changes in population mix and movement
- Medical advances
- New technologies, e.g., computers and the internet
- Globalized and more closely linked financial markets
- New asset classes owned
- Management behavior in response to common incentive schemes
- Different valuations used, making historical data not directly comparable to current values
- Effects of media on politics
- Changes to regulatory and market frameworks.

Such adjustments cannot realistically consider all differences between the present situation and that of the historical scenario. Nevertheless, the use of historical conditions (given the limitations on information and resources) can provide a useful framework from which to study the sensitivity to different environments.

Synthetic scenarios

In contrast to the use of historical scenarios, synthetic scenarios describe hypothetical conditions that have not been observed and that can thus be more easily tailored to a specific situation of interest. These hypothetical conditions might occur but have not been observed, for instance, because of sheer good luck, or because certain risks did not previously exist. Synthetic scenarios require more assumptions than do history-based scenarios. For this reason they are subject to a greater challenge and can be more difficult to communicate and discuss both within the firm and with third parties.

Examples of synthetic scenarios include events capturing potential losses due to a new technology such as a breakthrough in nanotechnology or cancer research, a not-yet observed financial market event, or a dirty bomb exploding in a major financial center.

Company-specific scenarios

Depending on a firm's exposure to risk, specific conditions and events might have a significantly different financial effect on the firm than on others in the firm's industry. Company-specific scenarios specify events that are tailored to the specific mix of risk exposures of a firm or of a particular portfolio within the firm.

For example, if the firm has a unique product, has a significant brand value that affects its relationships with its customers or distributors, or its offerings are highly concentrated in a particular product or market segment, then the extent of its exposure to a particular risk may be significantly different from that of otherwise similar firms.

Single event scenarios

Many scenarios can be described by the effect of a single event. For example, a hail storm will likely not lead to a cascade of further events, such as changes in agricultural prices. Such a scenario would constitute a mild test for most insurers, but could be devastating for certain insurers specializing in the area affected. These scenarios are usually well-described by defining the triggering event. The evaluation of such a scenario is relatively straightforward, as management actions subsequent to the event are not especially relevant and not likely to change the scenario, at least in the short-term.

Multi-event scenarios

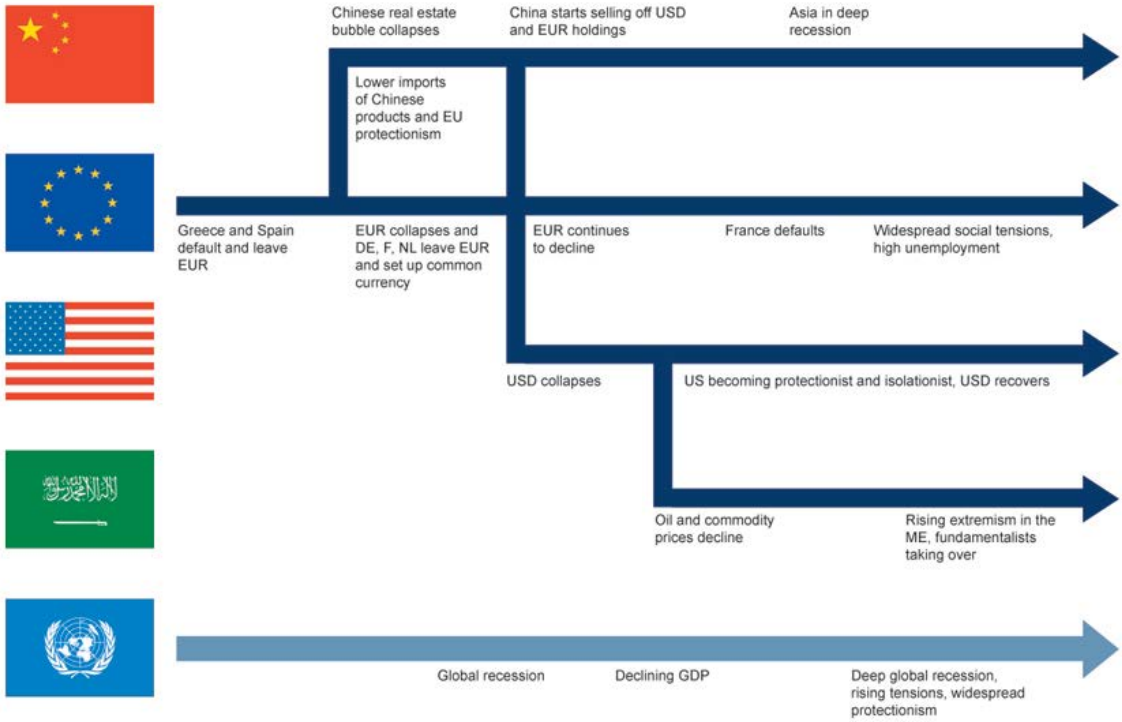
Multiple factors contribute to any future scenario. Specified current or future events will lead to a cascade of further events, possibly over months or years, particularly in the case of severe events that affect an entire industry or a large segment of the industry. Examples are global financial market crises, large natural catastrophes or severe terror events. For such an event, the evaluation of the financial impact on a firm has to take into account the actions management, regulators and the markets may be expected to take during the unfolding of the scenario.

Global scenarios

Some scenarios cover the effects on insurers and other financial institutions on a global level. Historical examples may be the period of the Great Depression starting in 1929, the influenza pandemic of 1918/1919 and the financial crisis that began in 2007. Such scenarios tend to unfold over years and often lead to a substantially changed environment. Global scenarios are particularly useful to assess global interdependencies between financial institutions operating in different regions, the vulnerabilities of these different regional markets and their linkages to banks, insurers, pension funds, other market players and regulators.

It is likely that in view of the emphasis on systemic risk and the linkages between different economic sectors, global scenarios will play an increasing role in regulation in the future. The figure below shows an example of a global scenario, detailing the impact of a possible development of the 2000s' financial crisis on different markets and regions.

Figure 5



Scenario/testing governance

Just as the process of developing financial reporting values requires adequate controls and audit, so does the process of scenario analysis and stress testing. Modeling controls can include the quality control of data input, the independent review of methodology and the assumptions underlying the scenarios and the projection of the effects of the scenarios on the firm. These might include an oversight committee or a peer review process.

Adequate experienced resources are invaluable to conduct proper oversight in a manner consistent with the rest of the firm's risk management government process. Top management may need to be seen as a sponsor and user of the results to ensure proper firm attention is given. That said, the resources devoted to these processes will never be unlimited -- a process is usually established to ensure that the scenarios developed will be limited to the major risk areas that the firm is exposed to, including any the regulator requires. It is good practice for the number and types of scenarios to be manageable and to address a range of the key firm-wide risks, then reviewed and refreshed as needed.

Scenario analysis and stress testing is often coordinated to provide appropriate input into and from the firm's corporate risk management and capital planning strategy development. A feedback loop reporting on actions taken as a result of the analysis is useful to confirm that the analysis is acted upon and not just added to a pile of “nice to see” management information.

In addition, highlights and the results of the analysis and testing are often presented to the firm's Board of Directors. As with any reporting, communication of the results will need to be appropriate for the audience. Communicating with the firm's regulator can be made in an appropriate manner, consistent with practice in the relevant jurisdiction(s).

Behavioral factors

The purpose of scenario analysis is not so much to predict future events, but rather to stimulate the firm and management to be prepared in case a disruptive event occurs. As such, it is important that the models be developed in an unbiased manner that can challenge management without being treated/ignored as a “the sky is falling” mentality nor be so mild, that they desensitize senior management to potential risks.

Thus, risk managers need to present their scenarios as plausible, being clear as to the extent of "invention" being applied, and to have a forthright discussion of the boundaries of conditions and events that should be anticipated. The aim is for senior management and the Board to be active participants and to consider risk to the firm when making strategic and tactical decisions. One way to build credibility is to enhance assurance of a good scenario and stress testing environment by enlisting at least a second set of eyes. This may take the form of an internal review, an external peer review or an audit. A peer review usually focuses on the methodology and assumptions underlying the scenarios tested. The assumptions may be reviewed by an internal committee formed for this purpose. These reviews can emphasize whether appropriate methods and relevant and internally consistent assumptions have been used. Lastly, an audit may incorporate a quality control process, focusing on inputs to the model.

Time frame

Whether a scenario involves hypothetical conditions or is directly based on historical precedents, it is not meant to represent a prediction, but rather a basis for reasonable tests of a firm’s financial strength and basis for management decisions and regulatory action. Developing a scenario requires the risk manager to describe conditions or events that may prove troublesome. This requires an appreciation of long-term historical experience, an understanding of current trends and developments in the overall and firm-specific environments, as well as a keen sense of how events may unfold in the future and an open mind concerning future possibilities.

An historical perspective should encompass a sufficiently long time-frame. Significant errors in risk management have occurred from using models and assumptions based upon short time spans that did not include much if any unfavorable experience. For example, many economic models used during the latter part of the twentieth century and early twenty first century did not recognize the possibility of anything close to the Great Depression of the 1930s. Had some of these models been calibrated to data spanning a longer period, they would likely have provided much better guidance for risk managers and financial firms prior to and during the financial crisis of the early twenty first century.

There is a tendency for markets to operate in very long term cycles. While history may not repeat itself exactly, the risk manager will want to imagine how the downside of a financial cycle might manifest itself in a current or near-future environment.

It is also important to have a good understanding of recent developments that have had or are likely to have an important influence on the types of upcoming risks or on the likelihood of adverse occurrences. An example of this is the increasing effect of technology and the speed at which information is transmitted through society, in particular on the operation of financial markets. Specifically, consequent reaction to significant events can create repercussions that may not have previously existed. Such effects will certainly affect some scenarios. Because these trends and, indeed in some cases, discontinuities are new, the incorporation of their effects into a scenario requires an open mind and some imagination.

Interdisciplinary approach

Many scenarios consist of a wide range of inputs. In formulating a scenario, the use of a multidisciplinary team is advantageous. Using this approach makes it more likely that the scenario will consider more types of effects and will be more coherent, realistic and believable. For example, in developing a pandemic scenario, an epidemiologist, a demographer, a financial markets expert and an actuary all may provide useful input. Incorporation of experiences and techniques from multiple disciplines and parts of a firm can be expected to provide a more rigorous scenario analysis, with more attention being given to correlation of risks or effects of a non-linear nature. It also increases the chances that a more consistent approach to risk management will be followed, with increased embedding of risk management in the firm and a reduction in silo-thinking.

It is also often a good idea to consult senior management or Board members when formulating scenarios, whose concerns regarding the financial effects of a scenario may also prove useful in enhancing the scenario. This type of consultation is also likely to increase their receptivity to a serious stress testing exercise.

Own Risk & Solvency Assessment (ORSA)

An ORSA, developed by the firm for communication with its regulator, includes the firm's quantification of risk and a description of its expected response to risk scenarios. It will be required in many jurisdictions. Knowing that a regulator will be able to compare the rigor of the stress tests used may encourage a firm to take this exercise more seriously. This is also likely to support a more thoughtful and disciplined internal risk culture. In addition, more education regarding the formulation and evaluation of scenarios as described below, will also act to strengthen internal risk cultures.

Formulation of a scenario

A scenario is formulated to enable the financial impact on the insurer or bank to be calculated under the assumptions of the conditions of the scenario. The formulation includes a narrative (a story) describing the conditions, usually including one or more triggering events leading up to it.

The quantification of its effect usually requires the use of an internal model and the identification and quantification of the relevant risk factors involved in that condition (e.g., interest rates, mortality rates, and policyholder behavior).

Narrative

In *Coherent Stress Testing*, Ricardo Rebonato[8] states

> "And when it comes to influencing decisions and prompting action, the power of a 'story' should never be underestimated. A 'plausible model of reality' is exactly that, a 'story' that connects a variety of visible and readily understandable inputs to more or less extreme outcomes."

Formulating a convincing and believable narrative or story is crucial to achieve buy-in from senior management, the Board and other stakeholders.

The first step in formulating a scenario is to explain in a concise, understandable, narrative the conditions expected during the scenario's life. This includes, where appropriate, the set of major factors that contributed to it, possibly a tipping point risk in a long-term trend or a sudden catastrophe of some kind, including their secondary consequences that might affect the scenario and potential future changes having a significant financial effect (e.g., with respect to mortality rates, asset defaults, or interest rates). The effects on other market participants can be relevant if, for example, the firm's financial position is impacted by counter-parties or if the concern is the extent of inherent systemic industry-wide risk. The narrative of the scenario is normally short and readable, usually one or two pages.

The following is a narrative that describes one possible hypothetical continuation of a credit crisis.

1. Over time, it becomes evident that a set of toxic assets is not a result of temporary liquidity needs, but represents a permanent impairment problem. This leads to losses that have to be realized by financial institutions and governments.
2. This causes the government bailouts to be more expensive than expected, substantially increasing the burden on tax-payers.
3. Firms that bet on it being a transitory crisis and kept their illiquid assets (e.g., privately placed corporate bonds or structured products) incur high losses and may fail or have to be bailed out.
4. The U.S. government gives up trying to keep the U.S. dollar as the global lead currency and starts printing money to reduce its debt.
5. Consequently, the Chinese government and other owners of U.S. debt start selling U.S. government bonds, which leads to an accelerating collapse of the U.S. dollar.
6. A trade war commences between the U.S. and countries that see the value of their foreign reserves reduced, resulting in the implementation of ever-more onerous protectionist measures.

[8] Rebonato, Ricardo, *Coherent Stress Testing.*

7. Increasing international tensions and reduced cross-border trade causes more companies to default, leading to generally high spreads and high default rates.
8. Global GDP decreases and oil and commodity consumption is reduced, leading to sharply lower prices.
9. Some sovereign countries default on their debt, with international lending institutions (e.g., the IMF) unable or unwilling to bail-out several large developing countries with high debt and reserves denominated in U.S. dollar. In a number of Middle Eastern countries, income is massively reduced and, in conjunction with high youth and adult unemployment, social unrest increases.
10. The European Currency Union decomposes as some EU member cannot cope with the fixed currency rate anymore.
11. After several years, despite stagnating oil consumption, prices for oil and gas creep up. This is due not only to social unrest in many of the oil producing countries, but also due to the general depletion of the largest oil reserves. Ripple effects spread as food production, transport and heating becomes more expensive and a period of high inflation ensues.

Another scenario might be described simply as a two-decade long worldwide Japanese-style lengthy period of stagnant growth, with historically low interest rates. During this long scenario, many companies would default on their debt, becoming insolvent. Government and monetary authorities do their best to encourage growth through an expanded monetary base and public spending, but the resultant low interest environment results in the inability of many life insurers to maintain their interest crediting guarantees, as they don't have other margins to fall back on. A consequence is that the supply of long-term capital is reduced, as life insurers have historically been significant investors in long-term debt instruments.

Initial event

Some scenario conditions emerge as at least a partial consequence of an initial powerful event that may give rise to a cascade of secondary consequences. Since there are an infinite number of events that could be considered, there is no stock set of categories to describe the type or range of these events and consequences. However, it may be useful to think of such events as falling in one of three categories, reflecting the scope of their impact:

1. Global events. Globally disruptive events are likely to affect most if not all insurers and financial institutions. These events may, for example, be economic in nature, such as the Great Depression of 1929 or the financial crisis beginning in 2007, or may be related to public health, such as a pandemic. Globally disruptive events are often seen as encompassing a sequence of different events that evolve over time. Therefore, a global scenario will expose a firm to multiple related stress consequences.
2. Regional events. Some events can affect firms that operate in a particular region or jurisdiction. These can take the form of a specific type of natural catastrophe, e.g., earthquakes, hurricanes or tsunamis, or exposure to certain public health, legal or regulatory risks. Examples of regional disruptive events have been the Swedish Banking

Crisis, the European Life Insurer Crisis of 2003, the Junk Bond Crisis of 1990 and Hurricane Katrina.

3. Company-specific events. Firms might be exposed to idiosyncratic risks in response to their liabilities, assets and strategies. This requires the analysis of the firms risk exposures to arrive at appropriate company-specific scenarios. To effectively conduct such an analysis, a detailed knowledge of the firm's assumptions and exposures is needed.

Scenario analysis and stress testing can be time and resource consuming. The complexity involved (possibly with spurious accuracy), speaks to keeping the number of moving parts and refinements to a manageable number. In addition, the set of scenarios used should reflect the major drivers of experience as well as estimates of their inter-relationships under relevant conditions, and capture in their totality the major potential risks the firm might face. The objective is less to predict in great detail future conditions, as that is not really possible anyway, but rather to have a small number of generic scenarios to reasonably cover the potential risks to the firm.

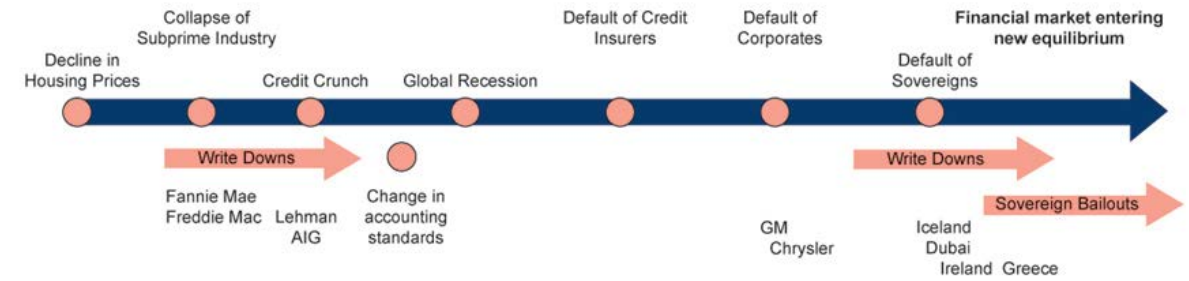
For example in certain cases, it may be sufficient in assessing the effect of a global financial crisis to consider a Japanese style scenario (characterized by low interest rates, no growth and deflation) and a high inflation scenario. Many potential financial crisis scenarios would, of course, differ from these two stylized ones, but the range of their effects may be captured by these two extreme ones. A further discussion of this approach is given in Case Study 1 below.

Time evolution

The sequence in which events occur can be quite important in assessing the financial impact on the firm. The qualitative description therefore should not only contain the sequence of effects but also a time-line. This is especially relevant for the evaluation of a scenario, which usually evolves over months and years, especially where management actions/reactions (e.g., de-risking assets or obligations) would be incorporated.

The example below shows an illustrative time evolution of a financial market crisis patterned after the credit crisis of 2007.

Figure 6



Risk Dependencies

Many risk factors that influence a scenario exhibit either a cause-and-effect (dependency) or a statistical relationship (usually expressed in terms of correlations). When formulating a stress scenario, it is important to incorporate these relationships as they may exist under stressful circumstances. Experience has shown that in many situations dependencies in stressed situations are different than corresponding dependencies under normal situations.

In certain scenarios, an initial event might affect one or a small number of risk factors. Over time, more risk-factors might be affected by the initial event.

As a simple example, consider the dependency between mortality and the financial market. Normally, mortality and financial markets are uncorrelated; even a substantial market drop does not normally have a material effect on mortality. Conversely however, if mortality increases severely (perhaps due to a pandemic), financial markets may be adversely affected. This might occur because of a reduction in economic activity or a panic that leads to a heightened demand for safe securities, e.g., government bonds.

Since stress situations are relatively rare, available historical data are often not relevant in estimating stressed dependencies. As a result, most observed dependencies would be inappropriate to be considered for the stressed scenario.

- Mathematically, one way of dealing with this issue is to assume that dependencies are given by a copula of a certain shape, e.g., by a copula with upper or lower tail dependency. Examples of such copulas are the Clayton and the Gumbel copulas.
- Another approach is to determine dependencies between two risk factors by finding common underlying factors that affect both of the risk factors. Ultimately, the final underlying factors are independent, with all subsequent dependencies a consequence of common exposure to them.
- In the usual case when dependencies under stress have not been observed, it is necessary to model them based on expert judgment based on a sufficiently detailed narrative, which outlines the expected outcome given an initial event.
- In real life, interdependencies evolve with an expanding web of relationships among risk factors, which might include sudden phase shifts when dependencies suddenly change, time-lagged dependencies, causal linkages and other functional and probabilistic dependencies. Simple correlations or copulas are not necessarily the right tool for defining dependencies, as they may not capture time-dependencies or the underlying causal relationships.

The following figures show stylized depictions of the dependencies of several risk factors over time. The figures are explained below.

Immediate Dependencies

Two or more risk factors are causally directly linked, in which case a change in one risk factor causes an immediate change in the other risk factor. An example would be a share index and the price of a share that belongs to the index.

Figure 7

Time-lagged Dependencies

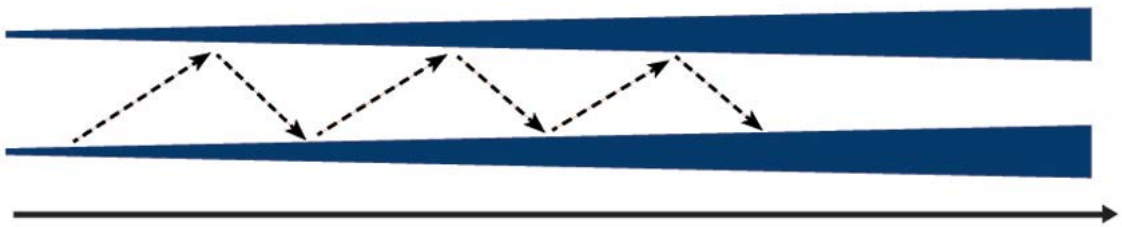
A risk factor is affected by the change in another risk factor after a certain period of time. For example, the default of a financial institution and a Directors & Officers claim.

Figure 8

Feedback

A change in a risk factor causes a change in a second risk factor, which in turn causes a change in the market price of a financial instrument a firm holds.

Figure 9



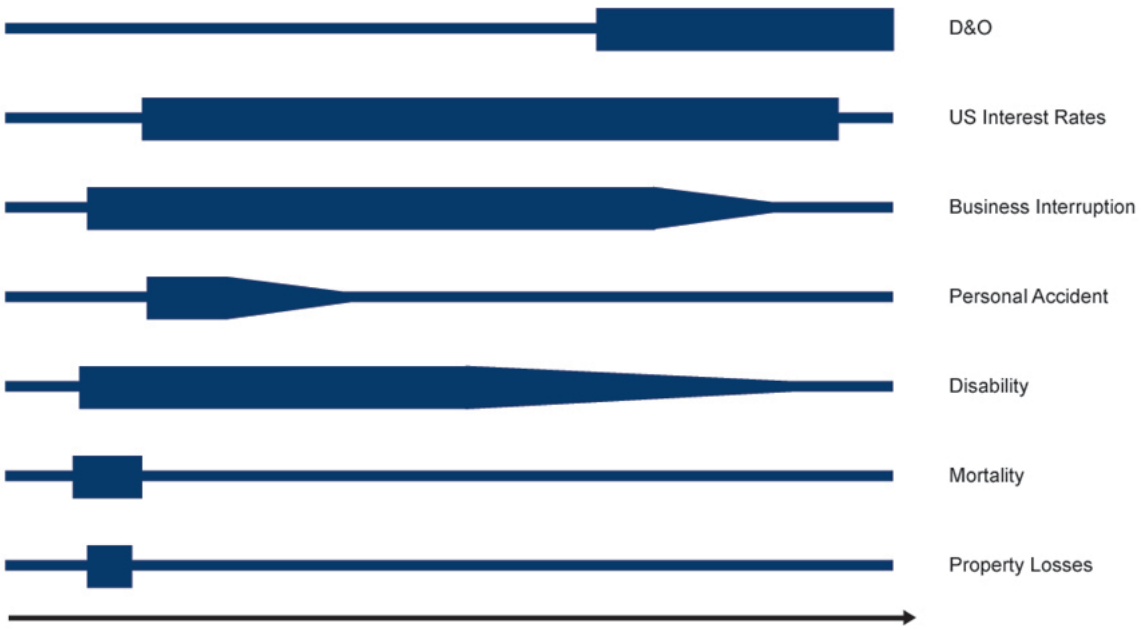
Phase-Shift

A risk factor is affected by the change of another risk factor if and only if the change exceeds a certain threshold. An example of such risk factors is an increase in mortality and a change in equity markets. In normal circumstances the financial markets are not affected by slight changes in mortality; however, a sudden large increase in mortality is likely to negatively affect the financial market.

Figure 10

In the development of a scenario, the different risk factors can be combined to illustrate dependencies over time. The figure below illustrates the example of a hypothetical earthquake that causes loss of life and property losses. The rebuilding leads to a depreciation of the U.S. dollar, assuming, that in this event, the government has to sell a significant amount of its U.S. Treasury securities.

Figure 11



Evaluation of Scenarios

An evaluation of a scenario includes the quantification of its effects on the firm's balance sheet and performance that depends on the applicable valuation standard. In many cases it may be useful to gain insight into the firm's financial position based on different valuation frameworks, e.g., economic valuation, statutory valuation and general purpose financial reporting. When a firm is in financial stress, it not only can be important to assess economic loss, but also the effect on what the regulator and external rating agencies look at.

When building a scenario and evaluating its outcomes it is important to consider the consequent state of the world and related parties including competitors, counterparties and regulators. In a given scenario, third parties to which the firm is exposed might also be affected by the same environment that results in an initial loss to the firm and might then "feedback" as secondary consequences, creating additional losses for the firm. This could for instance happen if the firm holds shares in firms that are in financial distress at about the same time, since the share prices of these firms would then likely fall, leading to a reduction in the asset value of the firm. Counterparties might include reinsurers to which risks have been ceded; banks to which the firm has exposures, e.g., through posted collateral. Some of these risk exposures might already be captured by the quantified risk factors that describe the scenario (e.g., spreads or equity prices). The effect of the scenario on other material exposures might have to be quantified individually.

Secondary Consequences

The impact of an initial event or set of conditions in a scenario can lead to secondary consequences or even to a cascade of secondary consequences that emerge concurrently or at a later time. These can also be viewed as risk propagation.

For example, a loss from an adverse event or change in the firm's circumstances might lead to a ratings down-grade, which in turn could trigger rating-linked debt repayment or collateral calls, or might force the firm to exit certain markets. This in turn could lead to liquidity strain, causing further losses, a further down-grade, and lapses of policyholders with consequential adverse selection. If this occurs, the firm might be forced to sell assets as a consequence of the loss that could lead, particularly when its assets are thinly traded, to a decrease in the market value of these assets, forcing the firm to sell even more assets, thus putting it under further strain.

Secondary consequences do not depend solely on the amount lost, but also on the specifics (or nature) of the resulting loss. As mentioned earlier, the secondary consequence of a large insurance loss (a part of the insurer's accepted risks, aligning its business model and the expectations of its stakeholders) can be treated in a quite different manner than being a loss of the same magnitude because of bad investments due to a rogue trader. One is an acceptable loss of conducting an insurance business and might even enhance the firm’s reputation if it were able to speedily pay out appropriate claims, whereas the other would be seen as a sign of incompetent management and poor corporate governance and lead to a loss of reputation.

Possible secondary consequences of a given scenario may include effects from:

- a ratings down-grade,
- rating triggers,
- collateral requirements,
- firm liquidity,
- non-regulated entities of the group or non-insurance entities (e.g., banks),
- inter-company capital movement in case of financial distress,
- assets sales,
- weakened firm reputation,
- increased policyholder lapses and resultant adverse selection,
- reduced new business volume,
- reduced dividends,
- regulatory constraints, and
- higher cost of capital.

Scenario rollout over time

If the scenario covers a multi-year period, the evaluation should include a quantification of the effects of the scenario over its entire period. If the duration of the scenario is more than one year, management actions become more important and their effects should be taken into account on a realistic basis.

For a scenario developing in discrete stages, its financial effects are assessed for each stage. In most cases the financial impacts during the different stages of the scenario (e.g., due to insurance losses and revaluation of assets or liabilities) can be aggregated to losses each year in order to assess yearly on an annual basis.

Risk mitigation

Risk mitigation techniques can take two forms: (1) those inherent in the assets held or contracts entered into (e.g., through features that transfer all or a part of a risk to counterparties or to policyholders) and thus less adversely affected to changes in conditions and (2) those that involve management discretion (action).

The evaluation of a scenario should take into account realistic risk mitigation programs (e.g., hedging, external reinsurance, intra-group retrocession, changes in dividend levels). If risk mitigation has a material influence on the financial effect of the scenario, care is needed to ensure that the risk mitigations would be expected to be effective, especially in stress scenarios. Where, for example, in case of a global scenario, reinsurers to which risks have been ceded might also be affected by the conditions driving the scenario environment, which might impair their ability to reimburse losses in a timely manner.

For some insurance groups, guarantees and other capital and risk transfer instruments between legal entities within the same group are used. Their use and implications on total required capital for the group may depend on applicable valuation and capital standards for the individual company. For example, consider a guarantee between two legal entities - a parent in the European Union and a subsidiary in the U.S. If an agreement specifies that in the event that the U.S. subsidiary's Risk Based Capital (RBC) ratio drops below a given value, capital will be transferred from the EU parent. In this case the effect of the guarantee depends on the current and future European valuation and solvency capital requirements, as well as the corresponding U.S. requirements.

Management Actions

There are usually several management actions that can be taken to mitigate, at least in part, the risk inherent in a particular scenario, either on an early warning or a preventative basis, a concurrent basis, or in reaction to scenario developments. Some of these decisions, such as the speed at which insurance losses are paid, can be taken by management as the scenario evolves. They can be incorporated into financial projections, simulating how a firm would likely react. The scenario can also include expected subsequent consequences. Secondary consequences can be as significant as the initial shock effect.

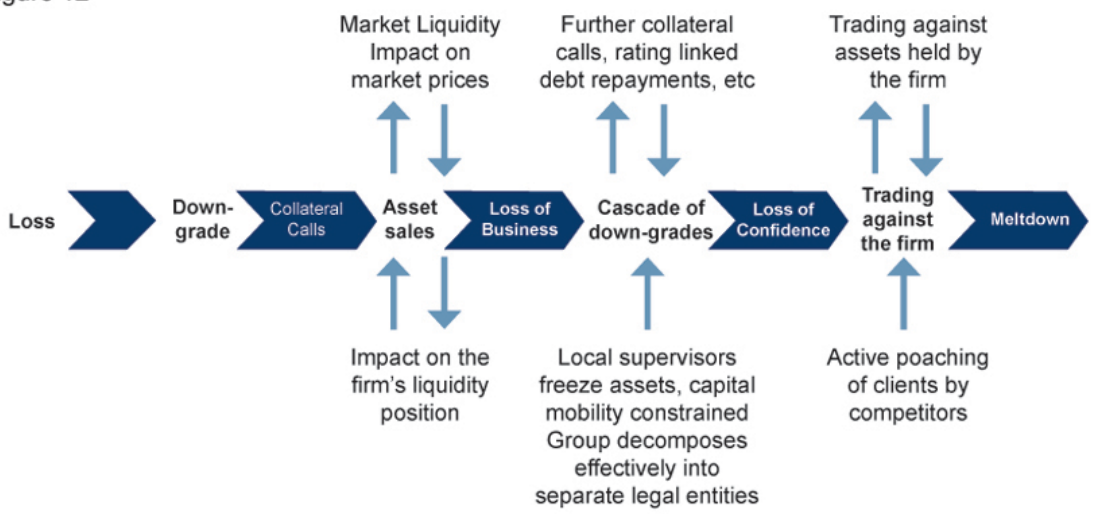
It should be remembered that in real life, especially where scenarios play out over a longer period, there is often a lack of clarity as to how the situation will further develop. This uncertainty can then lead to sub-optimal management actions.

For a multi-stage scenario, the scenario needs to be sub-divided into discrete intervals and management reactions are simulated in reaction to the condition of each of the intervals. Expected management actions can be allocated to the applicable discrete stages of the

scenario. At the beginning of each stage, the scenario developers would only have knowledge of the scenario up to that stage. The evaluation of the scenario would then proceed sequentially, reflecting the actual or assumed management actions up to that point. A comparison of the results of an alternative sensitivity test with no action taken can indicate the expected effect of the action.

To make the exercise more realistic, senior management could be interviewed regarding actions that would be considered at each scenario stage's situation, reflecting their realistic options and risk preferences in such a situation. In this way, the flow of information to senior management is more realistic and the behavior of management can be better simulated. Another approach would be to undertake the simulation of management's actions using an external party that would be less exposed to pressure than people reporting to senior management in the time of stressed conditions.

Figure 12

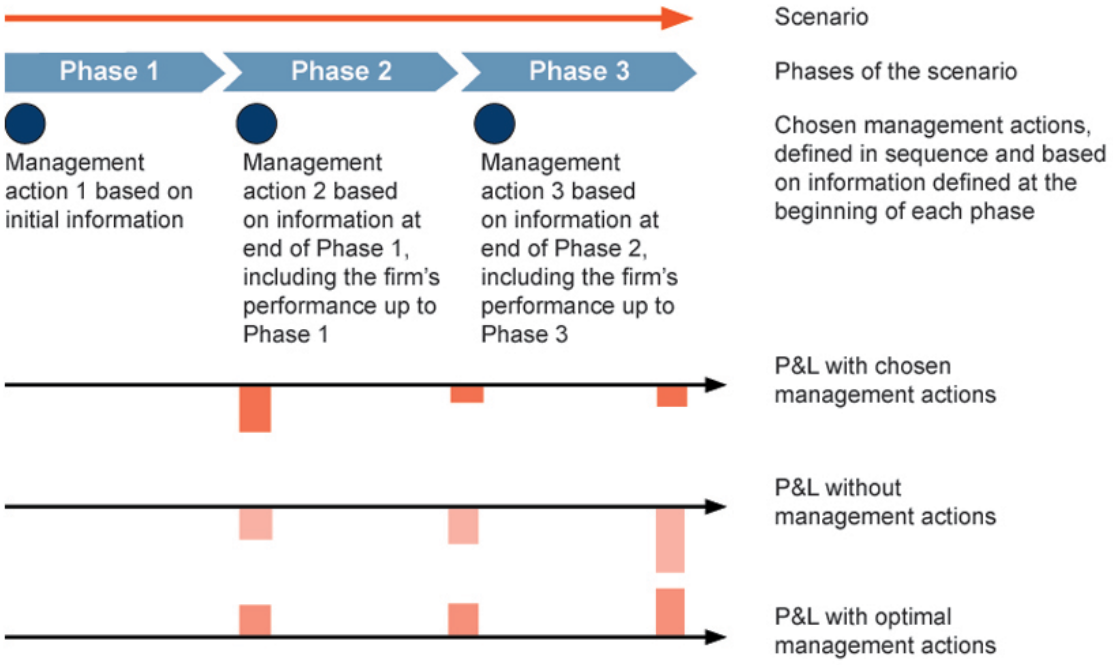


Possible constraints to management actions are also a consideration. For example, although capital mobility within an insurance group or conglomerate may be easy to accomplish in certain instances, potential regulatory restrictions on capital movement also have to be considered. If an insurer incurs material losses, regulators of some local subsidiaries may require capital injections from the group and may limit capital transfers out of their jurisdiction. In such a situation, the insurer could experience an immediate and potentially devastating liquidity shock. As part of the scenario analysis, an insurance group assesses the legal and regulatory environment in which its major subsidiaries operate and reflect historical flexibility of regulators in times of financial stress. In such cases, the group's structure and potential transfers of capital and risk through the legal entities of the group are part of the assessment process. Ideally, credible evidence that expected management actions under difficult conditions will be implemented would also be useful in increasing the credibility of the forecasts, although current management may have limited experience on which to base such an assessment.

Management actions may be better projected by using a "stochastic" scenario approach. A stochastic scenario consists, not of a single realization of an initial condition or driving event and the cascade of after-effects, but each stage has multiple possible future stages. This can also be viewed as a set of different scenarios, all emanating from the initial condition. However, this approach can be quite time consuming and complicated and should only be applied to the most relevant and significant scenario studied. Its advantage is that through its planning process management and other participants can obtain experience on how to make decisions in a fast changing environment with little or perhaps even conflicting information.

Evaluating a scenario together with senior management also can help embed risk management within the firm and can help senior management be prepared for potential disruptive events. Such approaches are already used by some firms, although usually with a focus on business planning using relatively simple models. They are more common outside of the financial services industry; for example, in the training of pilots or nuclear power plant operators.

Figure 13



A variation is to merge a sophisticated assessment of the financial effects of a scenario analysis with an interactive senior management simulation program. This requires significant preparation by risk managers and actuaries so their modeling capability can quantify the impact of a given management action within a very short time.

Analysis

More important than obtaining quantitative results, the purpose of a scenario framework is to gain sufficient insight to enable the firm to effectively manage its risks and better cope with unexpected conditions. Thus, it is important not to over-emphasize the numbers derived from such analyses, particularly for stress testing, as information on likelihoods, volatilities, the distribution of profits and losses of rare events are not known or are only based on expert judgment without historical support.

Although the factors studied and quantified in scenario analysis and stress testing will differ depending upon the type of firm and the risks likely to be encountered, there is much commonality. In any event, the quantitative analysis should be in sufficient detail to enable the development of strategies and contingency plans. These plans can include:

- risk avoidance, e.g., through change of the firm's business model or mix of business,
- risk mitigation, e.g., through reinsurance,
- contingent funds, e.g., collateral, contingent capital,
- capital increase, e.g., raising funds, decrease in dividends,
- change in the mix of assets.

In any scenario analysis or stress test, management actions in response to the conditions encountered that would mitigate the effects of the scenario would be identified and analyzed for their effectiveness and cost. Multiple scenarios of different types and severities may be considered, as well as multiple potential management actions for each scenario. This enables senior management and the Board to decide on an optimal course of action.

An important objective of such analyses is to be better informed on the effects of changing parameters and to identify key assumptions and sensitivities. It enables risk managers to gain insight into risks and possible futures for different levels of losses or confidence levels, while also facilitating an enhanced assessment of key parameters and sensitivities.

The following is a list of some of the factors that may need to be assessed (and documented), both for the base expected case and for the alternative sensitivity or stressed scenarios.

- Secondary consequences to be considered
- Impact on
    - Assets, split by asset type
    - Liabilities, split by line of business
    - Economic balance sheet / losses
    - Profit and loss
    - Reputation / brand value
- Effect of
    - Interest rate changes, although sometimes prepared by parallel interest rate curve shifts, as insurers are sensitive to change in interest rates at different durations,

more complex movements, e.g., sudden ups and downs and twists, may be more relevant
    - Equity changes, ideally split by shares, real estate, hedge funds, private equity
    - Changes in foreign exchange rates
    - Changes in spreads, split by rating class
    - Counter-part defaults and rating down-grades
    - Mortality and morbidity changes
    - Policyholder options and guarantees, and possible resultant adverse selection
    - Constraints on fungibility of capital
- Assumptions the firm has made for parameters that have not been specified
- Possible changes to prescribed assumptions
- Mapping of losses to different legal entities of the group before and after intra-group retrocession
- Description and effect of risk mitigation strategies and management actions considered
    - External, including reinsurance, coinsurance, hedges and securitization
    - Intra-group, including guarantees and retrocessions
- Description of inter-relationships between factors and risks incorporated into the scenario
- Description and effect of any deviations from the economic valuation framework, simplifications or lack of consideration of significant risks.

If the scenario evolves over several years, certain information, such as those that follow, should be determined:

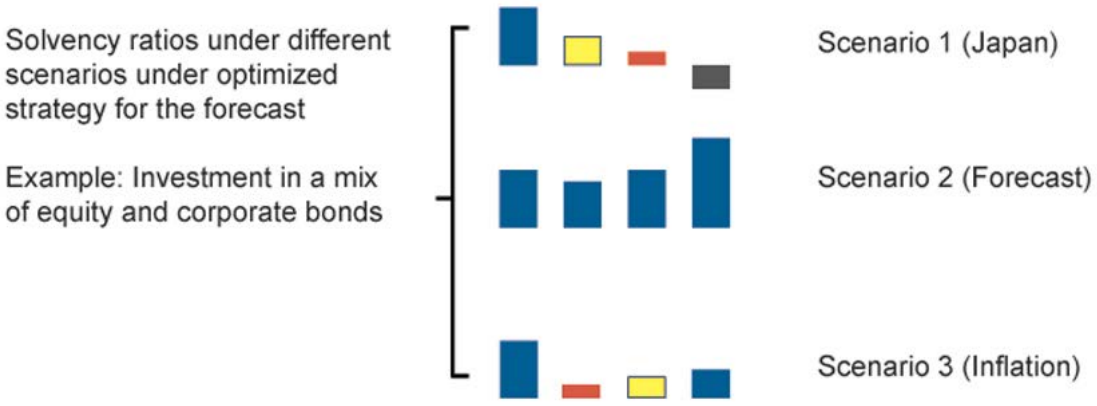
- Losses incurred at different stages of the scenario
- Annual economic balance sheet / losses
- Annual solvency and liquidity ratios
- Management actions as they occur.

Documentation of the scenario assessed, the actions taken as a result of the scenario analysis being implemented, and the quantitative results will also be important.

Case study 1: Effect of possible economic scenarios

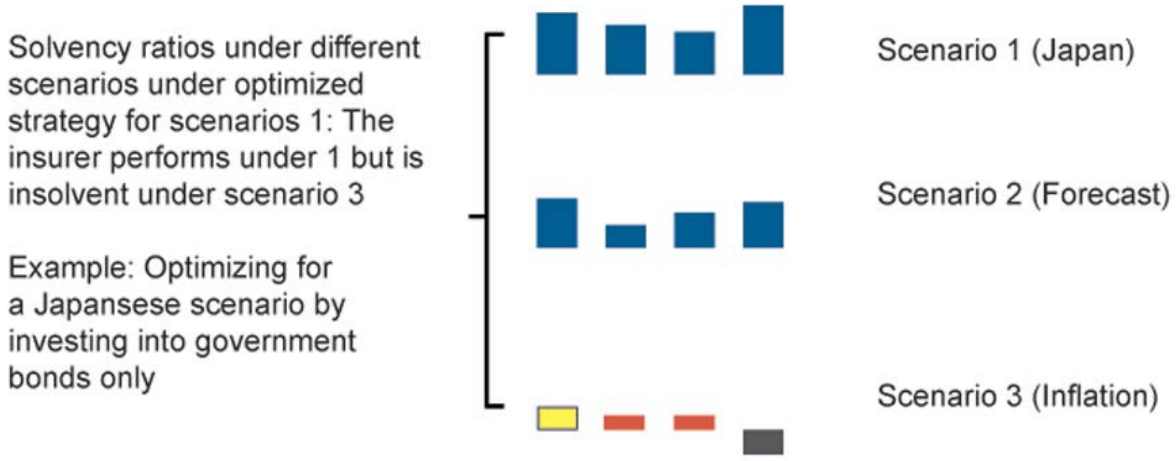
An insurer analyzes its financial position over the next five years to determine an optimal asset allocation and risk mitigation strategy. Currently it optimizes assets based on a baseline economic forecast. But since this scenario may not come to pass, it also considers a Japan type and a high-inflation scenario.

Figure 14



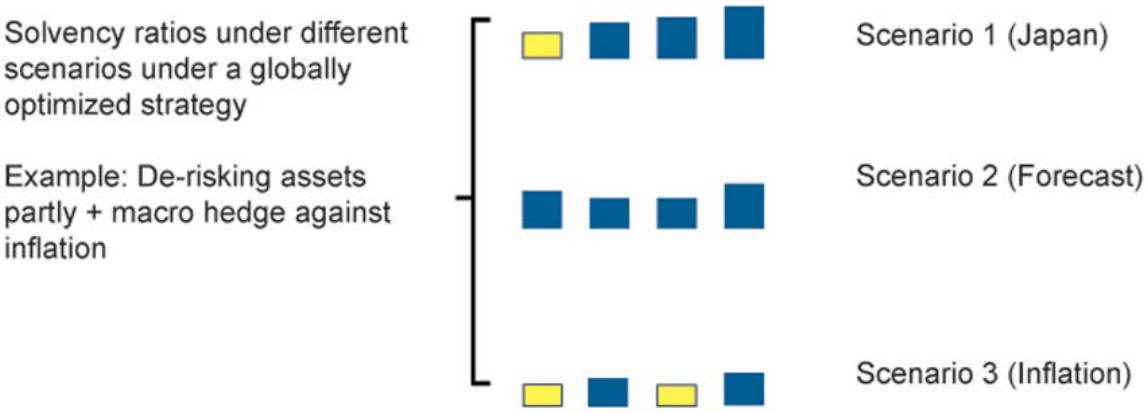
The figure above shows that the insurer would fare well under the forecast scenario but would eventually become insolvent (red bar triggers regulatory insolvency, black bar indicates amount of shortfall) under the Japanese and the inflation scenarios. Next, the insurer considers optimizing its assets to cope with a Japanese scenario by investing in government bonds only. With such a strategy, the insurer fares well under the Japanese scenario, slightly worse under the forecast scenario, but badly under the high-inflation scenario.

Figure 15



Next the insurer optimizes its financial position for all three scenarios by limiting its downside risk under each scenario. For this, it analyses the impact of partially de-risking its assets, implementing a macro hedge against inflation.

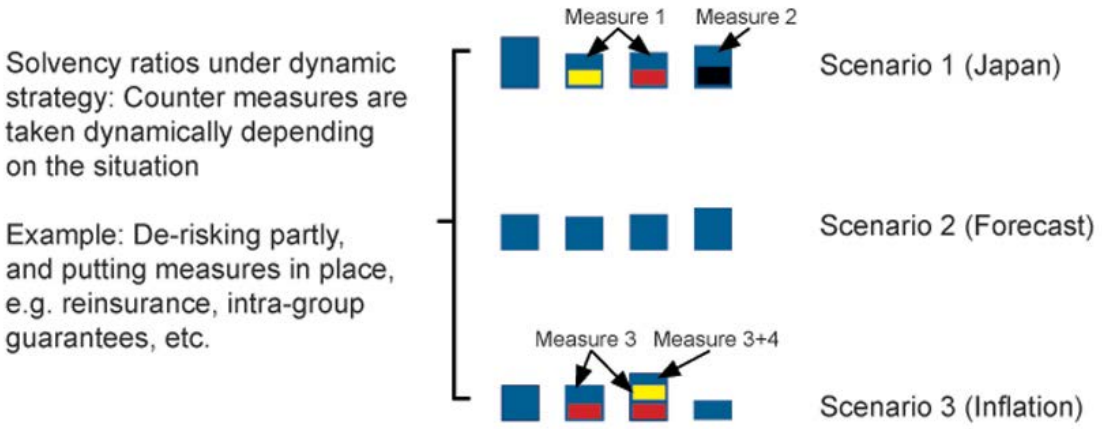
Figure 16



With such a strategy, the insurer fares well under the Japanese scenario, slightly worse under the forecast scenario, and worse again under the high-inflation scenario. However, the financial position is acceptable under all scenarios. It foregoes expected profit under the forecast, but would not face insolvency under either a high-inflation or a Japanese style scenario.

Finally, the insurer fine-tunes its strategy by also considering intra- and external-group reinsurance. By putting these additional measures in place, the solvency ratio can be improved for specific situations that would cause a short term financial strain.

Figure 17



Case study 2: Pandemic

This pandemic scenario case study illustrates some of the concepts involved in a scenario analysis, particularly concerning the extent of the assumptions included and the need for expert advice. It is not meant to serve as recommended scenarios for this kind of event.

To assess the impact of a pandemic on a firm's balance sheet, it is necessary to be clear on aspects such as:

1. Is it an influenza pandemic or a pandemic of a different type?
2. What is the severity of the pandemic considered?
3. Over what time horizon will the pandemic take place?
4. What will be the effect on insurance risk factors, e.g., mortality, morbidity, etc.?
5. What will be the effect on financial markets?
6. What will be the effectiveness of countermeasures, e.g., of health services and central bank interventions?

Once these and potentially other factors are agreed upon, the impact on the firm's financial position can be determined:

1. What will be the effect on life and health business?
2. What will be the effect on other lines of insurance business, e.g., medical expenses, business interruption, D&O claims, etc.?
3. What will be the effect on assets?

Many parameters that define a pandemic are highly conjectural. This is illustrated by the sample of possible influenza pandemic scenarios shown in the table below that have been formulated by regulators and other institutions. They have different assumptions regarding the severity of an influenza pandemic, as well as on its effect on the financial markets.

Each firm that conducts a stress test on the effect of a pandemic has to develop its own scenario assumptions.

	SST	**Singapore**		**McKibbin + Sidorenka**				**SOA**		**CBO**		**EU (based on CBO assumptions)**	
		Short Term Scenario 3a	Short Term Scenario 3b Mild		Medium	Severe	Ultra	Mild/ Moderate	Severe	Mild	Severe	Severe	Severe negative
Total deaths ('000)	40,000	20,000	40,000,000	1,440	14,400	72,000	144,000	6,688	60,800	2,000	60,000	60,000	60,000
Infection Rate	30%	30%	30%	30%	30%	30%	30%	25%	30%	25%	30%	30%	30%
Mortality Rate	1.67%	0.83%	1.67%	0.06%	0.60%	3.00%	6.00%	0.33%	2.53%	0.10%	2.50%	2.50%	2.50%
Excess Mortality	0.5%	0.25%	0.5%	0.02%	0.18%	0.90%	1.80%	0.08%	0.76%	0.03%	0.75%	0.75%	0.75%
GDP													
Equity													
FX													
Real Estate													
Spreads													
Interest Rates													

Firms need to understand the assumptions underlying a scenario assessment and consider other outcomes. But, just as making too many optimistic assumptions can lead to a false sense of security, it also has to be recognized that it easy to create an even more extreme outcome by conflating negative assumptions. The degree of speculation, of good or bad effects, needs to be understood and communicated. While the use of scenarios escapes the need for probability distributions, a sense of likelihood is still needed to convey the sense of urgency of the severity of such a scenario.

An influenza pandemic may not be the only type of pandemic to which a firm can have a high risk exposure. The firm will need to consider whether there are similar possible threats and whether an influenza epidemic is a good representative of the class of possible pandemics or more local events. For example, a sudden resistance to antibiotics would rollout in a very different manner than a flu pandemic. An influenza pandemic is characterized by a high infection rate (often assumed to be in the range of 20-30% of the population) and relatively low additional mortality. Will there be, for example, pandemics with lower incidence rates but higher mortality rates? This might lead to different effects by line of business, as well as on financial markets. It is possible that the panic during a pandemic where the incidence rate is low but the mortality of people infected is 80% or 90% will be far more profound than during an influenza pandemic, where the mortality is in the range of 1% to 3%. In considering the likelihood of such a pandemic the firm would have to recognize that for an outbreak with high mortality to spread widely it would need to have the necessary infectivity and be infective during the pre-symptom stage.

Below are three illustrative pandemic scenario narratives. The first is a standard influenza scenario with effective health service and central bank measures that limit the effect on financial markets. The second narrative is about a more severe influenza pandemic centering on Europe, with less effective responses. The third scenario is one describing an event with lower prevalence and higher mortality.

A mild influenza pandemic:

A global flu pandemic originates in Asia and then spreads to Europe and the U.S. Asia is most affected, followed by Europe and the U.S., influenced primarily by population density and the relative efficiency of health services and containment measures. As the severity of the flu pandemic becomes clear, markets become more risk averse and investors move into European and U.S. government bonds, while spreads widen and stock markets fall. The pandemic runs its course after 18 months and markets slowly stabilize, leaving 5 million dead.

Health supply chains are strained, but do not break. The relatively slow start of the pandemic allows governments to implement emergency measures in a relatively timely manner. However, services deteriorate, mostly in Asia as well as in Europe. This causes an increase in frequency and severity of fires, and particularly an increase in mortality of older persons that rely on care.

Asian markets fall most, as investors move capital to Europe and the U.S., and foreign exchange rates of Asian currencies drop markedly against the Euro and US dollar. Travel and leisure-related firms are hit hardest, while shipping and cargo flights continue but with slower

turnarounds and lower profit margins due to quarantine measures. Insurance stocks drop massively due to uncertainty regarding their exposures to pandemic claims.

Central banks act to mitigate the effects of the pandemic and try to calm the markets and to bolster public confidence. Most slash their interest rates by at least 100bp and inject liquidity into the financial system. These measures cannot wholly offset the dampening effect of the crisis on economic growth, which creates short-lived contractions in economic activity, the effect varying by country. But as the crisis passes, activity and risk appetite will recover, boosted by still-easy monetary conditions for some time.

A severe influenza pandemic

There is an initial outbreak of a flu pandemic with a medium level of additional mortality. Health services distribute flu vaccines that are moderately successful, limiting mortality to 0.5% among those infected, with an incidence rate of 25%. Subsequently the virus mutates into a more aggressive variant leading to an extremely high mortality rate of 25%, also with an incidence rate of 25% against which the vaccination is unlikely to be completely effective. This leads to widespread panic and a near collapse of the financial markets. Total deaths during the first phase are about 0.9 million, in the second phase 44 million.

The pandemic is most pronounced in Europe, where open societies and high population density make countermeasures less effective. The U.S. is able to close their borders and is less affected by the second wave than elsewhere. After the first wave, the EU prematurely declares the pandemic over, and is slow to ramp up measures when the second wave starts. In Asia, measures are more effective and outbreaks are contained. The pandemic finally runs its course after one year and financial markets slowly recover. However, the vaccination used during the first phase has led to complications in 1% of people with long term disability who will require long-term treatment. In the EU and U.S., with about 600 million people, this leads to 6 million disability cases, also causing class action suits against pharmaceutical companies.

A non-Influenza pandemic

A totally new virus combining the most damaging effects of its components, air-born hemorrhagic smallpox, has been created by a South Asian dictatorship. It is highly infectious and is being weaponized. Due to a breach in safety measures, the virus escapes and starts spreading. Lack of information and effective counter-measures cause the virus to spread rapidly, without the neighboring states being informed. After a few weeks, infections appear first in neighboring states, then globally, clustered in large cities with airports.

The specific nature of the pandemic with a relatively low infection rate (1%) but very high mortality once infected (80%) leads to widespread and extreme panic and a near complete shut-down of financial market and a severe impact on Asian economic activity.

Foreign investors and firms evacuate their staff and fly them out of Asia. This leads to a further spread of the infection. Among Western economies, Australia and Canada are most affected, followed by the U.S. and Europe, related to some extent to the number of Asian expatriates.

International travel and trade comes to a complete halt as the panic spreads. The virus is finally stopped, after a global death toll of 64 million. Of those infected and surviving, twenty percent face long-term effects due to kidney failure, resulting in numerous disability insurance claims.

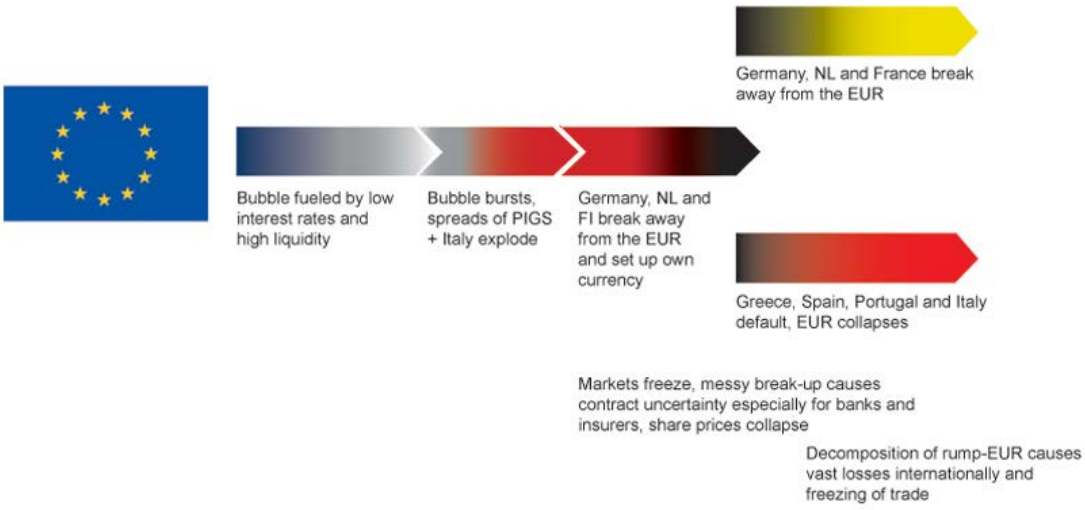
Case study 3: Sovereign default

Sovereign default is a scenario that is difficult to formulate, both from a technical point of view and for political reasons. There is a tendency to downplay its potential effects by considering only mild scenarios, since some believe that even discussion of such an event can make it more likely, by eroding market and public confidence. As an example, this case study addresses a sovereign default occurring in the Eurozone.

When formulating such a scenario, it is necessary to specify the ramification of the default in detail. For such a scenario, the sequence and time dimension is essential to gain insight into the potential exposures to the sovereign default event. For instance, the risks emanating from only a Greek default would be materially different than if Germany were to leave the Eurozone.

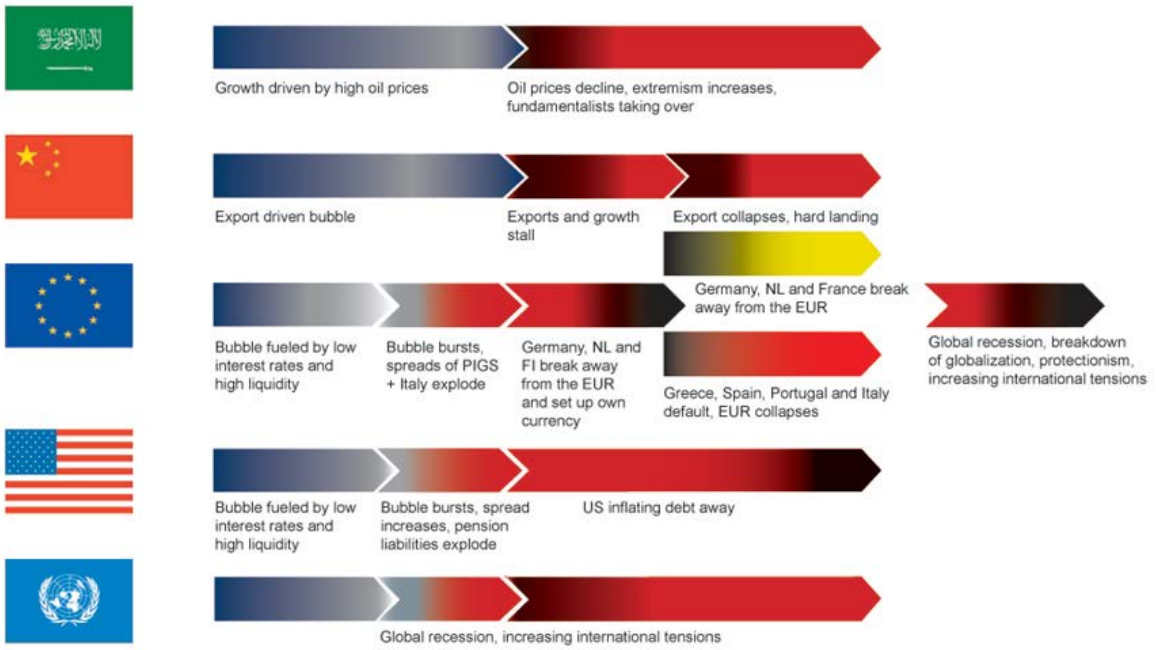
As an illustration, consider an example where Germany, the Netherlands and France leave the Eurozone. In this scenario, this development would lead to a cascade of sovereign defaults of Greece, Spain, Portugal and Italy, and ultimately to the dissolution of the Euro.

Figure 19



It is not realistic to consider such an event isolated only to the Eurozone. Such an event would have global repercussions. In a pessimistic scenario, this could lead to the U.S. inflating its debt away. Then the collapse of trade from the EU and the U.S. would lead to a hard landing of export oriented economies in Asia, resulting in a deep global recession.

Figure 20



Assumptions regarding risk free rates, spreads and foreign exchange rates of relevant currencies would be developed. Also the exposures and effect of the insurance and other financial service sectors would be assessed.

For an insurer, the effects on its operations and legal considerations would be analyzed. Questions might include:

- What would happen to contracts in EUR, when the currency doesn't exist anymore?
- What would be the situation between the time of default and when markets in the defaulting jurisdiction start working again?
- What would happen with collateral situated in defaulting currencies?
- What would be the effect on intra-group transactions / guarantees to legal entities in jurisdictions with defaulting currencies?
- What would happen to contracts with policyholders when the currency is changed?

The value of such a scenario analysis is not merely gaining insight into the potential financial loss, but also to be better able to formulate and implement countermeasures. Thinking through such an event allows management to make informed decisions, for example, on:

- Investments,
- Potential operational problems in case of a sovereign default, e.g., IT and financial reporting,
- Maximizing liquidity, e.g., by optimizing collateral and intra group transactions, and
- Improving contract certainty.

Conclusion and outlook

Scenario analysis and stress testing are emerging, powerful tools to assess a firm's and a nation's exposure to risks. These can be more than a mere complement to economic capital or solvency models, well suited to analyze the uncertain and non-quantifiable events that are most likely to surprise to both firms and regulators.

Both the process of developing scenarios and their financial effects can provide insight to the risks of a firm, and enable more appropriate risk limits, thus supporting the deeper embedding of risk management within the firm as a whole.

The financial crisis beginning in 2008 has reminded users that they can be blind to the limits of their models used to make business decisions. The crisis has also highlighted the need to have a deeper understanding of systemic risks that affect not only a small number of financial institutions and large parts of the financial market, but also how the regulatory framework itself may experience unexpected surprises. Regulators not only can supplement their risk based capital requirements with scenario analysis and stress testing, but they may also use them to enhance their own agreements with other regulators.

For instance, the Swiss Solvency Test has used scenarios since 2006 for all insurers and reinsurers in Switzerland, stress tests have been used by EIOPA to assess the resilience of large insurers, and the Federal Reserve Board has used scenarios to assess the financial state of banks. Australia used stress tests in 2004 and 2005 to assess their exposure to a housing bubble, thus avoiding much of the pain subsequently endured by other jurisdictions.

Scenario analysis and stress testing can be powerful tools for both firms and regulators. Their expanded use can enhance a multi-functional and multi-level involvement in a firm's risk management process, from the choice of conditions and events studied, to the formulation of possible scenarios, the evaluation of their effects, and the development of contingency plans and risk mitigation strategies. Similar to planning, the process used to develop and perform these analyses, underpinned by sound governance practices, can bring deeper understanding to the firm to enhance its normal business decision-making.