CURATED PAST EXAM ITEMS
- Solutions -

CP 351 – Asset Liability Management

Important Information:

- These curated past exam items are intended to allow candidates to focus on past SOA fellowship assessments. These items are organized by topic and learning objective with relevant learning outcomes, source materials, and candidate commentary identified. We have included items that are relevant in the new course structure, and where feasible we have made updates to questions to make them relevant.
- Where an item applies to multiple learning objectives, it has been placed under each applicable learning objective.
- Candidate solutions other than those presented in this material, if appropriate for the context, could receive full marks. For interpretation items, solutions presented in these documents are not necessarily the only valid solutions.
- Learning Outcome Statements and supporting syllabus materials may have changed since each exam was administered. New assessment items are developed from the current Learning Outcome Statements and syllabus materials. The inclusion in these curated past exam questions of material that is no longer current does not bring such material into scope for current assessments.
- Thus, while we have made our best effort and conducted multiple reviews, alignment with the current system or choice of classification may not be perfect. Candidates with questions or ideas for improvement may reach out to education@soa.org. We expect to make updates annually.

Exam Model Solutions – CP 351 Learning Objective 1

Learning Objectives: The candidate will understand the objectives of Asset Liability Management (ALM).

Exam	Question Part	Exam Points	Source Material	Learning Outcomes
QFIIRM Fall 20	5a	1	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 21	1c	1.5	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Fall 21	2b	1	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 22	2a	1	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 22	3a	2	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 22	4a	3	Financial Enterprise Risk Management, Ch. 20: Case Studies	1b
QFIIRM Spring 22	4b	3	Financial Enterprise Risk Management, Ch. 8: Risk Identification	1c
QFIIRM Spring 22	4c	2	Financial Enterprise Risk Management, Ch. 8: Risk Identification	1c
QFIIRM Fall 23	1a	1	Financial Enterprise Risk Management, Ch. 8: Risk Identification	1c
QFIIRM Fall 23	7a	0.5	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 24	1a	3	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 24	2a	1	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 24	2b	1	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Spring 24	9a	1.5	Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy	1c
QFIIRM Fall 24	2c	1.5	Financial Enterprise Risk Management, Ch. 8: Risk Identification	1c
QFIIRM Fall 24	9c	1	Quantitative Enterprise Risk Management, Ch. 20 Case Studies	1b
QFIPM Fall 20	6a	1	IAA Risk Book	1a
QFIPM Fall 20	6b	1	IAA Risk Book	1a
QFIPM Fall 20	6c	1	IAA Risk Book	1a
QFIPM Fall 20	6d	2	IAA Risk Book	1a
QFIPM Spring 22	1a	1	IAA Risk Book	1a
QFIPM Spring 22	1b	2	IAA Risk Book	1a
QFIPM Spring 22	1c	1.5	IAA Risk Book	1a
QFIPM Spring 22	1d	1.5	IAA Risk Book	1a
ILA LAM Fall 23	3c	6	CP351-101-25: ALM for Life, Annuities, and Pensions (section 3)	1d

			CP351-105-25: Chapter 16 of Asset/Liability Management of Financial Institutions, Tilman 2003	
ILA LAM Spring 24	3b	2	CP351-101-25: ALM for Life, Annuities, and Pensions (section 3) CP351-105-25: Chapter 16 of Asset/Liability Management of Financial Institutions, Tilman 2003	1d

QFI IRM Fall 2020 Question 5

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Candidate performance was fair on this question. Some candidates did not adequately describe how the risk was appropriate and others identified risks not present in the question, such as market risk.

Political risk: Political unrest in Country X.

Legal risk: if plane is developed too quickly and not adequately safety-tested, lawsuits will result

Reputational risk: reputation may be damaged if plane is rushed to market without adequate testing

Operational/Process risk: Company X may have processes in place to inadequately test product

QFI IRM Spring 2021 Question 1

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Candidate performance was fair on this question. Many candidates either provided a list of risks without a connection to XYZ's position, or simply restated the given information. No credit was given for including Mortality or Pricing risk in part (i), since the focus is on non-financial risks, and furthermore this topic is covered in part (ii).

(i)

- Political Risk: The behavior of the leaders of Country A could lead to repercussions that may adversely impact operation and cashflow of the company. The media scrutiny could contribute to political instability, leading to logistical challenges and other problems for XYZ.
- Environmental Risk: The actions of Country C are likely related to the increased rates of flooding, which could prompt regulatory changes that prove costly to the company.
- Regulatory Risk: Since Country B's legislature may impose new rules addressing workers' rights and safety, the company could be responsible for higher operational costs.
- Legal risk: Workers in Country B might be emboldened by the current regulatory regime to bring forward lawsuits against XYZ for perceived deficiencies in safety protocols or other workers' rights.

(ii)

It is inappropriate to apply XYZ's home country's mortality table to each of the foreign countries A, B, and C. The home country's table is unlikely to be representative of the actual mortality experienced in the other countries. There could be differences due to environment, local customs, etc. Using the same table could lead to mispricing of liabilities and/or insufficient reserving.

QFI IRM Fall 2021 Question 2

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Candidates performed very well on this question. Some candidates matched the risks correctly but failed to explain how each risk is applied to ZYX's specific situation. Some candidates struggled to explain how exchange rate risk impacts ZYX's foreign bond portfolio.

- Interest rate risk: The rising interest rates decrease the market value of bonds, exposing ZYX to interest rate risk.
- Exchange rate risk: If the FX rate of the currencies currently being traded strengthen, then the foreign bonds will cost more for ZYX to trade in USD.
- Credit risk: Because ZYX has two counterparties with high concentration (25%), any one of them defaulting could risk a lot of the assets.
- Model risk: ZYX uses bond pricing model to make trading decision. ZYX recently decided to use a new model but does not have an expert on the model. This imposes model risk on ZYX.

QFI IRM Spring 2022 Question 2

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

This question aims to test candidates' knowledge on the various kinds of risks, including market, credit, political, pricing etc. Candidates did well on the second and the third point, by identifying and justifying for the market risks and regulation risks. Some were able to receive partial credits for explaining the environmental risk from the first point. Only a few candidates correctly identified that the last risk is pricing risk.

- Strategic risk or environmental risk. - The insurer faces large losses if there is an incident in that region.
- Interest rate risk and exchange rate risk. – Bonds values fluctuate with interest rates, and the foreign bonds introduce the exchange rate risk.
- Regulation/Political Risk. – Insurance is a heavily regulated industry, even more so due to two layers of government.
- Pricing risk - Adverse selection can arise due to the better risks choosing to opt out of the insured population, leaving the worse risks, which means prices may have been set too low.

QFI IRM Spring 2022 Question 3

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

This question specifically asks for the names of a risk "category" for part (i), and specific risks under each "category" for part (ii). Candidates with clear understanding of risk category and detailed knowledge of specific risks under the categories will receive full credit. Those who did not identify all the correct categories receive partial credit. Most candidates did well on this question.

(i) External: Financial Market, Political and Regulatory
Internal: Strategic

(ii) **External:**

Financial Market:
Market Risk (Exchange Rate Risk or Stock Market Risk also acceptable) – The company is exposed to price movements and changes in volatility of CT. The CT exchange rate is a central determinant of the profits or losses of the product, with limited means of hedging. The ability of the company to find appropriate investments to support the product also subjects it to market risk.

Political and Regulatory:

Political Risk – The company appears to be circumventing the political will of Country XYZ, which comes with great risk. The political climate could directly oppose the company's interests beyond the scope of this product.

Internal:

Strategic:

Strategic Risk – The decision to launch this product represents a strategic risk for the company. This may be similar to the decisions with variable annuity guarantees in the US, with limited (or no) ability to hedge the exposure to CT.

QFI IRM Spring 2022 Question 4

Source Material: Financial Enterprise Risk Management, Ch. 20: Case Studies;

Financial Enterprise Risk Management, Ch. 8: Risk Identification

Learning Outcome:

1b) Understand the lessons learned from ALM failures

1c) Demonstrate an understanding of various ALM risks

(a)

Commentary on Question:

Candidates performed as expected in this question. Candidates able to identify case studies precisely relevant to the specific circumstances of the organizations are awarded full points.

Candidates will be awarded full score with two relevant case studies for each of the organizations.

Organization A:

Case	*Risk/context:*
Robert Maxwell	*avoid dominance or concentration of risk at the head of a company*

Organization B

Case	*Risk/context:*
The 2008 global financial crisis	*Should separate parties responsible for trading and back-office work* *Importance of incentives: Bonuses should reflect the term of the instrument being traded; Full bonuses should not be awarded until the risk inherent in any deal has run its course*
LTCM	*Model risk – heavy reliance on models at the expense of good judgement can be damaging*
The 2008 global financial crisis	*Model risk: should be used as tools; those making decisions using the output from models should*

	understand the model's capabilities and limitations

Organization C

Case	*Risk/context:*
Equitable Life	*important to avoid conflicts of interest – CEO vs appointed actuary for Equitable Life (CRO for Org. C)* *Risk culture – unwilling to learn from practices adopted by other firms, which meant that there was insufficient scrutiny of its own business model and slowness to respond to external environment*
The 2008 global financial crisis	*The manager in charge of ERM needs a higher status with the authority to stop undue risk being taken (concentration risk). The CEO/CRO is limiting what the other manager can do by declaring his comfort with the current risk.*

(b)

Commentary on Question:

Candidates performed generally good in this question. Their performance differed by how well they differentiated the objectives of each risk identification tools. Some candidates mixed up risk prompt list, risk checklist and risk-focused process analysis. Partial credit was given where one of the proper risk identification tools was identified with proper rationale.

Organization A:

SWOT analysis: covers both internal and external risk management contexts. Covers both positive and negative aspects of the risks for the small company. These align with the goal for the workshop.

Risk check lists: The company has been established for sufficiently long (since 2012) that experience is likely available to draw from in creating the risk check

list. Having the COO (a founder) in the group brings experiential knowledge, and documentation provides historical information, both of which act as sources for creating the check list.

Organization B:

Risk prompt lists: identify various categories of risk that should be considered. These can prompt a broader and more specific range of risks for the firm in question. This aligns with the goal for the workshop to start at a high level.

Risk taxonomy: more detailed than the prompt list, containing a wide range of risks, suitable for a relatively new firm. This aligns with the goal for the workshop to produce a detailed categorization of risks.

These two tools are more appropriate for Org B, since it is a new company (founded in 2021), so it will not have the experience/history to do some of the other tools like risk check list and risk trigger questions. It also has an unrepresentative group (too many portfolio managers), so a risk-focused process analysis is not appropriate.

Organization C:

Risk trigger questions: derived from situations or areas where risks have emerged previously – suitable since the company has been established for over 10 years with past experiences available (even from the past year)

Risk-focused process analysis: The group includes representatives from all key areas and is experienced, so they can establish flow charts for every process used and analyze the points at which risks can occur.

(c)

Commentary on Question:
Candidates performed unsatisfactory in the question. They were not able to assess different risk identification techniques with regards to the length, representation and specific knowledge held by participants.

(i) Org A: Delphi technique;

- Inappropriate given several iterations are required, need time between iterations for analysis. The workshop will only be 1-hour long.

Org B: Independent group analysis;

- Inappropriate since too many portfolio managers – finance/model risk may be ranked too highly

Org C: Brainstorming;

- Appropriate given representatives from key areas are already present, with a facilitator present to ensure as broad a range of points as possible is investigated

(ii) Gap analysis: with both senior and junior members present, junior employees have clearer ideas of the actual risk exposure and COO has strong views on the desired levels of risk exposure

QFI IRM Fall 2023 Question 1

Source Material: Financial Enterprise Risk Management, Ch. 8: Risk Identification

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Candidates performed well on identifying suitable risk identification techniques but did not perform as well on assessing the approach of using a standardized questionnaire.

(i) The Gap Analysis should be applied to the junior staff and the senior staff so that we can form a clear picture of desired and actual levels of risk exposure. The Delphi techniques can be applied to the experts to comment on the risks anonymously and independently.

(ii) A standardized questionnaire can allow results to be analyzed quantitatively. However, this will clearly have the effect of limiting the possible responses. Free text is suggested to capture this information but follow up surveys are needed based on the response of the initial survey.

QFI IRM Fall 2023 Question 7

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Candidates generally did well on this question. Most candidates were able to identify at least two risks and provided brief explanations to receive full marks. Some candidate only identified the risks without any explanation and therefore, only received partial credits.

Reputational Risk

Since the company loses a lawsuit, it will hurt its public image and have potential impact from the reputational risk such as lower sales, tighten regulation, etc.

Credit Risk

There is a risk that the buyer doesn't have the capability to pay the XYZ cash in 6 months.

QFI IRM Spring 2024 Question 1

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

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 (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 (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.
- 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.

QFI IRM Spring 2024 Question 2

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

(a)

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
- 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)

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

QFI IRM Spring 2024 Question 9

Source Material: Quantitative Enterprise Risk Management, Ch. 2: Risk Taxonomy

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

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.

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.

QFI IRM Fall 2024 Question 2

Source Material: Financial Enterprise Risk Management, Ch. 8: Risk Identification

Learning Outcome: 1c) Demonstrate an understanding of various ALM risks

Commentary on Question:

Most candidates can explain why the checklist is inadequate and recommend changes to rectify.

(i)

The proposed approach may lead to a risk check list that inadequately captures the risks that need to be considered. Under the proposed approach, we are primarily relying on the experiential knowledge of the panelist who lacks relevant experience investing in the transportation sector.

(ii)

- The CIO could hire external resources with more knowledge and approach relies on experiential knowledge, which may be limiting.
- The CIO could have the panelists prepare additional research on other documented information and resources to supplement the panel discussion with documented knowledge.

QFI IRM Fall 2024 Question 9

Source Material: Quantitative Enterprise Risk Management, Ch. 20 Case Studies

Learning Outcome: 1b) Understand the lessons learned from ALM failures

Commentary on Question:

Candidates performed very well on this part. Most candidates received full credits as the answers are straightforward and follow common sense.

- Pros: Promote good teamwork and cooperative environment as everyone is working towards the same goal.
- Cons: If the bonuses were mainly based on team performance, it would cause the individual to not differentiate themself from the team. The individual will then just copy the rest of the team and will benefit in good times and get protection in bad times.
- It leads to less diversity of opinion and discourages individuals from identifying issues in the team.

QFI PM Fall 2020 Question 6

Source Material: CP351-100-25: IAA Risk Book - Asset Liability Management: Techniques and Practices for Insurance Companies (2016)

Learning Outcome: 1a) Explain the principles of Asset Liability Management

Commentary on Question:

This question tests the candidate's knowledge of the considerations that must be taken for asset allocation strategies of long tail liabilities.

The candidates performed as expected on this question. Candidates that did well provided answers that related specifically to Company XYZ and the situation described by the question. Candidates that did poorly did not tie their answers back to the situation presented in the question.

(a)

Commentary on Question:

The candidates performed as expected on this section. The candidates that performed above averaged described in words each item listed, clearly identifying the key feature of that duration compared to the others in the list. For example, a description of Effective Duration included the concept of percentage change in the asset value to clearly contrast that to the Dollar Duration that included the concept of a dollar change to the asset value.

Macaulay duration – A measure of interest rate sensitivity of the present value of cash flows. It is calculated as the time weighted present value of cash flows divided by present value of cash flows.

Effective duration – A measure of interest rate sensitivity to parallel shifts in the yield curve. Can be calculated by shocking the yield curve used to value the asset up and down and dividing the difference by the unshocked asset value. Result is the sensitivity of the asset value for a parallel shift in yield curve as a percentage of the asset value.

Dollar duration – Similar to Effective duration but measures interest rate sensitivity in dollar terms of the present value of cash flows for parallel shifts in the yield curve. Can be calculated as the product of Effective Duration and Asset value.

Partial duration – Similar to Effective duration but measures interest rate sensitivity to a single point on the yield curve. Can be calculated by partitioning the yield curve by various terms and shocking each term separately to measure the impact to the present value of cash flows.

(b)

Commentary on Question:

The candidates performed above average on this section. Candidates that did well described the drawbacks of Effective durations and how these drawbacks occur in reality but are not captured by Effective duration.

Duration measures the exposure to an immediate shock on the present value of cash flows and assumes that shock persists indefinitely into the future; in reality present values are constantly changing due to constantly changing yields

Duration is based on small, parallel changes in the yield curve; in reality changes are not parallel, additionally history has proven that large shifts in yield curves can happen

Duration is based on the first derivative but the second derivative, Convexity, should be considered: as interest rates decrease, the increase in present value of asset cash flows increases at a faster rate

Duration is typically calculated using either a risk-free rate or a risky-rate with a static credit risk component; it is possible that the credit spreads may change

Optionality in the assets may cause asymmetric price changes as interest rates change. Consider the example of an MBS that has underlying prepayments that impact the assets cash flow.

(c)

Commentary on Question:

The candidates performed above average on this section. Candidates that did well listed the risk and described the risk. Candidates that did poorly only listed the risks. Three risks are provided below but describing two risks was sufficient for full marks as the question only asked for two risks.

Interest Rate risk / Asset-Liability Mismatch risk – Asset duration is shorter than liability duration; in falling interest rate scenario, liabilities will be much larger than asset values

Reinvestment risk – in a low interest rate environment, maturing bonds and cash inflow (e.g. reinvested assets) may not earn enough interest to support liabilities that were priced during the higher interest rate environment.

Options/Guarantee risk – policyholders may have incentives in a low interest rate environment to cash out in-the-money guarantees; bond issuers may be able to call the bond early (incentive to replace with a lower paying bond) reducing the higher interest coupon.

(d)

Commentary on Question:

The candidates performed poorly on this section. Candidates that did well described the shortfalls of the assistant's suggestion as it relates to XYZ's situation, particularly the large duration mismatch between the assets and liabilities.

The assistant's suggestion doesn't seem to consider the significant duration mismatch between the assets and liabilities. The primary goal of ALM is to minimize asset-liability mismatch to immunize the portfolio against interest rate risk. With this in mind, the assistant's suggestions need to consider the following:

Statement 1:

- Equity has a zero (or near zero) duration so allocating more to equities will shorten the asset duration, creating a larger mismatch between the asset and liability durations.
- Allocating more to equities can result in higher financial statement volatility.
- Allocating more to equities can result in higher capital requirements.
- Simply focusing on more return is not properly managing the surplus of the company.

Statement 2:

- Duration between asset and liability should be closely matched for better immunization, not just because the yield curve is flat.
- ALM frameworks are not based on timing interest rate changes because it is difficult to predict rates

Statement 3:

- Allocating to emerging market debt exposes the company to currency risk.
- Currency risk is not possible to hedge unless the liability duration is short.
- Historical interest rates are not predictors of future yields

QFI PM Spring 2022 Question 1

Source Material: CP351-100-25: IAA Risk Book - Asset Liability Management: Techniques and Practices for Insurance Companies (2016)

Learning Outcome: 1a) Explain the principles of Asset Liability Management

(a)

Commentary on Question:

Candidates performed brilliantly on this section. Most candidates described at least two ALM-related risks to which the business was exposed.

Applicable ALM-related risks include, but are not limited to:

- Interest rate risk: Risk of gains and losses generated on a portfolio through reinvestment and disinvestment activities
- Liquidity risk: Risk of having insufficient liquid assets to service liability payments
- Credit risk: Risk of gains and losses through defaults or changes in credit spreads on risky assets
- Currency risk: Risk associated with backing liabilities with assets in a different currency
- Asset-liability mismatch risk (C3 risk): Risk of losses from assets and liabilities moving in opposing directions

(b)

Commentary on Question:

Candidates performed below average on this question. Successful candidates provided adequate commentary on both the immunization and interest rate swap overlay. Some candidates only provided sufficient comments on the immunization strategy.

<u>Immunization:</u>

- Immunization addresses interest rate risk by ensuring that, among other things, the duration of the assets equals the duration of the liabilities
- By its nature, immunization covers small changes in the yield curve
- Immunization only addresses parallel shocks – if management is concerned about specific interest rate tenors then immunization would not be an adequate strategy

- There may also be issues with implementing an immunization strategy if there are no traditional fixed income assets available in the market that have sufficient duration

Interest Rate Swap Overlay:

- Interest rate swaps are an effective tool to execute ALM strategies and facilitate risk optimization of a portfolio
- Interest rate swaps can be used to target specific durations, or extend the duration of an asset portfolio
- Company does not have interest rate swaps in its current portfolio, so may need to hire/gain expertise with this new type of asset
- An interest rate swap overlay would do a better job at addressing senior management's concerns relative to an immunization approach

(c)

Commentary on Question:

Candidates performed as expected on this question. Successful candidates identified approaches to identify carve out points, as well as how assets are treated before and after the carve-out point. One common mistake was that candidates did not mention needing to immunize the liabilities.

The following approaches can be used to implement a carveout strategy for a block. Note that candidates only needed to provide one method to achieve full points.

Method 1:

- A carve out point is established for investments (i.e. the period after which investments will be allocated to equities)
- Construct an immunized portfolio using bonds up until the carve out point
- Calculate/hold the required amount of equities for cash flows after the carve out point

Method 2:

- Determine the amount of equities that will be held as part of the portfolio
- Based on the amount of equities held, determine the corresponding carve out point for liability cash flows
- Construct an immunized portfolio using bonds up until the carve out point

(d)

Commentary on Question:

Candidates performed as expected on this question. Those candidates that provided several critiques with commentary on the decision to add equity to the portfolio received full credit. Some candidates did not provide supporting statements.

Examples of statements in favor/against the decision include, but are not limited to:

- Equity provides an attractive method to improve investment performance
- Can set carveout point to be after the longest duration bond is available to minimize impacts to interest rate risk
- Using equities to manage returns may expose the portfolio to greater interest rate risk, as well as expose the insurance company to equity risk
- Addition of equity may result in higher capital/reserve requirements, which may be against the best interests of the insurance company
- May require more sophisticated modelling approaches (e.g. stochastic processes) to ensure asset adequacy

ILA LAM Fall 2023 Question 3c

Source Material:

- CP351-101-25: ALM for Life, Annuities, and Pensions (section 3)
- CP351-105-25: Chapter 16 of Asset/Liability Management of Financial Institutions, Tilman 2003

Learning Outcome:

1d) Describe how different pension and insurance contracts generate embedded options

Solution:

(c) Insurance products are often sold with embedded options for both the policyholder and the insurance company.

For the following products:

- Deferred annuity with a minimum guaranteed crediting rate
- Participating traditional whole life insurance that provides cash value and dividends
- Long-term care product with guaranteed premium

(i) Identify two embedded options offered to the policyholder that are shared by more than one product.

(ii) Explain which product features are triggered for the embedded option(s) in part (i).

(iii) Identify two embedded options available to the insurance company that are shared by more than one product.

(iv) Explain which product features are triggered for the embedded option(s) in part (iii).

Commentary on Question:
This part of the question tests candidates' ability to identify various options embedded in traditional life insurance products. As embedded options bring complex product risks to life companies', thorough understanding of product optionality is essential for managing product risks through ALM practices.

Successful candidates were able to identify correct options shared by correct products, with sufficient justifications provided. Partial marks were awarded to candidates who were able to reasonably explain how each option functions under each circumstance but failed to name the option correctly or identify the correct products. Few points were

given to candidates who only listed combinations of options and products with minimal justifications.

Part (i) and (ii) were graded in a consolidated fashion for candidates who answered both parts in the same answer box; same applied to part (iii) and (iv).

For part (i) and (ii), most candidates were able to identify a call and a put option. A number of candidates got partial marks thinking that a call on the value of future payment exists for the participating whole life product. In fact, although whole life product has a fixed premium structure, the insurer has the right to alter dividends, in which case policyholders are exchanging fixed premiums with non-fixed total policy value. Hence, the call does not apply to participating whole life.

For part (iii) and (iv), many candidates were able to identify and explain the two options well. Some candidates failed to justify the call action for the callable bond is only triggered when policyholders fail to pay their premiums due.

Part c (i)

For the three products provided, two embedded options offered to the policyholders are:

1. Call on the value of future payments; shared by deferred annuity and long-term care products.
2. Put on the value of the policy; shared by deferred annuity and participating traditional whole life insurance products.

Part c (ii)

The call on the value of future payments enables policyholders to purchase coverages at a pre-determined price.

- Deferred annuity policyholders have the right to deposit additional premiums into existing fixed-rate deferred annuities.
- Long-term care policyholders have the right to renew their existing policies at guaranteed premiums.

The put on the value of the policy enables policyholders to exit their in-force contracts for a guaranteed level of cash.

- A deferred annuity policyholder has the right to surrender the existing contract for a lump-sum value accumulated at a minimum guaranteed crediting rate.
- A participating whole life policyholder has the right to surrender the existing policy for a guaranteed cash surrender value.

Part c (iii)

For the three products provided, two embedded options offered to the insurance company are:

1. Callable bond; shared by long-term care and participating traditional whole life insurance products.
2. Swaption; shared by deferred annuity and participating traditional whole life insurance products.

Part c (iv)
A callable bond holder has the right to receive coupon cash flows before maturity or the face value of the bond if the bond issuer decides to call the bond.

A similar circumstance happens when an insurer has the right to receive premium cash flows when a policy is in-force or a lump-sum amount when the policyholder fails to pay the premium (or decides to lapse).

- The insurer has the right receive the reserve when a long-term care policyholder lapses.
- The insurer has the right receive the reserve, less any cash surrender values, when a participating whole life policyholder lapses.

A swaption gives the holder the right to exchange variable rate with fixed rate (or vice-versa).

An insurer can achieve similar outcome through strategically managing non-guaranteed elements of its product features.

- For deferred annuity, the insurer has the right to alter the crediting rate with respect to the desired return, given it remains above the minimum guaranteed level.
- For participating whole life, the insurer has the right to alter the dividends with respect to the overall return of its participating business.

ILA LAM Spring 2024 Question 3b

Source Material:

- CP351-101-25: ALM for Life, Annuities, and Pensions (section 3)
- CP351-105-25: Chapter 16 of Asset/Liability Management of Financial Institutions, Tilman 2003

Learning Outcome:

1d) Describe how different pension and insurance contracts generate embedded options

Commentary on Question:
This question is to test students are able to identify the embedded options from an insurance product & the risk arising from such options. They should be able to suggest ALM strategy accordingly to manage the risk.

Solution:
(b)

(i) Identify the option(s) granted to policyholders in this annuity product. Justify your answer.

(ii) Assess how changes in the interest rate environment can trigger policyholders to exercise the options described in (i).

Commentary on Question:
Most of the students are able to identify how interest rate environment can change policyholders' behaviour to exercise the options. Full mark is only given if the student can correctly identify the option associated with each of the product features as well as when each option will be exercised

(i) - The right to deposit additional premium constitutes a call on the value of future annuity payments. Policyholder have the right to purchase future growth on fund value at the guaranteed rate.

- The withdrawal option can be viewed as a put on the value of the policy. Policyholder have the right to sell the policy back to the insurer at fund value.

(ii) - When interest rates are low, policyholders can deposit additional premiums for the purposes of earning a guaranteed return on their premium payment that is higher than the prevailing market interest rates.

- When interest rates are high, policyholders can surrender their policies for a return of fund value (minus a surrender charge), and reinvest the money in a newer policy that credits a higher rate.

Exam Model Solutions – CP 351 Learning Objective 2

Learning Objectives: The candidate will understand how to measure risks from assets and liabilities.

Exam	Question Part	Exam Points	Source Material	Learning Outcomes
QFIIRM Spring 22	3c	1	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 23	1b	2	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 23	1c	3	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models Understanding the Connection Between RW and RN Generators, Strommen, 2022, sections 1-5 • Companion Excel-based Tool	2a, 2b
QFIIRM Fall 23	1d	0.5	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 23	1e	1.5	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 23	1f	1	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Spring 24	3a	2.5	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Spring 24	3b	2.5	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Spring 24	6a	1.5	IAIS Application Paper on Liquidity Risk Management	2b
QFIIRM Spring 24	6b	1.5	IAIS Application Paper on Liquidity Risk Management	2b
QFIIRM Spring 24	6c	1	IAIS Application Paper on Liquidity Risk Management	2b
QFIIRM Spring 24	6d	1	IAIS Application Paper on Liquidity Risk Management	2b
QFIIRM Spring 24	6e	1	IAIS Application Paper on Liquidity Risk Management	2b
QFIIRM Fall 24	5a	2	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 24	5b	2	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
QFIIRM Fall 24	5c	2	Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models	2b
ILA LAM Fall 20	2d, 2e	6	Key Rate Durations: Measures of Interest Rate Risk	2a
ILA LAM Spring 21	2b, 2c	6	Key Rate Durations: Measures of Interest Rate Risk	2a
ILA LAM Fall 21	3b	3	Key Rate Durations: Measures of Interest Rate Risk	2a
ILA LAM Spring 23	3b	6	Key Rate Durations: Measures of Interest Rate Risk IAIS Application Paper on Liquidity Risk Mgmt	2a, 2b
ILA LAM Fall 23	6a,6c,6d	2	ALM for Life, Annuities, and Pensions (section 4)	2a
ILA LAM Fall 24	4a,4b,4c	11	Key Rate Durations: Measures of Interest Rate Risk ALM for Life, Annuities, and Pensions (section 4)	2a
ILA LAM Fall 24	6b	4	ALM for Life, Annuities, and Pensions (section 4)	2a

			Ch 4 of Fixed Income Securities: Tools for Today's Markets, Tuckman, Bruce and Serrat, Angel, 4th Edition, 2022	

QFI IRM Spring 2022 Question 3

Source Material: Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models

Learning Outcome:

2b) Evaluate a company's or a portfolio's exposures to various risks

Commentary on Question:

This question tests the understanding of features of different models. In general, candidates performed well. Full credit is given to responses that clearly identified various the patterns from the graph and related the patterns correctly with the models. Partial credit is also given if not all the patterns are explained correctly. In addition to the model solution below, recommending GARCH model is also acceptable if proper justification is provided.

Although it is unclear from this data that any of these models is appropriate, the Regime Switching Model would be most suitable for the following reasons:

- Volatility is clearly not constant, which is a limiting attribute of lognormal (i.e. a lognormal model would have a constant volatility). GARCH and RSLN models can exhibit this characteristic.
- Volatility appears to cluster. Again, this rules out lognormal but not GARCH or RSLN.
- High volatility seems to be correlated with sudden drops in prices/returns. A GARCH model would not handle this feature, but RSLN can.

QFI IRM Fall 2023 Question 1

Source Material: Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models

Learning Outcome:

2b) Evaluate a company's or a portfolio's exposures to various risks

(b)

Commentary on Question:

Candidates overall did well on this question. Most candidates were able to list the relevant facts and explain whether they did or did not apply to the ILN and GARCH models.

(i)

(1) Volatility is stochastic not constant
(2) High volatility periods are fairly rare, but tend to be clustered together
(3) When the absolute value of the log-return is high, the return is more likely to be negative than positive
(4) When volatility does move from low to high, it is far more likely to be precipitated by a sudden drop in prices than a sudden increase in prices

(ii) ILN does not comply with any of the stylized facts. For ILN, the volatility is constant, and therefore there is no randomness and no clustering. The log-returns over each non-overlapping period are independent. The log-returns are symmetric about the mean, so jumps up are just as likely as jumps down. Finally, with constant volatility, there is no leverage effect.

(iii) The GARCH model incorporates stochastic volatility, through the dependence on Y_t. It also incorporates volatility clustering, through the $(Y_{t-1} - \mu)^2 \; and \; \sigma_{t-1}$. The GARCH model has no mechanism for incorporating the leverage effect, where higher volatility clusters are associated with market crashes or failures. Under the GARCH model, high volatility periods are equally likely to be instigated by a random jump up in the stock price as a random jump down.

(c)

Commentary on Question:

Candidates had mixed performance on this question. In part (i) many candidates could identify to use the Real-World measure but provided limited support. In part (ii), candidates could often calculate Y0 but many could not calculate the other needed values. Some candidates did not apply natural log when calculating the return and receive partial credits. In part (iii), most candidates calculated the long-term volatility but were unable to determine the amount of time needed to converge to the long-term volatility. In part (iv), most candidates correctly identified the impact of one parameter update but not all candidates provided accurate discussion of both.

(i) You should use real-world measure for this calculation. The real-world measure captures the true underlying dynamics of price movements and is more suitable for assessing tail risk or analyzing risk mitigation strategies.

(ii) $Y_0 = \ln(400/450) = -0.11778$

$$\sigma_1^2 = a_0 + a_1(Y_0 - \mu)^2 + b\sigma_0^2$$

$= 0.00065 + 0.1 * (-0.11778 - 0.003)^2 + 0.6 * 0.0036$

$= 0.004269$

$S_1 = 400 * 0.8 = 320$

$Y_1 = \ln(320/400) = -0.22314$

$$Z = \frac{Y_1 - \mu}{\sigma} = \frac{-0.22314 - 0.003}{\sqrt{0.004269}} = -3.46121$$

Using the Normal Distribution, Probability = 0.000269

(iii) Long-Run Variance = $\frac{0.00065}{1-(0.1+0.6)} = 0.002167$

$$\mathrm{E}_0[\sigma_t^2] = a_0\left(\frac{1-(a_1+b)^{t-1}}{1-(a_1+b)}\right) + (a_1+b)^{t-1}\sigma_1^2$$

Applying the equation above recursively, the value reaches required precision at t=23.

t	sigma
1	0.004269
2	0.003638
3	0.003197
4	0.002888
5	0.002671
6	0.00252
7	0.002414
8	0.00234
9	0.002288
10	0.002251
11	0.002226
12	0.002208
13	0.002196
14	0.002187
15	0.002181
16	0.002177
17	0.002174
18	0.002172
19	0.00217
20	0.002169
21	0.002168
22	0.002168
23	0.002167

(d)

Commentary on Question:

Most Candidates correctly identified that GARCH is not scalable but failed to provide the correct explanation.

The junior actuary is not correct. GARCH is not scalable. 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.

(e)

Commentary on Question:

Most Candidates did poorly on this question. Some candidates were able to correctly identify the use of risk-neutral measure and the use of risk free rates and received partial credits.

We need the equivalent Q-measure process to be risk-neutral in the period from *t*-1 to *t*, which means that

$$\mathrm{E}_{\mathbb{Q}}[e^{Y_t}|\mathcal{F}_{t-1}] = e^r,$$

where *r* is the risk free rate of interest. We can achieve this, retaining the original GARCH
variance process, with the distribution

$$\begin{aligned} Y_t|\mathcal{F}_{t-1} &\sim_{\mathbb{Q}} N(r - \tfrac{\sigma_t^2}{2}, \sigma_t^2) \\ &\Rightarrow Y_t|\mathcal{F}_{t-1} = r - \tfrac{\sigma_t^2}{2} + \sigma_t\,\varepsilon_t, \\ \sigma_t^2 &= a_0 + a_1(Y_{t-1} - (r - \tfrac{\sigma_t^2}{2}))^2 + b\sigma_{t-1}^2, \end{aligned}$$

where *a*0, *a*1, and *b* have the same values under the Q-measure as under the P-measure. This Q-measure is no longer a regular GARCH process, because of the term in $\sigma t2$ in the equation
The process is called a GARCH-M, or GARCH-in-Mean process.

(f)

Commentary on Question:

Most Candidates correctly identified the use of TGARCH but failed to provide the sufficient explanation and support.

TGARCH model (for Threshold GARCH) introduces an additional term in the variance equation if the previous period log-return was negative.

$$\text{TGARCH variance:} \quad \sigma_t^2 = a_0 + (a_1 + \gamma \min(Y_{t-1}, 0))(Y_{t-1} - \mu)^2 + b\sigma_{t-1}^2.$$

We expect $\gamma < 0$, so that there is more of a jump in volatility when *Yt*-1 is negative than when it is positive, creating the leverage effect that we identified in the data.

QFI IRM Spring 2024 Question 3

Source Material: Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models

Learning Outcome:

2b) Evaluate a company's or a portfolio's exposures to various risks

(a)

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.

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

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

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,

$\hat{\mu} = 6 * -0.02029 = -0.12171$

$\hat{\sigma} = sqrt(6) * 0.15798 = 0.38697$

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

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

(b)

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. 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
- 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

QFI IRM Spring 2024 Question 6

Source Material: CP351-109-25: IAIS Application Paper on Liquidity Risk Management

Learning Outcome:

2b) Evaluate a company's or a portfolio's exposures to various risks

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.

(a)

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)

Commentary on Question:

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

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)

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)

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)

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.

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. Description of use and interpretation of liquidity stress testing

QFI IRM Fall 2024 Question 5

Source Material: Quantitative Enterprise Risk Management, Ch. 8: Market Risk Models

Learning Outcome:

2b) Evaluate a company's or a portfolio's exposures to various risks

Commentary on Question:

This question aims to test candidates' understanding on the advantages and limitations of various risk metrics. To receive maximum points, candidates must not only demonstrate the ability to select the appropriate market risk models, but also provide explanation as to how different approaches form a set of complementary investment metrics. Overall, candidates did well in question (a), but most struggled to receive full credit in question (b) and (c).

(a)

Commentary on Question:

The candidate performed well on this question overall. Most were able to correctly identify that the ILN model is suitable for short-term applications, the RSLN model is better for longer-term horizons, and the GARCH model works for both. However, many candidates did not provide sufficient explanation to justify these choices, resulting in partial credit.

The ILN model is typically used for very short-term applications with higher frequency time steps.

- It is similar to geometric Brownian motion (GBM) and forms the basis for the Black-Scholes formula. It provides a good fit for stock data over short horizons, assuming no major market events occur.
- ILN is scalable, converging to GBM as time steps increase, offering tractability. However, it doesn't fit well for longer time periods and fails to capture volatility clustering or extreme market disruptions, making it unsuitable for long-term risk assessment.

The RSLN model needs more data for an adequate fit, and would be used for longer horizons.

- RSLN assumes that the stochastic log-return process randomly switches between K different underlying processes, each with different parameters. Each process represents a different regime for the state of the economy. The model can be used for continuous or discrete time processes.
- Regime switching lognormal models with 2 or 3 regimes have proved quite robust for fitting stock prices over longer time periods, and are also relatively tractable. Generally, more frequent data requires more regimes.
- Like GARCH model, the RSLN model allows sudden jumps in volatility. A major difference between the models lies in the subsequent behavior. In the GARCH model, the volatility will trend back to a lower value over some period. Under the RSLN model, the volatility switches suddenly from high to low. Goodness of fit tests for long-run returns have been found to favor the regime switching framework, because 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. Therefore, RSLN is a good fit for long term risk assessment.

The GARCH model is flexible, and is used in a wide range of short and longer term settings.

- GARCH is a part of a family of discrete time models with time-varying volatility.
- Unlike ILN, where stock returns/log-returns are independent and identically distributed normal random variables, the GARCH model incorporates stochastic volatility and volatility clustering, through the dependence on stock returns at a given time t.
- Even with fixed parameters, GARCH can take a wide range of paths, and are therefore more flexible in both short- and long-term risk assessment.

(b)

Commentary on Question:

Candidates performed poorly on this question, primarily because they did not effectively connect the practical considerations to the overall context, where the manager asked for a recommendation on the best model to evaluate equity risk using the expected shortfall measure. However, most candidates earned partial credit for discussing general factors to consider when choosing a model.

The GARCH and RSLN models are fatter tailed than the ILN model, and generate serial correlation in the log-returns and in the volatility. If this is not critical to the model results, then using the ILN model may be adequate.

When calculating a VaR risk measure, it may not be necessary or worthwhile to ensure that a model provides a good fit in the extremes of the distribution, beyond the relevant α-quantile. On the other hand, the Expected Shortfall risk measure takes the full tail of the loss distribution into consideration, so it is more important to fit a fat-tailed distribution to fat-tailed data.

(c)

Commentary on Question:

The candidate performed poorly on this question, as most were unable to correctly calculate the highest AIC or BIC. However, many earned partial credit for demonstrating the correct reasoning in selecting the appropriate model, assuming they had calculated the AIC and BIC correctly.

Akaike Information Criteria (AIC) or Bayes Information Criterion (BIC) should be used to choose the model with the highest AIC or BIC. AIC (= ll – k) and BIC = ll – (k log(n))/2, where ll is the maximum log-likelihood, k is the number of parameters, and n is the number of data points in the sample.

				Daily	Daily	Monthly	Monthly
Model	Maximum Log-likelihood (Monthly)	Maximum Log-likelihood (Daily)	Number of Parameters	AIC	BIC	AIC	BIC
ILN	595	1335	2	1,333	1,332	593	592
GARCH(1,1)	611	1609	4	**1,605**	**1,604**	607	606
RSLN	619	1579	6	1,573	1,571	**613**	**611**

ILN fit is poor for both data sets. Therefore, it is not recommended.

Daily, recommend: GARCH

The GARCH model provides a much better overall fit for the daily data, using both AIC and BIC, compared to the other two models.

Monthly, recommend: RSLN

Using AIC and BIC criteria, RSLN model provides a slightly better fit for monthly data. The monthly data is more relevant to your company’s assessment on stock monthly return.

ILA LAM Fall 2020 Question 2

Source Material: CP351-107-25: Key Rate Durations: Measures of Interest Rate Risk

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

(d)

Commentary on Question:

For (i), candidates did very well. For (iii), candidates did poorly as many candidates only discussed the interest rate exposure for asset only or effective duration only, without recommending any changes to address asset liability KRD mismatches.

(i)

X = sum of asset KRDs = 0.1 + 0.5 + 0.9 + 2 + 9.9 = 13.4

Asset Exposure = (-0.1%)*1,000,000*13.4*(-) = 13400

Liability Exposure = -13400+(-200) = -13600

Z = -13600/1,000,000/(-0.1) = 13.6

Y = Z - sum of Liability KRDs = 13.6 – 0.05 – 0.4 – 1 – 12 = 0.15

(ii)

Calculate income impact using the formula:

Income Impact = –1 × Rate Change × Net KRD × 1,000,000

1-Year:

Rate Change = +20 bps, Net KRD = 0.1 – 0.05 = 0.05

Income Impact = –(20 / 10,000) × 0.05 × 1,000,000 = –100

5-Year:

Rate Change = +15 bps, Net KRD = 0.5 – 0.15 = 0.35

Income Impact = –(15 / 10,000) × 0.35 × 1,000,000 = –525

10-Year:

Rate Change = –30 bps, Net KRD = 0.9 – 0.4 = 0.5

Income Impact = –(–30 / 10,000) × 0.5 × 1,000,000 = 1,500

20-Year:

Rate Change = –20 bps, Net KRD = 2 – 1 = 1

Income Impact = –(–20 / 10,000) × 1 × 1,000,000 = 2,000

30-Year:

Rate Change = –5 bps, Net KRD = 9.9 – 12 = –2.1

Income Impact = –(–5 / 10,000) × (–2.1) × 1,000,000 = –1,050

Therefore:

Total Income Impact = –100 – 525 + 1,500 + 2,000 – 1,050 = 1,825

(iii)

The portfolio is exposed to non-parallel curve movements because it is not key rate duration matched, particularly at the 30 year point where assets are shorter than liabilities.

To reduce the interest rate risk, the asset portfolio could be traded longer to close the key rate gaps. For example, buying more 30 year assets and selling some 10 and 20 year assets would close the majority of the risk.

(e)

Commentary on Question:

Candidates did well in this question. Most candidates correctly described the behavior at short-term KRD but did not mention the behavior for long-term KRD. Also come candidates did not explain why callable bonds with same or higher coupon would result the corresponding behavior.

(i)

Callable bonds can be exercised at any time, so the duration is naturally lower than a non-callable bond. Short-term KRD will increase and long-term KRD will decrease comparing to non-callable bond

(ii)

There is a higher probability the bond will be called so the effective duration is shorter. Short-term KRD will further increase and long-term KRD will further decrease comparing to non-callable bond with lower coupon rate

ILA LAM Spring 2021 Question 2

Source Material: CP351-107-25: Key Rate Durations: Measures of Interest Rate Risk

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

(b)

Commentary on Question:

For full credit, candidate should relate the answer to the given company information (aka MRK has interest sensitive products and thus would choose to minimize liability int rate exposure)

b(i):

Given that MRK Life's insurance liabilities are interest sensitive, minimizing surplus volatility is more advantageous as it aims to manage both assets and liability interest rate exposure. Managing surplus volatility aims to address the duration mismatch from both asset and liability.

b(ii)

MV change = - MV*Duration*Shock

Change to Assets = 1,000*10*(-0.5%) = +50

Change to Liabilities = 800*15*(-0.5%) = +60

Change to Surplus = 50 - 60 = -10

b(iii)

MRK would need a MV of +10 to offset its surplus decrease in part ii.

Change to swap = - Notional*Duration*Shock

Change to swap 1 = 100*15*(-0.5%) = +7.5

Change to swap 2 = 100*15*(-0.5%) = -5

MRK should execute 133.33 notional of swap 1 to offset its surplus decrease (10/7.5*100 = 133.33)

(c)

Commentary on Question:

Candidate could calculate either the rate of return or the amount of return.

Since the bonds are zero coupon, their durations are 10, 20, and 30 (which can also be proven from the given effective duration).

The key rate duration (KRD) for each portfolio = the proportion of MV * duration of bond

The scenario return at each duration = - KRD * change in spot rate

The change in return for each portfolio is the sum of changes of each KRD

Rate of Return:

Portfolio 1 = +0.583

Portfolio 2 = -0.25

Amount of Return:

Portfolio 1 = 350

Portfolio 2 = -150

ILA LAM Fall 2021 Question 3

Source Material: CP351-107-25: Key Rate Durations: Measures of Interest Rate Risk

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

Commentary on Question:

For part (i) the candidate must estimate the rate shock for year 19 by Linearly interpolating the year 10 and 30 shocks; to earn the fully credits, the candidates need to calculate the impact for each scenario and show all work. For example, for scenario #1, Candidates only get partial credit if candidate skip the calculation and jump to the conclusion of no impact because of the parallel shock and matched duration.

Part (i):

Assets:

MV(1) = 20

MV(2) = 30

MV(3) = 50

Duration:

D(1) = 5

D(2) = 10

D(3) = 30

Liability:

MV(L) = 100

D(L) = 19

Key Rate Duration (KRD)

KRD(i)

$= \frac{MV(i)}{\sum MV(i)} \times$ D(i)

Change in (Asset or Liability)

= - KRD * Shock

Change in net Surplus = Change in Asset - Change in Liability

Linearly interpolate Shock for year 19

= 30yr Shock × (19-10) / (30-10) + 10yr Shock × (30-19) / (30-10)

= 0.015 × 0.45 + (-0.0025) × 0.55

= 0.005375

	MV ($million)	**KRD - 5yr**	**KRD - 10yr**	**KRD - 19yr**	**KRD - 30yr**	**Effective Duration**
Liability	100			19		19
Asset	100	1	3		15	19

		5yr	**10yr**	**19yr**	**30yr**	**Change**
Scenario 1	Parallel shock - 50bp	-0.005	-0.005	-0.005	-0.005	**in MV**
	Change in liability	0	0	9.5	0	9.5
	Change in assets	0.5	1.5	0	7.5	9.5
	Change in net surplus					0

		5yr	**10yr**	**19yr**	**30yr**	**Change**
Scenario 2	Unparallel shock	-0.005	-0.0025	0.005375	0.015	**in MV**

Change in liability	0	0	-10.2125	0	-10.2125
Change in assets	0.5	0.75	0	-22.5	-21.25
Change in net surplus					-11.0375

Conclusion:

Scenario 1: Immunized to parallel shocks given no mismatch in total duration.

Scenario 2: Mismatch in KRD causes income volatility under unparallel interest rate movements. Asset & liability are NOT fully immunized.

Part (ii):

It is true that the assets and liability have the same effective duration, however effective duration assumes that spot curve shifts will be parallel. As demonstrated in part (i), the portfolio is immunized to parallel shocks in the yield curve (scenario 1); however, the portfolio is not immunized to non-parallel shocks (scenario 2) due to mismatched KRDs (key rate durations).

ILA LAM Spring 2023 Question 3

Sources:

- CP351-107-25: Key Rate Durations: Measures of Interest Rate Risk
- CP351-109-25: IAIS Application Paper on Liquidity Risk Management

Learning Outcomes:

2a) Demonstrate an understanding of various risk identification tools

2b) Evaluate a company's or a portfolio's exposures to various risks

Commentary on Question:
This goal of this question is to test the candidate's understanding of the steps required to establish a process for strategic asset allocation. It also tests the candidate's ability to interpret various efficient frontiers, and the calculation and use of key rate durations.

Solution:
(a) Critique the following statements:

A. *Given our company's historical success when limiting duration mismatch to within 0.5 years and limiting portfolio exposure to alternative assets to 10%, we will hold these constraints constant as we explore SAA.*

B. *Adding new asset classes will allow us to better diversify risks and optimize efficiency by considering possible correlations between various asset classes and correlations with our liabilities.*

C. *When building a replicating portfolio, we should prioritize matching the key rate duration (KRD) profile of liabilities instead of focusing only on minimum interest rate guarantees.*

D. *Given surplus volatility was the most severe impact of the recent recession, the SAA process will focus only on minimizing surplus volatility.*

E. *With an objective of closely matching the cash flows or interest rate duration of our liabilities, we maintain a separate investment portfolio to back the reserves for each of our major liability types.*

F. *A model should be built which seeks to maximize return for a given level of surplus volatility while factoring in our chosen constraints. This will provide an efficient frontier that can be used to determine our risk appetite.*

Commentary on Question:

Partial points were granted if the candidates opined on the accuracy of each statement. Full marks were only given when candidate critiqued each statement and defended their conclusion with information that aligns with source material.

Most of the candidates were able to receive partial credits

A. This statement is incorrect. While it is appropriate to establish constraints to maintain for SAA such as the items listed, it is expected that building an SAA process will require an iterative approach with targets and constraints. The company should allow flexibility around their constraints, regardless of historical precedent.

B. This statement is correct. Expanding asset classes considered for portfolio will increase ability to optimize both diversification and efficiency around targets. Understanding the correlations is key to accomplishing this, as the company notes.

C. This statement is incorrect. Including KRDs when building a replicating portfolio is appropriate, however both consideration of duration matching and risks associated with interest rate guarantees should be included in focus for risk minimization.

D. This statement is incorrect. While having a key metric in focus such as surplus volatility is appropriate for assessing performance, including multiple risk metrics allows for a complete understanding of the strategy's performance. The efficient frontier may vary under different metrics, and multiple perspectives should be accommodated.

E. This statement is incorrect. Holistic ALR and SAA consider the entire asset portfolio in aggregate to first optimize risk-adjusted returns within capital constrains and risk tolerance levels while simultaneously determining the most effective constraint for ALM

F. This statement is correct. To create an efficient frontier the model should be able to maintain established constraints in determining a portfolio that optimize risk and return

(b)

(i) Calculate the change in surplus under each shock. Show all work.

(ii) Assess if the investment strategy immunizes the company’s surplus.

(iii) Identify key considerations if implementing a liquidity risk policy for this product.

Commentary on Question:

Many of candidates were able to calculate the surplus change under each shock correctly. Almost all the candidates concluded the investment strategy does not immunize the company's surplus. However only a few candidates commented on the shocks and investment strategies.
Most candidate received partial credits on part iii.

(i) % change in Liability = [P* - P] / P = Δ P / P = ∑ (-1) * D(i) * d(i)
New liability value_1 = (1 + % change in liability_1) * P = [(1 + (-1.93%)] * 100 million = $98.08
New liability value_2 = (1 + % change in liability_2) * P = [(1 + (-1.67%)] * 100 million = $97.39
New liability value_3 = (1 + % change in liability_3) * P = [(1 + (0.08%)] * 100 million = $100.084
% change in Asset = (-1) * [wgt1 * D1*d1 + wgt2 * D1*d1] = (-1) * [1/2 * 5yr * d1 + 1/2 * 10yr * d1]
New Asset value = (1 + % change in Asset) * P = (1 + Δ P / P) * 100 million
New Asset value_1 = [(1 + (-1.88%)] * 100 million = $98.125
New Asset value_2 = [(1 + (-3.25%)] * 100 million = $96.75
New Asset value_3 = [(1 + (-2.50%)] * 100 million = $97.5

	Scenario 1	**Scenario 2**	**Scenario 3**
Δ% in Liab	-1.925%	-2.615%	0.084%
New Liab	$ 98.08	$ 97.39	$ 100.0840
Δ% in Asset	-1.8750%	-3.2500%	-2.5000%
New Asset	$ 98.125	$ 96.75	$ 97.5000
$Δ in Surplus	$ 0.050	$ (0.635)	$ (2.584)

(ii) Shock #1 is small parallel shifts to the yield curve; #2 is curvature shift of {1,0,1} where short rate drops and long rate raises. #3 is a steepness shift of {-1, 0,1} where short rate moves more than long rate;
As can been seen from part i's calculated results, surplus changes are much higher in non-parallel shifts (shock #2 and #3), than parallel shifts (shock #1). This indicates the assets and liabilities are not fully immunized against each other, causing the CFO's objective not being satisfied.
Since the yield curve rarely moves in parallel fashion, to minimize surplus movements caused by non-parallel shifts, portfolios that are immunized based on a KRD strategy is recommended since it doesn't need significant rebalancing of assets/liabilities. For example, trying to immunize the portfolio by investing the assets backing liabilities in a range of maturity levels (from 1yr to 10 yrs) could lower surplus movements.

(iii) Liquidity risk is both an asset and liability concern. The company needs to consider characteristics of both the annuity payments as well as the liability when setting a liquidity policy.

A company's strategic asset allocation and contingent liquidity planning should directly reflect the expected a contingent liquidity needs of its liabilities and potential sudden extreme shifts of liquidity in the financial market.

Because there is a cash flow timing mismatch of asset (5 and 10 year bonds) and liabilities (every year) this may lead to liquidity issues when selling or reinvesting bonds depending on shifts in the yield curve.

The company should have a written liquidity policy, a written liquidity stress management plan and should continually monitor the liquidity risk.

ILA LAM Fall 2023 Question 6

Sources:

- CP351-105-25: ALM for Life, Annuities, and Pensions (section 3)
- CP351-109-25: IAIS Application Paper on Liquidity Risk Management

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

2b) Evaluate a company's or a portfolio's exposures to various risks

Commentary on Question:
Commentary listed underneath question component.

Solution:
(a) Calculate the Macaulay Duration of the bond.

Commentary on Question:
Candidates generally did well on this part of the question. Common errors included not halving the coupon rate, discounting at the annual yield instead of the semi-annual yield, and weighting with annual coupons instead of semi-annual coupons (ie. t=1, 2, 3… instead of t=0.5, 1, 1.5,…) and partial credit was given accordingly.

Semi-annual coupons of 250,000 * 4.5% * 0.5 = 5,625
Face at maturity = 250,000
t1 = 0.5, 1, 1.5,…, 10 (weightings)
t2 = 1,2,3,…, 20 (discount periods)
Discount rate = 3% * 0.5 = 1.5% per period
Bond price = sum[(coupons +face) * discount rate] = 282,191
Numerator = sum[t1* (coupons+face) * discount rate] = 2,339,319

Macauley duration = numerator / bond price = 8.29

Detailed calculations below:

t2	Semi-annual Coupons	Discount factor	Bond price	t1	Numerator
1	5,625	0.98522	5,542	0.5	2,771
2	5,625	0.97066	5,460	1	5,460
3	5,625	0.95632	5,379	1.5	8,069
4	5,625	0.94218	5,300	2	10,600
5	5,625	0.92826	5,221	2.5	13,054
6	5,625	0.91454	5,144	3	15,433
7	5,625	0.90103	5,068	3.5	17,739
8	5,625	0.88771	4,993	4	19,974
9	5,625	0.87459	4,920	4.5	22,138
10	5,625	0.86167	4,847	5	24,234
11	5,625	0.84893	4,775	5.5	26,264
12	5,625	0.83639	4,705	6	28,228
13	5,625	0.82403	4,635	6.5	30,128
14	5,625	0.81185	4,567	7	31,967
15	5,625	0.79985	4,499	7.5	33,744
16	5,625	0.78803	4,433	8	35,461
17	5,625	0.77639	4,367	8.5	37,121
18	5,625	0.76491	4,303	9	38,724
19	5,625	0.75361	4,239	9.5	40,271
20	255,625	0.74247	189,794	10	1,897,940

(c) Determine the par value of the new bond needed to keep the duration of the portfolio constant.

Commentary on Question:
Candidates did poorly on this part of the question. The majority of candidates incorrectly calculated dollar duration based on market value instead of price. Partial credit was awarded to those who correctly calculated dollar durations.

Dollar duration(old) = price(old) * duration(old) / 100 = 90 * 5 / 100 = 4.5
Dollar duration(new) = price(new) * duration(new) /100 = 115 * 7 / 100 = 8.05

#units = MV(old) / price(old) = 350,000 / 90 = 3,889

MV(new) = dollar duration (old) / dollar duration (new) * 100 * #units
= 4.5 / 8.05 * 100 * 3,889
=217,391

Par value = MV(new) / price(new) * 100 = 217,391 / 115 * 100 = 189,036

(d)

(i) Explain why insurance companies have different liquidity concerns than banks.

(ii) Describe two possible liquidity risk metrics your company can use.

Commentary on Question:
Candidates received full credit for identifying at least four of the points below for part (i). Candidates generally did well on part (i) of this question. Most candidates correctly identified the long-term nature of insurance liabilities and upfront premiums leading to insurers being liquidity rich and the contrast with banks facing runs. Fewer candidates mentioned insurance liabilities being less liquid and that liability side risks still exist for insurers.

Candidates generally did very well on part (ii) of this question. Some candidates provided risk measures such as VaR and CTE and did not receive any credit.

(i)

- In the insurance business model, the payments/premiums are collected upfront and services/claims/benefits provided in the future. The cycle makes insurers liquidity rich.
- Insurers, unlike banks, generally have liabilities with a longer maturity than their assets, which makes them less vulnerable to customer runs. In addition, insurers' liabilities are in general less liquid than bank deposits, as the possibilities for savings withdrawals are restricted in most insurance contracts and are also more costly for customers (owing to tax and surrender penalties).
- Liability-side liquidity risks still exist for insurers. For example, life insurers, in particular, face the risk of simultaneous withdrawals or policy surrenders by policyholders.
- Insurance companies are much less interconnected than banks and by pooling a large number of risks and retaining the bulk of the risks underwritten on their balance sheet, potential liquidity issues are likely to be idiosyncratic.
- Liquidity is a key factor in insurers' investment strategies but it is less of a risk for the sector players than for banks which rely primarily on the wholesale funding market and engage in maturity transformation.

(ii) Metrics include liquidity coverage ratio, a calculation covering an excess or deficit liquidity amount, survival period, asset (only) liquidity, or liability (only) liquidity.

ILA LAM Fall 2024 Question 4

Source Material: CP351-107-25: Key Rate Durations: Measures of Interest Rate Risk

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

(a)

Commentary on Question:

Most of the students were able to identify that the two securities should have the same effective duration, although they are not able to calculate the correct key rate duration for security B at each tenor. Full points is only given to if everything is calculated correctly.

KRD = (Price of zero-coupon bond/total portfolio value) * zero-coupon bond's KRD

Total portfolio value = 217.91

t	Weight	Effective Duration	KRD
3	95.88/217.91=44%	3.00	44%*3=1.32
7	74.09/217.91=34%	7.00	34%*7=**2.38**
15	47.94/217.91=22%	15.00	22%*15=3.30

Key rate duration of year 7 is incorrectly calculated.

Effective duration of security A = 7year

Effective duration of security B = 1.32+2.38+3.3=7

Two securities have the same effective duration.

(b)

Commentary on Question:

*Most of the students were able to identify that the price change = key rate duration * rate change. However, only a few students understand that MV should be used in the calculation instead of Par value.*

Part ii and Part iii were very poorly done. Most of the students were not able to justify answers in associating with part i) and were only able to identify one advantage of using key rate duration over effective duration.

(i)

Scenario X:

- Portfolio A is unaffected since the 7-year rate does not change

- Portfolio B = -D(3) * 0.20% * MV + -D(15) * (-0.20%) * MV

Scenario Y:

Level shift so can use effective duration

- Portfolios A and B = -(EffD)*(-0.20%)*MV

Scenario Z:

- Portfolio A is unaffected since the 7-year rate does not change

- Portfolio B = -D(3) * (-0.20%) * MV + -D(15) * 0.20% * MV

Change

Portfolio	Scenario X	Scenario Y	Scenario Z
A	-	1.04	-
B	0.8	3.05	-0.8

(ii)

Effective duration predicts the change in price for a parallel yield curve shift. However, the spot curve rarely moves in a parallel fashion even on the infinitesimal level, which makes effective duration not precise enough in many bond portfolio strategies, such as hedging or immunization. When these strategies fail to be effective, often it is not because the yield curve shifts too much, but because the yield curve does not shift in a parallel fashion.

Observations from part (i):

Scenarios 1 and 3 do not affect portfolio A because the 7-year rate does not change, but portfolio B is affected. The portfolios have the same effective duration, but very different interest rate exposures. They behave very differently under non-parallel yield curve shifts. Therefore, effective duration is not useful for non-parallel yield curve shifts. You must understand the sensitivity of each key rate.

(iii)

KRDs recognize that the yield curve movement is driven by multiple market factors. The validity of key rate durations does not depend on any equilibrium model of the yield curve movement. Key rate durations are applicable over a broad range of arbitrary yield curve movements. It is easy to use KRDs to create a replicating portfolio of a bond with embedded options using zero-coupon bonds. Thus, the cash flow of the replicating portfolio correctly represents the instantaneous expected cash flow of the option. Hence, key rate durations can provide valuable insight into option-embedded bond behavior that other measures (such as effective duration) cannot.

(c)

Commentary on Question:

This section was done poorly. Most of the students were not able to compare and contrast the duration difference between these assets. Some students described the asset feature instead of focusing on the impact of different features on duration of each assets.

Callable Corporate Bond

Callability shortens the effective duration

The callable bonds are more sensitive to the shorter-term key rate changes however a callable bond with a lower coupon rate has less probability of being called which means that the effective duration is relatively higher and the bond also tends to be more sensitive to the longer-term key rate risk

The increase in interest rate risk exposure is not uniform across the yield curve but is more substantial for the long-term rate

Callable Bond with a Sinking Fund

The sinking fund reduces the effective duration of the bond

The sinking fund makes the bond more sensitive to the shorter-term key rates

Significantly reduces the long-term rate exposure since much of the portion of the bonds has been sunk over the years

European Call Option

The option is insensitive to the changes of any key rates with a term before the expiration date

The key rate duration for the expiration date is negative

A call option is exposed much more to a curvature yield curve movement than to a parallel movement

European Put Option

Has a positive key rate duration at expiration but negative key rate durations beyond the expiration date

The key rate duration profile of a European put option is almost the mirror image of that of a European call option, but the magnitude of the key rate durations is not the same

The relationship between the key rate durations of the call and the put can be derived from the put/call parity

ILA LAM Fall 2024 Question 6

Sources:

- CP351-101-25: ALM for Life, Annuities, and Pensions (section 4)
- Ch 4 of Fixed Income Securities: Tools for Today's Markets, Tuckman, Bruce and Serrat, Angel, 4th Edition, 2022

Learning Outcome:

2a) Demonstrate an understanding of various risk identification tools

Question:

You are given the following information about a bond:

Time to Maturity	15 years
Annual Coupon Rate	6.5%
Par Value	1,000,000
Market Value	1,000,000

Solution:

(b)

(i) Calculate the modified duration of the bond.

(ii) Calculate the convexity of the bond.

(iii) Estimate the change in market value of a 1% increase in interest rates using the information calculated in (i) and (ii).

Show all work.

Commentary on Question:
Candidates generally performed well when calculating the bond's duration. Common mistakes included using an incorrect interest rate or assuming semi-annual coupon payments. Partial credit was awarded in these cases. For part (ii), many candidates struggled with deriving the correct formula for convexity, leading to a higher frequency of errors. Candidates performed well in part (iii), where most candidates correctly applied the calculated duration and convexity from parts (i) and (ii).

The primary objective of this question is to calculate the modified duration and convexity of the bond. A key assumption is that when the bond's par value equals

its market value, the yield is equal to the coupon rate. For part (iii), candidates are required to use both duration and convexity to calculate the change in the bond's market value. It is important to note that when interest rates rise, the market value of bonds will always decrease.

Please see the Excel solution for detailed calculations

Exam Model Solutions – CP 351 Learning Objective 3

Learning Objectives: The candidate will understand tools and strategies to manage ALM risks.

Exam	Question Part	Exam Points	Source Material	Learning Outcome
QFIIRM Fall 20	4a	2	The Devil is in the Tails Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 20	4b	1	The Devil is in the Tails	3b
QFIIRM Fall 20	4c	1.5	The Devil is in the Tails Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 20	4e	1.5	The Devil is in the Tails	3b
QFIIRM Fall 20	4f	0.5	The Devil is in the Tails	3b
QFIIRM Spring 21	2a	1.5	The Devil is in the Tails Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Spring 21	2b	3	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Spring 21	2c	2.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas Quantitative Enterprise Risk Management, Ch. 7: Stress Testing	3b 3c
QFIIRM Fall 21	4a	2	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 21	4b	2.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 21	4c	1.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 21	4d	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 22	1a	0.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 22	1b	1.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 22	1c	2	Quantitative Enterprise Risk Management, Ch. 7: Stress Testing	3c
QFIIRM Spring 23	3a	1	Quantitative Enterprise Risk Management, Ch. 7: Stress Testing	3c
QFIIRM Spring 23	3b	2	Quantitative Enterprise Risk Management, Ch. 7: Stress Testing	3c
QFIIRM Spring 23	3c	2	Quantitative Enterprise Risk Management, Ch. 7: Stress Testing	3c
QFIIRM Spring 23	9a	0.5	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3f
QFIIRM Spring 23	9b	1	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3f
QFIIRM Spring 23	9c	2	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3f
QFIIRM Spring 23	9d	1.5	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3f
QFIIRM Fall 23	2b	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 23	2c	3	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 23	2e	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 23	4a	1	Quantitative Enterprise Risk Management, Ch. 14: Model Risk and Governance	3d
QFIIRM Fall 23	4b	1.5	Quantitative Enterprise Risk Management, Ch. 14: Model Risk and Governance	3d

QFIIRM Fall 23	4c	3	Quantitative Enterprise Risk Management, Ch. 14: Model Risk and Governance	3d
QFIIRM Fall 23	4d	1	Quantitative Enterprise Risk Management, Ch. 14: Model Risk and Governance	3d
QFIIRM Fall 23	7c	1	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 6	3f
QFIIRM Fall 23	7d	1.5	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 6	3f
QFIIRM Fall 23	7e	1	Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 6	3f
QFIIRM Spring 24	4f	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Spring 24	7a	3	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3e, 3f
QFIIRM Spring 24	7b	1.5	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3e, 3f
QFIIRM Spring 24	7c	1	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3e, 3f
QFIIRM Spring 24	7d	2	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3e, 3f
QFIIRM Spring 24	7e	1.5	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6	3e, 3f
QFIIRM Fall 24	4a	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 24	4c	0.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 24	4d	1.5	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 24	4e	1	Quantitative Enterprise Risk Management, Ch. 6: Copulas	3b
QFIIRM Fall 24	8a	2	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives	3e
QFIIRM Fall 24	8b	1	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives	3e
QFIIRM Fall 24	8c	2	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives	3e
QFIIRM Fall 24	8d	2	Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives	3e
QFIPM Fall 21	6a	1	LDI Explained	3a
QFIPM Fall 21	6b	1	LDI Explained	3a
QFIPM Spring 22	12a	1	LDI Explained	3a
QFIPM Spring 22	12b	1	LDI Explained	3a
QFIPM Spring 22	12c	0.5	LDI Explained	3a
QFIPM Spring 22	12d	1	LDI Explained	3a
QFIPM Spring 22	12e	1	LDI Explained	3a

QFIPM Spring 22	12f	1.5	LDI Explained	3a

QFI IRM Fall 2020 Question 4

Source Material: CP351-112-25: The Devil is in the Tails

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

(a)

Commentary on Question:

Candidate performance was fair on this question. Most candidates could accurately describe the steps to simulate the loss distribution, however some could not sufficiently contrast rank and linear correlations.

(i)

1. From the copula distribution, draw a joint sample of uniforms $(u_1, u_2, \dots, u_n)$

2. For each uniform calculate the percentile of the risk-distribution $F_i^{-1}(u_i)$

3. Sum the individual distribution percentiles to get the total loss $\sum_i F_i^{-1}(u_i)$

4. Repeat 1-3 for sufficient number of samples to produce the simulated loss disitribution

(ii)

- Both are simple scalar measures that cannot fully specify the joint distribution when the margianls are provided.
- For a given copula, rank correlation is invariant as the marginal distribution changes. This is an advantage not true of linear correlation.

(b)

Commentary on Question:

Candidates performed poorly on this question. Many candidates incorrectly stated that the first statement was false.

1. The first statement is correct.

The default behavior of these entities does not depend at all on how a separate entity may combine, tranche and sell exposure.

2. The statement is partially correct.

The one-factor Gaussian model assumes that all underlying entities share a uniform correlation with all others. However, using different correlations for each tranche allows the model to fit to market prices.

(c)

Commentary on Question:

Candidate performance was fair on this question. Many candidates correctly identified the Gaussian copula as inappropriate; however, some identified Gumbel as most appropriate.

- The Gumbel copula is symmetric, so fails to account for the first property. It does exhibit tail dependence.
- A Gaussian copula exhibits no tail dependence, so fails the second property.
- A Student t-copula has tail-dependence and can be asysmmetric with more than two dimensions, which addresses both properties. The Student t-copula is the most appropriate.

(e)

Commentary on Question:

Candidates performed poorly on this question, as most did not comment on the effectiveness of each action for each objective.

1. Sell protection on super-senior tranches instead of mezzanine tranches

Effective in limited credit losses: It is very unlikely that super-senior tranches would experience any credit losses or material impacts from single-name defaults, even in a financial crisis similar to 2008.

Not effective in maintaining liquidity: The value of the positions could still decrease substantially and may require posting collateral, limiting liquidity, similar to AIG's situation.

2. Reduce the allocation in CDOs and purchase treasuries

Effective in limiting credit losses: Limits direct credit exposure

Effective in maintaining liquidity: Removes risk of collateral calls; also, high-quality bonds provide regular interest income and maintain liquidity in crisis events

3. Purchase credit default swaps (CDS) for hedging

Not effective limiting credit losses: During the financial crisis, mezzanine tranche hedges often failed; indeed standard models sometimes gave hedge ratios with the wrong sign. Current standard models still suffer most of the same defects. A failed hedge would exacerbate the impact of spread widening or default.

Not effective maintaining liquidity: Purchasing a CDS hedge requires regular premium payments, and potentially delayed timing to settlement which can limit liquidity

(f)

Commentary on Question:

Candidates performed well on this question.

Reducing the allocation in CDOs and purchasing treasuries is the most appropriate action, as it best satisfies both of the company's objectives.

QFI IRM Spring 2021 Question 2

Source Material: CP351-112-25: The Devil is in the Tails;

Quantitative Enterprise Risk Management, Ch. 6: Copulas;

Quantitative Enterprise Risk Management, Ch. 7: Stress Testing

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

3c) Apply stress testing and scenario analysis to assess extreme ALM events

(a)

Commentary on Question:

Candidates performed well on this part of the question. Most candidates provided at least two limitations with sufficient explanation to earn full credit. Some candidates defined a stress test as opposed to providing an alternative approach as the question requested and did not earn full credit.

(i) Two limitations:
1. The Gaussian copula model exhibits no tail-dependence/default clustering; however, credit behavior of entities in CDOs can exhibit high tail dependence/default clustering.
2. Lack of modeling economic factors causing defaults weakens the ability to do stress testing.

(ii) Calibrate to a copula with tail dependence (t-copula, etc.) and analyze tail values of the stress test.

(b)

Commentary on Question:

Candidate performance was fair on this question. Most candidates were able to calculate the Spearman correlation coefficient, however many candidates struggled to assess the client's concern using the risk measures.

(i) Rank the values for x and y:

x_i^r	y_i^r
3	3
7	8
1	1
4	7
8	6
6	4
5	5
9	9
2	2

Calculate the sample Pearson calculation on the ranks:

$$\rho_s = \frac{1}{n-1}\sum_{1}^{9} \frac{x_i^r - \overline{x^r}}{s_x} \times \frac{y_i - \overline{y^r}}{s_y} = .850$$

$$s_x = s_y = 2.738613$$

(ii) Total concordance for the first pair can be found following the table below:

J	Rank(x)	Rank(y)	Sign(x1-xj)	Sign(y1-yj)	Sign $\prod(x_1 - x_j)(y_1 - yj)$
1	3	3	-	-	-
2	7	8	-1	-1	1
3	1	1	1	1	1
4	4	7	-1	-1	1
5	8	6	-1	-1	1
6	6	4	-1	-1	1
7	5	5	-1	-1	1
8	9	9	-1	-1	1
9	2	2	1	1	1
	Total Concordance				8

(iii) The Pearson correlation coefficient measures the linear relationship between the losses, which can yield misleading dependency conclusions and is not appropriate to address the client's concerns. Spearman's correlation and Kendall's τ are rank correlation coefficients and better suited. They are both high, indicating high dependency and reinforcing the misleading potential of Pearson correlation which indicated a weak dependency. The high value of Kendall's τ from the sample suggests the losses are highly concordant, meaning large losses in one portfolio are associated with large losses in the other. Therefore, the client's concern is valid.

(c)

Commentary on Question:

Candidates performed poorly on this question. Most candidates were able to describe reverse stress testing and appropriately explain at least one benefit. However, candidates performed poorly on the remainder of this part. Many candidates did not provide clear and logical work to support their answers.

(i)

1. Working backwards from a stressed outcome to identify scenarios could reveal hidden vulnerabilities and key risks.
2. Reverse stress testing can provide meaningful risk insights for portfolios with significant positions in new markets or instrument types which do not yet have historical periods of stress to use as references/benchmarks.

(ii) Given an independence copula, the joint probability distribution is:

Loss (Millions)	**Probability**
$200 (Loss in Both Portfolios)	$1.83\% = 1/e^2 * 1/e^2$
$100 (Loss in One Portfolio Only)	$23.40\% = 1/e^2 * (1-1/e^2) * 2$
$0 (No Loss in Either Portfolio)	74.76%

95% CTE = Average loss above the 95th percentile
The 95th percentile is in the $100M loss probability mass.

95% CTE = [$200 * (1.83%) + $100 * (5% - 1.83%)] / 5% = **$137 Million**

(iii) A CTE of $200M means losses in both portfolios simultaneously.
Solve for the joint probability of this occurrence to be at least 5%.
Probability[N<0, M<0] >= 5%
Copula[$1/e^2$, $1/e^2$] = EXP[-2 * 2^(1-τ)] >= 5%
τ >= 1 - LN[-1/2 * LN(5%)] / LN[2] = **0.41709**

QFI IRM Fall 2021 Question 4

Source Material: Quantitative Enterprise Risk Management, Ch. 6: Copulas

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

(a)

Commentary on Question: *Performance on this question part was fair. Most candidates correctly described each type of copula listed through qualitative descriptions and by providing correct examples. Few candidates, however, identified the explicit copula as the appropriate recommendation with sufficient justification.*

(i) Fundamental copulas capture basic relationships between random variables (e.g. independence, monotonicity, and counter-monotonicity) and are derived from a clear relationship between the risks.

Implicit copulas are derived from existing multivariate distributions

Explicit copulas are multivariate functions that meet the definition of a copula but are not otherwise derived from existing multivariate distributions

(ii) An explicit copula is the best choice for this portfolio.

Explicit copulas can be determined based on a statistical analysis of the dependency structure between the risks.

The asset classes in question (Venture Capital and Public Equity) have very different return distribution characteristics, including high skew and kurtosis for Venture Capital and high volatility for Public Equity. As a result, they are unlikely to conform to a single implicit copula.

Fundamental copulas are too simplistic for distinct asset classes.

(b)

Commentary on Question: *Candidates performed poorly on this question part. Many candidates did not identify all three requirements for a function to be a copula. Further, most struggled to assess whether each of Form A and Form B was a copula for the correct reasons. Many candidates, however, correctly identified the functional forms of the upper and lower bounds of all bivariate copulas.*

(i) A function $C: [0,1]^2 \rightarrow [0,1]$ must meet the following three criteria to be a copula:

- $C(u, v)$ must be non-decreasing in both u and v.
- The marginal distributions of C must be uniform, that is, $C(u, 1) = u$ and $C(1, v) = v$.
- C must satisfy the Rectangle Inequality, that is, for all $a_1 < b_1$ and $a_2 < b_2$, we must have $C(b_1, b_2) - C(a_1, b_2) - C(b_1, a_2) + C(a_1, a_2) > 0$.

(ii) Form A is not a copula as it fails the condition (for example) that the marginal distributions be uniform: $C(u, 1) = \max(u, 1) = 1 \neq u$.

Form B is a copula, as it can be demonstrated to satisfy all three requirements to be a copula as follows:

- Non-decreasing: For any $u_1 > u_2$ and $v_1 > v_2$, $C(u_1, v_1) = u_1 v_1 > u_2 v_1 = C(u_2, v_2)$. A similar argument shows that C is non-decreasing in v.

(iii) The functional form of the upper bound is $\min(u, v)$. The functional form of the lower bound is $\max(u + v - 1, 0)$.

(c)

Commentary on Question: *Candidates performed well on this part of the question. Most could qualitatively or quantitatively define upper and lower tail*

dependence, interpret tail dependence in a risk management context, and identify lower tail dependence in the copula listed.

(i) Lower tail dependence is the limit probability of loss beyond quantile q for one variable given loss below q for another. Similarly, upper tail dependence is the limit probability of gain beyond quantile q for one variable given gain above q for another.

Expressed mathematically, lower tail dependence is given by

$$\lambda_L = \lim_{q \to 0} \Pr[X \leq Q_q(X) | Y \leq Q_q(Y)]$$

And upper tail dependence is given by

$$\lambda_U = \lim_{q \to 1} \Pr[X > Q_q(X) | Y > Q_q(Y)]$$

(ii) The interpretation and importance of lower tail dependence in the context of portfolio risk management include the following:

- Risk management is focused on adverse tails of distributions and joint behavior in the tails is important for understanding how to manage such risks
- Tail dependency captures the insight that there is increased dependency in adverse conditions where "everything goes wrong together"
- Lower tail dependency indicates that, in severe down scenarios, losses are likely to occur together
- The more severe the loss is on one asset class, the more near-certain it is both asset classes experience large losses

(iii) The copula $C_c(u, v)$ is a Clayton copula which is known to exhibit lower tail dependence. Further, the lower tail dependence of the copula can be calculated as follows:

$$\lim_{q\to 0}\frac{C(q,q)}{q}=\lim_{q\to 0}\frac{\max\left(\left[q^{-\frac{1}{2}}+q^{-\frac{1}{2}}-1\right]^{-2},0\right)}{q}$$

$$=\lim_{q\to 0}\frac{\left[q^{-\frac{1}{2}}+q^{-\frac{1}{2}}-1\right]^{-2}}{q}=\lim_{q\to 0}\frac{\left[2q^{-\frac{1}{2}}-1\right]^{-2}}{q}$$

$$=\lim_{q\to 0}\frac{1}{q\left[2q^{-\frac{1}{2}}-1\right]^{2}}$$

$$=\lim_{q\to 0}\frac{1}{q(4q^{-1}-4q^{-\frac{1}{2}}+1)}=\lim_{q\to 0}\frac{1}{(4-4q^{\frac{1}{2}}+q)}=\frac{1}{4}$$

Because $\frac{1}{4}>0$, the copula is shown to exhibit lower tail dependence.

(d)

Commentary on Question: *Performance on this question part was fair. Most candidates correctly described at least one of the two methods below, but many could not identify and describe both.*

Two methods of calibrating the copula parameter are as follows:

- Estimate Kendall's Tau from the data sample. Then, choose the parameter such that the Tau of the copula generates the same value. This is appropriate because Tau depends only on the copula, not the marginal distributions.

- Apply Maximum Likelihood Estimation (MLE) to the sample using the empirical estimator for the marginal distribution function

QFI IRM Fall 2022 Question 1

Source Material: Quantitative Enterprise Risk Management, Ch. 6: Copulas;

Quantitative Enterprise Risk Management, Ch. 7: Stress Testing

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context,

3c) Apply stress testing and scenario analysis to assess extreme ALM events

(a)

Commentary on Question:

Candidates performed as expected on this question.

Candidates should calculate Tau using the formula 2/n(n-1) * 75 = 0.71429

(b)

Commentary on Question:

Candidates performed as expected on this question. Most candidates got partial points for part (i) because they did not identify reasons why the tau could have changed. Most candidates received full points for part (ii) by calculating the appropriate tau.

The lower value of Tau calculated with the 20 years of information identifies that the indices were less likely to move in the same direction in the past and the relationship of the concordance was not as strong during the additional 5 years as in the 15 years.

For part (ii) the calculation of the Gumbel copula Theta using the Tau would be

1 / (1 – tau) = 2

(c)

Commentary on Question:

Candidates performed poorly on this question. For part (i), candidates that attempted the question generally got full credit. Candidates did lose points for using the log function instead of LN when calculating the probability. For part (ii), few candidates attempted the question, and most did not receive full credit. Candidates failed to identify that the loss associated to Index A but not B would be included in the CTE (80) calculation and instead used an average of both having a loss.

For part (i),

1. Calculate the probability of loss for each index
    a. P (A < 0) = 30.85%
    b. P (B < 0) = 31.74%
2. Use the Gumbel Copula to calculate the joint loss chance
    a. Theta = 2; given
    b. EXP {-([-LN(.03085)]^2 + [-LN(.03174)]^2)^(1/2)} = 19.34%

For part (ii),

1. Identify that the joint loss accounts for 19.3% of the value calculated in the CTE (80)
2. Identify that the remaining portion of the CTE (80) calculation comes from when Index A has a loss and Index B does not.
3. Multiply each loss by the respective probability and scale the results out of 100%

CTE[80] = [(.193379)*(1035) + (.2 - .193379)*(500)]/.2 = 1017.29

QFI IRM Spring 2023 Question 3

Source Material: Quantitative Enterprise Risk Management, Ch. 7: Stress Testing

Learning Outcome:

3c) Apply stress testing and scenario analysis to assess extreme ALM events

(a)

Commentary on Question:

Most candidates successfully identified at least four uses of stress testing.

- Stress tests can explore extreme scenarios
- Stress tests can challenge the models and assumptions used in quantitative analysis
- New products may require it because of insufficient data for statistical modeling
- Can be used to focus effect of extreme scenarios on capital and liquidity
- Should serve to facilitate communication within an institution
- Can be used to establish and communicate a firm's risk appetite
- Integral component of deterministic micro-simulation modeling
- Often required by regulators in assessing capital adequacy

(b)

Commentary on Question:

Many candidates did not receive full credit on this part because the critique did not include enough information or both positive and negative aspects of the employee's recommendation.

Employee A

- The event is given in isolation, which is a scenario, not a stress test
- The event is not extreme

Employee B

- The event is so extreme, it may not be plausible
- Perhaps other factors should also be stressed

Employee C

- Historical scenarios are commonly used
- Constrained by the severity of the 2020 pandemic. Are other extreme but plausible events worthy of testing?

(c)

Commentary on Question:

Most candidates performed well on this part, providing a valid critique of the firm's current practices and offering at least three recommendations.

(i)

- Positive that objectives were shared with the Board.
- The stress tests should inform business decisions as well as be communicated to the Board
- Regular review of the models and results is positive
- Are the events plausible and extreme or implausible? Perhaps the employees' bias is preventing them from seeing the value in the stress testing

(ii)

- Better promote the formally adopted objectives and share results widely.
- Use the stress testing to inform business decisions as well as satisfy regulatory requirements
- Educate employees on value of stress testing and seek input on plausible, yet extreme scenarios to be included
- Be sure that data and IT systems are sufficient for the stress testing
- Continue to regularly review and challenge the results

QFI IRM Spring 2023 Question 9

Source Material: Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6

Learning Outcome:

3f) Understand interest rate derivatives and use them to mitigate interest rate risk

(a)

Commentary on Question:

Candidates generally did poorly on this question. Very few candidates recognized that the price of a futures contract is greater than the price of an otherwise equivalent forward contract, when the interest rates are positively correlated with futures prices. Most candidates received partial credits for stating that the daily settlement of futures could result in differences in the price, if all else equal.

Price of a futures contract is greater than the price of an otherwise equivalent forward contract.

If interest rates are positively correlated with futures prices, interest earned on cash from daily settlement gains on futures contract will be greater than the opportunity cost of interest on daily settlement losses, and a futures contract will have a higher price than an otherwise equivalent forward contract that does not feature daily settlement.

(b)

Commentary on Question:

Candidates overall did well on this question. For part (ii), most candidates were able to receive full credits by explaining that the value of the forward at inception is zero as no money changes hands.

(i) $F(0,0.5,1) = Z(0,1)/Z(0,0.5) = 93.51/96.79 = 0.96611$
$f = 2*(1/F(0,0.5,1)-1) = 7.02\%$

(ii) The value of the forward at inception is zero as no money changes hands.

(c)

Commentary on Question:

Candidates generally did well in part (ii), but poorly in part (i) and part (iii) of this question. In part (ii), most candidates were able to calculate the spot rate correctly, but some candidates calculated the continuously compounded rate instead of the semi-annually compounded rate and therefore, receive partial credits.

(i) At inception, M = Z(0,0.5)/Z(0,1) = 96.79/93.51 = 1.0351 T-bills maturing in 1 year.

FRA(0.5) = 100(M*Z(0.5,1) - Z(0.5,0.5)) = 100*(1.0351*0.9692 -1) = \$0.3219

(ii) r(0, 0.5) = 2*(1/Z(0,0.5) – 1) = 6.36%

(iii) f2(0, 0.5,1) is from b,i)
r2(0.5,1) is from c,ii)

Net payment of the firm at T2 = N/2 * [f2(0, 0.5,1) – r2(0.5,1)] = \$100 / 2 * (7.02% - 6.36%) = \$0.3298million (paid by the bank to the firm)

(d)

Commentary on Question:

Candidates generally performed poorly on this question. Many candidates were able to receive full credits or partial credits in part (i) by demonstrating the correct formula of the pull-call parity. Few candidates correctly stated the strategy and the net cashflow from the arbitrage opportunity.

(i) The securities are not correctly priced, as the put-call parity is violated.

Pfwd = 100*(0.9545/0.9692) = 98.4833

Call (K) = Put (K) + Z(0, 0.05)* (Pfwd – K), where

Z(0, 0.05)* (Pfwd – K) = 0.9692*(98.4833 – 99.12) = -0.6171

Call from Put-Call Parity = 0.1044 – 0.6171 = $-0.5127

(ii) Strategy should be to long call, short put, and short forward. This will give a positive cashflow of $0.8061 at no risk.

(iii) $0.2934 – (- $0.5127) = $0.8061

QFI IRM Fall 2023 Question 2

Source Material: Quantitative Enterprise Risk Management, Ch. 6: Copulas

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

(b)

Commentary on Question:

Candidates overall performed well on this question. Most candidates were able to provide a clear description.

Let (X*, Y*) be a bivariate random variable that has the same joint distribution as (X, Y) and is independent of (X, Y).

(i) X and Y are concordant when (X − X*)(Y − Y*) tend to be positive. That is, larger values of X are associated with larger values of Y, and smaller values of X with smaller values of Y.
(ii) X and Y are discordant when (X − X*)(Y − Y*) tend to be negative. That is, larger values of X are associated with smaller values of Y, and vice versa.

(c)

Commentary on Question:

Candidates performed very well on part (i) and part (ii) but had difficulties in part (iii). A common calculation error is a mixed use of population variance (covariance) and sample covariance (variance) in the correlation formula.

(i) Pearson's: 23.62%

CORREL(X_1 , X_2) would be the most simple Excel formula to use.

Alternatively, one can also calculate the covariance $\mathrm{Cov}(X_1, X_2)$ and standard deviation σ_1 and σ_2 first and then obtain the correlation by the formula $\frac{\mathrm{Cov}(X_1,X_2)}{\sigma_1\sigma_2}$. Note that one should either use population covariance COVARIANCE.P(…) and population standard deviations STDEV.P(…),

or sample covariance COVARIANCE.S(…) and sample standard deviations STDEV.S(…). Mixing them up will yield incorrect results.

(ii) Spearman's rank: 10.30%

One can first obtain the ranks of X_1 and X_2 respectively by using the Excel formula RANK(…), then calculate Pearson's correlation of the two arrays of ranks below:

Rank(X_1)	Rank(X_2)
7	8
5	4
2	1
9	9
3	2
6	5
10	3
4	7
1	10
8	6

(iii) Kendall's rank: 15.56%

$$t_k = \frac{\text{number of concordant pairs } - \text{ number of discordant pairs}}{\frac{1}{2}n(n-1)}$$

One way to count the concordant and discordant pairs is to construct the following table, where the concordant pairs will receive a value of 1, and the discordant pairs will receive a value of –1.

	X1	2.1%	10.2%	20.1%	-4.4%	19.7%	5.5%	-7.5%	10.6%	30.4%	-1.7%
	X2	-0.5%	2.0%	7.8%	-1.8%	3.8%	1.0%	2.4%	0.0%	-1.9%	0.5%
X1	X2										
2.1%	-0.5%										
10.2%	2.0%	1									
20.1%	7.8%	1	1								
-4.4%	-1.8%	1	1	1							
19.7%	3.8%	1	1	1	1						
5.5%	1.0%	1	1	1	1	1					
-7.5%	2.4%	-1	-1	1	-1	1	-1				
10.6%	0.0%	1	-1	1	1	1	-1	-1			
30.4%	-1.9%	-1	-1	-1	-1	-1	-1	-1	-1		
-1.7%	0.5%	-1	1	1	1	1	1	-1	-1	-1	

Using the top left highlighted cell as an example, the formula is:

$$\text{sign}\Big((10.2\% - 2.1\%) \times \big(2.0\% - (-0.5\%)\big)\Big) = \text{sign}(0.2025\%) = 1$$

where

$$sign(z) = \begin{cases} -1 & \text{if } z < 0 \\ 0 & \text{if } z = 0 \\ 1 & \text{if } z > 0 \end{cases}$$

The sum of all 1's and –1's in the table above is 7, which is essentially (number of concordant pairs $-$ number of discordant pairs) in t_k.

Therefore,

$$t_k = \frac{7}{\frac{1}{2} \times 10 \times (10-1)} = \frac{7}{45} = 15.56\%$$

(e)

Commentary on Question:

Candidates performed as expected on this part. Most candidates identified at least one advantage of using the copula approach in the context of tail risk modelling.

Unlike correlations that produce just a single number, copulas can describe the full dependency structure between two variables, providing additional information on how market risk and credit default risks are correlated in stressed scenarios.

Additionally, copulas disentangle the marginal distributions from the joint dependence structure. Consequently, we can choose specific copulas to capture

the tail dependence, which is crucial for understanding how risks interact with each other in a recessionary cycle.

QFI IRM Fall 2023 Question 4

Source Material: Quantitative Enterprise Risk Management, Ch. 14: Model Risk and Governance

Learning Outcome:

3d) Understand and evaluate model and parameter risks

(a)

Commentary on Question:

Candidates did well on this section, with most getting full credit on the first part of the question. Some candidates struggled with identifying key purposes of model governance. Only two model governance functions were required to receive full credit in (a)(ii).

(i) Model Risk can be from misused model or from incorrect models.

(ii) The main purposes of model governance are:
- Managing different life stages
- Managing inventory
- Assessing the materiality of the model being used

(b)

Commentary on Question:

Most candidates received partial credit for each subpart. To receive full credit on (b)(ii) candidates needed to call out both that the simplifications may only capture limited information, but also that proxy models are susceptible to relationships breaking down.

(i)

1. Representative scenarios – run a smaller set of scenarios that captures the same risks as the full set.
2. Parametric curve fitting – use the full set of simulations to fit a function that generates an output based on the set of important variables.

3. Non-parametric curve-fitting – use machine learning techniques or other advanced techniques to approximate the more sophisticated model; use that model prospectively in the form of an approximating function.
4. Replacing elements of full model with simplified model points – for example, using a smaller set of representative policies instead of the entire population of policies the insurer sells to/has inforce.

(ii)

1. Representative scenarios or simplifactions may capture only limited information or fail to capture tail risk; approximating functions may have limited domain of applicability.
2. Proxy models are also susceptible to relationships breaking down, which can happen very quickly.

(c)

Commentary on Question:

Most candidates struggled with this part, particularly the more technical subparts (i) and (iii). To receive full credit on (i), candidates needed to call out both the normality assumptions and the necessary sample size. For (iii), candidates often failed to describe each of the required steps from prior to simulation.

(i)

- Large sample sizes ensure an MLE estimate that is usually asymptotically normally distributed, and a robust standard error.
- Therefore, the standard errors can be used to construct a confidence interval around the MLE estimate of the parameter.

(ii) Bayesian methods provide the full range of potential parameters values along with associated probabilities, not just point estimates.

(iii)

1. Generate N samples parameter sets (θ_i) from the posterior $\pi = c \times L(\boldsymbol{\theta}) \times p(\boldsymbol{\theta})$ (only 1 pt if posterior function is not defined)
2. Generate N uniform variates U_j from the uniform distribution on (0,1), where j = 1, 2, …, N.
3. Convert the uniform random variates to values from the predictive distribution by calculating values X_j such that the CDF of each X_j using $\boldsymbol{\theta_i}$ is U_i
   i.e., $F(X_j | a = a_j, \theta = \theta_j) = U_j$

(d)

Commentary on Question:

Candidates did fairly well on this question; most received at least partial credit. Many did not appropriately evaluate on the third point, where suitable data proxies can be supportable given the lack of recent data and economic intermingling.

Point 1: Weekly projection is to be too fine-grained for the use, adding unnecessary complexity. Monthly data would likely be more appropriate.

Point 2: Neither pair is an appropriate benchmark. Canada is not emerging and neither Canada nor Mexico are in SE Asia; both economies are well understood. Currency pairs for countries similar in size, population, region, and other economic metrics should be used.

Point 3: This method may be appropriate if the two rates are highly correlated.

QFI IRM Fall 2023 Question 7

Source Material: Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 6

Learning Outcome:

3f) Understand interest rate derivatives and use them to mitigate interest rate risk

(c)

Commentary on Question:

Candidates generally did poorly in this question. Some candidates were able to correctly calculate the forward rate of 4.61% and therefore, received partial credits.

Because future price is \$95.39, then

$f_4(t, T_1) = (100\text{-}95.39)/100 = 4.61\%$

Min. price to accept = $\frac{100}{1+f_4(t,T_1)/4}$ = \$98.8606

(d)

Commentary on Question:

Candidates generally performed poorly on this calculation question. Some candidates were able to get some parts of calculation correct and received partial credits.

(iv) Total profit from futures: 0.25 x (\$97.2912 – \$95.3900) = \$0.4753

(v) The firm receive enough money that is needed to pay for the lawsuit. In fact, the firm actually receives more than what is needed (\$100M) and therefore was buying too many futures contracts.

P&L from futures = \$0.4753

Proceeds from Company ABC = $98.8606

Total = $99.3359

The total amount available to the firm after 90 days is:

99.3359 x (1 +3.7088%/4) = $100.2569 million

(e)

Commentary on Question:

Candidates generally performed well on this question, especially the first part. The question aims to test candidates' knowledge on identifying the shortcoming of hedging with futures based on the results of the part (d), which is the tailing of the hedge. Many candidates generally described the short comings of futures in general, and only received partial credits. For part (ii), candidates who simply stated that future should be used but did not provide any explanation did not receive any point.

(i) Tailing of the hedge

The firm is buying too many futures contracts, because the cash flows arising from the futures position accrue over time, which implies the need of the firm to take into account the time value of money between the time at which the cash flow is realized and the maturity of the hedge position. This will call for a reduction in the position in futures.

(ii) Tailing Tailing the hedge - It is a technique used to optimize the hedge ratio with the passage of time.

For example, one way to adjust the position in futures is to find a "tailing factor" through which we adjust the number of futures contract in order to return to the desired levels. Tailed hedge = untailed hedge x tailing factor.

QFI IRM Spring 2024 Question 4

Source Material: Quantitative Enterprise Risk Management, Ch. 6: Copulas

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

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%.

QFI IRM Spring 2024 Question 7

Source Material: Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives;

Fixed Income Securities: Valuation, Risk, and Risk Management, Pietro Veronesi, Ch. 5 and 6

Learning Outcome:

3e) Explain and implement techniques used to mitigate market risks

3f) Understand interest rate derivatives and use them to mitigate interest rate risk

(a)

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).

<u>Customization & Basis Risk</u>

- 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.

<u>Counterparty/Credit Risk</u>

- 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.

<u>Rollover Risk</u>

- 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)

Commentary on Question:

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

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)

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)

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.

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)

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.

QFI IRM Fall 2024 Question 4

Source Material: Quantitative Enterprise Risk Management, Ch. 6: Copulas

Learning Outcome:

3b) Demonstrate an understanding of and apply tools and techniques for measuring and managing interest rate risk in an ALM context

(a)

Commentary on Question:

Most candidates received full credit on this part by providing two advantages with some explanation.

Possible answers include:

- Copulas are useful for modeling dependent risks
- Copulas can be used to create multivariate distributions when the marginal distributions are not in the same family. In risk management this bottom-up capability can be very useful. It allows us to use copulas to bring together the risks from different parts of the firm, to generate a firm-wide model.
- A copula may be used to bring together the individual loss distributions, to create a model of the joint distribution of aggregate losses from all lines of business across the enterprise.

(c)

Commentary on Question:

To receive full credit on this part, candidates had to correctly identify the weakness in the colleague's suggestion.

Marginal normal distributions do not necessarily imply that the joint distribution has a multivariate normal distribution.

(d)

Commentary on Question:

Few candidates were able to identify two tests and describe them in enough detail to receive full credit for this part.

Use the Jarque-Bera Test to determine if each marginal distribution is normally distributed. Each marginal must be tested. Test statistic involves skewness and kurtosis and the test statistic has a chi-square distribution with 2 degrees of freedom.

Follow up using Mardia's test on joint multivariate samples. Test statistics based upon empirical multivariate measures of skewness and kurtosis. There are two test statistics, one follows a chi-square distribution and the other follows a standard normal distribution.

(e)

Commentary on Question:

Candidates struggled to identify three properties of the Archimedean copula.

Possible properties include:

$\phi(u)$ maps [0,1] to $[0, \infty]$;

$\phi(0) = \infty$ and $\phi(1) = 0$,

ϕ is continuous,

ϕ is strictly decreasing,

ϕ must be convex for bivariate distributions

QFI IRM Fall 2024 Question 8

Source Material: Quantitative Enterprise Risk Management, Ch. 15: Risk Mitigation using Options and Derivatives

Learning Outcome:

3e) Explain and implement techniques used to mitigate market risks

(a)

(i)

Commentary on Question:

Most candidates did not describe the details of Hedging with option combinations

Delta-neutral: Construct a portfolio with stock and options on the underlying to have zero delta

Delta-gamma-neutral hedging: Construct a portfolio with stock and options on the underlying to limit both delta and gamma value to zero

Hedging with option combinations:

- Construct a portfolio of options on the underlying
- Gives up some return to protect against tail loss due to equity prices drop

(ii)

Commentary on Question:

Candidates need to assess both difficulty of rebalancing and risk-return trade-off to get full points. Most candidates considered only 1 area against risk committee's requirement hence earned partial points.

Delta-neutral hedging is not suitable

- Removes the delta and does not prioritize the risk-return trade-off
- Requires constant rebalancing to keep zero delta
- Not sustainable for the small team

Delta-gamma-neutral hedging is not suitable

- Same shortfall as delta-neutral hedge
- Extra difficulty in rebalancing to keep zero gamma
- Further lowers the risk and drives down the return significantly

Hedging with option combinations is suitable

- Does not require frequent rebalancing and can be efficiently managed by the small investment team
- Can be constructed to provide a balance between risk-return trade-off to meet risk committee's requirement

(b)

Commentary on Question:

Most candidates earned full points on this part

(i)

put option price: $p_0 = K * \exp(-r*T) * N(-d2) - S_0 * N(-d1) = 1.5121$

portfolio value: $S_0 * 202.8 + p_0 * 624.3 = 5{,}000$

(ii)

delta of put: $-N(-d1) = -0.3248$

portfolio delta: $202.8 - 624.3 * N(-d1) = 0$

(c)

Commentary on Question:

For the candidates attempted this part, most of them were able to calculate the return for the portfolio without hedging. About half of the candidates were able to calculate the put option price at t=0.05 and the return for the hedging portoflio. For the candidates calculated the wrong d1 at t=0.05, they were not penalized for this again if the following calculations were correct based on the d1 they had.

Without hedging at t = 0.05, S = 22

- Units of stock = investment_0 / S_0 = 5000 / 20 = 250

- Return = 250 * 22 / 5,000 = 500 or 10%

With hedging at t = 0.05, S = 22

- d1 = (ln(S / K) + (r + (σ^2) / 2) * (T – t) / (σ * sqrt(T - t)) = 0.7775
- d2 = d1- σ * sqrt(T - t) = 0.485
- N(-d1) = 0.2184 and N(-d2) = 0.3138
- p = K * exp(−r * (T – t)) * N(−d2) – S * N(−d1) = 0.9345
- Portfolio Value = S * 202.8 + p * 624.3 = 5,045
- Return = 5,045 / 5,000 = 45 or 0.90%

(d)

Commentary on Question:

Most candidates did not do well or did not attempt this part. For the candidates attempted this part, some of them were able to calculate the portfolio deltas but did not apply the correct formula for 1-day VaR. For the Candidates correctly calculated the 1-day VaR, most of them did not express the VaR in percentage of the portfolio value as requested in the question.

Without hedging at t = 0.05, S = 22

- Delta = 250 * 22 = 5,500
- 1-day VaR_99% = delta * z_99% * sqrt(1/250) * σ = 242.7644
- As % of portfolio value = 242.7644 / 5,500= 4.41%

With hedging at t = 0.05, S = 22

- Delta = *202.8 – 624.3 * N(-d1) = 66.4389*
- *1-day VaR_99%* = delta * z_99% * sqrt(1/250) * σ = 64.5166
- As % of portfolio value = 64.5166 / 5,045 = 1.28%

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QFI PM Fall 2021 Question 6

Source Material: CP351-106-25: Liability Driven Investment Explained

Learning Outcome:

3a) Develop and critique asset allocation strategies appropriate to underlying liability profiles such as pension plans and long-tail insurance liabilities

(a)

Commentary on Question:

The candidates performed below average on this part. Many candidates provided only one benefit and one limitation of the proposed allocation. Some candidates were not able to distinguish that the proposed allocation is entirely in fixed income.

Benefits:

Price of bonds behave in the same way as pension liabilities. By holding bonds, pension plan can protect itself against changing interest rates.

Bonds are widely tradeable.

Limitations:

Scarcity of suitable long-dated bond assets available to set against long-dated liabilities.

Plan needs to sell out of equity to fund the purchase of bonds, which will exacerbate funding deficit.

Creditworthiness of bond issuer can change over time, which will influence bond price independent of interest rates.

(b)

Commentary on Question:

The candidates performed as expected on this part. Some candidates suggested TIPS, which are not derivative securities, and, thus, did not receive credit for that answer.

Interest rate swaps used to manage interest rate risk. Plan will receive fixed interest and pay variable interest.

Inflation swaps used to manage inflation risk. Plan will receive variable rate and pay fixed rate. Fixed rate equates to what the market expects inflation will average over the life of the swap.

Real rate swaps combine interest rate and inflation elements in one contract. Plan receive fixed real rate and pay variable rate.

Other derivatives and instruments such as total return swaps and futures.

QFI PM Spring 2022 Question 12

Source Material: CP351-106-25: Liability Driven Investment Explained

Learning Outcome:

3a) Develop and critique asset allocation strategies appropriate to underlying liability profiles such as pension plans and long-tail insurance liabilities

(a)

Commentary on Question:

The candidates performed brilliantly on this section. Many candidates were able to obtain the full points. A few candidates did not consider inflation and interest rates in the PVL or discounted the zero-coupon bond using the wrong maturity period.

Funding ratio = Present value of assets (PVA) / Present value of liabilities (PVL)

With zero-coupon bond of \$120 in 30 years, PVA = $120 / 1.05^{30} = 27.765$

With a lump sum pension payment currently worth \$100, that will be made in 34 years,

PVL = $100 * (1.01/1.05)^{34} = 26.699$

Therefore, the funding ratio = PVA / PVL = 104.0%

(b)

Commentary on Question:

The candidates performed brilliantly on this section. Some candidates received full credit for identifying at least three key factors, inflation, interest / discount rate, and an additional factor such as bond credit spread. Majority received at least partial credit.

Key risk factors that can adversely affect the funding ratio include:

- The rate of inflation because pension payment is linked to inflation.

- Interest rate / discount rate. If the interest rate falls, the PV liability will increase more than the PV of assets, thus decreasing the funding ratio.

- Bond's credit spread because if the bond is downgraded then the value of the bond will be severely negatively affected.

(c)

Commentary on Question:

The candidates performed as expected on this section. Almost all candidates received at least partial credit when they commented that swaps were more capital efficient than bonds. To obtain the full credit, the candidates needed to discuss either the availability of swaps to match the liability duration, or the limitation with respect to the availability of long-term bonds.

- Swaps are available for longer maturities and maturity can be more easily customized to meet the requirement to match the liabilities.

- Swaps are more capital efficient. Since swaps are priced to have no initial value, the only capital required will be collateral while bonds need to be purchased with capital.

(d)

Commentary on Question:

The candidates performed as expected on this section. A few candidates received full credit for successfully completing the calculation of all components. Three main types of mistakes were made by the other candidates: recognizing the equity investment as the LDI asset values, ignoring the collateral cash value, and not identifying the swap component. Candidates received partial credit for showing intermediate steps of calculation.

The amount of collateral available is 30% of the bond value, which is 30% of $27.765 = $8.330.

The swap has zero value at initiation. This is used to hedge the liabilities valued at $26.699.

The remaining amount of $19.436 is invested in equity.

Therefore, the LDI leverage is 26.699 / (8.330 + 0) = 320.5%

(e)

Commentary on Question:

The candidates performed below average on this section. A few candidates were able to correctly determine the funding ratio with the formula using all asset components and received the full credit. Many candidates incorrectly calculated the value of the swap using the wrong liability value. A few candidates calculated the funding ratio as (Equity value + (Liabilities / LDI leverage)) / Liabilities which was also appropriate. Candidates received partial credit for showing intermediate steps of calculation.

Funding ratio = (equity value + cash value + swap value) / PVL

PVL = $100 * (1.015/1.055)^{33} = 27.929$

Cash value = 8.330

Equity value = 19.436 * (1-0.1) = 17.492

LDI_leverage = PVL / (cash value + swap value) = 575%

then swap value = -3.472

Funding ratio = (17.492 + 8.330 + (-3.472)) / PVL = 80.0%

An alternative method:

Funding Ratio = (equity value + (PVL / LDI_leverage)) / PVL

PVL = $100 * (1.015/1.055)^{33} = 27.929$

LDI_leverage =575%

Equity value = 19.436 * (1-0.1) = 17.492

Funding Ratio = (17.492+(27.929 / 575%)) / 27.929 = 80%

(f)

Commentary on Question:

The candidates performed below average on this section. A minority of candidates who explained the significant deterioration of funding ratio also recognized the negative impact of inflation and equities investment as required. Almost all candidates missed mentioning the risk associated with the increase in leverage and its impact on the funding ratio. Very few candidates recognized the contribution of equity to future performance.

The funding ratio dropped significantly because the large exposure to equity with more than 78% of assets, the impact of inflation on liability and the important increase of leverage all these factors adversely affected the fund position.

The fund manager may consider capital injection from the pension sponsor or the equity position has to be partially liquidated at a loss. However, the reduction in equity exposure would sacrifice potential future performance.