
SOCIETY OF ACTUARIES
Enterprise Risk Management – Investment Extension

Exam ERM-INV

Date: Tuesday, October 31, 2017

Time: 8:30 a.m. – 12:45 p.m.

INSTRUCTIONS TO CANDIDATES

General Instructions

1. This examination has a total of 80 points.

This exam consists of 8 questions, numbered 1 through 8.

The points for each question are indicated at the beginning of the question. Questions 7 and 8 pertain to the extension readings and/or the Case Study, which is enclosed inside the front cover of this exam booklet.

2. Failure to stop writing after time is called will result in the disqualification of your answers or further disciplinary action.
3. While every attempt is made to avoid defective questions, sometimes they do occur. If you believe a question is defective, the supervisor or proctor cannot give you any guidance beyond the instructions on the exam booklet.

Written-Answer Instructions

1. Write your candidate number at the top of each sheet. Your name must not appear.
2. Write on only one side of a sheet. Start each question on a fresh sheet. On each sheet, write the number of the question that you are answering. Do not answer more than one question on a single sheet.
3. The answer should be confined to the question as set.
4. When you are asked to calculate, show all your work including any applicable formulas.
5. When you finish, insert all your written-answer sheets into the Essay Answer Envelope. Be sure to hand in all your answer sheets because they cannot be accepted later. Seal the envelope and write your candidate number in the space provided on the outside of the envelope. Check the appropriate box to indicate Exam ERM-INV.
6. Be sure your written-answer envelope is signed because if it is not, your examination will not be graded.

Tournez le cahier d'examen pour la version française.

CASE STUDY INSTRUCTIONS

The case study will be used as a basis for some examination questions. Be sure to answer the question asked by referring to the case study. For example, when asked for advantages of a particular plan design to a company referenced in the case study, your response should be limited to that company. Other advantages should not be listed, as they are extraneous to the question and will result in no additional credit. Further, if they conflict with the applicable advantages, no credit will be given.

****BEGINNING OF EXAMINATION****

- 1.** (6 points) You are an external consultant hired by ABC Life Insurance Company (ABC) to assist with the preparation of the company's first Own Risk and Solvency Assessment (ORSA).

You are provided with the following information regarding ABC:

- It sells term life insurance and variable annuities. All variable annuities have guaranteed benefits.
- It is U.S.-based and issues its products only in the United States.
- The Board of Directors consists of ten members, including the Chief Executive Officer of ABC. The CEO of ABC also acts as the Chairman of the Board.
- The company is a closely held family business and seven board seats are held by family members. Most members on the Board have served more than five years, including the Chairman of the Board.
- The Audit Committee, which reports directly to the Board, has a primary mandate to review the financial statements produced by ABC and to report on public disclosure documents containing financial information pertinent to ABC.
- The primary responsibilities for ABC's Enterprise Risk Management belong to the Audit Committee.

- (a) (3 points) After reviewing what ORSA is intended to achieve, you are prepared to recommend to the Board changes in the corporate structure of ABC.
- (i) Describe three weaknesses of the company's current organizational structure.
- (ii) Discuss how ABC's corporate structure needs to be modified to satisfy the requirements of ORSA.
- (b) (2 points) To implement ORSA, ABC decided to perform a single stress test combining the following three shocks:
- Equity Shock: Equities down by 5%
 - Interest Shock: Interest rate curve shift down by 1% for all maturities
 - Lapse Shock: Policy lapse / surrender level increase by a factor of 1.1 for all products and all durations.

Critique ABC's approach.

- (c) (1 point) Outline three major additional considerations necessary to comply with the ORSA requirements.

2. (13 points) You are working on a project to calculate VaR using different methodologies. As part of the project, you want to minimize computer runtime because of the extensive calculations for VaR. You assume that the claim distribution is given by the following table of actual insurance claims for the previous 100 months, ordered from smallest to largest.

Claim #	Claim Amount
1-50	100
51-90	150
91	5,100
92	5,200
93	5,300
94	5,400
95	5,500
96	5,600
97	5,700
98	5,800
99	5,900
100	6,000

- (a) (1.5 points) For these insurance claims,
- (i) Calculate the absolute VaR at 95% confidence level. Show your work.
 - (ii) Calculate the relative VaR at 95% confidence level. Show your work.
- (b) (3 points) Instead of calculating VaR from the full distribution of insurance claims, you are investigating a Monte Carlo simulation using the following 10 random numbers between 0 and 1, ordered from smallest to largest:

0.08	0.23	0.26	0.29	0.49	0.65	0.69	0.80	0.91	0.92
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Calculate the following items using direct simulation from the 10 random numbers (i.e., the “naïve” simulation):

- I. Mean
- II. Absolute VaR at 95% confidence level
- III. Relative VaR at 95% confidence level

2. Continued

- (c) (6 points) You plan to do a simulation using the importance sampling technique. You are given the change of measure from original equal probabilities to shifted unequal probabilities. Each original scenario has a 1.0% probability of occurrence. To test shifted unequal probabilities, you assume each of the scenarios 1-90 have a 0.1% probability and scenarios 91-100 each have a 9.1% probability of occurrence. The table of shifted probabilities is provided below:

Scenario #	Probability
1-90	0.1%
91-100	9.1%

- (i) Recalculate the simulated insurance claims for each of the 10 random numbers in part (b) using the accumulated shifted unequal probabilities. Show your work.
- (ii) After the shift of the probabilities, VaR needs to be calculated using a shifted confidence level.

Calculate the absolute VaR at 95% using the recalculated insurance claims in (i) and a shifted confidence level of 50%. Show your work.

The simulated insurance claims from shifted unequal probabilities need to be modified by reflecting the likelihood ratios. The following are the likelihood ratios for the ten simulated insurance claims from (i) (simulated claim 1 was generated using the random number 0.08):

Simulated Claim	Likelihood Ratio
1	10.00
2-10	0.11

- (iii) Calculate the claims based on the importance sampling method for each of the simulated insurance claims from (i). Show your work.
- (iv) Calculate the relative VaR at 95% confidence level using the importance sampling method. Show your work.
- (d) (2.5 points) After the calculations, you are ready to inspect the results based on the various approaches.

Analyze the results produced in your calculations of VaR using naïve simulation and importance sampling. Include the reasoning behind the results they produce.

3. (12 points) Bank MC is a fast growing derivatives dealer in an emerging market. MC currently does not have a formal derivatives credit risk management function. You are the leader of the derivatives products team in MC. MC currently has no netting or collateral agreements.

(a) (2 points) In derivatives activity, there are three important stakeholders:

- Dealers
- End-Users
- Supervisors

(i) Provide two examples of each stakeholder.

(ii) Compare and contrast the roles of each stakeholder with respect to derivatives risk management.

(b) (2 points) The CFO decided that the finance department would control the overall credit risk exposure and the company's risk appetite. The CFO asked you to add the responsibility of derivatives credit risk management into your existing team as an additional function.

(i) Describe the responsibilities of a derivatives credit risk management function.

(ii) Identify three areas of concern in regard to the CFO's decisions. Justify your response.

3. Continued

- (c) (5 points) You receive only the following reports for monitoring the derivatives credit risk.

Quarterly report – all counterparties – current derivatives portfolio (MV/MtM in \$M)

Counterparty	Credit Exposure	Products					
		1	2	3	4	5	6
A	\$ 61.2	\$ 29.1	\$ 18.9	\$ 13.2	\$ (5.2)	\$ (12.1)	\$ -
B	\$ 295.8	\$ 84.5	\$ 133.7	\$ 77.6	\$ (89.2)	\$ (98.3)	\$ (100.5)
C	\$ 75.3	\$ 62.1	\$ 13.2	\$ -	\$ -	\$ (25.2)	\$ -
Other small counterparties	\$ 275.2	\$ 120.2	\$ 65.7	\$ 89.3	\$ (71.2)	\$ (131.2)	\$ (24.2)
Total	\$ 707.5						

Weekly report – new derivatives transactions only (MtM in \$M)

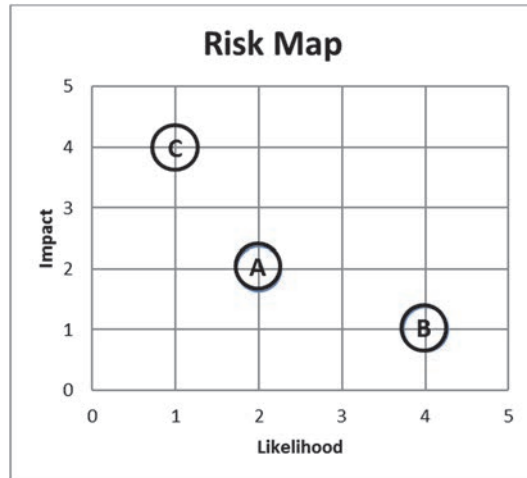
Counterparty		Products					
		1	2	3	4	5	6
A		\$ 1.1	\$ -	\$ 2.2	\$ (1.5)	\$ -	\$ -
B		\$ 8.4	\$ 2.3	\$ 25.0	\$ (2.9)	\$ (11.3)	\$ (13.2)
C		\$ 7.8	\$ -	\$ -	\$ -	\$ (2.1)	\$ -

- (i) Describe three areas of concern in regard to Bank MC's reporting process and current counterparty exposure.
- (ii) Recommend a risk mitigation strategy for each of the concerns identified in (i).
- (iii) MC wants to evaluate the impact of entering into a bilateral netting agreement with Counterparty B.

Calculate the impact of this agreement, from MC's perspective, on the counterparty credit default risk for both MC and Counterparty B using the provided weekly data. Show your work.

- (iv) Recommend additional steps Bank MC should take to help monitor and mitigate its current counterparty exposure.
- (d) (3 points) The CFO has approached you about the management of market risk within your department. Your team currently uses a dynamic hedge on option-based derivatives.
- (i) Describe advantages and disadvantages of using dynamic hedging versus static hedging on option-based derivatives.
- (ii) Describe the risks associated with the dynamic hedging of MC's market risk.

4. (9 points) Health Insurance Company (HIC) uses risk maps to assess its risks and identify key risks. Below is the risk map used by HIC for three of its key risks. HIC's risk tolerance level is 99.3% for each risk.



The following key risks are shown in the risk map above:

- A. Inappropriate investment of assets
- B. Cyberattack
- C. Severe epidemic

(a) (2 points)

- (i) List advantages and disadvantages of using a risk map.
- (ii) Rank the risks. Justify your answer.

4. Continued

- (b) (3 points) To evaluate severe epidemic risk, the following annual aggregated loss probability distribution table for losses caused by epidemics is used. The table was developed using hard data and soft data from both internal and external sources.

Annual Aggregate Loss	Probability
\$1,000	20.5%
\$10,000	60.0%
\$100,000	18.0%
\$10,000,000	0.8%
\$20,000,000	0.7%

- (i) Calculate the aggregated expected loss and aggregated unexpected loss. Show your work.
- (ii) Your manager has recommended that only hard data be used when developing the annual aggregated loss probability distribution table.

Critique your manager's statement.

Question 4 continued on the next page.

4. Continued

(c) (4 points) You are given the following information.

- The company aggregates the three risks using three methods with the risk value populated for two of them.

Method	Aggregate Risk Value
Correlation Matrix	
Copula	\$13,607,900
Scenario-based	\$17,533,829

- The correlation matrix among the three risks is given in the table below.
- Aggregated Unexpected Loss for inappropriate investment of assets is \$8,000,000.
- Aggregated Unexpected Loss for a cyberattack is \$5,500,000.

Risks Correlation Matrix			
	A	B	C
A	1.00		
B	0.20	1.00	
C	0.02	0.01	1.00

- (i) Calculate the aggregate unexpected loss using the correlation matrix. Show your work.
- (ii) Recommend a method for aggregating the three risks. Justify your response.
- (iii) The maximum risk capital you are prepared in any given year for aggregate unexpected risk loss of the three risks is \$20,000,000.

Determine whether the current risk capital meets HIC's risk tolerance level.

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5. (12 points) You are the pricing actuary for MH Life Reassurance. MH pricing guidelines require a minimum Return on Capital (ROC) of 20%. Capital is established at the VaR (95%) level.

You are provided the following annual loss distributions determined by cedents relating to different reinsurance opportunities of underlying annual group life insurance business. Both cedents are concerned with their tail risks.

Treaty	Cedent A		Cedent B	
Annual Loss Distribution	<u>Probability</u>	<u>Loss</u>	<u>Probability</u>	<u>Loss</u>
	5%	-	5%	-
	5%	1.5	10%	33.0
	80%	2.0	50%	36.0
	5%	2.5	10%	38.0
	5%	15.0	10%	44.0
			10%	46.0
			5%	49.0

- (a) (2.5 points) Consider each of the following deficiencies of VaR:

- Bricolage
- Historical Data and Observation Period
- Agency Risk

For each of the deficiencies identified above:

- (i) Define the deficiency.
- (ii) Explain whether or not the deficiency is relevant in the context of the MH pricing exercise.
- (b) (3 points) Your manager wants you to calculate premiums for the two reinsurance opportunities, and tells you to use the following simplified formula for profit:

$$\text{Profit} = \text{Premiums} - E(\text{Loss})$$

- (i) Demonstrate that the VaR (95%) for both options is 12.45.
- (ii) Demonstrate that the minimum premiums which satisfy MH's pricing objectives are 5 for Cedent A and 39 for Cedent B.

5. Continued

- (c) (1.5 points) Propose two conditions to be introduced to MH pricing guidelines which would complement the ROC based pricing hurdle.
- (d) (1 point) MH can enter only one of the two reinsurance treaties.

Explain whether MH should be indifferent between these two treaties from a capital perspective. Justify your response.

- (e) (4 points) You have been informed that the minimum required premium for Cedent B was considered too expensive by the cedent and exceeded the direct premium assessed by Cedent B. You are asked to evaluate the following options aimed at reducing the reinsurance premium:

- I. MH reinsures 75% of the entire underlying risk using a Quota Share treaty.
- II. MH reinsures 100% of the entire underlying risk subject to a maximum payout of \$36.55.
- III. MH provides stop-loss coverage which attaches at \$36.55.

- (i) Provide a loss distribution reflecting each of I, II and III from MH's perspective.
- (ii) Explain using qualitative arguments why options I and II are unlikely to be attractive reinsurance structures for the cedent.
- (iii) Provide qualitative and quantitative arguments supporting option III.

6. (8 points) NewCo is an insurance company that recently sold its first structured settlement policy which provides the policyholder payments for the next five years, as shown below.

Year	1	2	3	4	5
Payout (\$ thousand)	100	210	530	220	110

NewCo's actuary, Brian, provides you with the following information:

- The reserves as of today are \$1.1 million.
- The assets backing the reserves have not yet been purchased but NewCo is targeting a duration of 3 with a value of \$1.1 million.
- The net single premium from the policy, after all commissions and expenses were paid, was \$1.1 million.

The company's objective is to fully immunize its surplus against changes in interest rates.

Brian wants to test the balance sheet under different interest rate scenarios and provides the following information:

Year	Liability Key Rate Duration	Scenario 1: Level	Scenario 2: Steepness	Scenario 3: Curvature
1	0.09	+10 bps	+0 bps	-20 bps
2	0.36	+10 bps	+0 bps	+1 bps
3	1.36	+10 bps	+0 bps	+20 bps
4	0.73	+10 bps	+25 bps	+34 bps
5	0.46	+10 bps	+35 bps	+60 bps

- (a) (2 points) Construct a replicating portfolio using cash and zero-coupon bonds that immunizes against any yield curve shift. Show your work.

The product was priced assuming half of the assets are invested in 2-year zero coupon bonds and the other half are invested in 4-year zero coupon bonds. Your actuarial student has suggested using the same assets for investments and the yield curve shift in scenario 3 to estimate the asset value.

- (b) (3 points)
- Calculate the change in surplus (equity) under scenario 3 using the actuarial student's approach. Show your work.
 - Provide a qualitative description of the change in surplus under Scenarios 1 and 2.

6. Continued

(c) (3 points)

- (i) Describe the advantages and disadvantages of your actuarial student's suggestion with respect to the portfolio determined in (a).
- (ii) Determine whether the suggestion satisfies NewCo's objective. Show your work.
- (iii) Recommend whether the company should accept the suggestion.

**Questions 7-8 pertain to the Case Study and/or extension readings.
Each question should be answered independently**

7. (9 points) An investment consulting firm has proposed having SLIC’s pension committee contract the firm to perform a risk factor-based strategic asset allocation (SAA) for the Defined Benefit (DB) Pension Plan. The committee has requested that you help them understand what this would entail.

(a) (1.5 points)

- (i) Explain to the committee what risk factors represent.
- (ii) Describe a key shortcoming of traditionally constructed asset portfolios that a risk factor-based SAA could overcome.

(b) (1.5 points) Consider the following individual risk factors:

- I. Real Rates
- II. Inflation
- III. Volatility
- IV. Credit Spread

Explain an investable index position(s) that would gain positive exposure to each of the factors above.

You further demonstrate that classic tools and techniques of asset portfolio management can be applied to factor-based portfolios, comparing a traditional 60/40 Equity/Bond Plan allocation to an equally-weighted portfolio of factor groups.

Assuming the following traditional Plan asset allocation profile:

Portfolio Mix	Exposure	Expected Return	Volatility	Variance-Covariance	
				Equity	Bonds
Equity	60%	6%	15%	0.0225	0.0012
Bonds	40%	3%	4%	0.0012	0.0016

(c) (1 point) Calculate the 1-year 97.5% VaR of the traditional asset portfolio. Show your work

7. Continued

Next you consider the following three risk factor groups:

- I. Developed Economic Growth
- II. Macroeconomic
- III. Fixed Income

Assume the three risk factor groups have the following profile:

Risk Factor Group	Expected Return	Individual 1-year 97.5% VaR	Correlation		
			Dev. Eco. Growth	Macro-economic	Fixed Income
Dev. Eco. Growth	4.5%	19.6%	1.00	-0.30	-0.05
Macroeconomic	2.8%	3.9%	-0.30	1.00	0.75
Fixed Income	3.6%	11.8%	-0.05	0.75	1.00

- (d) (3 points)
- (i) Calculate the 1-year 97.5% VaR of an equal-weighted portfolio of the three risk factor groups. Show your work.
 - (ii) Explain the sources of difference in VaR between the traditional asset portfolio and the risk factor group portfolio.
- (e) (2 points) Describe four challenges in using a risk factor-based approach to SAA.

**Questions 7-8 pertain to the Case Study and/or extension readings.
Each question should be answered independently**

- 8.** (11 points) SLIC has increased its allocation to equity investments recently in an attempt to increase investment returns in the ongoing low interest rate environment. SLIC's Chief Investment Officer (CIO) wants to ensure that SLIC's equity investments do not expose the company to undue risk. In particular, the CIO is focused on \$40 million of assets allocated to U.S. equity, benchmarked against the S&P 500 Index.

The current investment team has some experience in trading U.S. equities and a lot of experience in hedging Variable Annuity equity exposure with derivatives. Thus, the CIO is confident that his existing team could deliver passive exposure to U.S. equity either directly through managing an in-house S&P 500 Index fund or synthetically using derivatives on the S&P 500 Index.

However, the company also needs the incremental returns generated from active investment management. The CIO recognizes that his investment team does not include active equity investment expertise. To achieve active exposure to U.S. equity, the CIO is considering outsourcing its active U.S. equity management to either or both of SLIC's DB Plan active U.S. equity managers, Alpha Management and Beyond Beta Group.

- (a) (1 point) The S&P 500 Index currently has an expected return of 7% and an annual volatility of 15%.

Estimate SLIC's standalone absolute 1-year VaR at the 95% confidence level from its allocation to U.S. equity. Show your work.

Three equity derivative positions on the S&P 500 Index are:

- I. Long an S&P 500 Index swap.
 - II. Short futures on the S&P 500 Index.
 - III. Long a put on the S&P 500 Index.
- (b) (2 points) Sketch the payoff profile from SLIC's perspective for each of the three equity derivative positions. Label key aspects of your diagram.
- (c) (2.5 points) Assess the merits of each of the three equity derivatives positions as a means for SLIC to gain passive exposure to the S&P 500 Index.
- (d) (1.5 points) Explain the advantages and disadvantages of having the SLIC investment team gaining passive U.S. equity exposure synthetically versus through managing an index fund.

8. Continued

The CIO wants to determine the allocations to the two active U.S. equity managers and his in-house passive team that would maximize the information ratio for the overall \$40 million U.S. equity portfolio subject to a risk appetite constraint.

Assume that the deviations for each asset manager, i , are independent of each other. Optimizing the portfolio information ratio (IR_p) subject to a fixed tracking error volatility (TEV) results in the following solution:

$$x_i \omega_i = IR_i \left(\frac{1}{IR_p} \omega_p \right)$$

- (e) (3 points) Determine the optimal allocation to each of the active U.S. equity managers and to the in-house passive team if a total U.S. equity portfolio TEV of 5% is the risk appetite constraint. Show your work.
- (f) (1 point) Determine the allocated principal and relative risk budget (in \$000s) for each of the three U.S. equity managers under the optimal manager allocation, at a confidence level of 95%. Show your work.

****END OF EXAMINATION****

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