1. **Learning Objectives:**

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.

2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

**Learning Outcomes:**

1c) Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

(2e) Evaluate the theory and applications of extreme value theory in the measuring and modeling of risk.

(2f) Analyze the importance of tails of distributions, tail correlations, and low frequency/high severity events.

(2h) Construct approaches to modeling various risks and evaluate how an entity makes decisions about techniques to model, measure and aggregate risks including but not limited to stochastic processes.

(4e) Develop an appropriate choice of a risk mitigation strategy for a given situation (e.g., reinsurance, derivatives, financial contracting), which balances benefits with inherent costs, including exposure to credit risk, basis risk, moral hazard and other risks.

**Sources:**

Financial Enterprise Risk Management, Sweeting, 2011, Ch. 12 Extreme Value Theory

ERM-102-12: Value-at-Risk: Evolution, Deficiencies, and Alternatives

ERM-106-12: Economic Capital-Practical Considerations-Milliman

Financial Enterprise Risk Management, Sweeting, 2011 Ch. 16 Responses to Risk
1. Continued

Commentary on Question:
In general, candidates did well on the first two parts of the question. The candidates who did well on parts (c) and (d) were able to draw information from the question specific to the lines of business to justify their responses.

Solution:
(a)

(i) Explain why the GPD is an important distribution in the context of Extreme Value Theory.

(ii) Match the appropriate shape parameters of 2.5, 0, and -2.5 to each of the functions A, B, and C in the figure above. Justify your identification for each curve.

Commentary on Question:
Most candidates did well on sub-part (i) by identifying that the distribution of $X$ in excess of $U$ converges to a GPD and that EVT looks at extreme events (so modelling $X$ in excess of $U$ is appropriate). Most candidates also did well on sub-part (ii). Some candidates used the distribution formula to calculate $G(x)$ at 1 with each of the parameters, and others compared the shape of each of the distribution and comments on the size of the tail and identified how the parameters would impact the tail. Both justifications were accepted.

(i) Extreme Value Theory is looking at tail events, which can be represented by a distribution $(X)$ in excess of a threshold $(u)$. For a sufficiently large sample, the distribution of $X$ in excess of $U$ converges to a GPD.

(ii) A parameter of 2.5 would have the fattest tail, and therefore the $G(x)$ would converge to 1 the slowest. Therefore, $C(x)$ represents a parameter of 2.5. Similarly, a parameter of -2.5 would have the smallest tail, converging to 1 the fastest. Therefore $A(x)$ represents a parameter of -2.5. A parameter of 0 would be in between the other two, therefore $B(x)$ represents a parameter of 0.
1. Continued

(b) The GPD CDF is as follows:

\[ G(x) = \Pr(X - u \leq x \mid X > u) = \frac{F(x + u) - F(u)}{1 - F(u)} \]

\[ = \begin{cases} 
1 - \left(1 + \frac{x}{\beta y}\right)^{-\gamma} & \text{if } \gamma \neq 0 \\
1 - e^{-\frac{x}{\beta}} & \text{if } \gamma = 0
\end{cases} \]

(i) Select the most appropriate shape parameter for the Medical Stop Loss business from part (a)(ii). Justify your choice.

(ii) Calculate the 98th percentile of losses in excess of the threshold for the Medical Stop Loss business using the shape parameter from part (i), and a scale parameter of $500 million.

Commentary on Question:
Most candidates acknowledged they should be looking for the largest tail, but some had mixed up which parameter from part (a)(ii) produced the fattest tail. Candidates who didn’t do well on part ii were unable to appropriately use the given formula correctly.

(i) Given the tail risk of the Medical Stop Loss, they should be using the parameter which produces the fatter tail. That would be \( C(x) \), where the parameter is equal to 2.5.

(ii) \( C(x) = 1 - (1 + (x / B * y))^{(-y)} \)
\[ .98 = 1 - (1 + (x / 500 * 2.5))^{(-2.5)} \]
\[ .02 = 1 + (x / 1250)^{(-2.5)} \]
\[ 4.78 = (1 + x / 1250)^{(-2.5)} \]
\[ X = 4,727 \]

4.727 billion

(c) Critique BA’s risk metric choice for each line of business.

Commentary on Question:
The stronger candidates typically critiqued the choice of metric while also applying their analysis to the information provided on the specific lines of business (in other words, not just a general critique of the metric).
1. Continued

Term – CTE is a coherent risk measure that takes the information in the tail into account. Given that the maximum loss ($11,500) is not significantly higher than the mean loss ($9,000), the tail does not appear to be too large. So, VaR could be used in this instance as well, but there is no issue with using CTE95 either.

Fixed – VaR is not a coherent risk measure. The information also implies that the fixed annuity line of business has a larger tail (maximum loss of $9,900 is significantly higher than the VaR 95 of $5,400). As a result, they could be ignoring important information in the tail by using VaR.

Stop Loss – EVT is an appropriate way to model the tail given the lack of data that they have. They should be careful in setting the parameters for the distribution and may want to calculate sensitivities in setting the parameters.

(d) BA’s ERM committee would like to mitigate tail risk arising from the following uncertainties:

- Higher than expected medical losses
- Unanticipated changes in interest rates
- Pandemic mortality risk

Propose a mitigating strategy that BA could implement to address each uncertainty. Justify your proposal.

Commentary on Question:

Answers that recommended product design changes such as surrender charges were not as strong as those changes don’t help to manage the risks already sold. Also, stating they could add reinsurance without specifying stop loss (since it is the tail risk they are concerned with) were not as strong.

High Claims Volume – Excess of loss reinsurance would allow BA to cap their losses at a threshold. Any losses in excess of that threshold would be covered by the reinsurer.

Interest Rate Risk – Entering into an interest rate floor would allow them to protect themselves against a scenario where they are not able to earn enough return to credit 2% (but would still have to credit 2% since it is guaranteed).

Pandemic Risk – Issuing a catastrophe bond would allow them to pass the tail risk onto investors.
2. **Learning Objectives:**

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

**Learning Outcomes:**

(1c) Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

(4c) Demonstrate means for reducing risk without transferring it.

(4j) Demonstrate risk management strategies for other key risks (for example, operational, strategic, legal, and insurance risks).

**Sources:**

ERM-127-17 Quantitative Enterprise Risk Management, Hardy, Ch. 2: Risk Taxonomy

Financial Enterprise Risk Management, Sweeting, 2011 Ch. 16: Responses to Risk

ERM-123-14: S&P Enterprise Risk Management Criteria (paragraphs 1-71, 86-88)

ERM-133-19: Emerging Risks and Enterprise Risk Management (p.2-6)

ERM-103-12: Basel Committee-Developments in Modelling Risk Aggregation (p.72- 89)

ERM-120-14: IAA Note on Stress Testing and Scenario Analysis (pp. 1-6 and 14-17)


ERM-702-12: IAA Note on ERM for Capital and Solvency Purposes in the Insurance Industry, Pages 9–38

Group Insurance, Chapter 39: Risk Based Capital Formulas
2. Continued

Commentary on Question:
This question tested the candidate’s understanding of risk identification and risk management/mitigation actions in the context of a company’s plan to outsource certain services to another company, how such risks are impacted by an acquisition, how certain operational risks are considered emerging risks, how an elevated cyber risks impact other risks, and how certain risks arise when conducting business in a foreign currency. Candidates do not need to have knowledge of cryptocurrencies or Blockchain Technology to successfully answer this question.

Candidates generally performed better in part (a) and poorer in part (d). Depending on the quality, candidates received full credit by responding to the specific question being asked (e.g., explain, describe, evaluate, and not list), and to the quantity of items asked for. Similarly, candidates received full credit when answering in the context of the question stem as opposed to providing generic answers.

Solution:
(a) The VP is concerned that FirstMed’s operational risk will increase as a result of outsourcing to MHG.

(i) Explain two ways in which each of the following operational risks could increase for FirstMed if it outsources to MHG.

   I. People Risk
   II. Process Risk

(ii) Describe how each risk identified in (i) can be mitigated if Atria were to acquire MHG.

Commentary on Question:
For sub-part (a)(i), some candidates did not receive full credit because they explained only one way instead of two or because they explained two ways but described the risks in general terms and not specific to outsourcing.

For sub-part (a)(ii), some candidates did not receive full credit because they were answering in generic terms and not specifically discussing risk mitigation as a result of an acquisition.

(a)(i)
I. People Risk
   o There is risk that the skill, knowledge and expertise of MHG’s surgeons and nurses do not keep up with those of surgeons and nurses at FirstMed’s affiliate Florida hospitals, resulting in errors which may results in patient harm or death.
2. Continued

- Although English is a common language for both FirstMed and MHG, there may be cultural differences in how people work between these two companies.

II. Process Risk
- FirstMed, MHG or both may have little or no experience dealing/transacting with foreign currency or cryptocurrency, leading to inaccurate recording of accounting entries.
- Risk may arise from incomplete or fragmented medical records being transferred from FirstMed to MHG which could negatively impact patient health/customer experience.

(a)(ii)
I. People Risk
- With MHG under Atria as an acquired company, Atria can impose continuing professional development requirements to all employees of Atria's subsidiaries and affiliates, elevating overall professionalism standard and reducing people risk.
- Atria and FirstMed can more effectively enforce and maintain communication with MHG to address existing and future issues, thus reducing people risk.

II. Process Risk
- Under the same corporate structure, Atria can more easily impose Atria’s presumably higher standards of operation, i.e., corporate, auditing and accounting standards onto both FirstMed and MHG.
- During the integration phase, there may be gains in selecting best practices from all parties involved leading to better patient health and safety, including the transfer of medical records.

(b) The VP has identified the following as emerging risks if FirstMed outsources to MHG:

- Technology / Artificial Intelligence
- Pandemic
- Environmental

(i) Explain why each of these risks may be considered an emerging risk.

(ii) Describe how each of these risks may be impacted by outsourcing.

(iii) Describe three best practices for future identification of emerging risks for FirstMed.
2. Continued

**Commentary on Question:**
Some candidates received zero or partial credit, depending on the quality of their answers because one or more of the following:
- For sub-part (b)(i), they provided generic reasons on why these three risks may be considered emerging risks
- For sub-part (b)(ii), they did not address the impact to FirstMed with regards to either outsourcing to or acquisition of MHG
- For sub-part (b)(iii), they merely listed three best practices without describing them

(b)(i)
I. Technology / Artificial Intelligence (AI)
   a. There is a lack of consensus on whether humans or the emotional intelligence needed for health services can ever be provided by robots.
   b. There is a high level of uncertainty regarding timing of the emergence of this technology.

II. Pandemic
   a. Considered emerging because of high level uncertainty - pandemics have not directly occurred on US territory in recent history
   b. Difficult to assign ownership – pandemics may not be the sole responsibility of FirstMed/MHG because this risk likely requires coordination with different branches of governments in the US, Montseguay, and other countries.

III. Environmental
   a. Lack of consensus- Are anomalies (e.g., hurricanes, extreme heat and extreme cold) with the weather normal or the result of global warming?
   b. High level of uncertainty
      i. if or when Montseguay’s volcano will remain dormant;
      ii. if - or when - Montseguay will finally be impacted by a hurricane

(b)(ii)
I. Technology / Artificial Intelligence (AI)
   a. The risk of simple medical procedures/surgeons being replaced or assisted by robots, and services provided by nursing staff and administration staff being replaced by robots and automation.
   b. Such technological progress could potentially disrupt MHG’s low-cost value proposition and then the outsourcing to - and the acquisition of - MHG may become a poor strategic decision.
2. Continued

II. Pandemic
   a. Increased risk of introducing spreading communicable illness/disease, through patient/employee transport across borders
   b. Result of the risk could potentially disrupt normal operations of FirstMed’s Florida health care providers plus the services outsourced to MHG, and significantly increase claim costs for FirstMed

III. Environmental
   a. The risk of higher category level hurricanes hitting Florida will also soon be hitting Montseguay; risk of volcanic activity in Montseguay
   b. Result: disruption of normal operations in Florida and Montseguay and nearby states, affecting normal operations and negatively impacting business continuity plans

(b)(iii)

1. Challenge conventional thought processes and expectations
   o What are the assumptions as to how the risk will manifest in terms of timing and impact? Could an emerging risk manifest itself in a manner that is different from expected?

2. Conduct emerging risk reviews
   o How – document a formal process
   o When – periodic meetings
   o Who – members of leadership, management, and business unit risk teams
   o How – create a channel to escalate new emerging risks.

3. Integrate emerging risk review into the strategic planning process in order to enforce a disciplined approach in risk-taking decisions.

(c) The VP thinks cyber risk would become one of FirstMed’s top risks should FirstMed proceed with the acquisition.

(i) Evaluate how an elevated cyber risk exposure may impact the following four risks for FirstMed. Justify your response.
   
   I. Data Risk
   II. Political Risk
   III. Regulatory / Legal Risk
   IV. Supplier / Third Party Risk

(ii) Recommend one action to mitigate each risk identified in part (i).
2. Continued

Commentary on Question:

Some candidates provided overly general responses without considering the context of potential acquisition or an elevated cyber risk; depending on the quality of their answers, some received partial credit.

For sub-part (c)(ii), some candidates did not provide justification for their recommended action; these candidates received partial credit.

Some candidates answered with the context of MHG as the Supplier/Third Party risk; others answered with the context of MHG’s own suppliers/third parties. Candidates could receive credit for either context.

(c)(i)
I. Data
   o An elevated cyber risk would lead to an increase in data risk as health care providers are potential soft target for cyber crime. MHG may mishandle patient data due to people or people process risk. As a non-US entity, MHG may be subject to lax regulations on data security & privacy.

II. Political
   o Cyber risk may disrupt Montseguay’s political environment – it may no longer be peaceful, idyllic nation leading to disruption of MHG’s normal operations.

III. Regulatory / Legal
   o Cyber risk regulation, including privacy laws, have the potential to become too restrictive to conduct business in the U.S. and with international partners
   o Montseguay may have little or no cyber risk regulation or may have regulations that differ from those of the U.S. and Florida

IV. Supplier / Third Party
   o An elevated cyber risk leads to increase in Supplier/Third Party risk as cyber criminals could disrupt FirstMed’s normal operations by attacking weaker links in its supply chain – either MHG or MHG’s suppliers.

(c)(ii)
I. Data
   o Increase senior management oversight of the system integration between the two companies - watching for potential gaps or entry points for cyber criminals to exploit

II. Political
   o Monitor the political landscapes in both countries and at the state level in order to take early risk-mitigating steps
2. Continued

III. Regulatory / Legal
   o Take early steps in anticipation of new regulations being enacted/proposed elsewhere, e.g. progressive U.S. states, EU, Canada, the rest of the Americas

IV. Supplier / Third Party
   o Assign risk limits: limit the number of patients being treated by MHG, and/or limit the type of procedures, surgeries, and treatments. Periodically assess if the limits can be increased after a period of success and comfort with respect to cyber risk and the supplier/third party

(d) Because FirstMed has had no previous experience transacting in MontsCoin, the VP is concerned with the following additional risks:

   • Exchange rate risk associated with transacting in MontsCoin
   • Liquidity risk associated with transacting in MontsCoin
   • Credit risk associated with outsourcing services to MHG

For each risk:

(i) Describe the risk as it relates to FirstMed.

(ii) Propose an appropriate risk management technique for FirstMed to implement.

Commentary on Question:
For sub-part (d)(i) some candidates described Credit Risk as non-payments from MHG to Atria, where such payments were profits or dividends payable by MHG as an acquired company by Atria. If well described, this response was eligible for full credit.

For sub-part (d)(ii), some candidates did not provide support for their proposal and therefore received minimal credit. In particular, for III. Credit risk, some candidates merely listed credit default swaps (CDS) but they did not describe the credit risk event the CDS was intended to mitigate; for such an answer, they received minimal credit.

(d)(i)
I. Exchange rate risk
   o The risk that the value of MontsCoin dramatically rises against the USD so that outsourcing becomes too expensive. FirstMed may have contractual obligations which are specified in MontsCoin, but FirstMed received premiums in USD, resulting in exposure to exchange rate fluctuations.
2. Continued

II. Liquidity risk
   o If the outsourcing/intra-company service agreement is settled in MontsCoin, FirstMed needs to have a sufficient amount of MontsCoin to pay MHG. It would also be prudent for FirstMed to not hold too much of the cryptocurrency in the event of a dramatic decrease in value against the USD, which could make MontsCoin illiquid.

III. Credit risk
   o The risk that MHG may not provide the promised surgical services and FirstMed will incur additional expenses in arranging for alternative coverage.

(d)(ii)

I. Exchange rate risk
   o FirstMed should develop backup plans to contract alternate health care providers onshore. If MontsCoin dramatically increases in value, FirstMed could outsource to a lower-cost provider.

II. Liquidity risk
   o Consider a contingency funding plan to provide liquidity in times of stress or in the first few years of the FirstMed-MHG relationship, which may include uncommitted bank lines of credit or holding more cash.

III. Credit risk
   o FirstMed could ask for and hold acceptable letters of credit from MHG, or FirstMed could incorporate agreement language to withhold funds designated for MHG, preferably in USD.
3. Learning Objectives:
2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.

3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:
(2b) Evaluate how risks are correlated, and give examples of risks that are positively correlated and risks that are negatively correlated.

(2c) Analyze and evaluate risk aggregation techniques, including use of correlation, integrated risk distributions and copulas.

(3c) Analyze quantitative financial data and insurance data (including asset prices, credit spreads and defaults, interest rates, incidence, causes and losses) using modern statistical methods. Construct measures from the data and contrast the methods with respect to scope, coverage and application.

(4k) Apply best practices in risk measurement, modeling and management of various financial and non-financial risks faced by an entity.

Sources:
ERM-103-12: Basel Committee - Developments in Modelling Risk Aggregation, pages 72 - 89

ERM-101-12: Measurement and Modeling of Dependencies in Economic Capital (Ch 3-5)


ERM-130-18: AAA Model Governance Practice Note

Commentary on Question:
Commentary listed underneath each question component.

Solution:
(a) 
(i) Calculate each correlation metric based on the data provided. Show all work.

(ii) Describe the advantages and disadvantages of each metric that you should consider when selecting an appropriate correlation metric for parameterizing a copula.
Commentary on Question:
Part (a) was well performed in general. Many candidates at least were able to obtain credit for knowing the formulas for each correlation metric and a few key advantages and disadvantages. Candidates lost credit for not knowing how to use the formula for the corresponding correlation metric and for make generic comments for the metric without specifying if it was an advantage or disadvantage.

Candidates whose responses included illogical numerical answers (e.g. a correlation coefficient > 1) left without an explanation, were awarded minimal credit. This comment applies to other parts as well.

Credit was awarded for providing the alternative Spearman’s Rho formula, even though the correct answer could not be found by using it with the given data.

\[ \rho(j, k) = \frac{\text{Cov}[j, k]}{\sqrt{\text{Var}(j)\text{Var}(k)}} = \frac{E[jk] - E[j]E[k]}{\sqrt{\text{Var}(j)\text{Var}(k)}} \]

\[ = \frac{0.006\% - (-0.109\%) \times (-0.155\%)}{\sqrt{0.034\% \times 0.021\%}} = 0.2182 \]

Spearman Rho
Using rank summary statistics (here \( j \) and \( k \) represent rank of series \( j(t) \) and \( k(t) \)):

\[ \alpha(j, k) = \frac{\text{Cov}[j, k]}{\sqrt{\text{Var}(j)\text{Var}(k)}} \]

\[ = \frac{18.45}{\sqrt{74.92 \times 74.92}} = 0.2463 \]

Kendall’s Tau:
Number of Concordant Pairs = 253 (Given)
Total Pairs = \((30 \times 29) / 2 = 435\)
Number of Discordant Pairs = 435 - 253 = 182

\[ \tau = \frac{C - D}{0.5n(n - 1)} = \frac{253 - 182}{0.5 \times 30 \times 29} = 0.1632 \]
3. Continued

a(ii)
Pearson’s Rho has the advantage that it is easy to calculate, but it is possible to have highly dependent variables with 0 correlation (e.g. X and $X^2$)

Spearman’s Rho has the advantage that it does not depend on marginal distribution of both values so it can be used to calibrate copulas from empirical data. However, it has the disadvantage that there is the additional complexity of ranking of observations

Kendall’s Tau has the advantage that it is robust to outliers, but it is time consuming (i.e. more computational power is required) for large data sets.

(b)

(i) Determine which fund has the higher expected variance. Show all work.

(ii) Assume that the $t_0$ conditional variances for each fund are equal to the empirical variances shown in the table on the previous page.

Calculate the conditional variances for the next two time steps, $t=1$ and $t=2$ for each fund using the GARCH(1,1) model. Show all work.

(iii) Maggie explains that there are simple modifications that can be made to the basic GARCH(1,1) model in order to more accurately reflect the behavior of typical financial time series.

Explain why the following modifications may be implemented for volatility forecasting:

- Using the absolute value of the innovation term
- Using a separate parameter for positive shocks and negative shocks

Commentary on Question:
Candidates did not do well on this part in general. While they were often able to demonstrate the ability to determine which fund has the highest expected variance, they were not able to forecast the conditional variances for time steps 1 and 2. Most candidates used the same formula for steps 1 & 2, which is incorrect. Candidates were also not able to explain the benefits of using the absolute value of the innovation term.
3. Continued 

b(i) 
Expected (unconditional) variance of Fund ABC

\[ h_t = \alpha_0 + \alpha_1 r_{t-1}^2 + \beta h_{t-1} \]
\[ h = 0.0001 + 0.161 h + 0.777 h \]
\[ h = \frac{0.0001}{1 - 0.161 - 0.777} = 0.0016 \]

Expected (unconditional) variance of Fund XYZ

\[ h_t = \alpha_0 + \alpha_1 r_{t-1}^2 + \beta h_{t-1} \]
\[ h = 0.0002 + 0.257 h + 0.565 h \]
\[ h = \frac{0.0002}{1 - 0.257 - 0.565} = 0.0011 \]

b(ii) 
Fund ABC:  
Step 1:
\[ h_{t+1} = \alpha_0 + \alpha_1 r_{t}^2 + \beta h_{t} \]
\[ h_{t+1} = 0.0001 + 0.161 r_{t}^2 + 0.777 h_{t} \]
\[ h_{t+1} = 0.0001 + 0.161(0.0501)^2 + 0.777(0.00034) = 0.00077 = 0.077\% \]

Step 2:
\[ h_{t+2} = E_t (r_{t+2}^2) = E_t (\alpha_0 + \alpha_1 r_{t+1}^2 + \beta h_{t+1}) = \alpha_0 + \alpha_1 h_{t+1} + \beta h_{t+1} \]
\[ h_{t+2} = 0.0001 + 0.161 h_{t+1} + 0.777 h_{t+1} \]
\[ h_{t+2} = 0.0001 + 0.161(0.00077) + 0.777(0.00077) = 0.00082 = 0.082\% \]

Fund XYZ:  
Step 1:
\[ h_{t+1} = 0.0002 + 0.257 r_{t}^2 + 0.565 h_{t} \]
\[ h_{t+1} = 0.0002 + 0.257(0.0489)^2 + 0.565(0.00021) = 0.00093 = 0.093\% \]
3. Continued

Step 2:

\[
\begin{align*}
    h_{t+2} &= 0.0002 + 0.257h_{t+1} + 0.565h_{t+1} \\
    h_{t+2} &= 0.0002 + 0.257(0.00093) + 0.565(0.00093) = 0.00096 = 0.096%
\end{align*}
\]

b(iii)

a. Since the basic GARCH(1,1) model incorporates the squared value of the current innovation, large shocks tend to have substantial impact on the forecasted volatility. Using the absolute value instead mutes the impact of large innovations.

b. The basic GARCH(1,1) is symmetric, only the magnitude of the deviation influences the forecast (as innovations are squared). For some series, large negative returns have a bigger/different effect on risk than do positive returns.

(c) The formula for forecasting the covariance using the RiskMetrics approach is given below.

\[
h_{12,t+1} = \lambda h_{12,t} + (1-\lambda)r_{1,t}r_{2,t}
\]

(i) Identify two arguments in favor of using the RiskMetrics approach for forecasting covariance.

(ii) Calculate the forecasted t=1 Pearson correlation coefficient using the RiskMetrics approach and the results of part (b)(ii). Show all work.

Commentary on Question:

Candidates were typically able to determine one correct argument in favor of using the RiskMetrics approach, however they were not able to demonstrate that they understood how to calculate the forecasted t=1 Pearson correlation coefficient. Candidates did not lose credit if incorrect values from previous steps were used correctly in a subsequent calculation.

c(i)

- The most general GARCH model for forecasting correlation has a prohibitively high number of required parameters (7). As additional risk factors are added, number of parameters increases rapidly. RiskMetrics only has 1 estimated parameter, and is therefore more robust to estimation error.
- RiskMetrics approach has a relatively small number of effective observations, placing more importance on recent observations.
3.  Continued

c(ii)
First you must calculate the current covariance (time t) between the funds (possibly derived in part a(i)):

\[ h_{12,t} = E[j_k] - E[j]E[k] \]
\[ h_{12,t} = 0.006\% - (-0.109\%) \times (-0.155\%) \]
\[ h_{12,t} = 0.0058\% \]

Using this covariance value, and the given forecasted variance values, the one-step ahead covariance is calculated as:

\[ h_{12,t+1} = \lambda h_{12,t} + (1 - \lambda)r_{1,t}r_{2,t} \]
\[ h_{12,t+1} = 0.95(0.0058\%) + (0.05)(0.0501)(0.0489) = 0.0177\% \]

Finally, use the resultant forecast to calculate the one-step ahead correlation coefficient (note results from b(ii) are used in the denominator):

\[ \rho_{12,t+1} = \frac{h_{12,t}}{\sqrt{h_{1,t}h_{2,t}}} \]
\[ \rho_{12,t+1} = \frac{0.0177\%}{\sqrt{0.0058\% \times 0.0093\%}} = 0.2091 \]

(d) Based on the results of your analysis, your team plans to implement the forecasting model to assess short-term capital adequacy for the annuity block.

(i) Explain how model risk could arise while calibrating and implementing the models described above.

(ii) Recommend three model validation best practices that could be incorporated to help manage and mitigate model risk. Justify your response.

Commentary on Question:
Candidates did very well on this part of the question. Most candidates were typically able to describe at least one source of model risk which could arise while calibrating and implementing the models. Furthermore, most candidates were able to recommend model validation best practices to help manage and mitigate model risk.
3. Continued

d(i)
1. Model must be assessed for appropriateness - does the chosen model (i.e. GARCH, RiskMetrics) accurately reflect the dynamics of the time series under investigation?
2. The validation of model results should be performed to assess that both inputs and outputs are accurate. Errors in input data could lead to misleading output.

d(ii)
1. Employ a robust model validation procedure that includes a review of Design Use/Fit, Design Method/Processing, Data, Assumptions, Results, and Governance.
2. Designate a Model Steward: A model steward could help to ensure modeling best practices related to documentation, validation, and governance. The role of model steward can provide a segregation of duties between the activities connected with the initial model and the subsequent activities associated with model and system updates, change control management testing, and validation of these models.
3. Fully document the model and explain the intended purpose of the models and how the user’s needs are addressed by those models.
4. **Learning Objectives:**
   1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
   2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.
   3. The candidate will understand the concept of economic capital, risk measures in capital assessment and techniques to allocate the cost of risks within business units.

**Learning Outcomes:**

1. Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

2. Demonstrate how each of the financial and non-financial risks faced by an entity can be amenable to quantitative analysis including an explanation of the advantages and disadvantages of various techniques such as Value at Risk (VaR), stochastic analysis, and scenario analysis.

3. Analyze and evaluate risk aggregation techniques, including use of correlation, integrated risk distributions and copulas.

4. Analyze and evaluate model and parameter risk.

5. Construct approaches to modeling various risks and evaluate how an entity makes decisions about techniques to model, measure and aggregate risks including but not limited to stochastic processes.

6. Propose techniques for allocating/appropriating the cost of risks/capital/hedge strategy to business units in order to gauge performance (risk adjusted performance measures).

**Sources:**

Financial Enterprise Risk Management, Sweeting, 2011, Ch. 8 Risk Identification

ERM-106-12: Economic Capital-Practical Considerations-Milliman

ERM-118-14: Model Validation Principles Applied to Risk and Capital Models in the Insurance Industry

ERM-119-14: Aggregation of risks and Allocation of Capital (Sections 4-7 Excluding 6.3)
4. Continued

Risk Aggregation for Capital Requirements Using the Copula Technique, by Song Zhang

Commentary on Question:
This question sought to test candidates on various aspects of economic capital and risk identification. Overall candidates did well on this question.

Solution:
(a) Prepare a SWOT analysis of Big Ben.

Commentary on Question:
Candidates in general did not score as well on this part of the question. The main reason for candidates not scoring well was that there was not enough written to get full credit given the number of exam points allocated to this question. For example, many candidates only provided 1-2 points within each assessment section which was insufficient to receive full credit. Another area where candidates lost points was providing solutions which were too general and did not directly relate to the case study.

Strengths:
- World leader in the ETF market
- Strong brand and loyal customer base
- Good product innovation in commercial banking (all online)
- Comprehensive list of asset management products

Weaknesses:
- Low market share in investment banking
- Asset management expenses
- Limited liquidity risk assessment
- Poor capital allocation methods

Opportunities:
- Additional demand for asset management products through commercial banking line
- Innovation for holistic wealth management products
- Creating economy of scale to lower minimum investable assets requirement

Threats:
- Competition in rapidly evolving global financial services industry
- Competition from emerging new financial technology firms with innovative technologies
- Increasing stringency of banking regulations
- Price pressure on ETF MERs
4. Continued

(b) Evaluate the following components of the economic capital model.

I. The method used to quantify each risk.
II. The capital allocation method.
III. The model governance and validation.

Commentary on Question:
Candidates generally did well on this part. Candidates received only partial credit if they described, rather than evaluated, the components for each subpart. In addition, some candidates provided recommendations even though it was not asked for; no credit was given for them.

I.

• Credit risk: The method incorporates various systematic risk factors to model dependence between borrowers. This is an important component as when modelling credit risk the interaction between credit exposures is just as important as the assessment of each individual credit exposure. There is limited information as to how the probably of default and loss given default is modelled but a Monte Carlo simulation approach is used which is appropriate for a complex risk such as credit risk. Currently a joint normal distribution is used but may want to consider a distribution with fatter tails to capture more extreme scenarios.

• Market risk: Market risk is a complex risk that requires stochastic simulation. This is currently being used and is therefore appropriate.

• Operational risk: A simple add-on approach is generally appropriate for operational risks. An alternative solution would be to model low frequency/high severity and high frequency/low severity operational risks separately by developing loss distributions.

• Strategic/Business risk: Given that these are generally high severity/low frequency events, scenario analysis is an appropriate method for quantifying this risk.
4. Continued

II. 
- Currently economic capital allocation is only performed on an ad hoc basis. Allocation should instead be done on a regular basis and used to support pricing, risk budgeting and risk adjusted performance measures.
- There are various other approaches that could be used such as: marginal approaches, pro-rate/linear approaches, game theory, etc.
- Big Ben is allocating capital to risk types which is useful for managing the types of risks accepted across the company but less useful for decision making.

III. 
- A more robust governance structure needs to be established. Currently there is no validation scheduled until the following year, this is inappropriate for a model that impacts financial results.
- Since the models impact financial reporting the model should not be used for published results until it has been validated.
- Given this is a highly complex model that impacts financial reporting there should be a robust validation process in place

(c) Big Ben asked Caerus to review the economic capital model’s risk aggregation technique to address the concern related to non-linear dependence and tail dependence among risk factors.

(i) Evaluate the current risk aggregation method.

(ii) Recommend a copula to aggregate the risks. Justify your answer.

Commentary on Question:
Candidates in general did well on subpart (i) and not as well on subpart (ii). Similar to part (a), a main reason for candidates not scoring well was that there was not enough written to get full credit given the number of exam points allocated to this question. For subpart (ii), candidates did not receive credit for simply writing down a copula without any justification. Recommending the t-Copula was not the only valid answer to this question, and recommending other copulas received credit with appropriate justification.
4. Continued

(i)

- The current method is a simple way to reflect the fact that all risks are not 100% correlated.
- However, the Correlation Matrix approach may overstate the benefits of diversification. This is because the observable correlations are assumed to apply in the tails of the risk distribution and the observable correlations may break down in these types of scenarios (e.g. correlations may increase in an extreme stress scenario).
- There is limited information as to how Big Ben calculates its correlations currently. If the correlations are calibrated to tail event this can minimize the issue but there still exists superior risk aggregation techniques.

(ii)

- Recommend the t-Copula. The t-Copula is able to incorporate tail dependence and a linear relationship is not assumed.
- This should help address the concerns that Big Ben has expressed. In addition, the t-Copula allows for a correlation matrix of the risk factors to be fed in, so the current correlation matrix can still be used.
- Lastly, the marginal distributions of individual risks can be of any form which allows for flexibility.
5. **Learning Objectives:**
1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.

2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.

5. The candidate will understand the concept of economic capital, risk measures in capital assessment and techniques to allocate the cost of risks within business units.

**Learning Outcomes:**

(1c) Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

(2h) Construct approaches to modeling various risks and evaluate how an entity makes decisions about techniques to model, measure and aggregate risks including but not limited to stochastic processes.

(5a) Describe the concepts of measures of value and capital requirements (for example, EVA, embedded value, economic capital, regulatory measures, and accounting measures) and demonstrate their uses in the risk management and corporate decision-making processes.

(5b) Define the basic elements and explain the uses of economic capital. Explain the challenges and limits of economic capital calculations and explain how economic capital may differ from external requirements of rating agencies and regulators.

(5c) Apply risk measures and demonstrate how to use them in capital assessment. Contrast regulatory, accounting, statutory and economic capital.

(5d) Propose techniques for allocating/appropriating the cost of risks/capital/hedge strategy to business units in order to gauge performance (risk adjusted performance measures).

**Sources:**
ERM-101-12: Measurement and Modeling of Dependencies in Economic Capital (Ch 3-5)

ERM-106-12: Economic Capital-Practical Considerations-Milliman

ERM-119-14: Aggregation of risks and Allocation of Capital (Sections 4-7 Excluding 6.3)
5. Continued

ERM-130-18: AAA Model Governance Practice Note

Risk Appetite: Linkage with Strategic Planning Report

Ch. 13 Liquidity Risk

Commentary on Question:
This question was intended to test different topics and questions related to Economic capital, in particular for liquidity risk and was integrated with the core case study. Overall candidates did well on this question. Most candidates struggled with part (c). Many were able to indicate some impacts, but often the causal loop was not specific to Big Ben. There was an issue with part (e) that is described in future detail under that section.

Solution:
(a) Big Ben is evaluating its current Economic Capital (EC) model and has determined that the only shortcoming is the absence of liquidity risk in the model.

(i) Identify three additional shortcomings with the current EC process followed by Big Ben.

(ii) Recommend an improvement to address each of the shortcomings you have identified in (i).

Commentary on Question:
Most candidates did well on this part. Minimal points were given if a candidate responded to sub-part (i) by only identifying three risks that weren’t specifically mentioned in the case study and recommending in sub-part (ii) only that those three risks be included.

(i)
1. EC is calculated in the Corporate Treasury Department
2. Allocation of the economic capital to the business divisions is done based on simple rules of thumb and is only done upon request
3. Diversification Benefit methodology – they use var-covar but state that correlations are difficult to obtain.
5. **Continued**

(ii)

1. EC should be done in an area that understand the EC model and all of the components. ERM would be a better area for this.
2. The allocation of capital should be based on the return on the capital for each division.
3. Determine a way to effectively calculate the correlations, or switch to a copula or other method, casual modelling

(b) A recent FSA assigned to the task of evaluating Big Ben's liquidity risk has made the following report.

- The company is positioned well to handle all liquidity needs for the next six months
- Big Ben should obtain a letter of credit with another financial institution
- Big Ben should limit the types of assets to those in which the investing team has strong expertise. This would reduce the number of asset classes invested in by 50%

Critique each of these statements.

**Commentary on Question:**

Candidates did poorly on this part, often commenting on the structure of the statement instead of the content in the statement. For example, candidates would comment only that the company should look at more than just the next six months for liquidity, instead of evaluating the actual liquidity position of the company over the next six months. Minimal credit was awarded for candidates who didn’t critique the statements, which should include why the statement was valid or not.

- Based on Exhibit B, the company is NOT positioned well to handle the liquidity needs for the next 6 months
  - Exhibit B shows total liabilities over next 6 months = 34,728
    - (28,285+2,161+4,282) is greater than the assets = 31,181 (27,786 + 1,825 + 2,205)
- Yes, obtaining a letter of credit would be relevant. They have a liquidity issue. Having a LOC would allow Big Ben to get credit needed. Although obtaining a LOC would also create counterparty risk.
5. Continued

• Big Ben should not limit their assets to those they have expertise in. Limiting
  the types of assets, would increase the amount of each asset they have, which
  could lead to
  o Difficulty selling because you only have limited types of assets to sell.
  o The price of the asset could be impacted because of the amount you are try
    need to sell
  o The assets you have left could be highly correlated and cause credit issues.

(c) A CERA in the ERM department states that a causal loop should be drawn to
identify the impacts of the following liquidity-related events on the solvency of
the bank.

• Increase in the cost of letters of credit
• Thinning of the real estate market
• Increase in mortgage prepayment rates
• Financial markets deepening
• Negative regulatory review
• Increase in interest rates
• Asset/liability mismatch increasing

Develop a causal loop for Big Ben failure indicating the type of relationship (“+”
for a positive feedback / “-” for a negative feedback).

Commentary on Question:
Candidates did poorly on this section.
• Most candidates showed a relationship only between two events, and not
  recognizing that one event could impact multiple events.
• Most candidates didn’t include “Bank Failure due to Liquidity” or “Solvency
  of Big Ben” as an event.
• Many candidates indicated overall market relationships, and not the impact of
  the event specific for Big Ben.

Credit could be earned if the candidate described the impacts without drawing the
actual loop.

Increase in cost of Letters of Credit
• Positively correlated with Bank Failure. Can have an impact on the solvency of
  the bank as in part (b) it specifically says they are considering obtaining a LOC

Thinning of the Real Estate Market
• Does not impact any of the others as they don’t have much real estate
5. Continued

**Increase in Mortgage Prepayment Rates**
- Negatively correlated with Bank Failure due to liquidity, as it brings in more cash

**Financial Market deepening**
- This term is used in chapter 13 of Jorian
- Negatively correlated with Increase in cost for LOC, as it could provide alternative for LOC
- Negatively correlated with Bank failure as it would be easier to sell our assets

**Negative Regulatory Review**
- Positively correlated with Increase in cost of LOC (specifically for Big Ben)
- Positively correlated with Bank Failure, but NOT directly with Bank Failure due to liquidity
- Positively correlated with Increase in Interest Rates (specifically for Big Ben liabilities)

**Increase in Interest Rates**
- Negatively correlated with Increase in Mortgage Prepayment Rates
- Positively correlated with Asset/Liability Mismatch

**Asset/Liability Mismatch**
- Positively correlated with Increase in Interest Rates
- Positively correlated with Negative Regulatory Review
5. Continued

Drawing is below
Green lines indicate (+) positive, red lines indicate (-) negative.

(d) A new liquidity risk model for EC is created that calculates the required capital for this risk independently for each line of business. The quantile used for the VaR calculation is 99.5%.

The results of the model are shown in the table below.

<table>
<thead>
<tr>
<th>Economic Capital Required</th>
<th>Asset Management</th>
<th>Commercial Banking</th>
<th>Investment Banking</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidity Risk</td>
<td>40</td>
<td>70</td>
<td>20</td>
<td>130</td>
</tr>
<tr>
<td>Revised Diversification Benefit</td>
<td>-110</td>
<td>-68</td>
<td>-46</td>
<td>-224</td>
</tr>
</tbody>
</table>

Assess if Big Ben still satisfies its capital adequacy objective globally and by line of business compared to its existing situation as shown in Exhibit C, table III of the Case Study. Show all work.

Commentary on Question:
Most candidates did very well on this section. Partial credit could be earned if the candidate didn’t have the correct result but provided a formula and demonstrated accurate use of that formula.
Big Ben is able to satisfy the capital adequacy objective of 140% globally and for Asset Management and Investment Banking, but not for Commercial Banking.

(e) The following table shows the long-term expected risk-adjusted return and updated EC for each business unit after one year. The available capital for each business unit has not changed.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Asset Management</th>
<th>Commercial Banking</th>
<th>Investment Banking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk-Adjusted Return</td>
<td>70</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Total Required EC</td>
<td>530</td>
<td>300</td>
<td>220</td>
</tr>
</tbody>
</table>

(i) Calculate the RAROC and RARORAC for each line of business. Show all work.

(ii) Evaluate the performance of each of the business units relative to the other units based on the results of (i).
5. Continued

(iii) Evaluate the four future expansion plans for Big Ben outlined in the Case Study based on the results of (i).

Commentary on Question:
Candidates provided feedback immediately after the exam that RARORAC was removed from the syllabus prior to this exam sitting. This immediate feedback was appreciated, and the grading of this part was adjusted to reflect this. As a result, most candidates received full or nearly full credit for this section.

(i) RARORAC isn't part of the syllabus for Fall 2019.
In the Risk Appetite: Linkage with Strategic Planning Report source doc it states that RAROC can be defined different ways including reflecting actual capital or required capital.
All candidates will get full credit if RAROC is calculated using either definition.

(ii) Full credit was awarded to all candidates as long as a response was provided.

(iii) Full credit was awarded to all candidates as long as a response was provided based on their analysis in part (i), and the responses reflected the future expansion plans outlined in the Case Study.

(i)
RAROC = risk adjusted return / capital
RARORAC = risk adjusted return / required capital

<table>
<thead>
<tr>
<th></th>
<th>Asset management</th>
<th>Commercial</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Adjusted Return</td>
<td>70</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Required capital</td>
<td>530</td>
<td>300</td>
<td>220</td>
</tr>
<tr>
<td>Available Capital</td>
<td>778</td>
<td>466</td>
<td>311</td>
</tr>
<tr>
<td>RAROC</td>
<td><strong>9.00%</strong></td>
<td><strong>8.58%</strong></td>
<td><strong>6.43%</strong></td>
</tr>
<tr>
<td>RARORAC</td>
<td><strong>13.21%</strong></td>
<td><strong>13.33%</strong></td>
<td><strong>9.09%</strong></td>
</tr>
</tbody>
</table>

(ii)
Based on RAROC, not taking into account the cost of capital for extreme risks associated with a line of business, Asset management would be the most profitable.
5. Continued

However, from an internal asset allocation purpose, RARORAC is showing us that the Commercial Banking is the best performer, contributing more per dollar of capital allocated to take into account underlying risks associated with that line of business. Investment is the least profitable on both measures.

(iii)
- Investment banking expansion should definitively not be envisioned as it destroys value from both measures.
- Big Ben is a leader in Asset management. It may want to continue to invest in that line of business, both returns are positive and high.
- Regardless of the result, Commercial Banking will need to be reevaluated, if they wish to undertake this in a few years.
- Expansion of Private banking clients - ex. lowering investable assets - would have to be evaluated separately from the commercial banking return calculation. Difficult to assess from limited and overall calculations from commercial banking.
6. **Learning Objectives:**

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.

3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

**Learning Outcomes:**

(1b) Explain risk taxonomy and its application to different frameworks.

(1c) Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

(3a) Apply and construct risk metrics to quantify major types of risk exposure such as market risk, credit risk, liquidity risk, regulatory risk, etc., and tolerances in the context of an integrated risk management process.

(3b) Analyze and evaluate the properties of risk measures (e.g., Delta, volatility, duration, VaR, TVaR, etc.) and their limitations.

(4a) Demonstrate and analyze applicability of risk optimization techniques and the impact of an ERM strategy on an organization’s value. Analyze the risk and return trade-offs that result from changes in the organization’s risk profile.

(4e) Develop an appropriate choice of a risk mitigation strategy for a given situation (e.g., reinsurance, derivatives, financial contracting), which balances benefits with inherent costs, including exposure to credit risk, basis risk, moral hazard and other risks.

(4h) Analyze funding and portfolio management strategies to control equity and interest rate risk, including key rate risks. Contrast the various risk measures and be able to apply these risk measures to various entities. Explain the concepts of immunization including modern refinements and practical limitations.
6. Continued

(4i) Analyze the application of Asset Liability Management and Liability Driven Investment principles to Investment Policy and Asset Allocation.

(4j) Demonstrate risk management strategies for other key risks (for example, operational, strategic, legal, and insurance risks).

Sources:
Value at Risk, Jorion, Chapter 17, VAR and Risk Budgeting in Investment Management (excluding 17.3 and 17.4) (INV)

ERM-330-17: Barton Waring Liability-Relative Investing I (INV)

ERM-613-17: Managing Investment Portfolios, Maginn and Tuttle 3rd Edition, Chapter 6, Sections 4-5, pp. 346-385 (INV)

An Asset-Liability Version of the Capital Asset Pricing Model with a Multi-Period Two-Fund Theorem; Barton Waring and Duane Whitney (INV)

Commentary on Question:
This question tested several concepts related to the funding and asset allocation of pension plans. The mathematical portions of the question were typically done well when read correctly. Candidates had more trouble with applying the COLA concept to the given pension plan.

Solution:
(a)

(i) Demonstrate that the current portfolio is not a minimum surplus variance portfolio.

(ii) Construct a portfolio by modifying the bond and equity mix which minimizes the surplus variance. Assume bond and equity betas remain the same.

Commentary on Question:
Some candidates produced different answers to sub-part (ii) due to rounding differences. Full credit was given as long as candidates showed their work.

(i) To minimize surplus variance, \( \beta(\text{asset}) = \frac{\text{Liability/Asset} \times \beta(\text{Liability})}{\text{Total Asset}} \)

Minimum \( \beta(\text{asset}) = \frac{900}{700} \times 1.1 = 1.41 \)

Current \( \beta(\text{asset}) = \frac{(\beta(\text{Bond}) \times \text{Bond} + \beta(\text{Equity}) \times \text{Equity})}{\text{Total Asset}} = 1.26 \)
6. Continued

Since the minimum $\beta$ (asset) is not equal to the current $\beta$(asset), this is not a minimum surplus variance portfolio.

(ii) Need to solve for Bond and Equity from the following equations:

\[
\begin{align*}
(1) \quad (\beta(Bond) \times Bond + \beta(Equity) \times Equity)/\text{Total Asset} &= 1.41 \\
(2) \quad Bond + Equity &= \text{Total Asset}
\end{align*}
\]

\[
\begin{align*}
(1) \quad (0.9 \times Bond + 1.5 \times Equity)/700 &= 1.41 \\
(2) \quad Bond + Equity &= 700
\end{align*}
\]

Bond = 100 and Equity = 600

(b) Compare the dual duration approach and the single duration approach.

The single-duration approach uses a nominal duration to manage the nominal interest rate risk.

On the other hand, the dual duration approach uses both the real interest duration as well as the inflation duration to manage both the real interest rate risk and the inflation rate risk.

If the liability provides the full protection against the inflation and liability will have a close to zero inflation duration. It is not necessary to take the dual duration approach to measure the liability.

(c) Evaluate the consultant’s suggestion that adopting a dual duration approach is appropriate when adding a COLA to the plan.

Commentary on Question:

Many candidates incorrectly stated that COLA added inflation risk to the pension plan and thus the dual duration approach should be used. This response did not receive credit.

The liability provides the full protection against the inflation. It is not necessary to take the dual duration approach to measure the liability. Moreover, it will cost more than the single duration approach.

(d) Recommend one duration matching approach for SLIC’s current pension plan. Justify your answer.
6. Continued

**Commentary on Question:**

*Similar to part (c), candidates would mix up the need for single and dual duration in the COLA environment. The question also referred to the current pension plan, which did not include COLA, while many candidates continued with the pension plan including COLA from part (c).*

I would recommend the dual duration approach. Since SLIC’s current plan is a non-COLA pension plan that does not provide the full protection against the inflation, it is recommended to separate the real duration and the inflation duration from the single nominal duration to hedge the real interest rate risk and the inflation rate risk more effectively.

However, the approach should be carefully analyzed to determine if the dual duration approach brings enough benefit to justify the higher cost.

(e) Assume a 10% equity allocation.

Construct the liability relative risk-free portfolio for the illustrative plan based on the dual duration matching approach. Show your work.

**Commentary on Question:**

*While this question was typically answered well, one common source of error was in attempting to answer the question based on the pension details at the beginning of the question rather than using the illustrative plan given prior to part (e).*

Since we know the plan is 100% funded and the allocation of equities is 10% and the inflation duration of TIPS is 0, we can set up an equation which has the weight of nominal bonds as the only unknown.

\[
D(\text{Inflation Liabilities}) = w(\text{Nominal Bonds}) \times D(\text{Inflation Nominal Bonds}) + w(\text{TIPS}) \times D(\text{Inflation TIPS}) + w(\text{Equities}) \times D(\text{Inflation Equities})
\]

\[
6 = w(\text{Nominal Bonds}) \times 8 + w(\text{TIPS}) \times 0 + w(\text{Equities}) \times 4
\]

This gives \(w(\text{Nominal Bonds}) = 0.7\), and since the total allocation must add to 1 we have the following solution:

\[
W(\text{Nominal Bonds}) = 0.7, \quad w(\text{TIPS}) = 0.2, \quad w(\text{Equities}) = 0.1
\]
7. **Learning Objectives:**

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.

2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.

3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

**Learning Outcomes:**

(1a) Explain risk concepts and be able to apply risk definitions to different entities.

(1c) Identify and assess the potential impact of risks faced by an entity, including but not limited to market risk, currency risk, credit risk, counterparty risk, spread risk, liquidity risk, interest rate risk, equity risk, hazard/insurance risk, inflationary risk, environmental risk, pricing risk, product risk, operational risk, project risk and strategic risk.

(2a) Demonstrate how each of the financial and non-financial risks faced by an entity can be amenable to quantitative analysis including an explanation of the advantages and disadvantages of various techniques such as Value at Risk (VaR), stochastic analysis, and scenario analysis.

(2b) Evaluate how risks are correlated, and give examples of risks that are positively correlated and risks that are negatively correlated.

(2c) Analyze and evaluate risk aggregation techniques, including use of correlation, integrated risk distributions and copulas.

(2f) Analyze the importance of tails of distributions, tail correlations, and low frequency/high severity events.

(3a) Apply and construct risk metrics to quantify major types of risk exposure such as market risk, credit risk, liquidity risk, regulatory risk, etc., and tolerances in the context of an integrated risk management process.

(3b) Analyze and evaluate the properties of risk measures (e.g., Delta, volatility, duration, VaR, TVaR, etc.) and their limitations.

(3c) Analyze quantitative financial data and insurance data (including asset prices, credit spreads and defaults, interest rates, incidence, causes and losses) using modern statistical methods. Construct measures from the data and contrast the methods with respect to scope, coverage and application.
7. Continued

(4a) Demonstrate and analyze applicability of risk optimization techniques and the impact of an ERM strategy on an organization’s value. Analyze the risk and return trade-offs that result from changes in the organization’s risk profile.

(4d) Demonstrate how derivatives, synthetic securities, and financial contracting may be used to reduce risk or to assign it to the party most able to bear it.

(4e) Develop an appropriate choice of a risk mitigation strategy for a given situation (e.g., reinsurance, derivatives, financial contracting), which balances benefits with inherent costs, including exposure to credit risk, basis risk, moral hazard and other risks.

Sources:
The devil is in the tails: actuarial mathematics and the subprime mortgage crisis; Catherine Donnelly and Paul Embrechts

ERM-613-17: Managing Investment Portfolios, Maginn and Tuttle 3rd Edition, Chapter 6, Sections 4-5, pp. 346-385

Commentary on Question:
This question tests the candidates’ understanding of securitization structures, financing, and payouts in different scenarios, as well as applying concepts of duration and hedging. Candidates generally performed better in parts (a), (b) and (c).

Solution:
(a) Sketch a diagram showing all parties to the deal, as well as the cash flows among the different parties.

Commentary on Question:
Candidates needed to include all elements of the chart below in order to score full credit. Candidates who included an SPV in the diagram only scored partial credit, since the question stem did not include an SPV structure. A combination of diagrams, or bullet points, were also awarded full credit as long as candidates demonstrated a full understanding of the securitization structures.
7. Continued

(b) Describe the risk-reward profile for each tranche.

**Commentary on Question:**
*Most candidates received full credit for this part.*

Tranche T1 is the senior tranche and has the lowest risk/reward. Coupons are the lowest of the tranches. It has the lowest risk since 20% of principal would have to be lost before T1 suffers losses.

Tranche T2 is the mezzanine tranche, with medium risk/reward. This tranche has higher risk than T1 since only 5% of principal would have to be lost before the tranche suffers from losses. This tranche has higher coupons than tranche T1 to compensate for the additional risk.

Tranche E is the equity tranche with the highest risk/reward. This is the first tranche to absorb losses and is compensated with a very high reward (all residual yields) to make up for the risk.

(c) Critique Big Ben’s assumptions in modeling the occurrence of natural disasters.

**Commentary on Question:**
*Most candidates did well on this part. Only 3 observations needed to be provided to earn full credit. The list below is not exhaustive.*

- The use of the Binomial distribution is inappropriate because it underestimates tail risk.
- Assuming only 1 occurrence may be unrealistic, as extreme events may have multiple occurrences.
- Assuming the probability of disasters is independent and identically distributed may be unrealistic.

(d) Calculate the total payments to Tranche E for each of the next 5 years. Show your work.

**Commentary on Question:**
*Few candidates did well on this part. Candidates needed to correctly calculate the amount paid out to tranche E each year in order to earn full credits. Many candidates correctly identified the first year’s payment to tranche E but could not calculate the payments made to E after the principal is lost. Candidates who assumed the principal reduction occurred at the beginning of year 2 instead of at the end of year 2 also received full credit.*
7. Continued

Total payments to Tranche E = 680 + 680 + 620 + 620 + 620 = 3,220

(e) Calculate the dollar duration of the Corporate portfolio of SLIC after adding Tranche T1. Show your work.

**Commentary on Question:**
Many candidates performed poorly on this part. Some candidates used the entire SLIC portfolio Market Value instead of just the Corporate portfolio and thus did not receive full credit. Candidates should note that there is a discrepancy between the solution and the source material (Managing Investment Portfolios, Maginn and Tuttle 3rd Edition, Chapter 6), which incorrectly states that the dollar duration for a portfolio is the weighted average of the dollar durations of the components. Instead, the dollar duration of the portfolio should be the sum of the dollar durations. Using the weighted average method as well as the sum method both were eligible to receive full credit.

Dollar duration of the Corporate portfolio = \( \frac{226 \times 4.82}{100} = 10.89 \text{M} \)
Dollar duration of tranche T1 = \( \frac{8.5 \times 5.76}{100} = 0.49 \text{M} \)
Dollar duration of the portfolio adding tranche T1 = \( 10.89 + 0.49 = 11.38 \text{M} \)

Alternatively, using the weighted average method:
Dollar duration of the portfolio adding tranche T1 = \( \frac{226}{226+8.5} \times 10.8932 + \frac{8.5}{226+8.5} \times 0.4896 = 10.52 \text{M} \)

(f) Calculate the number of futures contracts needed to remain compliant with SLIC’s market risk policy. Show your work.

**Commentary on Question:**
Candidates who were able to recall the correct formula did well on this part. A few candidates confused the sign of the number of contracts and incorrectly stated that futures contracts needed to be bought instead of shorted. Credits were awarded to candidates who used either the sum method or weighted average method from part (e).
7. Continued

Dollar duration of each futures contract = \( \frac{8.87}{100} = 0.00887 \text{M} \)
Number of futures contracts to be bought = \( \frac{(10.89 - 11.38)}{0.00887} = -55.2 \)
Short 55 contracts.

Alternatively, if using the weighted average method in part (e):
Number of futures contracts to be bought = \( \frac{(10.8932 - 10.5161)}{0.00887} = 42.51 \)
Buy 43 contracts.

(g) Recommend whether SLIC should approve Hawke’s proposal to purchase Tranche T1. Justify your recommendation.

Commentary on Question:

either recommending or not recommending is acceptable with reasonable justification. Candidates only needed to provide 3 non-overlapping justifications to earn full credit. Other reasonable remarks outside of the list below will also earn credit.

Recommend because:

- This is similar to a cat bond with low correlation to financial markets.
- This will diversify the portfolio.
- The asset has attractive yields compared to traditional asset classes.

Do not recommend because:

- This security will expose SLIC to catastrophic risk.
- SLIC needs to evaluate the tail risk further as the probability of loss to the senior tranche may be higher than assumed.
- There is no guarantee that crop yields will return 12% per year.