QFI IRM Model Solutions
Spring 2025

1. Learning Objectives:

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

Learning Outcomes:

(1b) Describe and apply various risk identification tools.

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

Sources:

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

Chapter 1 Introduction to ESG (CFA Society UK) (pages 3-36)

Commentary on Question:

This question aims to test the candidates understanding of environmental, social and governance (ESG) risks and explain how they factor into investment management. To receive full points, it is important for the candidate to provide the correct conclusion together with sufficient explanations. In general, candidates did well on part (a), (b) and (d)(i) of the question, but relatively poorly on part (c) and (d)(ii) part of the question. See further commentaries below.

Solution:

(a) Explain, for each of the remediation actions, whether it mitigates any one of three risks: environmental, social, governance.

Commentary on Question:

Candidates generally did well on this part of the question. For the first and third remediation actions (replacing senior management and the board, and regulatory engagement), candidates generally were able to explain how these mitigate governance and/or social risks. For the second remediation action (investing in new technology and cybersecurity infrastructure), a common mistake is to identify it as an environmental risk mitigation measure instead of social risk, or to identify it as an IT risk mitigation measure unrelated to ESG. Partial points were given if the candidate was able to identify the correct risk but did not provide sufficient justification, or if the candidate provided good justification but identified the wrong risk type.

1. Continued

Model Solution to part (a)
The company's actions:

Replacing senior management and the board – This measure pertains to governance risks. By changing the personnel on the board, the company is increasing board diversity and therefore how the company conducts business.

Investing in new technology and cybersecurity infrastrucutre – Improvements to technology and infrastructure addresses social risk in this context. The purpose of the new technology and cybersecurity program is to prevent future data breaches and also allow employees to work more efficiently.

Regulatory engagement – This action also helps to mitigate both social and governance related risks. Engaging with regulators to develop regulation will help the company anticipate future regulatory changes and adjust business practices accordingly. In turn, this will also prevent future data breaches and related social costs.

(b) The fund manager wants to refresh the estimates of LIC's expected returns. As part of his due diligence, the manager prepares a single questionnaire about the levels of desired and actual risk exposure and distributed it to senior management. He tells you: "This gap analysis accurately identified and measured risk exposures of LIC."

Recommend changes to the manager's approach.

Commentary on Question:
Candidates generally did well on this part of the question. Most candidates were able to recommend changes to the manager's approach and explain how the recommendation would form a more effective gap analysis. Partial points were given for insufficient explanations.

Model Solution to part (b)
The portfolio manager's suggestion isn't sufficient for accurately measuring actual risk exposure. When conducting a gap analysis, different questions should be addressed to different individuals, by level of seniority.

The questionnaire should also be given to junior employees and middle managers. Senior mamangement will generally have a better sense of the dersired levels of risk, but more junior employees are likely to be more familiar to the actual levels of risk the company is exposed to.

1. Continued

(c) Explain how the measures taken by LIC will enhance its expected returns in the long term.

Commentary on Question:
Candidates performed relatively poorly on this part of the question. Some common mistakes include but are not limited to:

- *List out the financial impact areas without providing sufficient explanations (awarded partial points)*
- *List and explain only part of the financial impact areas (awarded partial points)*
- *List and explain based on legal fees, settlements and investment in new technology and not based on the remediation actions (awarded partial points)*

Model Solution to part (c)
Incorporating ESG considerations into the financial analysis requires considering how incorporation of ESG factors by corporations can be financially material. In the case of LIC:

Reduced costs and increased efficiency – By improving its technology, LIC can improve efficiency and reduce costs associated with outdated software or hardware. Improved technological capabilities can improve employee experience, effectiveness, and output.

Reduced risk of fines – By engaging with regulators and advocating on new regulation, LIC can better prepare for future regulations that may incur additional fines, thereby reducing expenses.

Reduced externalities – There are signficant social costs to poor cybersecurity infrastructure, which become incurred when private data gets stolen or leaked. This can become internalised, as lack of trust in the corporation may result in fewer sales and lower profits.

Imrpoved adaptability to sustainability megatrends – By improving its technological capbilities and using up-to-date technology, the company is better equipped to handle disruptions from rapidly developing technology.

1. Continued

(d)

(i) Assess whether the fund manager's decision is consistent with the participants' desire to have ESG factors incorporated into decision making.

(ii) Recommend another action the fund can take to integrate ESG practices, beyond security selection.

Commentary on Question:
Candidates generally did well on sub-part (i) of this question. Most candidates were able to provide the correct conclusion with appropriate justifications. Partial points were given for insufficient justifications.

Candidates generally did poorly on sub-part (ii) of this question. Some common mistakes include but are not limited to:

- *List actions without providing sufficient explanations (awarded partial points)*
- *Recommend action around security/asset selection when the question asked to recommend actions beyond security selection*
- *Recommend actions irrelevant to integrating ESG practices*

Model Solution to part (d)

(i) The manager's decision does not support the incorporation of ESG factors into the funds decision making process. The challenge is that fund managers often get evaluated on returns over short time horizons. However, the costs and benefits of ESG factors generally materialize over longer time horizons. Since the manager is making a decision based on the poor short term returns, this suggests that ESG factors may not be fully considered.

If ESG issues were fully considered, the manager would consider that the improved long-term outlook is driven by the materialization of the company's consideration of ESG factors. Therefore, the manager should be either maintaining or increasing the fund's position in LIC (ignoring changes in alternative investment options).

(ii) In addition to portfolio selection, the fund managers can practice ESG through active ownership. There are two ways the fund can do this:

Shareholder Engagement – As the fund has an ownership stake in LIC, the fund managers can encourage the asset owners (participants) to actively vote in the company's annual general meeting or represent the asset owners in engaging in discussions with LIC's management on implementing ESG practices.

1. Continued

Policy Engagement – As an institutional investor the fund managers can engage with regulators, standard setters, and other parties to improveme to the financial system in ways that imrpove outcomes for particiapnts and encourages incorporation of ESG into decision making.

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:

Commentary listed underneath question component.

Solution:

(a)

(i) Assess the effectiveness of this bonus structure based on prospect theory.

(ii) Recommend an alternative bonus structure to improve long-term stability.

Commentary on Question:

Candidates performed above average on this part of the question. Most candidates were able to identify why the strategy was ineffective and recommend an alternative bonus structure. Some candidates did not provide adequate support of their recommended solution.

(i) The fund managers are likely to take the expected level of the bonus as their reference point. As a result, they are likely to become more risk-seeking and may even exceed risk limits when the fund is underperforming, especially because there is no additional loss to them if returns become worse.

(ii) To reduce the risk, a material portion of their compensation should be related to meeting fund objectives over time, rather than just focusing on the current year, and the bonus should reward complying with risk limits. This will remove the incentive to take high risks to maximize a short-term bonus.

2. Continued

(b) Describe how each manager is displaying a behavioral bias.

Commentary on Question:
Overall, candidates performed as expected on this question. Candidates could generally identify the bias exhibited and describe how that bias applied.

- Manager A: The manager is displaying outcome bias by evaluating the viability of the strategy only taking into account the results.
- Manager B: The manager displaying self-attribution bias by taking credit for successful years but attributing poor performance to luck.
- Manager C: The manager is displaying confirmation bias by failing to update their expectation based on new information
- Manager D: The manager is displaying overconfidence bias, overestimating their skills relative to others.

(c) Describe how each risk is applicable to YUL.

Commentary on Question:
Overall, candidates performed below expectations on this question. Many candidates did not present risks from the perspective of YUL, instead describing risks from the perspective of a client.

- Stock Market Risk – For YUL, movements in stock markets will directly change the value of the funds it is offering. If there are negative equity movements, the amount of fund revenue YUL collects will decrease due to lower AUM.
- Systemic Risk – For YUL, a systemic risk, such as the failure of a large bank, may cause substantial losses, even among investments that were considered uncorrelated due to triggering further defaults across the industry. This could lead to the failure of YUL's funds or a major drop in fund value reducing fund revenue to YUL.
- Reputational Risk – Given the prominent focus on YUL in the industry, any allegations of improper conduct against one of its fund managers could result in a loss of customer trust for all its funds or regulatory penalties.

3. Learning Objectives:

2. The candidate will understand and be able to apply different approaches to measuring and assessing risk exposures.
3. The candidate will understand and be able to apply the components of an effective risk management system to investment management.

Learning Outcomes:

(2a) Explain the advantages and limitations of different risk metrics.

(2f) Evaluate a company's or a portfolio's exposures to various risks, including liquidity risk.

(3e) Apply principles of liquidity risk management

Sources:

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

Commentary on Question:

Overall, candidate performance was in line with expectations. Those who had engaged thoroughly with the source material tended to perform well on this question.

Commentary listed underneath question component.

Solution:

(a) Critique your boss' concerns.

Commentary on Question:

Candidates performed as expected on this question. Most were able to correctly identify the key distinction between banks and pension funds—the duration of their liabilities—and recognized interest rate mismatch as the primary risk. Partial credit was awarded for reasonable observations related to the use of leverage strategies.]

- While some concerns about liquidity are valid, the use of a Liability-Driven Investment (LDI) strategy is appropriate for pension funds due to the long-term nature of their obligations. As interest rates rise, both the value of their fixed-income assets and the present value of their liabilities decline, helping to maintain a degree of balance.

- In contrast, commercial banks have predominantly short-term obligations. Therefore, investing in long-term bonds exposes them to significant interest rate risk and potential liquidity mismatches, making such a strategy much less suitable.

(b) Explain how market liquidity and funding liquidity are related.

Commentary on Question:

Candidates performed as expected on this question.

3. Continued

Market liquidity refers to how easily investors can buy or sell an asset without significantly affecting its price, while funding liquidity refers to how easily traders and financial institutions can obtain the capital necessary to finance their positions.

These two forms of liquidity are closely interconnected. Traders' ability to provide liquidity to the market depends on their access to funding, while their funding requirements—such as capital and margin calls—are influenced by the market liquidity of the assets they hold. Brunnermeier and Pedersen developed a model illustrating that, in times of market stress (e.g., a financial crisis), this relationship can become destabilizing. In such cases, deteriorating funding liquidity reduces market liquidity, which in turn worsens funding conditions—resulting in a liquidity spiral.

(c) Define each of the four dimensions of trading liquidity.

Commentary on Question:
Candidates performed well on this part of the question. The majority were able to correctly identify all four dimensions and received full marks.

i. Depth refers to the presence of a large volume of buy and sell orders without having a substantial impact on prices. Depth can be measured by the possible number of trades (i.e., volume of transactions) that does not lead to a change in the quoted price.
ii. Resilience can be proxied by the speed required for a trade's price impact to dispel and considers the elasticity of supply and demand.
iii. Immediacy refers to the speed at which an order can be executed at the prevalent price. It mirrors the efficiency of the trading and settlement systems.
iv. Tightness or breadth can be assessed by the magnitude of the bid-ask spread. According to Hasbrouck (2003), liquidity tightness is associated with the costs of providing liquidity, particularly the cost of immediacy.

(d) Describe these two liquidity measures below and their advantages and disadvantages.

(i) Amihud Illiquidity Ratio (ILLIQ)

(ii) Effective Spread (as introduced by Roll)

3. Continued

Commentary on Question:
Candidates performed well on part (i), with most earning full or partial credit for correctly identifying the Amihud Illiquidity Ratio and discussing its advantages and disadvantages. However, performance on part (ii) was weaker. Many candidates incorrectly equated the effective spread with the bid-ask spread
(d)(i)

Amihud (2002) designs a volume-based liquidity ratio called the Amihud illiquidity ratio (ILLIQ), which is the ratio of the absolute value of the daily stock return to the corresponding daily dollar volume: ILLIQ_it=|R_it |/(Σ_(i=1)^N P_it×Q_it), where R_it is the return in time t of an asset i expressed in absolute value; P_it is the price; Q_it is the trade volume; and N is the number of transaction over period of time t. This measure can also be averaged over a month (year) to get the monthly (yearly) liquidity measure. The intuition behind the ILLIQ is that a trade of a given amount has a larger price impact for more illiquid assets. In fact, the ILLIQ is designed to capture the price impact of trades that characterizes liquidity depth and resilience.

Advantage: The volume-based measures are simple and easy to obtain given the widespread availability of volume data.

Disadvantage: Volume is also correlated to volatility, which can impede liquidity. Moreover, using trade volume as a proxy for liquidity suffers from a double counting problem.

(d)(ii)

Roll (1984) offers the most popular spread measure known as the effective spread, which is constructed using a model that attempts to depict market prices and/or returns. The effective spread can be calculated as the square root of the negative covariance between adjacent price changes.

Advantages: Transaction cost measures tend to measure implicit and explicit transaction costs besides their ability to convey insight about information asymmetry in the market.[Does not need to collect information about volume]

Disadvantages: Because Roll's model is based on the assumption that information is homogenous across traders, it does not elaborate on the possible components of the spread.

3. Continued

(e) Calculate the ILLIQ (average over the 18 periods) for Security A and Security B.

Commentary on Question:
Most candidates who demonstrated a clear understanding of the Amihud Illiquidity Ratio performed well on this part.

$$Average\ ILLIQ = \frac{1}{17}\Sigma_{t=1}^{17}\left(\frac{|R_{it}|}{P_{it} \times Q_{it}}\right)$$

	Security A	Security B
ILLIQ	$22{,}320.14 \times 10^{-12}$	1.88×10^{-12}

4. Learning Objectives:

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

Learning Outcomes:

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

(2g) Apply different techniques of assessing tail risks, including stress testing and scenario analysis.

Sources:

Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022, Ch. 6 – 7

Commentary on Question:

Commentary listed underneath question component.

Solution:

(a) Calculate the probability that the returns of both X and Y are below 0 using the Gumbel copula with $\theta = 2$.

Commentary on Question:

Candidates performed as expected on this question. Several candidates did not correctly identify the correct values of u and v, or did not apply the correct copula formula. Partial credits were awarded as appropriate.

X	Y	Empirical Cumulative Distribution
-1.5	-2	0.0833
-1	-1.2	0.1667
-0.9	-0.7	0.2500
-0.5	-0.5	0.3333
-0.3	-0.3	0.4167
0.3	0.1	0.5000
0.8	0.6	0.5833
1.2	1.5	0.6667
1.4	1.8	0.7500
2.1	1.9	0.8333
2.3	2.6	0.9167
2.7	3.2	1.0000

4. Continued

$$C(u,v) = exp\left\{-\left((-log(u))^{\theta} + (-log(v))^{\theta}\right)^{\frac{1}{\theta}}\right\}$$
$$= exp\left\{-((-log(0.4167))^2 + (-log(v0.4167))^2)^{\frac{1}{2}}\right\} = 0.2899$$

(b) Calculate the following between X and Y:

(i) Kendall's rank correlation coefficient τ

(ii) Spearman's rank correlation ρ

(iii) Pearson correlation

Commentary on Question:
Candidates performed above average on this question. This is another calculation heavy question and candidates had the most difficulty with the calculation of Kendall's τ. Partial credits were awarded if working was shown.

$\boldsymbol{i}$	$\boldsymbol{rank(X_i)}$	$\boldsymbol{rank(Y_i)}$
1	3	4
2	9	8
3	5	10
4	11	2
5	6	5
6	12	12
7	7	11
8	1	1
9	10	7
10	4	6
11	8	9
12	2	3

Kendall $\tau_k = \frac{2}{n(n-1)}\sum_{i=1}^{n-1}\sum_{j-i+1}^{n} sign\left(\left(x_i - x_j\right)\left(y_i - y_j\right)\right) = 0.3939$
$Spearman's\ \rho = correl(rank(X), rank(Y)) = 0.5105$
$Pearson\ correlation = correl(X,Y) = 0.5745$

(c) Describe how the copula plays a role in stress testing by providing two applications.

4. Continued

Commentary on Question:
Candidates performed above average on this question. Full credits were awarded if at least two applications were described. Candidates that listed but did not describe correct applications were awarded partial credits. Candidates that did not address the question, but instead wrote about another aspect of copulas such as fitting its parameters, were awarded no credits.

In the field of financial risk management and stress testing, copula functions are highly effective tools. They allow for the modelling of intricate relationships between variables while preserving the individual traits of each variable. This makes them especially useful for stress testing, which involves evaluating the consequences of rare and extreme events on a financial system or portfolio. The following explains how copulas assist in stress testing.

1) Generating Extreme Scenarios: Stress tests are conducted to evaluate how a portfolio performs under severe yet realistic circumstances. Copulas are used to create artificial scenarios that combine extreme values from different variables' distribution, generating scenarios beyond what is observed in the data range.
2) Scenario Analysis: Stress testing based on copulas enables scenario analysis by adjusting the parameters of the copula function. This allows for the investigation of various stress scenarios and the evaluation of their effects on the portfolio.
3) Tail Risk Assessment: Using copulas for stress testing is beneficial in identifying tail risks that might be overlooked by traditional linear correlation methods. By having an understanding of tail risks, institutions can implement more effective risk management strategies.
4) Tail Dependence: The use of copulas is valuable in measuring tail dependence, which occurs when extreme events in one variable are connected to extreme events in another variable. When conducting stress tests, it's important to consider the possibility of simultaneous occurrence of such events, and copulas are particularly adept at modelling these tail dependencies.
5) Communication & Regulatory Compliance: Stress tests can help institutions demonstrate their capacity to withstand extreme events. Copula-based stress tests offer a structured approach to measuring and reporting the potential consequences of such events.
6) Modelling Multivariate Dependencies: In financial markets, asset returns and other risk factors are often not normally distributed and exhibit non-linear, non-Gaussian, and tail-dependent behaviours. Copulas allow you to capture these complex dependencies accurately, making them ideal for modelling the joint distribution of variables.

4. Continued

7) Preserving Marginal Distributions: When it comes to stress testing, it's essential to separate the modelling of joint distribution from individual marginals using copulas. This ensures that each variable's distribution maintains its realistic characteristics while focusing on the joint behaviour during extreme events.

5. Learning Objectives:

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

Learning Outcomes:

(2a) Explain the advantages and limitations of different risk metrics.

(2d) Explain the difference between real-world and risk-neutral processes and select appropriate market risk models.

(2g) Apply different techniques of assessing tail risks, including stress testing and scenario analysis.

Sources:

Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022, Ch. 8

QFII-123-21: IAA Note on Stress Testing and Scenario Analysis

Commentary on Question:

This question aims to test candidates' understanding of market risk models and stress testing. Candidates performed above average on the numeric parts of this question answered in excel and below average on the written parts of this question.

Solution:

(a) Identify the type of scenario, as defined by the IAA, to which each scenario belongs.

Commentary on Question:

Candidates performance on this question was mixed. Several types of IAA scenarios were accepted as valid answers.

i. Historical Scenario
ii. Multi - Event Scenario
iii. Company Specific Scenario
iv. Reverse Scenario

Alternate types of IAA scenarios were accepted.

(b)

(i) Recommend which model should be chosen based on completed statistics.

(ii) Describe two other factors you might take into consideration in deciding which model to use for stress testing.

5. Continued

Commentary on Question:
Candidates performed well on part i this question. To receive full marks candidates needed to provide an explanation for why they picked a model and not just state which one was better.
Candidates generally performed below average on part ii. Many candidates did not provide a description of the factors or why they should be considered. Some candidates discussed scenarios as opposed to models.

i. The completed chart is below.
AIC = ll - k
BIC = ll - k*log(500)/2

Model	*log-likelihood (ll)*	*k*	*AIC*	*BIC*
A	122	2	120	116
B	138	6	132	119

Model B has a better fit to the data based on the likelihood statistics. The log-likelihood, AIC and BIC are all higher for Model B.

ii. Materiality is a consideration and if the model provides a good fit in the extremes of the distribution. Simpler models, like Independent Log-Normal (ILN), are fine for relatively normal distributions, while others like GARCH and RSLN are better equipped to deal with fatter tails and can generate serial correlations in log-return and volatility. The focus of stress testing is often on the tails of the distribution.

The time horizon, frequency of time steps and amount of data of your problem may help you decide which model to use, as these factors influence the adequacy of the model fit. A simpler model (e.g. independent log-normal model) can be used for short period, high frequency time steps. A more complex model (e.g. RSLN) would be suitable for a longer time horizon, but needs more data for an adequate fit. The GARCH model is flexible and can be used for short and long term time horizons.

Several other factors were accepted as valid answers.

5. Continued

(c) Calculate $E[Y_t]$ and $Var[Y_t]$

Commentary on Question:
Candidates performed well on this question. Common mistakes were to have the wrong formula for the Var(Yt) and the wrong numerator for the unconditional probabilities.

The unconditional probabilities of being in each regime are:

$$\pi_1 = \frac{p_{21}}{p_{12} + p_{21}} = 0.75$$

$$\pi_2 = \frac{p_{12}}{p_{12} + p_{21}} = 0.25$$

i. $E[Y_t] = \pi_1\mu_1 + \pi_2\mu_2 = 0.0105$

ii.

$E\left[Var[Y_t|\rho_t]\right] = E\left[\sigma^2_{\rho_t}\right] = \pi_1\sigma_1^2 + \pi_2\sigma_2^2 = 0.0028$

$Var\left[E[Y_t|\rho_t]\right] = Var\left[\mu_{\rho_t}\right] = E\left[\mu^2_{\rho_t}\right] - E\left[\mu_{\rho_t}\right]^2 = \pi_1\mu_1^2 + \pi_2\mu_2^2 - (\pi_1\mu_1 + \pi_2\mu_2)^2 = 0.000169$

$Var[Y_t] = E\left[Var[Y_t|\rho_t]\right] + Var\left[E[Y_t|\rho_t]\right] = 0.002969 = 0.0545^2$

(d) Describe how you would estimate the magnitude of the decline in the S&P500 associated with a 1-in-100-year event at the end of year 1.

Commentary on Question:
Candidates performed poorly on this question. Most candidates did not recommend using a Monte Carlo simulation. Partial marks were given if a candidate recommended using the Variance at Risk (VaR).

Use a Monte Carlo simulation with a large number of paths (ie. 1000).

Enter parameters and starting values for $\mu_1, \mu_2, \sigma_1, \sigma_2, p_{21}, p_{12}$ and ρ_0.

Generate a 1000 x 12 matrix of independent N(0,1) random variates denoted *Z*.
Generate a 1000 x 12 matrix of independent Unif(0,1) random variates denoted *U*.

For each simulation i = 1, 2, …, 1000 do the following calculations:
For each time period t = 1, 2, …, 12 determine the regime ρ_t as follows:

if $U_{i,t} < p_{\rho_{t-1},1}$; 1 then $\rho_t = 1$; otherwise $\rho_t = 2$;

5. Continued

and hence simulate a value for the log-return, using the mean and standard deviation appropriate to the simulated regime:

$$Y_t = \mu_{\rho_t} + \sigma_{\rho_t} Z_{i,t}$$

A 1-in-100 year event can be associated with the VaR(99) log-return (ie. 10th worst log-return, i=991) at the end of 1 year (ie. t=12).

The decline in the S&P500 associated with a 1-in-100 year event at the end of year 1 is $e^{Y_{991,12}}$.

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.

(3b) Identify and describe various approaches for managing portfolio risks including VaR/ES methods, position limits, etc.

Sources:

QERM-Hardy-Saunders-Ch 09

Commentary on Question:

The question aimed to assess candidates' abilities to apply knowledge, recall relevant information, and analyze results in order to make informed recommendations. This comprehensive approach tested both their understanding of the material and their critical thinking skills. Candidates generally performed well in applying the material. They demonstrated a solid grasp of the concepts and were able to integrate them into their responses effectively. A notable area of difficulty for candidates was in making clear recommendations. Many responses lacked specific, actionable suggestions, which is critical for demonstrating the ability to synthesize information into practical advice.

Solution:

(a) Calculate the following for one share of each stock in the portfolio:

(i) 10-day 99% VaR

(ii) 10-day 97.5% ES

Commentary on Question:

Most candidates received partial credit with a majority missing either one or two parts of the formulas to receive full credit

Value at Risk = VaR = SQRT((Days/[Trading Days]) * [Closing Price]^2 * σ^2) * $z(.99)$

Expected Shortfall = ES = $\phi(z(.975)) / (1 - \alpha) * \sigma_s * S$

Stock	99% VaR	97.5% Expected Shortfall
X	11.63	11.69
Y	8.14	8.18
Z	3.58	3.60

6. Continued

(b) Calculate the following for the portfolio:

(i) 1-day 99% VaR

(ii) 1-day 99% ES

Commentary on Question:
Most candidates did poorly on this question by not appropriately calculating the variance of the portfolio correctly

σ of each position: [Shares] * [Closing Price] * [Sigma]
σ of the portfolio: $\sqrt{(\sigma_x^2 + \sigma_y^2 + \sigma_z^2 + 2 \times (\sigma_x \times \sigma_y \times \rho_{xy} + \sigma_x \times \sigma_z \times \rho_{xz} + \sigma_y \times \sigma_z \times \rho_{yz})}$

Stock	Sigma
X	18,750
Y	52,500
Z	(30,800)
Portfolio	61,510

	Portfolio
99% VaR	9,050
99% ES	10,368

(c) Interpret the results from part (b)

Commentary on Question:
Most candidates did poorly on this question. The candidates would compare expected shortfall and VaR to each other instead of applying their knowledge of what each metric represents. Full credit was given to candidates who identified that the metric was only for the next day and the expected shortfall was if a loss occurred passed α% then it was the average of the loss

VaR = There is a 99% probability that the portfolio value will lose less than 9,050 over the next trading day
ES = If the 1% worst case event occurs, the expected loss is 10,368.27 over the next trading day

6. Continued

(d) Compare Delta-Gamma-Normal Method, Delta-Gamma-MC method, and Full Monte Carlo simulation.

Commentary on Question:
Most candidates did poorly on this question by how to use each of the methods. To receive full credit the candidate needed to compare the methods across two different aspects

Delta-Gamma-Normal is quickest, but makes contradictory assumptions about asset and derivative returns, as they both are assumed normal.

Delta-Gamma-MC is more accurate, because it does not make contradictory assumptions about asset and derivative returns, but does not capture all higher order terms.

Full MC is the most accurate, but requires the most simulation as there are no analytical shortcuts

(e) Assess whether Empirical VaR is appropriate to model the returns of this new portfolio.

Commentary on Question:
Most candidates did poorly on this question by not stating a position on appropriateness nor giving sufficient justifications. To receive full credit the candidate was required to identify that the Empirical VaR is not appropriate and provide 2 valid justifications

i. Captures non-normal returns directly, and we know it is not normally distributed
ii. The empirical method is limited to what has occurred in the past, which in this case is only a few months.

Because there is limited data, this method is unlikely to yield robust results and thus the Empirical VaR is not appropriate. An alternative method should be considered.

(f)

(i) Design a statistical test to determine whether the VaR is both adequate and not too conservative.

(ii) Identify two assumptions used in backtesting.

6. Continued

Commentary on Question:
Candidates were either very successful on this question or did very poorly. To receive full credit the candidate needed to describe the two sided hypotheses test, how to conduct it, and what to do in a success or failure. While for part (ii) candidates needed to provide at least 2 valid assumptions of backtesting

(i)

- Two-sided hypothesis test
- Null hypothesis is that the observed number of VaR exceptions over a given horizon (m) is consistent with the binomial distribution **Bin**(n, 1-alpha), where n is the number of days and alpha is the VaR level.
- Alternative hypothesis is that exceptions are not consistent with the distribution.
- If the number of observed VaRs exceeds the p-value then reject the null

(ii)

- The basic calculation assumes trading does not occur.
  Assumes that returns are independnet, when in fact they may be serially correlated.

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:

Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi

- Ch. 5: Interest Rate Derivatives: Forwards and Swaps
- Ch. 6: Interest Rate Derivatives: Futures and Options

Commentary on Question:

Commentary listed underneath question component.

Solution:

(a) Calculate the amount the bank will pay at the end of the forward contract.

Commentary on Question:

Candidates performed poorly on this section. Most got partial credit for calculating the discount rates needed though a lot of candidates overlooked that the question was quarterly and used continuous rates. Additionally, only a very small percentage of candidates explained which formulas they were using to do the calculations making it difficult to understand if the candidates knew the material.

See Excel File for details and formulas demonstrated:
(This was done rounding to 5 decimal places but that was not required.)

Answer: 5,292,240

Fill in the chart using formulas from chapter 5:

5.2 $F(t,T1,T2) = Z(t,T2)/Z(t,T1)$

5.4 $f(t,T1,T2) = -\ln (F(t,T1,T2)/ (T2-T1)$

5.21 $r(0,Tn) = (1/Tn)\ Sum(f(0,Ti-1,Ti)xDelta)$

$r(0,Tn) = -\ln(Z(0,Tn)/Tn$

Fixed Leg of payoff is FRA is N * Delta * f(0,3,8)
N = $100 Million
Delta = 1.25 = (8-3)/4
f(0,3,8) can be determined from the chart

$f0,3,8 = -\ln((Z0,8/Z0,3)/1.25) = 0.04233791$

Chart (See Excel File for all calculations, and note that two approaches to the spot rate are demonstrated just to indicate that multiple approaches were valid.)

7. Continued

Quarter T	Time	zero coupon price (Z(0,T)	Forward Rate(0, I,i+1) f(0,T-1,T)	Spot Rate r(0,T)
0	0	1		
1	0.25	0.99000	4.020%	4.020%
2	0.5	0.98000	4.061%	4.041%
3	0.75	0.97000	4.103%	4.061%
4	1	0.96000	4.145%	4.082%
5	1.25	0.95000	4.189%	4.103%
6	1.5	0.94000	4.233%	4.125%
7	1.75	0.93000	4.278%	4.147%
8	2	0.92000	4.324%	4.169%
9	2.25	0.90999	4.376%	4.192%

(b) Calculate the current value (time 0) of any additional investment Company A would need to fund the liability given that Company A were entering into this FRA.

Commentary on Question:
For the candidates that attempted to solve this part, most did reasonable well. As long as the information calculated in part a was used to calculate the answer, full credit was given for this part.

Answer: (191,139)

First, determine how much money you will have at time 8:

Notional From FRA at time 8:	100,000,000
Payoff From Part B:	5,292,240
Liability to Fund:	(105,500,000)
Shortfall:	(207,760)

That number then needs to be brought back to time 0.
(Apply the zero price to discount it back.)

Discount factor:	0.92000
Discounted Amount needed at time 0:	-191139.0662

(c) Assess whether each investor should enter into the FRA being offered by the bank.

Commentary on Question:
Candidates did ok on this part of the question. Most candidates understood that the larger company could take on additional risk, but oversimplified the analysis on the smaller investor without any justification.

Investor X should enter into the FRA.
The FRA allows the company to remove the interest rate risk from a change in rates in 9 months, aligning the risk profile with the company view.

7. Continued

Investor Y should also enter into the FRA as the decrease in rates means that the amount of money earned in the future will be less than that being offered given the current assumptions.

(d) Recommend another strategy based on Investor Y's view on the future movement of interest rates.

Commentary on Question:
Candidates who answered this part of the question generally performed well as long as they made a recommendation, described it, and explained why it was appropriate and fit in with the view that interest rates would decrease.

Examples of possible strategies that could be described:

- Forward Contracts – take fixed side as expect less to pay from floating
- Futures – same fixed side, but marked to market daily. Shouldn't be an issue for large company
- Options (Need to specify Put or Call and a strike price.)

And reasoning behind them:

- Forward Contract would work given that it operates in a similar way as the FRA but locks in the price of the Treasury Note / Bond.
- Similar explanation for a Futures as well. (so receive fixed, pay floating) Futures would be settled daily as compared to Forward or FRA.
- If an option is used, ensure that the payoffs make sense given a strike price. It could be important on whether you are going short/long on the put and call.

8. Learning Objectives:

4. The candidate will understand and be able to apply different approaches to mitigate investment risks using derivatives.

Learning Outcomes:

(4c) Understand credit derivatives and use them to mitigate credit risk.

(4d) Understand CDS valuations and marking-to-market counterparty risk in credit derivatives.

Sources:

Handbook of Fixed Income Securities, Fabozzi, Frank J., 9th Edition, 2021 Chapter 69 Credit Derivative Valuation and Risk

Commentary on Question:

Candidates generally performed poorly on this question. To receive full credit, they were expected to provide all necessary calculation steps in Excel in addition to arriving at the correct answers. While most candidates did well on part (e), many struggled with part (c), particularly in setting up the correct formula required to use the Goal Seek function effectively.

Solution:

(a) Calculate the following for 1-year CDS contract:

(i) Value of protection leg, at contract issue date

(ii) Value of premium leg, at contract issue date

Commentary on Question:

Candidates performed above average on this part of the question. Most were able to correctly identify the formulas for the value of the protection and premium legs. However, many did not apply the exponential function to the hazard rate when calculating Q(T), resulting in only partial credit.

Using the following formulae:

$$V_{\text{Premium}} = \frac{C(T)}{2}\sum_{i=1}^{N}\Delta(t_{i-1},t_i)Z(t_i)(Q(t_i)+Q(t_{i-1}))$$

$$V_{\text{Protection}} = (1-R)\sum_{n=1}^{M}Z(t_n)(Q(t_{n-1})-Q(t_n))$$

$$Q(T) = \exp\left(-\int_0^T h(t)dt\right)$$

T	$V_{premium}$	$V_{protection}$
1	0.0079	0.0079

8. Continued

(b) Describe the calibration steps to obtain the term structure of survival probabilities.

Commentary on Question:
Most candidates performed poorly on this question. Many failed to identify the use of the bootstrap method and did not mention the need to use the market-quoted price and the given fixed coupon to back-solve for the hazard rates. However, a number of candidates correctly noted that the hazard rates are solved progressively from shorter to longer maturities, using previously calibrated values of h(t) to determine subsequent rates, and received partial credit for this understanding.

- This is done using a bootstrap method
- Search for the value of h(0.5) for which the model-implied upfront value equals to the market quoted upfront of the six-month contract given the fixed coupon.
- Using h(0.5), now search for the value of h(1.0) for which the model-implied upfront value equals to the market quoted upfront of the one-year contract given its fixed counpon.
- Repeat the step for each next longer maturity CDS, each time using knowledge of all the previously calibrated values of h(t) to calculate the next one
- At the end of the process, we should have a value of h for each market price
- Compute the market-implied value of Q(T) to any future time

(c) Calculate (use the "Goal Seek" function as needed) the following for each CDS contract:

(i) Hazard rate

(ii) Value of protection leg, at contract issue date

(iii) Value of premium leg, at contract issue date

Commentary on Question:
Most candidates performed poorly on this question, with a range of errors observed. Common mistakes included using incorrect fixed coupon rates, miscalculating the survival probability Q(T), and errors in summation. However, most candidates correctly recognized the use of the Goal Seek function by setting the value of the premium leg equal to the protection leg and received partial credit for this.

8. Continued

Using the following formulae:

$$V_{\text{Premium}} = \frac{C(T)}{2}\sum_{i=1}^{N}\Delta(t_{i-1},t_i)Z(t_i)(Q(t_i)+Q(t_{i-1}))$$

$$V_{\text{Protection}} = (1-R)\sum_{n=1}^{M}Z(t_n)(Q(t_{n-1})-Q(t_n))$$

$$Q(T) = \exp\left(-\int_0^T h(t)dt\right)$$

To achieve the correct answer, we have to perform calibration starting with the shortest term CDS.

- *The T-year par spread is defined as the coupon that would be paid for protection on a T-year contract which has no initial cost. This means $V_{protection} = V_{premium}$, or $V_{protection} - V_{premium} = 0$*
- *After entering all the formulas for 1-year maturity CDS, using goal seek should return you the hazard rate (h)*

T	*h(t)*	*$V_{premium}$*	*$V_{protection}$*
2	*0.01669*	*0.0174*	*0.0174*
3	*0.01759*	*0.0270*	*0.0270*

(d) Calculate the coupon payment that the protection buyer would pay assuming a credit event is triggered on Feb 4, 2021.

Commentary on Question:
Most candidates performed poorly on this question, primarily due to failing to calculate the number of days accrued between the previous coupon payment date and the credit event. However, most were able to correctly calculate the total coupon amount of $9,000 and received partial credit for that portion.

Payment terminate following a credit event. All that is paid by the protection buyer on the premium leg is the amount of coupon that has accrued beteween the previous coupon payment date and the credit event.

- number of days between Dec 20, 2020 and Feb 4, 2021 using actual/360 day convention = 46 days
- coupon = 46/360 * $9000 = $1,150

8. Continued

(e)

(i) List two mechanisms for the protection buyer to receive the protection payment.

(ii) Describe what the protection buyer would receive under each mechanism.

Commentary on Question:
Overall, candidates performed well on this question. However, some demonstrated confusion between the roles of the protection buyer and the protection seller, and received partial credit as a result.

e(i)

- physical settlement
- cash settlement

e(ii)

Physical settlement

- The protection buyer will receive the notional amount ($1 million) in cash,
- and deliver the corresponding face value of the deliveryable obligations at the price determined by the auction
- The protection buyer can choose which deliverable obligations to deliver

Cash settlement

- The protection buyer receive a cash amount equal to par minus the recovery price determined by the auction.
- cash amount = (1 – 40%) * $1 million = $600,000

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.

(5a) Explain the importance of risk culture and ethics in an investment firm.

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

Sources:

Risk Management: Foundations for a Changing World (Chapter 45)

Commentary on Question:

This question evaluates candidates' comprehension of risk culture and governance, with particular emphasis on operational risk and due diligence. It is structured to assess both knowledge recall and the ability to apply that knowledge in context. Overall performance on this question fell short of expectations. Potential contributing factors include insufficient emphasis on operational risk during candidates' exam preparation, or a tendency among candidates to divert answers toward ethical considerations related to investment practices..

Solution:

(a) Describe two ways that internal controls are related to the loss.

Commentary on Question:

The majority of candidates did not earn full credit on this question, with only a small number demonstrating a comprehensive understanding. Many responses failed to address operational due diligence and internal controls altogether, while others mentioned key concepts only briefly and without sufficient elaboration.

- Operational due diligence helps investors uncover risks and avoid the types of operational problems that can lead to the loss of clients' money through operational efficiency and proper internal controls.
- Internal controls help identify operational risks ahead of time and take actions accordingly, this prevents financial losses from unidentified and unevaluated operational risks.
- Consistent and effective internal controls around decision support, trade execution, risk management, compliance, and accounting systems are essential to manage operational risks.

9. Continued

(b) Describe the operational risk associated with each of the findings.

Commentary on Question:
The majority of candidates performed well on this part of the question, particularly in addressing the last two findings. However, many answers either lacked sufficient detail or failed to address the first two findings, which prevented candidates from achieving full credit.

- Lack of operational due diligence: a complete understanding of the corporate structure and service providers used is critical as many potential problems can occur due to lack of controls or function integration such as outsourcing function(s) from a third party.
- Watch out for warning signs of operational failure before a disaster occurs such as employee turnover and the firm's morale as well as conflicts where different answers came from the same managers on the same questions. Those red flags of operational risks are indications of the risks of talent retention and are the threats that can lead to potentially circumvented existing controls.
- Lack of segregation of function: Having the reporting team take on the auditing role leaves the reporting team an opportunity to cook the books or hide errors. Lack of segregation and independence is the most significant weakness of internal control system, it makes the firm vulnerable to trade errors and rogue trade-type situations.
- Lack of documentation and communication: this indicates that the operational due diligence was not performed by Oliver's company for the companies it chose to invest in, which makes it difficult to benchmark and support the verification of an operational infrastructure and to find weaknesses in the operations of business partners.

(c) Recommend actions to address each of the risks identified in Part (b).

Commentary on Question:
Similar to Part B, the majority of candidates performed well on this part of the question, particularly in addressing the last two findings. However, many responses either lacked sufficient detail or failed to address the first two findings, which prevented candidates from achieving full credit.

- Build an operational due diligence team and provide them with veto power to enable them to hold back an investment that does not meet minimum internal financial control standards, Conduct on-site review of the operations function. Gain a complete understanding of the corporate structure and service providers used. Given the outsourced accounting function, the administrator's role, frequency of involvement, process, and infrastructures need to be well documented, understood, integrated, and managed.

9. Continued

- Be vigilant about red flags on operational risks. Follow-up interviews should have been conducted to dig deeper on the discrepancies in answers received in the initial interviews. Hiring or moving around resources to help the auditing team should have been done to ensure that the internal controls won't be compromised.
- Have reporting team and internal auditors work independently to ensure the investment performance is accurately reported. Any manipulation of the book or influence from the top should be identified and investigated. Proper segregation often involves independent bodies doing simple things such as independently valuing the portfolio and reconciling the books.
- Perform proactive and thorough documentation of operational due diligence and internal controls. Use this to identify weak areas of potential investment companies to make the organization more resilient to potential operational risks, facilitating ongoing evaluation through documentation and communication to make best investment decisions.

10. 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.

Sources:

Investment Ethics, Pecks, Chapters 2 and 3

Commentary on Question:

Overall, candidates performed well on this question.

Solution:

(a) Explain two potential unethical behaviors that may arise based on Eric's suggestions.

Commentary on Question:

Candidates needed to identify both the long surrender period and the commission structure to receive full credit.

The variable annuity product has a long surrender charge period. It may not be suitable for policyholders who would want liquidity in a few years, such as the 70+-year-olds that Eric suggests selling to, as this older population may have an immediate need for their savings. Otherwise, they would be subject to surrender charge when they withdraw their funds.

Eric also thinks of increasing commission for the financial advisors, this will incentivize financial advisors to sell the variable annuity product and may create a situation where financial advisors would want to sell this products to clients who are not suitable for the variable annuity.

(b) Recommend two actions to address the potential issues identified in (a).

Commentary on Question:

At least two of the following actions (or another appropriate action with justification) needed to be provided for full points.

10. Continued

Disclosure : While explaining the product to older retirees, the company should make sure to disclose the surrender charges to the policyholders.

Documentation of goals: ensure that policyholders' wishes are translated into an investment policy statement and that this matches up with the variable annuity in terms of suitability.

The company should consider adjusting commissions in the same way across all ages for the product rather than targeting the 70+ population in order to avoid the potential unethical behavior of selling the product to older retirees who are not well suited to this product.

Candidates could provide other responses and receive credit if well-justified.

(c) Compare these two funds based on the information provided.

Commentary on Question:
It was difficult for candidates to receive full credit on this part. Candidates needed to compare the return and volatility, management fee, index, use of derivatives, performance history, and tracking ability to earn full credit.

Fund A has higher gross return and higher volatility than Fund B. However, the management fee of Fund A is higher than Fund B so when we evaluate the performance of the fund, we should calculate the net return after subtracting the management fee.

Fund A is focused on a particular industry sector (Technology) within the S&P while Fund B is focused on a particular stock nature (Value vs Growth) within the S&P index. This implies Fund A has more concentration than Fund B.

Fund B indicated the use of derivatives, which imply there is leverage involved. This may mean the fund could be riskier than it seems. Fund B also has a relatively recent inception date so performance history is limited. Fund B uses derivatives, so it may be difficult to tell if the performance tracks the benchmark well. Suggest to look at tracking error.

(d) Explain the potential unethical behaviors that may arise based on Eric's suggestion.

Commentary on Question:
Candidates performed well on this part.

10. Continued

A suitable response includes at least one of the following:

The default option may potentially create a conflict of interest as the company automatically directs all the premium to go into Fund A, which is managed by the company. It may also not be suitable for the policyholder.

The bonus provides incentive for policyholders to invest in Fund A, but the fund is risky and may not be suitable for their investment goals. Allocating at least 50% to Fund A might also represent a high concentration, which increases risk to the policyholder.

(e) Recommend one approach to address an unethical behavior identified in (d).

Commentary on Question:
Candidates performed well on this part of the question.

A suitable response suggests at least one of the following:

Disclosure: provide a consent form for policyholder to acknowledge that all proceeds will go to Fund A first before they make fund allocation decision. Alternatively, offer policyholder fund allocation choices when they sign the contract.

Let policyholder be aware of the risk of the Fund A and make opt out of default investment option available.

Change the bonus structure – for example to attract larger amount of money, they can offer bonus if the fund deposit amount exceeds certain threshold.