QFI IRM Model Solutions
Spring 2024

1. Learning Objectives:

1. The candidate will understand and be able to identify and describe types of risk present in investment management.

5. The candidate will understand the importance of risk culture and governance.

Learning Outcomes:

(1a) Identify and describe the various kinds of risks, including strategic, market, credit, operational, liquidity etc.

(1d) Identify environmental, social and governance (ESG) risks and explain how they factor into investment management.

(5e) Understand and apply the lessons learned from risk management failures.

Sources:

Financial Enterprise Risk Management, Sweeting, Paul - Ch. 8: Risk Identification

QFI-131-24: Chapter 1 Introduction to ESG (CFA Society UK) (pages 3-36)

Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 - Ch. 2: Risk Taxonomy

Commentary on Question:

Part (a) of this question tests candidates' ability to identify risks inherent in a company's operations and knowledge of how incorporating ESG factors in investment decision making can mitigate risks. To receive full credit, candidates needed to address all the risks listed and then provide support for their explanations based on the information provided about the company.

The second part of this question (b) tests candidates' understanding of ESG factor definitions and their ability to apply it to a situation. To receive full credit, candidates needed to classify the company's activities under the correct factors and then justify their choices based on the definitions of each ESG factor.

1. **Continued**

Solution:
(a)

    (i)   Explain how each key risk applies to DEF.

    (ii)   Explain how incorporating ESG factors into the investment decision making can mitigate each key risk.

Commentary on Question:
Candidates generally performed well on part (i). Most were able to explain how each of the key risks tie to the pieces of information provided about the company.

For part (ii), candidate performance was mixed. Many candidates only made general statements or did not provide sufficient support explaining how considering ESG factors in the investment process specifically addresses each of the risks based on the information provided about the company.

For question (i):
- Regulatory – The potential new law that could be passed may result in fines that would have adverse impacts on the company's total cash flow.
- Reputational – Consumer activities that focus on the company's investment activity the company's reputation may also be brought to attention. Poor investment decisions or investments in unethical industries could result in negative press, for example.
- Market – The company's investment activity subjects it to market risk, or the risk that the value of it's securities declines due to changes to the creditworthiness of the companies it had invested in.
- Environmental – Pandemic risk is a form of environmental risk, as it has significant impacts on how the company interacts with the environment. As the company writes life insurance a pandemic can have direct impacts operating cash flows, in addition to secondary disruptions on other operations.

For question (ii):
- Regulatory – By practicing responsible investing, the company can stay ahead of potential ESG disclosure laws and reduce the risk of having to pay any fines or changing its practices.
- Reputational – As consumers and other stakeholders are becoming increasingly aware of ESG practices, they increasingly require transparency on how their money is being invested. Considering ESG factors in investment decision making reduces the risk that investment practices get called into question for being unethical.
- Market – Incorporating ESG factors investment concerns helps to price in the impacts of social and environmental factors, which may help to lower volatility and improve long-term returns on securities.

1. Continued

- Environmental – Pandemic risk is a form of environmental risk as it has significant impacts on how the company interacts with the environment. The company writes life insurance and is exposed to mortality risk. Therefore, a pandemic can have direct impacts operating cash flows, in addition to secondary disruptions on other operations.

(b) Identify, from ABC's daily operations and corporate practices, two activities that it performs in each of the following categories: environmental, social, and governance.

Commentary on Question:
Overall, candidates performed well on this question. Most candidates were able to correctly classify all or almost all the operational activities. A common error was to categorize the activities of government affairs as a social factor and expansion of the workforce as a governance factor.

Environmental – factors that relate to the natural world:
- Searching for new drilling locations - Prospecting drilling locations involves deforestation, which is a direct interaction with the natural world. This activity will affect local ecosystems and biodiversity.
- Operating machinery - Operating oil rigs requires the use of natural gas. This activity will deplete a non-renewable resource.

Social – factors that impact the lives of humans:
- Hiring staff - Company hiring practices determine the employee and work environment, which directly relates to working conditions.
- Safety inspections - Ensuring that company equipment is functioning safely and correctly is necessary to creating safe working conditions, which directly impacts employee well-being.

Governance – factors that relate to issues regarding business practices and interests of broader stakeholder groups:
- Board elections - Shareholders elect the board of directors and are thereby given a say in the structure and make-up of the company's governing body. This will influence how the company makes business related decisions.
- Government lobbying - Through lobbying, the company can influence legislation and regulations around the industry. This will impact business practices and competition within the industry.

2. **Learning Objectives:**
1. The candidate will understand and be able to identify and describe types of risk present in investment management.

Learning Outcomes:
(1a) Identify and describe the various kinds of risks, including strategic, market, credit, operational, liquidity etc.

(1c) Identify behavioral risks and explain how they factor into investment management.

Sources:
Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 Ch. 2: Risk Taxonomy

Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 Ch. 19: Behavioural Risk Management

Commentary on Question:
Overall, candidates performed well on this question. Most candidates were successful in identifying risks and suggesting strategies to mitigate them. Some candidates struggled to connect specific aspects of groupthink and ways to prevent them to the specific example presented.

Solution:
(a) You have identified the following risks for XYZ:

- Stock Market Risk
- Interest Rate Risk
- Default Risk
- Liquidity Risk

Explain how each risk applies to XYZ.

Commentary on Question:
Overall, candidates did well on this question. Most candidates provided a specific example tied to the products sold and investment strategy used. Candidates who did not receive full credit often provided unrelated risks or incorrectly applied the risks identified.

- Stock Market Risk – XYZ is exposed to this risk due to its equity-linked universal life product design which will cause its liabilities to move directly with equity markets.
- Interest Rate Risk – XYZ is exposed to this interest rate risk due to its heavy investments in a bond portfolio

2. **Continued**

- Default Risk – XYZ is exposed to default risk due to the risk that reinsurer ABC could default or that its MBS and other investments could default
- Liquidity Risk – XYZ is exposed to liquidity risk because its long-term bonds may not be sufficiently liquid to meet short-term claims

(b)   Recommend one mitigating action for each of the risks identified in part (a).

Commentary on Question:
Overall, candidates did well on this question. Most candidates provided a mitigating strategy clearly connected to the risk identified in the first part.

- Stock Market Risk – purchase hedging instruments to match the credits
- Interest Rate Risk – duration match the bond portfolio to the expected liabilities
- Default Risk – purchase credit swaps on ABC
- Liquidity Risk – purchase high quality assets that will have higher liquidity

(c)   Explain how each of the following aspects of groupthink may be affecting the investment team:

- Mind-guards
- Self-censoring
- Collective rationalization

Commentary on Question:
Candidates performed poorly on this question. Many candidates only provided general comments on groupthink or incorrectly applied the requested aspects.

- Mind-guards – Due to the observed high degree of conformity on ideas, mind-guards are likely preventing dissent to the manager's opinions after the manager approves.
- Self-censoring – With one much more experienced team member, newer members may assume their concerns are incorrect and so not speak up
- Collective rationalization – Due to a history of success, the group is more likely to rationalize future decisions based on their previous collective success.

(d)   Recommend three strategies that could reduce groupthink in the team decision-making process.

2. **Continued**

Commentary on Question:
Candidates had mixed performance on this question. Successful candidates identified specific strategies and explained why these recommendations applied to XYZ. Less successful candidates only provided general strategies without connecting them to XYZ.

- Use the devil's advocate system – As most decisions are made unanimously, use of the devil's advocate system will ensure robust discussion
- Promote diversity – By increasing diversity of age and education, the committee can ensure broader coverage of perspectives
- Have group members evaluate ideas individually and in advance – By requiring independent evaluation, the group members will not be as influenced by the most experienced member

3.   **Learning Objectives:**
2.   The candidate will understand and be able to apply different approaches to measuring and assessing risk exposures.

Learning Outcomes:
(2d)   Understand the difference between real world and risk neutral processes and select appropriate market risk models.

(2f)   Apply different techniques of assessing rare event risks, including stress testing and scenario analysis.

Sources:
Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 – Ch. 8: Market Risk Models

Investment Risk Management, Baker, Kent and Filbeck, Greg, 2015 – Ch. 8: Liquidity Risk

Commentary on Question:
This question tested candidates' understanding of market risk and liquidity risk models along with their practical applications. Candidates generally had better understanding of market risk models compared to liquidity risk models; few showed strong understanding of the latter.

Solution:
(a)
(i)   Estimate the monthly mean log-return, $\hat{\mu}$, and monthly volatility, $\hat{\sigma}$, from the provided data.

IJK's current share price is $35.

(ii)   Calculate the probability that IJK's share price is above $40 in 6 months.

Commentary on Question:
Candidates performed as expected on this question. Candidates are reminded to show their calculation steps to receive partial credits.

For part i) the mean and monthly volatility are calculated as follows. Note that both the population and sample volatility were accepted.

$$\hat{\mu} = \hat{x}$$
$$= \frac{ln\left(\frac{39}{50}\right) + \cdots + ln\left(\frac{40}{39}\right)}{11}$$
$$= -0.02029$$

3. **Continued**

$$\hat{\sigma} = \sqrt{\frac{(\ln\left(\frac{39}{50}\right) - -0.02029)^2 + \cdots + (\ln\left(\frac{40}{39}\right) - -0.02029)^2}{11}}$$
$$= 0.15798$$

For part ii), the starting stock price of $35 provided in the question must be used.
$S_6 = \$40$
$S_0 = \$35$

Scaling to 6 months,
$\hat{\mu} = 6 * -0.02029 = -0.12171$
$\hat{\sigma} = sqrt(6) * 0.15798 = 0.38697$

$$\frac{S_6}{S_0} \sim logN(-0.12171, 0.38697)$$

$$\Pr(S > 0.4) = 1 - \Pr\left(Z < \frac{(\ln\left(\frac{40}{35}\right) - -0.12171)}{0.38697}\right)$$
$$= 0.254755$$

(b)

    (i)   Describe the shortcomings of the ILN model.

    (ii)   Recommend an alternative model to address the ILN model's shortcomings.

Commentary on Question:
Candidates performed above average on this question, with most able to describe the shortcomings and propose an alternative model. For part i), at least three shortcomings were needed to receive full credits. Candidates that listed and did not describe the shortcomings, or justify their choice of model, received only partial credits.

For part i),
The ILN does not capture important behaviors of stock price movements:
1. Volatility under ILN is constant, while it's observed that volatility is **random** (changes over time) and **tends to cluster** (if volatility is high today, it's more likely for it to be high tomorrow and vice versa).
2. The log-returns are assumed to be **independent** over each non-overlapping period, while in reality when **the absolute value of the log-return is high, it is more likely to be negative than positive**. That is, stocks are more likely to fall in value quickly, but recover more slowly, than they are to jump up in value.

3. Continued

    3. The log-returns are **assumed to be symmetric about the mean**, so jumps up are just as likely as jumps down. However, **negative spikes are more common than positive**, and the **negative spikes are more extreme than the positive**. Furthermore, when a large positive return is recorded, it almost always follows a large negative return, so is part of a recovery from an event.

    4. There is no **leverage effect**. The leverage effect means that **high volatility is associated with crash type events**, and with the immediate recovery period following a crash, while rising markets tend to be associated with periods of lower volatility. When volatility does move from low to high, it is far more likely to be precipitated by a sudden drop in prices (a negative return) than by a sudden increase in prices

For part ii),
Recommend either the GARCH model or Regime Switching model. Variants of these models were also accepted.

GARCH
- Incorporates stochastic (random) volatility
- Incorporates volatility clustering
- However, no mechanism to incorporate the leverage effect. Some variations on the GARCH model address this
- Not scalable, i.e. if we generate daily returns following a GARCH process, and observe the resulting weekly returns, we are observing the sum of dependent random variables, with no simple analytic form for the variance or the distribution
- The GARCH model is flexible, and is used in a wide range of short and long term settings
- Fatter tailed than the ILN model

or

Regime Switching model
- like the GARCH model, the regime switching model allows sudden jumps in volatility.
- Volatility switches suddenly from high to low. The swift change from low to high volatility, and from high to low volatility in the RS model is more consistent with markets, where sudden upward jumps in volatility are common, and a few market influencers switching from selling to buying can create sudden downward volatility shifts.
- Relatively easy to use especially in Monte Carlo simulations

3.   **Continued**

- Fatter tailed than the ILN model
- Needs more data for an adequate fit, and would be used for longer time horizons (need more than one year of data if decide on this model)

(c)

(i)   Calculate the monthly ILLIQ of IJK's shares and STU's shares over the last 12 months.

(ii)   Assess the liquidity of IJK compared to STU under the ILLIQ measure from (i).

(iii)   Describe four sources of illiquidity.

Commentary on Question:
Candidates performed as expected on this question. Few candidates were successful in calculating the ILLIQ measures over the past year. Full credits were awarded for part ii) if the interpretation was correct, even if the values from part i) were incorrect. Candidates that listed and did not describe the sources of illiquidity received only partial credits.

For part i),

$$ILLIQ_{ABC,t} = \frac{|R_{ABC,t}|}{P_{ABC,t} * Q_{ABC,t}}$$

Over a year, it is the averaged monthly ILLIQ ratios.

$$ILLIQ_{ABC} = \frac{\frac{\left|\frac{\$39}{\$50} - 1\right|}{\$39 * 7} + \cdots + \frac{\left|\frac{\$40}{\$39} - 1\right|}{\$40 * 4}}{11}$$
$$= 0.000639$$

$$ILLIQ_{DEF} = \frac{\frac{\left|\frac{\$43}{\$50} - 1\right|}{\$43 * 8} + \cdots + \frac{\left|\frac{\$21}{\$19} - 1\right|}{\$21 * 4}}{11}$$
$$= 0.000802$$

For part ii), since the Amihud illiquidity ratio for ABC < DEF, ABC shares are less illiquid than DEF. Assets with higher illiquidity may involve greater execution risk, as the price impact of trading can be substantial.

3. Continued

For part iii), the four sources of illiquidity are:

1. **Search costs**. When finding a counterparty to execute a trade requires time, an investor may be forced to make price concessions to facilitate and expedite the transaction. Thus, search costs induce the uncertainty about the price needed to complete the trade. Search costs are prevalent especially in over-the-counter (OTC) markets.

2. **Exogenous trading costs**. These costs are associated with executing a trade and include broker commissions, exchange fees, transaction taxes, and remuneration for setting up a trading system.

3. **Inventory risk for the market maker**. When a counterparty is unavailable to complete a sell transaction, an investor may have to sell to a market maker who then needs to carry inventory. Accordingly, the market maker bears inventory risk that is compensated by the bid-ask spread.

4. **Private information**. Uninformed investors face information risk when trading with informed traders. Hence, the informed party requires compensation in the form of the bid-ask spread in the case of the market maker as a protection against potential losses that can occur when trading against an informed counterparty. Easley and O'Hara (2004) develop a rational expectations model with asymmetric information and show that adverse selection generated by private information leads to equilibrium differences in asset returns. Specifically, in a finite economy, uninformed investors demand a premium for holding shares in firms with greater private information and less public information.

(d)   Compare and contrast the ILLIQ and the Hui and Heubel (HH) liquidity index.

Commentary on Question:
Candidates performed poorly on this question. Candidates needed to identify that both were volume-based measures and provide at least three valid comparison points (that are not just pointing out differences in the formulas) for full credit.

Both the Amihud illiquidity ratio (ILLIQ) measure and the Hui and Heubel (HH) liquidity index are volume-based measures. The basic idea behind volume-based measures is that they link the volume of an asset to its price and try to capture the depth dimension of liquidity. The intuition is that more actively traded assets tend to be more liquid.

The main advantage of the trade volume measure is that it is simple and easy to obtain given the widespread availability of volume data. However, volume is also correlated to volatility, which can impede liquidity. As volume-based measures, both ILLIQ and HH share the same shortcoming of not differentiating between price changes due to anticipated versus unanticipated trade volume.

3. **Continued**

The HH index also has a major shortcoming that is the fact that a 5-day period is long enough to allow for stock prices to adjust to the illiquidity problem.

The ILLIQ measure is more flexible as it can be measured over any period of days, and can also be averaged over a month (year) to get the monthly (yearly) liquidity measure. ILLIQ is designed to capture the price impact of trades that characterizes liquidity depth and resilience.

4.

Learning Objectives:
2.   The candidate will understand and be able to apply different approaches to measuring and assessing risk exposures.

Learning Outcomes:
(2b)   Explain how different approaches and tests form a set of complementary investment risk metrics.

(2c)   Analyze and evaluate the use and misuse of correlation, integrated risk distributions and copulas.

(2e)   Understand, evaluate, and apply credit risk models.

Sources:
Credit Risk Modeling, Bolder, David, 2018, Chapter 1-4

Investment Risk Management, Baker, Kent and Filbeck, Greg, 2015, Chapter 8

Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 Ch. 6: Copulas

Commentary on Question:
This question tests candidates' knowledge on evaluating and applying credit risks model. To receive full credit, candidates needed to provide support for their analysis.

Solution:
(a)   Describe two reasons why default events are not expected to be independent.

     Commentary on Question:
     Candidates performed well on identifying systematic risk as a reason but did not identify a second reason.

     There may exist important industry interlinkages between specific credit obligors. Consider, for example, supply-chain relationships or competition. Poor performance could, therefore, lead to a deterioration or an improvement of other possible credit counterparts.

     We should also expect shared regional or country risk exposures and, in the most general sense, common exposure to global economic conditions. If a particular region, country, or the entire planet faces difficult macroeconomic conditions, we should expect to observe correlation in degradation of creditworthiness and, ultimately default.

4. **Continued**

(b) Calculate the probability of experiencing one or more defaults within the portfolio under the aforementioned binomial-mixture model.

Commentary on Question:
Candidates did not do well for this question. Most were not able to correctly identify the need for taking the expected value of Z^2. Candidates received partial credits for identifying probability of one or more defaults as 1 – probability of zero defaults.

First, the unconditional zero default probability can be calculated via

$$P(N = 0) = E[P(N = 0 | Z)] = E[Z^2] = \int_0^1 z^2 dz = 1/3.$$

Then the unconditional non-zero default probability is

$$P(N > 0) = 1 - P(N = 0) = 2/3 = 0.6667.$$

(c) Calculate the covariance $Cov\ (\mathbb{I}_A, \mathbb{I}_B)$.

Commentary on Question:
Candidates had mixed performance on this question. Candidates received partial credits for identifying that the covariance equal to the variance of Z.

The unconditional covariance of default indicators under the binomial-mixtures model is computed via

$$Cov\ (\mathbb{I}_A, \mathbb{I}_B) = \text{Var}(P(\mathbb{I}_A = 1|Z)) = \text{Var}(Z) = 1/12.$$

(d) Describe the difference between the probabilities of non-zero defaults obtained based on the independence and binomial-mixture models.

Commentary on Question:
Candidates did poorly on this question. Most candidates believed that the probabilities of non-zero defaults for binomial-mixture models were higher than independence because the probability of both companies defaulting is higher, but the probability of both companies not defaulting together is higher as well so the probability of overall non-zero defaults is lower.

4. Continued

The independence model yields a higher probability of non-zero defaults. This order is attributed to the positive dependencies observed among default events in the binomial-mixture model, as computed in question (b). Positive dependence implies that counterparties' default statuses are more likely to align. Consequently, the probability of non-zero defaults is higher under the independence model (1-1/4=3/4) , in comparison with that under the binomial-mixture model (1-1/3=2/3) .

(e) Calculate the probability of default for each company in one year using Merton's model.

Commentary on Question:
Candidates had mixed performance on this question. Most candidates received partial credits by calculating the probability of default using either normal distribution or log-normal distribution.

Merton's model gives the probability of default at time T as:

$$\Pr\left(X\_T \leq B\right) = \Phi\left(\frac{\ln\left(\frac{B}{X_0}\right) - [r_X - \left(\frac{\sigma^2 X}{2}\right)T]}{\sigma_X \sqrt{T}}\right)$$

$$\Pr\left(X \leq 300\right) = \Phi\left(\frac{\ln\left(\frac{300}{500}\right) - [0.10 - \left(\frac{0.30^2}{2}\right)]}{0.30}\right) = 0.0296$$

$$\Pr(Y \leq 750) = \Phi\left(\frac{\ln\left(\frac{750}{800}\right) - [0.05 - \left(\frac{0.1^2}{2}\right)]}{0.1}\right) = 0.1367$$

(f) Calculate the probability that both companies will default in one year.

Commentary on Question:
Most Candidates did well in this question. Most candidates were able to apply the formula despite not being able to correctly calculate the individual probabilities of default in part e and receive full credit.

Using the copula given
$$\Pr(X \leq 300 \text{ and } Y \leq 750) = -\frac{1}{2.5}\ln\left[1 + \frac{(-0.0714)(-0.2894)}{e^{-\alpha} - 1}\right]$$

$$= 0.0091$$

The probability that both firms will be insolvent is, therefore, 0.91%.

4. Continued

(g)   Contrast reduced-form models and structural models as they are applied to modelling default probabilities.

Commentary on Question:
Most Candidates did well in this question. Most candidates were able to identify at least one characteristic for each type of models and received partial credits.

The first approach is based on reduced-form models which treat the default event as exogenous. That is, there is no structural description of the underlying cause of default. It simply occurs with a particular probability. The driving idea is that the default event is modelled in an empirical sense, rather than informing it from a structural or theoretical perspective. A reduced-form model might simply involve collecting some data and describing defaults with a classic probability model. This is a purely statistical approach.

The second approach is based on the structural models which are descriptive; they say something about the reason behind the default event. In this setting, default is endogenous to the model. This is consistent with the way the term structural is used in other modelling frameworks. It denotes the imposition of specific model behavior as suggested by theory.

Reduced form models are generally agnostic about the underlying reasons and are informed by data, whereas structural model seek to impose certain relationships often imposed by theory or logic.

(h)   State whether each of the following models is a reduced-form model or a structural model:

- Binomial-mixture model
- Merton's model

Commentary on Question:
Most Candidates did well in this question. Most candidates were able to correctly classify the type of models and receive full credits.

Binomial-mixture model: Reduced-form model. It only models the default probability.
Merton's model: Structural model. It models the asset value of the firm which determines whether the firm will default.

5. **Learning Objectives:**

3. The candidate will understand and be able to apply the components of an effective risk management system to investment management.

Learning Outcomes:
(3d) Explain risk budgeting approach to portfolio construction.

Sources:
QFII-129-23: Ch 2 "Risk Budgeting Approach" of Introduction to Risk Parity and Risk Budgeting, T. Roncalli

Commentary on Question:
Overall, candidates performed below expectations. Most candidates were able to explain concepts at a high level, but not form and execute the necessary calculations, nor utilize properties of various portfolio construction method in developing their solutions.

Solution:
(a) Calculate the 99th percentile VaR of the portfolio, assuming a normal distribution of returns.

> **Commentary on Question**:
> *Some candidates performed above expectations by fully solving for the VaR while most either missed multiplying by the portfolio value or incorrectly applying the correlation of each asset in the portfolio*

Volatility =

$$\mathrm{SD}_c(x) = -x^\top \mu + c \cdot \sqrt{x^\top \Sigma x} \qquad (2.1)$$

The weights of asset A, B, C are 25%, 25%, and 50% respectively.

The covariance matrix is defined as $\Sigma_{i,j} = \rho_{i,j}\sigma_i\sigma_j$,

we deduce the covariance matrix: $\Sigma = \begin{pmatrix} 0.01 & -0.01 & 0.0375 \\ -0.010 & 0.04 & -0.015 \\ 0.00375 & -0.015 & 0.0225 \end{pmatrix}$

$$\sigma^2 = 0.25^2 * 0.01 + 0.25^2 * 0.04 + 0.25^2 * 0.0225 + 2 * 0.25 * 0.25 * -0.01 + 2 \\ * 0.25 * 0.5 * 0.00375 + 2 * 0.25 * 0.5 * -0.015 = 0.0046875$$
The volatility is then $\sigma = \sqrt{0.0046875} = 0.06846532$

$$\mathrm{VaR}_\alpha(x) = -x^\top \mu + \Phi^{-1}(\alpha)\sqrt{x^\top \Sigma x} \qquad (2.2)$$

$VaR_{99} = 400M * (0 + 2.326 * 0.06846532) = 63.700M$

5. **Continued**

(b)   Explain why VaR is not a coherent risk measure.

Commentary on Question:
Most candidates were able to receive full credit.

VaR fails to meet the subadditivity property, i.e. VaR(A + B) can be greater than
VaR(A) + VaR(B).

(c)   Calculate the marginal risks (MR) and risk contributions (RC) for assets A, B, and
C.

Commentary on Question:
*Most candidates did poorly on this part with very few actually attempting
calculating the risk contributions. A typical error was the wrong application of
the covariance matrix calculated in part (a)*

Marginal Risk (MR) = $\dfrac{\Sigma x}{\sqrt{x^\top \Sigma x}}$

$$MR = \frac{1}{0.0685} * \begin{pmatrix} 0.01 & -0.01 & 0.0375 \\ -0.010 & 0.04 & -0.015 \\ 0.00375 & -0.015 & 0.0225 \end{pmatrix} * \begin{pmatrix} 0.25 \\ 0.25 \\ 0.5 \end{pmatrix} = \begin{pmatrix} 0.0274 \\ 0.0000 \\ 0.1232 \end{pmatrix}$$

Risk Contribution (RC) = $x \circ \dfrac{\Sigma x}{\sqrt{x^\top \Sigma x}}$

$$RC = \begin{pmatrix} 0.25 \\ 0.25 \\ 0.5 \end{pmatrix} * MR = \begin{pmatrix} 0.25 \\ 0.25 \\ 0.5 \end{pmatrix} * \begin{pmatrix} 0.0274 \\ 0.0000 \\ 0.1232 \end{pmatrix} = \begin{pmatrix} 0.0068 \\ 0.0000 \\ 0.0616 \end{pmatrix}$$

(d)   Calculate the amount of assets A and C needed for this risk budget portfolio.

Commentary on Question:
*Very few candidates attempted to answer the question; those who did generally
received full credit. Commonly, candidates that attempted the question applied
the correct weighting to the assets.*

This is an ERC (equal risk contribution) portfolio with 2 assets, where the risk
budget for both assets is the same.

$$risk\ budget\ b_i = \frac{1}{n} = 1/2$$

5. **Continued**

In this case, the weights are defined as:

$$w^* = \frac{1}{\sigma_1} / (\frac{1}{\sigma_1} + \frac{1}{\sigma_2})$$

The weights for asset D and E are:

$$w_A = \frac{\sigma_C}{\sigma_A + \sigma_C} = \frac{0.15}{0.1 + 0.15} = 60\%$$

$$w_C = \frac{\sigma_A}{\sigma_A + \sigma_C} = \frac{0.1}{0.1 + 0.15} = 40\%$$

$$\sum = \begin{pmatrix} 0.01 & 0.00375 \\ 0.00375 & 0.025 \end{pmatrix}$$

$$MR = \begin{pmatrix} 0.079057 \\ 0.11859 \end{pmatrix}$$

$$RC_i = x_i * MR_i$$

$$x_A = \frac{20M}{0.079057} = 253.0M \text{ and } x_C = \frac{20M}{0.11859} = 168.7M$$

(e) Assess whether the portfolio is optimal when $PC_A = 2\%$ and $PC_C = 3\%$.

Commentary on Question:
Candidates who attempted this part did well and were able to conclude that the portfolio was not optimal.

The portfolio is not optimal. The portfolio is optimal only if PC_A and PC_C are proportional to their respective risk budget b = (0.5, 0.5), i.e. $PC_A = PC_C$,

(f)

   (i) Identify the portfolio construction method corresponding to each of the three approaches above.

   (ii) State the relative ranking of resulting portfolio risks using an appropriate inequality relation.

Commentary on Question:
Most candidates were able to identify portfolio two as a minimum risk portfolio with very few identified the weight budgeting and risk budgeting portfolios. Candidates that identified all three portfolios typically ranked them correctly.

5. **Continued**

- Portfolio 1 is a weight budgeting (WB) portfolio, where the ratio between the weight and the budget is the same for all the assets
- Portfolio 2 is the minimum risk (MR) portfolio, where the marginal risk of asset is the same for all assets
- Portfolio 3 is the risk budgeting (RB) portfolio, where it is a combination of the portfolio 1 and 2 properties. i.e. $x_i \partial_{x_i} R(x)/b_i = x_j \partial_{x_j} R(x)/b_j$. Thus, can be viewed as a portfolio located between the MR and WB portfolio.

From Bruder amd Roncalli (2012), we are told that:

$$\mathcal{R}(x_{mr}) \leq \mathcal{R}(x_{rb}) \leq \mathcal{R}(x_{wb})$$

(g)   Three portfolios are constructed using Approach 3 with different budgets $\{b_i\}$. The resulting portfolios have weights x_i and risk contributions $RC_i^* = RC_i/R(x)$. Your portfolio construction objective is to minimize the variance of the portfolio.

Portfolio	Asset	x_i	RC_i^*
	F	33.33	45.81
X	G	33.33	22.23
	H	33.33	31.96
	F	18.11	33.33
Y	G	47.23	33.33
	H	34.66	33.33
	F	0.00	0.00
Z	G	30.34	30.34
	H	69.66	69.66

Assess which portfolios described above meet the objective.

Commentary on Question:
Very few candidates identified that the portfolios were risk budgeting portfolios and thus were not able to calculate the minimum variance correctly.

As these portfolios are RB portfolios, $RC_i/b_i = RC_j/b_j$.

The minimum variance portfolio is a RB portfolio when risk budgets are equal to the weights, i.e. $b_i = x_i$. Hence $RC_i/x_i = RC_j/x_j$.

Among the 3 portfolios listed, only portfolio Z satisfies the above equation and therefore it is the minimum variance portfolio.

6. **Learning Objectives:**

3.　　The candidate will understand and be able to apply the components of an effective risk management system to investment management.

Learning Outcomes:

(3a)　　Explain the best practices of investment risk management.

(3e)　　Apply principles of liquidity risk management.

Sources:

QFII-132-24: Application Paper on Liquidity Risk Management (IAIS)

Commentary on Question:

This question aims to test candidates' understanding of liquidity risk, its relationship to capital, and the key components of liquidity risk management. It also tests candidates' ability to utilize a balance sheet to assess liquidity needs.

Solution:

(a)　　Critique your colleague's conclusion about liquidity risk.

Commentary on Question:

Candidates overall did poorly on this question. Many candidates were able to recognize that maintaining an adequate capital ratio does not necessarily limit liquidity risk. However, few candidates were able to explain that liquidity fundamentally differs from capital or to elaborate on the relationship between a company's capital management framework and liquidity risk management. Most candidates received partial credit.

- In the ongoing management of its business, an insurer relies on the availability of capital and liquidity. Capital risk could transform into liquidity risk.
- Liquidity fundamentally differs from capital; both are essential to remaining a going concern; liquidity has a real time dimension and capital does not.
- Liquidity events can cause sudden distress and/or default in insurers that are otherwise well-capitalized.
- The insurer's capital management framework may be inappropriate or inapplicable to liquidity risk management.
- Events that have a significant impact on capital may not have a significant impact on liquidity. As such, stress testing work for capital purposes may not be relevant or adequate for liquidity risk management.

(b)　　List six liquidity risk drivers to be considered when developing a liquidity stress scenario.

Commentary on Question:

Candidates did well on this question. Most were able to correctly identify the risk drivers.

6. **Continued**

1. Contingent exposures from derivative cash-flows and collateral
2. Availability of external funding sources and correlations between such availability
3. Ability to transfer assets between portfolios
4. Outflows resulting from downgrades or deterioration of financial condition
5. Policyholder behavior
6. Exposures to catastrophic insurable events

(c) Summarize four key characteristics of highly liquid assets.

Commentary on Question:
Candidates overall did well on this question. Most candidates were able to receive at least partial credit for listing the key characteristics of highly liquid assets.

1. Easily and immediately convertible into cash
2. Low credit risk and low volatility
3. Transparent valuations
4. Low correlation with risky assets

(d) Calculate the amount of Secondary asset sales needed to meet a short-term liquidity need of 30,000, based on assumptions described above and the current balance sheet.

Commentary on Question:
Candidates did poorly on this question. The majority of the candidates were able to apply the haircut correctly, but only a few candidates were able to correctly identify the three primary assets. Therefore, most candidates only received partial credit.

The only primary assets are sovereign bonds, demand deposits, and money markets. The total amount of these assets is 22.5k, so an additional 7.5k in liquid assets is needed. With a 5% haircut, this means 7.5/.95 = 7.9k of secondary assets would need to be sold, well below the total of 55k of secondary assets available.

(e) List six key features of a liquidity risk management report.

Commentary on Question:
Candidates did very well on this question. Most candidates were able to list key features of a liquidity risk management report. Some candidates overlooked the assessment of the current liquidity position with respect to any risk limits.

6. **Continued**

1. Liquidity risk appetite statement
2. Liquidity risk limits
3. Current position with respect to liquidity risk limits
4. Strategies, processes, and policies in place for liquidity risk management
5. Vulnerabilities and how to address them
6. DEescription of use and interpretation of liquidity stress testing

7. **Learning Objectives:**
4.   The candidate will understand and be able to apply different approaches to mitigate investment risks using derivatives.

Learning Outcomes:
(4a)   Explain and implement techniques used to mitigate market risks.

(4b)   Understand interest rate derivatives and use them to mitigate interest rate risk.

Sources:
Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022
  o   Ch. 15: Risk mitigation using options and derivatives
Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi
  o   Ch. 5: Interest Rate Derivatives: Forwards and Swaps
  o   Ch. 6: Interest Rate Derivatives: Futures and Options
 Investment Risk Management, Baker, Kent and Filbeck, Greg, 2015
  o   Ch. 25: Futures
  o   Ch. 26: Swaps

Commentary on Question:
Commentary listed underneath question component.

Solution:

(a)
  (i)   Contrast the advantages and disadvantages of forward agreements and future contracts, regarding the following risks:

          Customization and Basis Risk
          Counterparty/Credit Risk
          Rollover Risk
          Liquidity Risk

  (ii)   Recommend the most appropriate financial instrument of the two for the business.

  Commentary on Question:
  Candidates generally did well on part (a)(i) with exception of rollover risk, which most candidates conflated with tailing of risk. However, many candidates were unable to meaningfully relate the circumstances presented in the question to develop suitable recommendations in part (a)(ii). Instead, some recommendations tended to rely on solely on restating select generic advantages from part (a)(i).

7. Continued

Customization & Basis Risk
- Forward agreements are customizable and can be designed to specifically meet needs.
- Futures contracts are standardized and not customizable. The underlying assets may not have a matching futures contract, which creates basis risk if futures are used to hedge.

Counterparty/Credit Risk
- Forward agreements come with higher default risk since there is no third party and they're traded OTC.
- Futures contracts involve an intermediary/clearinghouse and mark-to-market to nearly eliminate credit risk.

Rollover Risk
- For both, the initial contract may be a shorter term than fully needed.
- The customizability of forward agreements could address this concern. But for futures contracts, the initial contract would need to be reversed before delivery with subsequent purchase of another position to extend the hedge, creating rollover risk.

Liquidity Risk
- Futures contracts are very liquid; going in and out of positions is relatively easy. Closing a forward agreement is difficult and can be expensive.
- An advantage of both contracts is that no money is exchanged at inception, decreasing the immediate liquidity strain for the company.

The company is a startup with limited resources. It may not have the bandwidth to negotiate a forward contract, monitor it, or survive a possible default. A forward contract's illiquidity may also not leave the company enough adaptability to changing circumstances. I recommend a futures contract to alleviate many of these challenges. As an agricultural commodity, there is likely either a matching futures contract available for commodity A or a suitable cross-hedge with acceptable basis risk. The three-year time horizon the company is concerned with is also not unheard of for agricultural commodities, as are available for soybeans.

(b) Explain which graph most likely represents the commodity futures and which one represents the yield curve.

Commentary on Question:
Most candidates correctly identified the graphs, but not all provided robust explanations supporting their determinations.

---

7. Continued

> Graph A is most likely the commodity futures prices. For agricultural commodities, the lows and highs tend to correspond with the planting and harvesting cycles. Prices are low for expirations dates during harvesting when supply is high; and prices are high during planting when supply is limited.
>
> The yield curve is usually smoother and typically slightly upward sloping. Graph B is atypically downward sloping (inverted) implying rates are expected to decrease from the present short-term rates.

(c) The CEO suggests entering into an interest rate swap agreement to avoid any financial impact implied by the yield curve identified in part (b).

Assess the CEO's suggestion.

Commentary on Question:
While candidates were able to demonstrate knowledge on interest rate swaps and their potential hedging use, some candidates chose to challenge the premise that the company faced interest rate risk or questioned the company's priorities rather than directly assessing the use of swaps.

> In an interest rate swap, one party pays a fixed rate and the other party pays a floating rate. The yield curve is downward sloping, meaning the CEO is concerned about decreasing rates. Paying a floating rate and receiving a fixed rate can provide protection from decreasing rates but will not avoid the financial impact implied by the yield curve since the swap is priced from the yield curve. If rates follow exactly as implied by the yield curve, the company would forego higher rates now in exchange for higher-than-market rates in the future. Entering into a swap will effectively lock-in the implied forward curve the CEO was concerned about; therefore, I recommend not executing a swap as an attempt to achieve the CEO's desired outcome.

(d)

(i) Calculate the number of contracts for this cross-hedge.

(ii) Describe three factors that would impact the effectiveness of the cross-hedge if using futures.

Commentary on Question:
Nearly all candidates performed an appropriate calculation for (d)(i), but most did not recognize that the number of contracts should be a whole number. Part (d)(ii) was more challenging for candidates, but many were able to respond with at least two reasonable factors.

7. **Continued**

11,200 / 250 * 0.7 = 31.36

Since fractional contracts are not possible, either 31 or 32 contracts would be purchased.

Three factors that would impact effectiveness:
1. How closely the futures contract is related to the investment being hedged.
2. The degree to which the correlation between the futures and investment changes over time.
3. Potential losses from rolling the futures contracts through time.

(e) Recommend a mutually beneficial arrangement between your company and company Y.

Commentary on Question:
The advantages of each company were clear to candidates. The difficulty was describing a mutual comparative advantage agreement to capitalize on these effectively. The best responses proposed arrangements that benefited both companies and was a financial agreement rather than requiring the purchase, storage, transportation, and delivery of materials from one company to another.

Since company Y has a competitive advantage in USD which it cannot realize due to the additional foreign currency costs and my company already operates in USD but receives no discount, I recommend a currency swap. The relative difference in costs is the 2% foreign transaction cost, which can be split equally between the two companies. My company exchanges currency USD to company Y for currency CY with a 1% margin/fee. Company Y can now make use of its competitive advantage on commodity A in currency USD without it being completely lost on foreign currency exchange costs. And our company has effectively reduced its purchase cost for commodity A by the proceeds from the swap, leveraging its foreign currency exchange advantage.

8.

Learning Objectives:
5.   The candidate will understand the importance of risk culture and governance.

Learning Outcomes:
(5b)   Identify sources of unethical conduct and explain the role of a fiduciary.

(5c)   Compare the interests of key stakeholders and describe governance mechanisms that attempt to address conflicts.

(5d)   Explain how governance may be structured to gain competitive advantages and efficiencies.

Sources:
Investment Ethics, Sarah Peck Chapters 1-3, 7

Commentary on Question:
Candidates performed well on this question. The question tests candidates' knowledge of what makes an effective board, CEO compensation, and ethics.

Solution:

(a)   You are asked to review the structure of an insurance company's board of directors and its recent activities.

The current board structure is as follows:

- The board has 13 members, amongst which are 7 members who used to have a work relationship with the company as employees or service providers, which means that they are familiar with the company's business.
- The chairman of the board is the CEO of the company, who participates in all board meetings.

Critique the effectiveness of the board structure of the company.

Commentary on Question:
Candidates performed very well on this part. The 2ⁿᵈ and 4ᵗʰ bullets were the ones most frequently missed.

- 13 members is too many for effective decision-making. Board size should ideally be between 6 and 10.
- Majority of the board members need to be independent. In this case, 7 out of 13 is a majority, and these members are not independent given their prior work relationship with the company.

8. **Continued**

- Ideally, the chairman is not the CEO because the chairman can dominate the board meetings and decisions.
- Board members should be able to meet occasionally without the CEO present. Always having the CEO present at the board meetings because of dual role (as chairman and CEO) creates some challenges for candid discussions, especially on topics such as the performance of the company and the CEO.

(b)   A candidate is identified to fill an open director role on the board. The candidate's background information is listed below:

- Age: 61
- Has 30+ years of insurance experience and extensive expertise in accounting and finance.
- Serves as a board member at three different companies in the industry where she has done so for many years.
- Partner of a consulting firm that mainly provides investment services to insurance companies, including this one.
- A friend of the current CEO.

Critique the suitability of this candidate for the director role

Commentary on Question:
Candidates performed very well on this part, with most receiving full credit, as this part was relatively straightforward.

- Independence: not ideal, as he is a friend of the CEO and consults for the company, which makes him less independent.
- Tenure: serving as a board member for years indicates the candidate's persistency or loyalty, or has less chance of turnover, although a certain level of turnover is healthy, too much turnover can make it difficult for the board to be effective.
- Competence: it is good to have familiarity and a strong relationship with the industry, as the candidate may be able to bring in a fresh perspective and ideas.
- Time: full-time job means less time spent on this board's activities; additionally, holding 3 other board memberships is not ideal as he won't have enough time to fulfill his duty to this board. It may also be necessary to check for any conflicts of interest (i.e. serving on boards of competitors).

8. **Continued**

(c) The compensation committee of the board is evaluating CEO compensation, where there is a proposal to replace the current CEO's generous golden parachute with golden handcuffs and a golden coffin in order to encourage the CEO to stay with the company and consistently increase shareholder wealth.

Evaluate this proposal.

Commentary on Question:
Candidate performance was fair for this part, which differentiated candidates' understanding and judgement on CEO compensation. Some candidates provided the definitions of the three golden packages without providing any recommendation or judgement. Some candidates made judgements but did not explain the reasons or provide a brief description of the packages. The latter received more credits than the former if their judgements indicated their understanding of what these three golden packages are.

- Removing golden parachute can be considered a good suggestion as a golden parachute is a generous severance package triggered by control-related events.
- Golden handcuffs defer compensation. A portion of the CEO's compensation won't be paid until pre-specified future date, so it is an effective way to encourage CEO to stay with the company. This is a good idea as it better aligns the CEO with shareholder interests.
- Golden coffin offers generous death benefit to the CEO. It does not create significant incentive for the CEO to stay. Therefore, it is less effective or irrelevant to maximizing shareholder wealth.

(d) The investment manager of the company's pension fund, Sarah, invested a significant portion of the pension fund in ZZZ company's stock. Three days after the transaction was made, Sarah sold her own stake in ZZZ.

Assess Sarah's professional conduct.

Commentary on Question:
Candidate performance was fair for this part. Most candidates were able to identify two out of three misconducts. Very few candidates mentioned that Sarah's research results are questionable, as not even she believed her own research as she sold the stock she bought for her clients and herself.

---

8. **Continued**

- Responsible investing: Violated this principle by putting self-interest before client, knowingly making an investment recommendation to harm others and benefit herself.
- Ethical use of information: Sarah's research results regarding ZZZ are questionable, insufficient, or manipulative, since she sold her own shares after recommending buying to her client.
- Trust: Sarah abused the trust that the company placed in her and did not fulfill her fiduciary duty.

9.

Learning Objectives:
1. The candidate will understand and be able to identify and describe types of risk present in investment management.

5. The candidate will understand the importance of risk culture and governance.

Learning Outcomes:
(1a) Identify and describe the various kinds of risks, including strategic, market, credit, operational, liquidity etc.

(5b) Identify sources of unethical conduct and explain the role of a fiduciary.

Sources:
Quantitative Enterprise Risk Management, Hardy and Saunders, Ch. 2: Risk Taxonomy

Investment Ethics, Sarah Peck, Ch. 9

Commentary on Question:
Candidate performance was fair for this question. Only a handful of candidates scored close to full credit. This question tested candidates' ability to identify risks and ethical misconduct.

Solution:

(a) You work as an ALM actuary for a mid-size insurance company with core businesses of life insurance and annuities. As interest rates rose in the last few years, the experience studies team reported significantly higher than expected surrenders for the fixed deferred annuities, especially those issued with a lower minimum crediting rate guarantee, when interest rates were low.

Explain potential risks associated with the above situation.

Commentary on Question:
Candidate performance was fair for this part. Typically, this question was not answered completely by candidates. Better prepared candidates alluded to liquidity and interest rate risks. However, the two aspects of interest rate risk (duration mismatch and capital losses) were often not called out specifically.

a) interest rate risk
- Sudden massive surrender shortens the duration of liability significantly, this causes asset liability duration mismatch.
- When interest rates rise, the fixed-income assets that have longer duration are devalued more. To meet the obligation, the assets have to be sold at these lower prices, which can cause capital losses.

9. Continued

b) liquidity risk
- Assets invested in long-duration fixed income are generally less liquid, leading to lower market value of assets, which means that more or less liquid assets have to be sold to meet the liquidity need.

(b) You have received several recommendations from your colleagues in response to excess losses from interest rate movements:

1. Your company's investment manager recommends that you invest in a company that he knows will be making a public announcement about a merger imminently, where their stock price will likely increase after the announcement.
2. Invest in a company today that your company investment manager knows has a large buy order being placed the next day.
3. In order to discourage surrenders, the company raises the crediting rate to a very attractive level for the existing policyholders and uses the same high crediting rate to attract new money from new policyholders. A substantial amount of the new money will be used to support a higher crediting rate for the existing contracts.
4. Accept the losses because any potential actions to fix prior mistakes would create a bigger mistake.

(i) Evaluate each recommendation.

(ii) Recommend the most appropriate active risk management action, which may or may not be from the above list. Justify your recommendation.

Commentary on Question:
Candidate performance was fair for this part. Most of the candidates could somewhat evaluate each recommendation. However, specific identification of misconduct was generally missing. Only the better prepared candidates could identify the Ponzi scheme & inappropriate replacement as well as identify the problem around ignoring policyholders' interest. Passive risk management strategy was rejected by very few candidates.

Candidates generally performed poorer on the second part. Capital raising strategy was mentioned by only a handful of candidates. A few candidates referred to more proactive risk management in future state but didn't respond on how to address the current situation.

9. **Continued**

Part (i)

1) Insider trading: the investment advisor possesses insider information, which is illegal to use to make investment decisions for clients

2) Front Running: this trading scheme is based on the propriety information, which the advisor is not allowed to share outside the firm or act upon per SEC rules.

3) <u>Ponzi scheme and inappropriate replacement</u>: using new money to pay for the surrender is a type of Ponzi scheme when the crediting rates are not supportable by investments. This will create a big hole over time and eventually lead to bankruptcy as the loss accumulates. Another misconduct is inappropriate replacement.

    Switching to a different product in order to mitigate the liquidity crisis without taking <u>policyholders' interest</u> into account is not appropriate. The company needs to sell the product to meet policyholders' insurance need rather than to resolve its own crisis.

4) Simply accepting the loss as inevitable is passive risk management, which is not recommended. Risk management should take full responsibility to identify potential risks and manage them effectively to ensure businesses are sustainable and can weather stress events.

Part (ii)
- None of the recommendations is the right choice as they are all illegal, unethical, or passive.
- The right thing to do is to raise capital through issuing debt or equity in order to get through the difficult time of paying the surrender benefits to policyholders according to the contracts. The company needs to learn a lesson and avoid the same mistake going forward.