Study Guide for Casualty Actuarial Exam 7 on Actuarial Aspects of Internal Models for Solvency II

Study Guide Created by G. Stolyarov II, CPCU, ARe, ARC, AIS, AIE –

Spring 2012

This is an open-source study guide and may be revised pursuant to suggestions.

Reference: Brooks, D.; Care, R.J.; Chaplin, M.B.; Kaufman, A.M.; Morgan, K.A.; and Roberts, D.N., "Actuarial Aspects of Internal Models for Solvency II," draft paper presented to the Institute of Actuaries, 23 February 2009, Chapters 1, 4, 9, and 14-28.

Problem S7-SII-1. According to Brooks et al., what are the five areas on which the actuarial profession should focus its attention in the immediate future with regard to internal models for Solvency II? (Brooks et al., Subsection 1.2.1, page 3)

Solution S7-SII-1. 1. Diversification and co-dependency of risks;

2. Time horizon over which to measure risks;

3. Extreme events;

4. Group risk;

5. Data quality.

Problem S7-SII-2. The Brooks et al. paper concluded that life insurance and general insurance are not very different when looked at from a capital-modeling / risk-management perspective. However, the paper did note differences in risk characteristics between these types of insurance. Which type of risk is more problematic for life insurance, and which is more problematic for general insurance? (Brooks et al., Subsection 1.2.2, page 4)

Solution S7-SII-2. Asset-related risks are more problematic for life insurance, and **underwriting risk** is more problematic for general insurance.

Problem S7-SII-3. What does the draft of Solvency II allow insurers to do as an alternative to using the Standard Formula to determine Solvency Capital Required (SCR) for some or all of their business? What have insurers tried to do in response? (Brooks et al., Subsections 1.3.2-1.3.4, page 4)

Solution S7-SII-3. The draft of Solvency II allows insurers to utilize internal models to determine their Solvency Capital Required (SCR). Many insurers have focused on developing such internal models, which are based on the insurers' own assessment of risk and are thought to be a more realistic and risk-based answer than what is given by the Standard Formula.

Problem S7-SII-4. The Brooks et al. paper cautions that certain human factors should be kept in mind when designing and using insurer models. What are two of these factors? (Brooks et al., Subsection 1.3.7, page 5)

Solution S7-SII-4.

1. The power of incentives;

2. The natural tendency to underestimate the likelihood and severity of tail events.

Problem S7-SII-5. How does the International Association of Insurance Supervisors (IAIS) define an internal model? (Brooks et al., Subsection 1.3.8, page 5)

Solution S7-SII-5. An internal model is a risk-management system developed by an insurer to analyze its overall risk position, to quantify risks, and to determine the economic capital required to meet those risks. Internal models may also include partial models which capture a subset of the risks borne by the insurer using an internally developed measurement system which is used in determining the insurer's economic capital.

Problem S7-SII-6.

(a) Identify the six tests or standards for internal models in the draft Solvency II Framework Directive (Brooks et al., Subsection 1.3.9, page 6).

(b) What requirement underlies all six of these tests or standards? (Brooks et al., Subsection 1.3.10, page 6)

(c) Why might a European insurer need an internal capital model even if it does not intend to use such a model for developing its SCR pursuant to Solvency II? (Brooks et al., Subsection 1.3.12, page 6)

Solution S7-SII-6. (a) 1. Use test;

2. Statistical quality standards;

3. Calibration standards;

4. Profit and loss attribution;

5. Validation standards;

6. Documentation standards.

(b) The requirement for the firm to have **adequate risk-management systems** underlies all six tests or standards.

(c) The draft Solvency II directive would also implement a requirement for insurers to evaluate their own risks and determine if they have sufficient capital to meet those risks via an Own Risk Solvency Assessment (ORSA). Internal models could be used for the ORSA even if they are not used for the SCR.

Problem S7-SII-7. (a) Briefly explain two reasons why it is difficult to analyze extreme events. (Brooks et al., Subsections 4.1.1 and 4.3.1, page 19)

(b) Brooks et al. recommend using six types of existing tools in a more carefully structured manner for the purpose of analyzing extreme events. What are these tools? (Brooks et al., Subsection 4.2.1, page 19)
(c) In addition to the tools in part (b), what two other approaches could help ensure that extreme events are properly considered? (Brooks et al., Subsection 4.2.2, page 19)

Solution S7-SII-7. (a) Difficulties in analyzing extreme events (any two will suffice):

1. Extreme events are very infrequent and so have little or no representation in available historical data.

2. The dynamic systems generating the extreme events evolve and change in response to a particular event – which will in turn affect the likelihood and severity of the risk.

3. Government interaction in markets will affect market behavior, which can affect the risk of extreme events.

(b) Existing tools for analyzing extreme events:
1. Expert opinion;

2. Models for natural and man-made disasters;

3. Economic scenario generators;

4. Selection of distributions with fatter-than-observed tails;

5. Examination of "worst historic events";

6. Management consideration of events in other sectors or markets.

(c) Additional approaches:
1. More professional guidance on realistic disaster scenarios;

2. Minimum levels of provision for extreme events.

Problem S7-SII-8. (a) What are two areas identified by Brooks et al. for further research on extreme events? (Brooks et al., Subsection 4.3.2, page 19)
(b) Describe the purpose and operation of the Delphi method. (Brooks et al., Subsection 4.3.2, page 19, footnote 3)

Solution S7-SII-8. (a) Areas for further research:

1. Improving the scope and depth of models for natural and man-made disasters;

2. Developing techniques for reducing biases in judgment.

(b) The Delphi method is a technique for gathering expert opinion and achieving a consensus view while minimizing biases. A group of independent experts are individually asked their view through carefully structured questionnaires. The views and reasons for the views are reported back to each expert without attribution. Then there are further rounds for anonymously gathering views. The method seeks a convergence on the "right" answer without a bias toward the views of any particular expert.

Problem S7-SII-9.

(a) How is modeling for extreme events typically done currently with respect to *market risk*? (Brooks et al., Subsection 4.4.1, page 20)

(b) For what kind of risks is modeling for extreme events particularly difficult? (Brooks et al., Subsection 4.4.2, page 20)

Solution S7-SII-9.

(a) For market risk, extreme events are usually reflected through the choice of a model with tails that are fatter than indicated purely by historical data.

(b) Modeling for extreme events is particularly difficult for risks where the time series of data is short or very volatile – such as credit spreads and implied volatilities.

Problem S7-SII-10. Describe three major limitations of current insurance models for extreme risks. (Brooks et al., Subsections 4.4.3-4.4.5, page 20)

Solution S7-SII-10. Limitations of current models for extreme risks:

1. The models often focus on the outcomes of the risk, rather than the causes, and so are not truly predictive. They make limited or no adjustment for the possible evolution of the risk environment which may make extreme outcomes more or less likely.

2. The models often draw on extremely sparse data to determine the potential magnitude of a catastrophic event and then attempt to estimate the impact of such an event, allowing for changes in conditions. The frequency of occurrence of extreme events of a particular magnitude remains very difficult to predict accurately, and a high degree of judgment is necessarily involved.

3. Insurance catastrophe-risk models are often built separately from models created to capture more normal fluctuations in insurance claims. These models involve widely varying degrees of detail and research, and the assumed frequency of occurrence of the modeled event is usually entirely based on judgment.

Problem S7-SII-11. For modeling extreme operational risks, what are two additional limitations discussed by Brooks et al.? (Brooks et al., Subsections 4.4.6-4.4.7, page 20)

Solution S7-SII-11. Limitations of modeling extreme operational risks:
1. Some insurers use operational-risk loss data taken from third-party databases to fit distributions. These losses often include extreme events in the banking industry and must be scaled to a size appropriate to the insurer that is conducting the modeling. There is risk in this approach.

2. Operational-risk extreme events are often developed solely based on discussion among experts in a business, who draw on their own experiences and knowledge of the experiences of other similar companies. This is subject to the biases inherent in the use of judgment.

Problem S7-SII-12. Fill in the blanks (Brooks et al., Subsection 9.1.1, page 48): Under the Solvency II Framework Directive, the Pillar 1 SCR is calibrated to a ____ level of sufficiency over a _____ timeframe.

Solution S7-SII-12. Under the Solvency II Framework Directive, the Pillar 1 SCR is calibrated to a **99.5%** level of sufficiency over a **1-year** timeframe.

Problem S7-SII-13. Define and briefly describe the determination of four possible ways to determine economic capital discussed by Brooks et al. (Brooks et al., Subsection 9.1.2, pages 48-49)

Solution S7-SII-13.

1. Rating-agency capital: Amount of capital that rating agencies expect firms to maintain for a particular rating level. This can be calculated using a rating-agency factor-based model or approximated within a firm's internal model.

2. Economic capital level: Amount of capital required to protect against economic insolvency, which generally reflects overall risk appetite of the firm. This is generally calculated within an internal model and is calibrated at a different confidence level than regulatory and/or rating-agency capital.

3. Economic-impairment earnings level: Amount of losses for which the firm is placed in danger of economic impairment. This "earnings at risk" measurement is often assessed within an internal model at a lower return period (e.g., the 90% level of sufficiency) and is used to help define risk appetite more often than target capital.

4. Protection of franchise value: An amount of capital such that adverse events will not decrease franchise value beyond a level of tolerance with a selected probability level.

Problem S7-SII-14. (a) What are three different areas of an earnings distribution on which it may be possible to focus capital metrics? (Brooks et al., Subsection 9.2.1, page 49)

(b) Define "'at-risk' threshold". (Brooks et al., Subsection 9.2.2, page 49)

Solution S7-SII-14. (a) 1. Normal volatility (e.g., 1-in-5 event)

2. Tails (e.g., 1-in-200 event)
3. Extreme tails (e.g., 1-in-500 event)

(b) An "at-risk" threshold is a tolerance limit for risk appetite.

Problem S7-SII-15.

(a) According to Brooks et al., what is the main area of concern with internal capital models? (Brooks et al., Subsection 9.3.1, page 49)

(b) Give three reasons why it might not be practical to utilize a single firm-wide internal capital model for all applications. (Brooks et al., Subsection 9.3.1, pages 49-50)

Solution S7-SII-15.

(a) The main area of concern is whether the internal model can be utilized to assess capitalization levels for a number of different purposes.

(b) Any three of the following would suffice:

1. A company-level internal model may be simpler than a product-specific internal model, such as those used for pricing or bonus-setting.

2. Day-to-day business decisions, such as product approvals and pricing, are difficult to make with a company-level internal model that has a long run time. Thus, a different internal model will be required for these specific applications.

3. A group of companies may have a variety of models to use when the group has decentralized lines of business. Aggregating such results produces an amalgam of models.

4. Methods for reconciling a company-level economic-capital assessment against other methods are not well established. Furthermore, allocating back the company-level assessment to individual lines of business can be computationally intensive, and sometimes impractical due to the lack of granularity in company-level models.

Problem S7-SII-16. Identify four different motivations for companies choosing different measures for economic capital. (Brooks et al., Subsection 9.3.2, page 50)

Solution S7-SII-16. Any four of the following would suffice:

1. Balance-sheet basis of asset and liability recognition could be different (e.g., depending on jurisdiction.

2. Time horizons may differ (e.g., considering business-planning horizon versus a view on long-term solvency).

3. Regulatory view vs. management view (e.g., level of volatility in business, level of margins).

4. Regulatory view vs. industry view (e.g., co-dependencies between certain generic risks, degree of industry operational risk).

5. Modeling limitations (e.g., co-dependency assumptions).

6. “Solvency management” vs. “Business strategy”.

Problem S7-SII-17. According to Brooks et al., what is one way to address the likelihood that the free surplus backing a capital requirement will itself fall in a market stress scenario? (Brooks et al., Subsection 9.4.2, page 52)

Solution S7-SII-17. The capital requirement can be "grossed up" to allow for the effect of such a fall.

Problem S7-SII-18. What, according to Brooks et al., is a danger arising from the Solvency II requirements? (Brooks et al., Subsection 9.4.2, page 52)

Solution S7-SII-18. The danger is that the one-year VaR will be viewed by some as the only "right" answer for an economic-capital assessment, when it is not an appropriate sole multi-purpose measure for all circumstances.

Problem S7-SII-19.

(a) What are four main sources of underwriting risk, according to Brooks et al.? Identify and briefly describe each.

(b) In addition to these four sources, what three other aspects should a model of underwriting risk consider? (Brooks et al., Subsection 15.1.3, page 64)

Solution S7-SII-19.

(a) Four main sources of underwriting risk?
1. Pricing risk: The risk that the premium paid is inadequate, largely due to market pressures, including the pricing or underwriting cycle.

2. Attritional claims: The risk that there is higher frequency of small claims or that these claims have a higher average cost than expected.

3. Large claims: The risk that there are more large claims than expected or that the large claims received are more severe than expected.

4. Catastrophes: The risk that a catastrophe may occur, causing much higher claim frequency and/or severity than expected.

(b) Other considerations for modeling of underwriting risk are **(1)** correlations, **(2)** latent exposures, and **(3)** expenses.

Problem S7-SII-20.

(a) Why, according to Brooks et al., is it important to avoid the mistake of assuming that loss ratios are independent from year to year for some lines of business, such as large motor and group term assurance? (Brooks et al., Subsection 15.2.1, page 65)

(b) According to Brooks et al., what is a way to address correlation among loss ratios for various years within an internal model? (Brooks et al., Subsection 15.2.2, page 65)

Solution S7-SII-20.

(a) In these lines of business, much of the variability in underwriting results arises from changes in the rating environment driven by the marketplace. Thus, assuming the independence of loss ratios from year to year would oversimplify the true composition of underwriting risk.

(b) The internal model should include an input for the expected rating environment and some limited volatility around the mean selected. This volatility should increase over the new-business projection period.

Problem S7-SII-21.

(a) Why might it not be practical to model small "attritional" claims individually?
(b) Describe an alternative to individual modeling of attritional claims. (Brooks et al., Subsection 15.2.3, page 65)

(c) Describe a further complication arising from attritional losses from longer-tail business. (Brooks et al., Subsection 15.2.4, page 65)

Solution S7-SII-21.

(a) Modeling small claims individually would increase the length of the model run time and would not usually add any material accuracy to the model.

(b) Attritional claims can be modeled as a cost per unit of exposure. This cost is stochastic, and the shape and parameters of the distribution will be estimated from the data.

(c) Claims from longer-tail business will often involve bodily injury. Such claims are sometimes subject to legislative change, whereby all cases settled after a particular date will be materially higher than previously experienced. The risk will correlate across years and business classes, affecting both underwriting and reserving risk.

Problem S7-SII-22.

(a) From what source does an insurer's need to model large losses separately often arise? (Brooks et al., Subsection 15.2.5, page 65)

(b) Fill in the blanks (Brooks et al., Subsection 15.2.6, page 66): Large losses will usually be modeled using an appropriate _____ distribution whose _____ and _____ are fit to the data.

(c) What are three challenges in modeling large losses? (Brooks et al., Subsection 15.2.6, page 66)

Solution S7-SII-22.

(a) An insurer's need to model large losses separately often arises from the insurer's **reinsurance program**, as these large losses will often be ceded to a reinsurer.

(b) Large losses will usually be modeled using an appropriate **skewed** distribution whose **shape** and **parameters** are fit to the data.

(c) Challenges in modeling large losses:

1. Very large losses occur infrequently, and thus the data will be necessarily incomplete.

2. Identifying trends is challenging.

3. The distribution used may be incorrect.

Problem S7-SII-23. Why is it important for an internal model of underwriting risk to consider correlations among different classes of business? (Brooks et al., Subsection 15.2.10, page 66)

Solution S7-SII-23. Otherwise uncorrelated classes of business might exhibit some dependency in the tails of their distributions. Such dependency may not be contained in the available data.

Problem S7-SII-24. (a) According to Brooks et al., what kinds of insurer expenses should be modeled directly, and what kinds will be simulation-specific? (Brooks et al., Subsection 15.2.12, page 67)

(b) Fill in the blank (Brooks et al., Subsection 15.2.12, page 67): An internal model of insurer expenses should reflect the fact that, over time, expenses levels will be linked to _____.

(c) Fill in the blank (Brooks et al., Subsection 15.2.13, page 67): As the period over which business is written is shorter than the full projection period, an internal model will include a _____.

Solution S7-SII-24. (a) Proportionate expenses (e.g., commission) should be modeled directly, and **profit commissions** will be simulation-specific.

(b) An internal model of insurer expenses should reflect the fact that, over time, expenses levels will be linked to **inflation.**

(c) As the period over which business is written is shorter than the full projection period, an internal model will include a **run-off period.**

Problem S7-SII-25. Fill in the blanks (Brooks et al., Subsection 15.2.15, page 67): The accuracy of an internal model's planning assumptions _____ [increases or decreases?] with time, and this should be reflected through _____ of planned results over time. _____ and _____ should be enhanced to complement stochastic models in order to improve accessibility to interpret the results and understand whether management actions are likely to be as appropriate and effective as reflected in stochastic models.

Solution S7-SII-25.

The accuracy of an internal model's planning assumptions **decreases** with time, and this should be reflected through **increased volatility** of planned results over time. **Stress testing** and **scenario testing** should be enhanced to complement stochastic models in order to improve accessibility to interpret the results and understand whether management actions are likely to be as appropriate and effective as reflected in stochastic models.

Problem S7-SII-26. Identify three barriers to the modeling of underwriting risk, as described by Brooks et al. (Brooks et al., Subsections 15.3.1-15.3.4, page 67)

Solution S7-SII-26. Any three of the following would suffice:
1. Choosing parameters for correlations and tail dependencies is highly judgmental, as data will often be sparse or non-existent.

2. The concept that underwriting results are correlated between years is not universally accepted.

3. Allowance for future profits is not always accepted as a legitimate source of capital.

4. Performance targets are based on optimizing competing objectives. This may lead to sub-optimal performance if incentives are not set carefully.

Problem S7-SII-27.

(a) On what sorts of metrics for underwriting risk do Brooks et al. recommend an increase in research? (Brooks et al., Subsection 15.3.5, page 68)

(b) Fill in the blanks (Brooks et al., Subsection 15.3.6, page 68): It is desirable that the level of segmentation and granularity used within product pricing will extend through to _____, _____, and _____. However, there may not be sufficient _____ throughout an organization in the _____ and _____ to achieve this.

Solution S7-SII-27.

(a) Brooks et al. recommend an increase in research on metrics that can provide early indication that the assumptions underlying the premium adequacy and claims variability continue to hold.

(b) It is desirable that the level of segmentation and granularity used within product pricing will extend through to **capital**, **value**, and **performance measurement**. However, there may not be sufficient **consistency** throughout an organization in the **modeling** and **understanding of risks** to achieve this.

Problem S7-SII-28. According to Brooks et al., what are two ways in which the potential for major catastrophes should be incorporated within the insurer's internal-model framework? (Brooks et al., Subsection 16.2.1, page 69)

Solution S7-SII-28.

1. Proprietary catastrophe models

2. Internal analysis to develop potential losses that could arise from specific catastrophes

Problem S7-SII-29. Identify three important caveats/considerations that, according to Brooks et al., an insurer needs to take into account when using a proprietary catastrophe model. (Brooks et al., Subsections 16.2.2-16.2.4, page 69)

Solution S7-SII-29. 1. There is a need to avoid dependence on a single model for catastrophe risk, which contains significant uncertainty.

2. The use of a proprietary catastrophe model does not reduce the responsibility to understand the model, the important parameters, and the input into those parameters.

3. It may be necessary to adjust the models to make them more relevant to the company – such as incorporating additional levels of demand surge for extreme losses or including non-modeled perils.

Problem S7-SII-30. What are three recommendations that Brooks et al. give for the creation of future catastrophe models? (Brooks et al., Subsections 16.2.6-16.2.10, pages 69-70)

Solution S7-SII-30. Any three of the following would suffice:

1. Insurers should more fully understand the key risk drivers for a catastrophe, in order to have greater impact on the frequency and severity of catastrophes. This involves a multi-disciplinary approach that uses external experts.

2. The catastrophe model should be used to consider the risks that could impact the business in the short term, rather than any long-term trends.

3. All risks that could change the loss cost – including demand-surge and business-interruption losses – should be incorporated into the models.

4. The catastrophe-model data should be documented and signed off by internal experts (typically an underwriter). Quality-control processes around data collection and entry should be carried out to ensure that the information going into catastrophe models is valid and appropriate.

5. Catastrophe-model output should be formally reported to senior management. An analysis of change should be carried out so that the key drivers of catastrophe risk are properly understood and communicated to senior management.

Problem S7-SII-31. What are three barriers described by Brooks et al. with regard to the development of catastrophe models? (Brooks et al., Subsections 16.3.1-16.3.3, page 70)

Solution S7-SII-31.

1. Extreme catastrophes are rare and individual event. This makes validating the output from catastrophe models difficult. Typically, following a particularly large event, the additional information from that event causes a material change to the underlying proprietary catastrophe models.

2. There are many judgmental assumptions required when considering potential uplift factors from a base catastrophe model. These are difficult to validate in the absence of real-life loss data.

3. Catastrophe models have come under recent criticism due to incorrect assessment of the value of some of the large natural catastrophes. This could lead to management skepticism and/or apathy regarding catastrophe models and their output.

Problem S7-SII-32. Identify the eight steps suggested by Brooks et al. as a way of overcoming the difficulties posed by various sources of reserve variability. (Brooks et al., Subsection 17.2.1, page 72)

Solution S7-SII-32.

1. Use bootstrap or other techniques to derive a distribution.

2. Assess the need to overlay stochastic inflation to simulate future cash outflows.

3. Assess the need to adjust existing data triangles for inflationary effects.

4. Consider an adjustment to the emerging results to allow for any underwriting/reserving-cycle effects.

5. When dealing with recent events, assess all results in terms of probabilistic distributions.

6. Overlay a "shock" distribution to allow for the possibility of future legislative changes.

7. Overlay an assessment of the probability and severity of future latent claims not otherwise allowed for in the data.

8. Derive a "best estimate" from the adjusted data.

Problem S7-SII-33. What are three barriers (and additional areas of research) described by Brooks et al. with regard to adequately reflecting reserving variability? (Brooks et al., Subsections 17.3.1-17.3.3, page 72)

Solution S7-SII-33.

1. Commonly used existing methods are inadequate to cover the full range of reserving variability, and further research should be devoted to improving reserving analysis.

2. Commercially available reserving software includes techniques to assess the statistical patterns within the data with more granularity than is normally applied. Further research could address the practical value of this capability.

3. Application of bootstrap and other methods requires analysis of the assumptions regarding the underlying distribution. Some believe that actuaries do not normally investigate those assumptions rigorously enough.

Problem S7-SII-34. Identify five of the sources of uncertainty in insurance unpaid claim reserves, as discussed by Brooks et al. (Brooks et al., Subsection 17.4.1, page 73)

Solution S7-SII-34. Any five of the following would suffice:
1. Uncertainty in development, frequency, severity, and other parameters.

2. Understated or overstated initial loss ratios due undetected changes in terms and conditions.

3. Change in inflationary environment.

4. Changes in company operational procedures.

5. Statistical variability.

6. Difficulty in assessing the true cost of an event occurring close to the balance-sheet date.

7. Legislation affecting all open claims – adversely in most cases.

8. Emergence of latent claims.

Problem S7-SII-35. What are two reasons why, according to Brooks et al., it may not be sufficient to rely on available data for estimating reserving variability? (Brooks et al., Subsection 17.4.2, page 73)

Solution S7-SII-35.

1. Some of the sources of reserving variability may not have occurred within the period to which the data relate.

2. The data will only record the outcome of one historical inflation path, compared with the unlimited number of possible future paths.

Problem S7-SII-36.

(a) According to Brooks et al., for SCR purposes, what is the difference between how future business should be treated for life versus non-life insurance in insurers' internal capital models?

(b) What, according to Brooks et al., should be similar in treatment of future business for life and non-life insurance?

(c) According to Brooks et al., how should new business be considered for purposes of assessing solvency at future dates and for ORSA purposes? (Brooks et al., Subsection 18.2.1, page 74)

Solution S7-SII-36.

(a) For life insurance, the models could only consider run-off business, or could additionally stress-test a "shock" period. For non-life insurance, the models should consider one year of new business.

(b) For both life and non-life insurance, new business should be calibrated to achieve a result no better than zero profitability (i.e., zero present value of underwriting results). This tests the run-off as if it were a going concern at the valuation date, but without assuming gain from new business.

(c) For assessing solvency at future dates and for ORSA purposes, new business should be modeled for a short period (1 year or less) that is expected to be necessary before identifying issues and correcting them. It is also possible to model for a business-plan period (1-3 years) and/or a long-term period (3+ years).

Problem S7-SII-37. According to Brooks et al., what two aspects should the insurer's internal model be able to handle with regard to new business, in order to "help with calibration and validation"? (Brooks et al., Subsection 18.2.2, page 75)

Solution S7-SII-37.

1. Scenario testing for unfavorable new business concurrent with other stresses.

2. Tests of historical "worst case" or related scenarios.

Problem S7-SII-38. What are four barriers identified by Brooks et al. to modeling the impact of new business? (Brooks et al., Subsections 18.3.1-18.3.4, page 75)

Solution S7-SII-38.

1. Modeling future premium and future profits requires making assumptions in various areas – such as volume for new business, expenses, pricing cycle, reinsurance strategies and costs, operational risk, latent exposures, asset behaviors, and management actions.

2. The degree of uncertainty in forecasts of future business and future profits is often greater than the degree of uncertainty in technical provisions which relate to previously underwritten business.

3. The distribution of possible outcomes from assumptions about new business is wider, as the assumptions relate to events further into the future.

4. There is little research on ways to establish how much wider this distribution of possible outcomes for new business should be.

Problem S7-SII-39.

(a) Identify four risks that are not currently considered in the standard formula SCR. (Brooks et al., Subsection 19.4.3, page 76)
(b) Identify four risks that are currently considered in the standard formula SCR, but in a less granular way than in typical internal models. (Brooks et al., Subsection 19.4.4, page 77)

(c) Identify four risks that are currently only modeled by a small number of internal models. (Brooks et al., Subsection 19.4.5, page 77)

Solution S7-SII-39.

(a) Any four of the following would suffice:
1. Shocks to equity implied volatility;

2. Shocks to interest-rate implied volatility;
3. Movements in government bond yields relative to swap rates;

4. The effect of various risks on staff pension schemes;

5. Shocks to implied RPI inflation;

6. Random variation in observed mortality/morbidity rates;

7. Random variation in observed persistency rates.

(b) Any four of the following would suffice:

1. Changes to the shape of the yield curve;

2. Returns on a wider range of asset classes and considering any basis risk;

3. Changes in corporate bond spreads due to rating transition as well as general spread volatility;

4. Mortality/longevity risk split into uncertainty about the base level and about future improvements;

5. Persistency risk by product;

6. Operational risk.

(c) Any four of the following would suffice:

1. Changes in the shape of the implied volatility surface across term structure and strike;

2. Shocks to property implied volatility;

3. Shocks to credit default rate, transition rate, and spread "implied" volatility;

4. Shocks to investment-risk "implied" correlations;

5. Shocks to assumed management actions;

6. Shocks to assumed dynamic policyholder behavior rules (e.g., guaranteed annuity option exercise);

7. Changes in the shape of persistency across terms;

8. Changes in the shape of future mortality improvements;

9. Differentiated changes in rates of policyholders becoming paid-up and surrendering;

10. Changes in early/late retirements and partial withdrawals;

11. Shocks to the cost of capital;

12. Contagion;

13. Reputation risk;

14. Tax changes;

15. Other regulatory risk;

16. Funding risk (ability to refinance commercial paper/debt).

Problem S7-SII-40.

(a) Fill in the blanks (Brooks et al., Subsection 20.2.1, page 78): The pricing cycle is considered in the selection of _____ and _____.

(b) Fill in the blanks (Brooks et al., Subsection 20.2.2, page 78): The potential for adverse reserve development related to the pricing cycle is reflected in both _____ (as an impact on _____ and _____) and _____.

Solution S7-SII-40.

(a) The pricing cycle is considered in the selection of **loss ratios** and **business volumes**.

(b) The potential for adverse reserve development related to the pricing cycle is reflected in both **technical provisions** (as an impact on **best estimates** and **risk margins**) and **new business**.

Problem S7-SII-41. Identify three issues/research areas discussed by Brooks et al. with regard to risk arising from pricing/underwriting cycles. (Brooks et al., Subsections 20.3.1-20.3.3, page 78)

Solution S7-SII-41.

1. For reserving, there are currently no established methods of including pricing-cycle adjustments to either best estimates or the distributions of outcomes around the best estimates.

2. The use of pricing indices to measure the current position of the pricing cycle is more effective than in the past, but there may be ways to improve the reliability of those indices for that purpose.

3. There may be ways other than pricing indices for determining the position and direction of the pricing cycle.

Problem S7-SII-42. According to Brooks et al. (Subsection 20.4.1, page 78), it has been shown that in some cases there is a correlation between the pricing cycle and *what*?

Solution S7-SII-42. It has been shown that in some cases there is a correlation between the pricing cycle and **development in unpaid claim reserves.**

Problem S7-SII-43. For what kind of market risk is the model likely to be less robust than for other kinds, and why? (Brooks et al., Subsection 21.2.2, page 79)

Solution S7-SII-43. For **property-value risk,** the model is less likely to be robust, because of the relative scarcity of data.

Problem S7-SII-44. Identify three areas in which, according to Brooks et al., research is needed with regard to modeling market risk? (Brooks et al., Subsection 21.3.1, pages 79-80)

Solution S7-SII-44. Any three of the following would suffice:

1. Inconsistencies between co-dependencies in economic scenario generators and co-dependencies in the capital stress situation;

2. Concentration risk;

3. Models for property values and other less-well-studied asset classes;

4. Basis risk for company portfolios compared to the risks reflected in the economic scenario generator or other asset models;

5. Need for and use of distributions with fat tails;

6. Currency risk, which particularly affects reinsurers and insurer groups;

7. Asset-liability correlations in general insurance.

Problem S7-SII-45. (a) According to the Solvency II Directive, what kinds of losses should be reflected in a model of credit risk ("counterparty default risk")?

(b) Give examples of four kinds of risk-mitigating contracts that, according to the Solvency II Directive, should be covered by the counterparty-default risk module. (Brooks et al., Subsection 22.1.2, page 81)

(c) Fill in the blanks (Brooks et al., Subsection 22.1.2, page 81): The Solvency II Directive requires that for each counterparty, the counterparty-default module shall take account of the _____ of the insurance or reinsurance undertaking concerned to that counterparty, irrespective of the _____.

Solution S7-SII-45.

(a) According to the Solvency II Directive, the counterparty default risk should reflect possible losses due to the unexpected default, or deterioration in the credit standing, of the counterparties and debtors of insurance and reinsurance undertakings over the next twelve months.

(b) Examples of risk-mitigating contracts that should be covered by the counterparty-default risk module:

1. Reinsurance arrangements;

2. Securitizations;

3. Derivatives;

4. Receivables from intermediaries.

(c) The Solvency II Directive requires that for each counterparty, the counterparty-default module shall take account of the **overall counterparty-risk exposure** of the insurance or reinsurance undertaking concerned to that counterparty, irrespective of the **legal form of its contractual obligations to that undertaking**.

Problem S7-SII-46. Briefly describe four elements that Brooks et al. consider to be part of "good practice" with regard to modeling credit risk. (Brooks et al., Subsections 22.2.1-22.2.7, pages 81-82)

Solution S7-SII-46. Any four of the following would suffice:

1. Each of the areas of credit risk identified in the IAA paper is considered in the internal model.

2. Credit quality and concentration is monitored using commercial or proprietary credit models.

3. The company assesses the results of those proprietary models, so it has its own view of credit quality not solely reflective of the credit models.

4. Major correlations between credit risk and other risks are reflected with models or judgment, as practical (e.g., linking reinsurance default rates with natural catastrophes that will affect reinsurers).

5. "Basis risk" – the difference between the company portfolio and the portfolio assumed in the credit model – is monitored, and the internal model reflects those differences.

6. Overlap, if any, between market-risk assessment and credit-risk assessment is removed.

7. Credit-risk assessment reflects suitable management actions.

Problem S7-SII-47. What are the five areas identified by Brooks et al. for further research with regard to modeling credit risk? (Brooks et al., Subsection 22.3.1, page 82)

Solution S7-SII-47.

1. Correlations among credit risks;

2. Correlations between credit risks and other risks – e.g., catastrophe risk and credit risk on reinsurance;

3. Concentration risk – e.g., risk of events such as the widespread recent problems in the US mortgage market;

4. Methods of adjusting for basis risk;

5. Dealing with the limitations of credit models.

Problem S7-SII-48. (a) According to Brooks et al., how is credit risk evaluated currently? (Brooks et al., Subsection 22.4.1, page 82)

(b) According to Brooks et al., what assumption is currently often made with regard to economic scenario generators and credit risk? (Brooks et al., Subsection 22.4.2, page 82)

Solution S7-SII-48.

(a) Credit risk is currently evaluated based on counterparty ratings from rating agencies and historical default rates.

(b) Economic scenario generators are often assumed to include an appropriate amount of risk related to counterparty downgrade on financial instruments.

Problem S7-SII-49.

(a) Under existing Solvency I rules, how is cashflow-mismatching risk addressed under Pillars 1 and 2? (Brooks et al., Subsection 23.1.2, page 83)

(b) How is the treatment of cashflow-mismatching risk different under Solvency II? (Brooks et al., Subsection 23.1.3, page 83)

(c) What two areas of improvement do Brooks et al. identify with regard to modeling cashflow-mismatching risk? (Brooks et al., Subsection 23.1.4, page 83)

Solution S7-SII-49.

(a) Solvency I, Pillar 1: Firms are required to hold explicit prudent reserves to cover cashflow-mismatching risks.

Solvency I, Pillar 2: Firms are required to consider explicitly liquidity risk in general (of which cashflow-mismatching risk is a subset).

(b) Solvency II, Pillar 1: Rules do not include any explicit capital/reserve requirements regarding cashflow-mismatching risk.

Solvency II, Pillar 2: Requirement to consider liquidity risk in general remains.

(c) Areas for improvement with regard to modeling cashflow-mismatching risk are **(1)** accuracy of cashflow modeling and **(2)** closer scrutiny of the more commonly used simplifying assumptions.

Problem S7-SII-50. Identify the three elements of "good practice" with regard to modeling cashflow-mismatching risk, according to Brooks et al. (Subsection 23.2.1, page 83).

Solution S7-SII-50.

1. A detailed investigation of cashflow-mismatching risk should be carried out on a regular basis, using the internal model, and reported to senior management. The investigation should be a close collaboration between actuarial and investment-management staff.

2. Any simplifying assumptions in the internal model that might affect the accuracy of modeling should be clearly flagged in any reports on cashflow-mismatching risk. Views on materiality should be stated and justified.

3. Stress scenarios that consider an increase in specific drivers of cashflow-mismatching risk should be investigated regularly using the internal model as part of a firm's risk management.

Problem S7-SII-51. What three areas of additional research do Brooks et al. identify with regard to modeling cashflow-mismatching risk? (Subsection 23.3.1, pages 83-84)

Solution S7-SII-51.

1. Modeling of the volatility of bid-offer spreads of commonly held assets, such as bonds and equities;

2. Quantification of the potential impact of commonly used liability-model simplifications (e.g., model-point compression) on the accuracy of cashflow projections;

3. Investigation of how the extreme events of 2008 affected the cashflow-mismatching risk of insurers and consideration of how this kind of extreme event can be modeled (if at all) as part of good liquidity-risk management.

Problem S7-SII-52. According to Brooks et al., what is a "founding principle" of the approach of market-consistent valuations? (Subsection 23.4.1, page 84)

Solution S7-SII-52. Two identical sets of cash flows must have an identical value, and thus, by finding a portfolio of assets with cash flows that match those of a liability portfolio across a wide range of economic conditions and by being to identify the market value of that portfolio of assets, we can determine the market value of the liability portfolio.

Problem S7-SII-53. Identify four practical "compromises" that Brooks et al. describe with regard to modeling cash flows in light of existing constraints. (Subsection 23.4.2, pages 84-85)

Solution S7-SII-53. Any four of the following would suffice:

1. The use of heavily compressed asset-model points;

2. The use of heavily compressed liability-model points;

3. The lack of granular modeling of different policyholder options that have significantly different effects on cash flows;

4. The lack of granular modeling of some asset and non-policyholder liability types that may have a significant effect on cash flows;

5. The absence of any liquidity-based constraints on the amount and timing of asset-allocation changes in management decision-rule models;

6. The use of economic scenario generators that focus on total returns, rather than separating dividends/rents and capital growth;

7. The use of economic scenario generators calibrated to a consistent series of prices that make no allowances for the additional volatility of the bid-ask spread over time;

8. The use of annual or monthly, rather than daily, projection steps where possible in asset-liability models.

Problem S7-SII-54. Fill in the blanks (Brooks et al., Subsection 23.4.3, page 85): Stochastic models often assume that _____ cash flows during a period are accumulated at some _____ until the end of the period, when some _____ rules are used to determine the necessary disposals to meet the _____ cash flow. This may or may not be appropriate depending on the _____ or _____ of the assets held.

Solution S7-SII-54. Stochastic models often assume that **negative** cash flows during a period are accumulated at some **cash rate of return** until the end of the period, when some **asset-sale** rules are used to determine the necessary disposals to meet the **negative** cash flow. This may or may not be appropriate depending on the **nature** or **liquidity** of the assets held.

Problem S7-SII-55. According to Brooks et al., why has there not been a great impetus for enhancements to existing cash-flow models, and what recent developments might lead to resurgence of interest in this area? (Brooks et al., Subsection 23.4.4, page 85)

Solution S7-SII-55. There has not been a great impetus for enhancements to existing cash-flow models because these models have faced limited challenge from auditors and supervisors. The increasing popularity of replicating-portfolio models and heightened attention to liquidity risk in the wake of the recent banking crisis might lead to resurgence of interest in this area.

Problem S7-SII-56. According to Brooks et al., what two kinds of data pertaining to liquidity risk are currently very scarce? (Brooks et al., Subsection 23.4.5, page 85)

Solution S7-SII-56. Data pertaining to **(1)** liquidity (e.g., volumes traded) and **(2)** movements in bid-ask spreads are currently very scarce.

Problem S7-SII-57. According to Brooks et al., for what two purposes can Monte Carlo simulation be used? (Brooks et al., Subsection 25.1.2, page 86)

Solution S7-SII-57. Monte Carlo simulation can be used to **(1)** assess the value of technical provisions at a point in time and **(2)** to determine capital requirements by modeling the variability of elements of the balance sheet in extreme conditions.

Problem S7-SII-58.

(a) In deciding whether risks are to be modeled using deterministic or stochastic techniques, what characteristic of each risk should be considered in depth, according to Brooks et al.?

(b) With regard to this decision process, what, according to Brooks et al., could be kept as part of the process documentation associated with an internal model?

(Brooks et al., Subsection 25.2.1, page 86)

Solution S7-SII-58.

(a) The **extent to which each risk is asymmetric** should be considered in depth.

(b) A **matrix of all risk types,** identifying how each risk is modeled and providing reasons, could be kept as part of the process documentation associated with an internal model.

Problem S7-SII-59. Identify three "good practices" recommended by Brooks et al. with regard to the use of stochastic techniques in an internal model.

(Brooks et al., Subsections 25.2.1-25.2.6, pages 86-87)

Solution S7-SII-59. Any three of the following would suffice:

1. The process to decide whether risks are modeled using deterministic or stochastic techniques should be transparent and well-documented.

2. A central register of all options and guarantees should be kept and updated regularly, enabling easier monitoring by senior management. Each option/guarantee should be fully understood, documented, and (where material) modeled using stochastic techniques.

3. Companies should utilize the best available technology, within practical constraints, to monitor their capital positions in a manner close to real time.

4. Use of computing power and replicating-portfolio software should be used intelligently in situations where closed-form solutions are not possible.

5. Where Monte Carlo simulation is required, firms should understand and quantify the sampling error associated with the technique and attempt to minimize it to the extent this is practical.

6. As part of model development and testing, firms should test the results of the model (and in particular any dynamic algorithms) in tail simulations to ensure the results are sensible.

Problem S7-SII-60. According to Brooks et al., what three challenges may constrain the development of good practice in stochastic modeling techniques? (Brooks et al., Subsection 25.3.1, page 87)

Solution S7-SII-60.

1. The capability to increase the number of model points and/or simulations used relative to current practice will be limited by computing power.

2. Use of replicating-portfolio packages may require a significant front-end investment to implement or may not be appropriate. For some firms, there may already be insufficient time left to implement such systems before Solvency II takes effect.

3. Convincing stakeholders of the need to invest in new technology may be challenging. There is likely to be a lack of understanding about the limitations of existing modeling technology among non-actuarial stakeholders.

Problem S7-SII-61. According to Brooks et al., any internal model brings together a representation of **(a)** the insurance company or group structure and **(b)** its interaction with various uncertain factors. Provide three examples of elements of both the company/group structure and the uncertain factors. (Brooks et al., Subsection 25.4.1, pages 87-88)

Solution S7-SII-61.

(a) Elements of company/group structure (any three would suffice)**:**

1. Legal form

2. Capital structure

3. Policies written

4. Company/group assets

5. How management might exercise its discretion

6. Tax regime to which the company/group is subject

(b) Uncertain factors (any three would suffice)**:**

1. Future investment returns

2. Level of future expenses

3. Level of future insurance claims paid

4. Level of future premiums received

Problem S7-SII-62. (a) According to Brooks et al., what question is it important to ask with respect to a risk when constructing or applying an internal model involving that risk?

(b) On what three elements will the answer to this question depend?

(Brooks et al., Subsection 25.4.3, page 88)

Solution S7-SII-62.

(a) It is important to ask whether or not it is important to capture the stochastic nature of the risk.

(b) The answer will depend on the following three elements:
1. Structure of the product;

2. Structure of the company or group;

3. Use to which the internal model will be put.

Problem S7-SII-63.

(a) Fill in the blanks (Brooks et al., Subsection 25.4.4, page 88): In the market-consistent frameworks of market-consistent embedded value and Solvency II, financial risks are almost invariably modeled stochastically if they _____ and if _____.

(b) Discuss how these conditions affect the modeling of cash flows for the majority of non-life insurance companies' liabilities and life insurance companies' annuity liabilities.

(c) Discuss a key assumption of the approach in part (a). (Brooks et al., Subsection 25.4.4, page 88)

Solution S7-SII-63.

(a) In the market-consistent frameworks of market-consistent embedded value and Solvency II, financial risks are almost invariably modeled stochastically if they **have a direct effect on the magnitude and timing of the cash flows** and if **the structure of the product, company/group, or tax regime introduces an asymmetry to the effect on the cash flows**.

(b) The majority of non-life insurance companies' liability cash flows and life insurance companies' annuity liability cash flows do not depend directly on financial risk and so are modeled using a deterministic ("risk-free") discount rate.

(c) This approach assumes that inflation does not introduce any asymmetry such that the mean/average of the cash flows across a range of inflation scenarios would not longer equal the cash flows based on the mean/average inflation scenario.

Problem S7-SII-64. Fill in the blanks (Brooks et al., Subsection 25.4.5, page 88): Unit-liked liability cash flows are directly dependent on _____, but the ____ link between investment performance and the liability cash flow means that, under the certainty-equivalent principle, the cash flows may be evaluated deterministically provided that _____.

Solution S7-SII-64. Unit-liked liability cash flows are directly dependent on **financial risks**, but the **linear** link between investment performance and the liability cash flow means that, under the certainty-equivalent principle, the cash flows may be evaluated deterministically provided that **the gross earned investment return is the same as the discount rate applied**.

Problem S7-SII-65.

(a) According to Brooks et al., for which kinds of insurance products are stochastic techniques required?
(b) How might the techniques differ between simple instances of such products, as compared to more complex instances?
(c) For which of the more complex products are the more advanced stochastic techniques particularly relevant? (Brooks et al., Subsection 25.4.6, page 88)

Solution S7-SII-65.

(a) Stochastic techniques are required for insurance products where financial guarantees or options are present.

(b) For simple products, the mean of the present value of the cash flows (which are driven by stochastically varying financial risks) can be calculated analytically using a closed-form solution such as a mathematical formula. For more complex products, the mean and present value of the cash flows can only be determined via simulation.

(c) More advanced techniques (e.g., simulation) are particularly necessary for products where the impact of management discretion is significant and where this discretion is applied based on the performance of the company as a whole.

Problem S7-SII-66.

(a) According to Brooks et al., how are non-financial risk influences on cash flows usually applied at present?

(b) Give two examples of the approach in part (a). (Brooks et al., Subsection 25.4.7, page 89)

(c) Under which three situations might this approach not be appropriate? (Brooks et al., Subsection 25.4.8, page 89)

Solution S7-SII-66.

(a) At present, non-financial risk influences on cash flows are usually applied **deterministically.**

(b) Examples of deterministic application:

1. Chain-ladder techniques in projecting best-estimate non-life claims;

2. Using historical experience analyses to determine an estimate of the appropriate mortality or lapse assumption.

(c) This approach might not be appropriate if
1. The sample mean is taken from a relatively short historical period;

2. The distribution of the risk is likely to be highly skewed;

3. There is a significant asymmetry in the cash flows resulting from changes in non-financial risks.

Problem S7-SII-67. According to Brooks et al., what three "capital-modeling issues" are raised by attempts to fully apply stochastic modeling? (Brooks et al., Subsection 25.4.9, page 89)

Solution S7-SII-67.

1. Solvency II and economic-capital calculations of required capital specify a target percentile or conditional-tail-expectation threshold. While the lack of data for some risks has led to expert judgment being used to estimate the risk at the required percentile directly, the majority of risks are evaluated using statistical techniques.

2. In the case of life insurers, where a Monte Carlo simulation is required to determine the technical provisions, the lack of computing power that would be necessary to run nested stochastic simulations often restricts the insurer to running deterministic stress tests on a risk-by-risk basis.

3. Non-life insurers do not generally use stochastic simulation to calculate their technical provisions. This makes the calculation simpler, and consequently the internal models are able to project forward their cash flows and technical provisions using stochastic simulation to generate the capital required.

Problem S7-SII-68. According to Brooks et al., what four assumptions, which are unlikely to be true in practice, are made by the method of aggregating deterministic stress tests and the capital required under those tests for each risk? (Brooks et al., Subsection 25.4.9, page 89)

Solution S7-SII-68. Assumptions of the method of aggregating deterministic stress tests and the capital required under those tests:

1. Elliptic risk distributions

2. Linear relationship between capital and stress level

3. Constant correlations

4. Additive impact of risks

Problem S7-SII-69. According to Brooks et al., what is the approach of most existing internal capital models with regard to granularity of output? (Brooks et al., Subsection 26.1.2, page 90)

Solution S7-SII-69. Most existing models are typically used in a company-level context to model aggregate economic-capital requirements, and may not always be designed for reporting at lower levels of granularity.

Problem S7-SII-70. (a) What, according to Brooks et al., is the general criterion for the level of granularity in an internal model?

(b) Identify four areas discussed by Brooks et al. with respect to granularity and describe what "good practice" in each of these areas would be. (Brooks et al., Section 26.2, page 90)

Solution S7-SII-70. (a) The general criterion is that the internal model should allow analysis and understanding of the firm's business at the level of granularity which supports how the firm makes business decisions as part of the use test.

(b) Areas with respect to granularity:

1. Time granularity: Frequency of the projection steps within the model – e.g., annual or monthly calculations. Monthly steps within the internal model are good practice for life companies. For non-life companies, annual calculations with the ability to roll forward or adjust assumptions on a monthly or quarterly basis are good practice.

2. Time horizons: Shorter projection periods may result in shorter time steps, while longer projection periods may need to use coarser granularity.

3. Policy data: For life firms, policy data should be modeled at the individual policy level to allow the maximum understanding of the results where practical. Where grouped data are used, the results produced should be validated against individual policy data to ensure appropriateness.

4. Products: All products should be included within the internal model, with minimal grouping of similar products for modeling purposes. In this way, accurate analysis at the individual product level is achievable.

Problem S7-SII-71. According to Brooks et al., what three challenges may constrain development of good practice with respect to granularity? (Brooks et al., Subsection 26.3.1, page 91)

Solution S7-SII-71. Challenges include the following:

1. Balancing the granularity and accuracy of the results against the cost of producing them;

2. Overcoming the barrier of limited computer power and run times to undertaking more granular steps, using less grouped data, and modeling more products or product features.

3. Combining efforts at greater granularity with stochastic modeling requirements.

Problem S7-SII-72. What three observations do Brooks et al. make regarding current practice on model granularity, which leads them to question whether modeling is at a sufficiently granular level to support decision-making within a firm? (Brooks et al., Subsections 26.4.1-26.4.3, page 91)

Solution S7-SII-72.

1. Some models currently have the ability to project events on a monthly basis, although often even when this is the case, the outputs are not set up to utilize this information.

2. Policy data are sometimes grouped for modeling purposes, although individual data may be used for deterministic modeling. The approach to grouping can vary from firm to firm in terms of what grouping criteria are used and what testing is undertaken to ensure that accuracy is not impaired.

3. Currently, outputs from models do not form part of the monthly management information/decision-making cycles within firms and are only considered for large strategic decisions or considered less frequently (e.g., annually).

Problem S7-SII-73. Identify six elements of what Brooks et al. consider “good practice” with regard to modeling dynamic management actions in a stochastic asset-liability model. (Brooks et al., Section 27.2, pages 92-93)

Solution S7-SII-73. Any six of the following would suffice:
1. Both management actions and policyholder behavior should be modeled together and consistently, such that both actions by the firm and behavior of policyholders are considered in every scenario.

2. Policyholder behavior should be explicitly considered both before and after the management action.

3. Actions should be considered in conjunction with correlations among risks and non-linearity tests, and all management actions should be included within the modeling.

4. Issues regarding continuous management actions, such as adjustments to bonus rates, should be considered and validated against historical data.

5. Management actions should be modeled dynamically where significant to the business, and suitable scenario-based modeling should be carried out for less significant risks.

6. Data should be available to show that management actions have been rigorously implemented in the scenarios that are modeled with regard to management actions undertaken by the firm in question and management actions taken by competitors where known, and the possible impact on policyholders and their advisors.

7. Management actions should cover all business where management discretion is available, not just with-profits business.

8. Management actions should cover the upside scenarios as well as the downside scenarios, including reversal of management actions in good scenarios.

9. Management actions should be used in the business-planning process and consistently with the company's view on future strategy and market environment.

10. Management actions are examined across a range of future scenarios and not just extreme events.

11. The firm should undertake customer research to understand policyholder behavior in relation to proposed management actions.

12. The firm should seek legal and other advice on the legality and fairness of proposed management actions.

13. Policyholder literature should be reviewed before setting contingent management actions.

Problem S7-SII-74. Identify four of the challenges discussed by Brooks et al. to modeling dynamic management actions. (Brooks et al., Subsection 27.3.1, pages 93-94)

Solution S7-SII-74. Any four of the following would suffice:
1. Modeling difficulties around dynamic management actions, especially when linking to combinations of multiple variables;

2. Ability to test the modeled management actions in reality;

3. Lack of data relating to implications of management actions in stressed scenarios;

4. Difficulties in determining which actions will be taken by competitors in stressed scenarios – and what the impact on policyholders would be;

5. Whether modeling management actions based on historical data could lead to asymmetrical

management actions in bad and good times, and potential issues regarding competition and customer fairness;

6. The possibility of misstating the effectiveness of management actions when experience changes at a faster or slower rate than assumed in the controls. (If experience changes rapidly, there may be insufficient time to implement the management action. If experience changes slowly, management actions might not be triggered.)

Problem S7-SII-75.

(a) Give two examples of management actions that are often modeled dynamically at present. (Brooks et al., Subsection 27.4.2, page 94)

(b) Give five examples of other management actions that have been subjected to dynamic modeling. (Brooks et al., Subsection 27.4.5, page 94)

Solution S7-SII-75.

(a) (1) Bonus rates and **(2)** investment strategies in connection with future investment returns are often modeled dynamically at present.

(b) Any five of the following would suffice:
1. Changes to market-value adjustments;

2. Cuts in regular bonuses;

3. Cuts in final bonuses;

4. Changes in equity-backing rates (EBR);

5. Increase in charges for insurance benefits;

6. Increase in administration charges;

7. Change in new-business levels;

8. Change in new-business mix;

9. Change in asset allocation;

10. Change in hedging strategy;

11. Removal of miscellaneous/planned enhancements;

12. Change to charges for cost of guarantees;

13. Change to defined-benefit pension schemes;

14. Change in reinsurance agreements.

Problem S7-SII-76.

(a) Fill in the blanks (Brooks et al., Subsection 28.1.2, page 95): The technically correct approach for the calculation of economic capital is to _____. This approach automatically allows for _____ effects between risks and for the impact of risks in the _____, and accurately allows for _____ effects between risks.

(b) Why is the approach in part (a) often not used in practice? (Brooks et al., Subsection 28.1.3, page 95)

(c) What alternative approach for the calculation of economic capital is discussed by Brooks et al.? (Brooks et al., Subsection 28.1.4, page 95)

Solution S7-SII-76.

(a) The technically correct approach for the calculation of economic capital is to **allow risks to vary stochastically within an integrated model**. This approach automatically allows for **non-linear** effects between risks and for the impact of risks in the **capital required**, and accurately allows for **diversification** effects between risks.

(b) This approach has immense computational requirements. Integrated stochastic modeling of all risks is rarely practical for a with-profits business. The method is also prone to accusations of spurious accuracy.

(c) An alternative approach for the calculation of economic capital involves setting or determining distributions for capital for individual risks or combinations of risks. The economic capital is then calculated by aggregating the distributions of risk capital.

Problem S7-SII-77. What three areas of further research are recommended by Brooks et al. with regard to determining the probability distribution of economic capital?

Solution S7-SII-77. Areas of recommended research:

1. Developing criteria to determine the circumstances and extent to which the method of combining risks is adequate;

2. Research on techniques that increase the degree to which models can be constructed on an integrated basis;

3. Best practice in combining risks to determine the overall risk distribution.

Problem S7-SII-78. Discuss five important considerations to keep in mind when selecting a probability distribution for economic capital. (Brooks et al., Subsections 28.4.1-28.4.5, pages 95-96)

Solution S7-SII-78.

1. It is important to appreciate that the determination of economic capital involves a number of stages, and therefore assumptions or approximations made at one stage flow on to further stages.

2. The real world is considerably more complex than can be fully reflected through the use of distributions, so parsimony is an important consideration.

3. It is important to understand how the distributions will be used, as an inappropriate choice of distribution can lead to understatement or overstatement of economic capital – but it is difficult to approximate the impact unless the assumptions and approximations are thoroughly understood.

4. The type of economic-capital calculation (VaR, TVaR, etc.) is instrumental in the choice of distribution. The ideal is to use a distribution that accurately represents the entire range of outcomes.

5. It is generally more difficult to represent the entire distribution of capital requirements for a risk using a probability density function. The fact that management actions and particular contract structures often determine capital requirements adds to the difficulty.

Problem S7-SII-79.

(a) What underlying distribution does the "sum of squares" approach assume?

(b) Why is this assumption often unrealistic? (Brooks et al., Subsection 28.4.6, page 96)

Solution S7-SII-79.

(a) The "sum of squares" approach assumes a **multivariate normal** distribution.

(b) Real-world distributions tend to be fat-tailed, and therefore a normal distribution can only fit a very limited range.

Problem S7-SII-80.

(a) If a distribution of capital for individual risks is generated, what approach do Brooks et al. recommend as an alternative to representing the distribution as a probability density function?

(b) What is a benefit of this approach? (Brooks et al., Subsection 28.4.7, page 96)
(c) Fill in the blanks (Brooks et al., Subsection 28.4.7, pages 96-97): The aggregation of capital requires a _____ method. This can be achieved by mapping one distribution to another using the _____. This approach is a limited form of _____, but can be extended to a full _____.

Solution S7-SII-80.

(a) The sampled capital values themselves can be used to represent the distribution, without the need for a probability density function.

(b) This approach avoids introducing approximations to the distribution.

(c) The aggregation of capital requires a **non-parametric** method. This can be achieved by mapping one distribution to another using the **observation ranks**. This approach is a limited form of **copula**, but can be extended to a full **copula**.