

Exam ERM-INV

Date: Thursday, April 30, 2020

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 4 and 6 pertain to the Case Study and questions 7 and 8 pertain to the Case Study and/or extension readings. The Case Study 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.

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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. (7 points) You are a senior analyst at JMR, an advisory firm specializing in cyber security consulting. You are working on a project for a client who would like to gain a better understanding of methods for modeling cyber risks.

(a) (2 points) Your junior analyst, Dan, has identified the following risk metrics:

- VaR
- Total Exposure
- Standard Deviation
- CTE
- Average

Discuss advantages and disadvantages of using each of these risk metrics.

(b) (2 points) Upon further research, Dan suggests that Extreme Value Theory (EVT) might be a more appropriate solution to model cyber risks. For that proposal, Dan drafts the following presentation slide outlining certain EVT aspects for the client.

Extreme Value Theory (EVT):

- EVT is a tool to help measure tail risk better than VaR.
- VaR assumes normal distribution
- Specifically, EVT can help quantify both the maximum of your experience data, and the frequency of values above the maximum.
- EVT uses historical data; VaR does not.
- This type of modeling can respond to fat-tailed distributions better than VaR, which is based on a normal distribution, and therefore can be a better predictor of extreme values.
- EVT accentuates agency issues compared to traditional VaR.
- EVT is a coherent risk measure unlike VaR.

Critique the statements made by Dan.

1. Continued

- (c) (3 points) The client has asked you to assess the impact of cybersecurity risk on the client's financial performance. You propose to apply the Generalized Pareto Distribution (GPD), which is one of EVT's potential distributions, as the estimation method.

Based on observed losses due to past cybersecurity events, Dan prepared the table below for your analysis.

Selected information about historical observed losses.

Percentile	Losses	Number of losses at higher percentiles	GPD Parameter Estimates	
			s	k
85th	105	75	150	-0.140
86th	121	70	140	-0.125
87th	202	65	150	-0.097
88th	298	60	130	-0.113
89th	323	55	120	-0.135
90th	366	50	120	-0.135
91st	438	45	120	-0.135
92nd	536	40	120	-0.135
93rd	598	35	120	-0.135

The CDF of the GPD distribution is $G(x) = 1 - (1 - kx/s)^{1/k}$.

- (i) Identify the GPD threshold percentile you should use for your analysis. Explain your choice.
- (ii) Calculate the probability of a total loss greater than 700. Show all work.
- (iii) Explain how fuzzy logic might be a suitable alternative method to assess cyber risk exposure.

2. (12 points) KRW is a regional annuity carrier based in the U.S. that specializes in the following products:

- Fixed deferred annuities
- Single premium immediate annuities

You are an actuary reporting to KRW's CRO. You are provided with the following information regarding KRW's ERM practice.

- I. Risk management reports risk metrics including economic capital (EC), asset liability duration and regulatory risk-based capital ratio every six months to senior management
- II. Capital levels are primarily based on regulatory capital requirements and are allocated by product line
- III. Current ALM and asset allocation are driven by cash flow matching
- IV. Sensitivities on liability discount rate and mortality are performed annually by the valuation department

KRW is interested in improving its overall risk management framework.

(a) (2 points) Evaluate each of KRW's four current ERM practices given its current product portfolio.

2. Continued

(b) (4 points) KRW decides to change its objectives for the asset allocation methodology to the following:

- Maximize net excess yield
- Minimize surplus volatility while constraining asset-liability duration gap

You are given the following selected data:

	Current Portfolio Mix	Return	Volatility	Duration
Cash	5%	0.5%	0%	
Government Bonds	10%	2.5%		9
Corporate Bonds – AAA	10%	3.3%		4
Corporate Bonds – BBB	75%	6.7%		3
Equity	0%	8.0%	11%	
Real Estate	0%	7.0%	8.5%	
Total Assets				3.5
Total Liabilities				7.5

- (i) Outline the steps in the process of implementing strategic asset allocation.
- (ii) Explain the trade-offs associated with changing the allocation to each of the following asset classes:
- Government Bonds
 - Corporate Bonds
 - Equity
 - Real Estate
- (iii) Recommend how each component of the current portfolio should change, considering the new asset allocation objectives. Justify your response.

Question 2 continued on the next page

2. Continued

(c) (4 points) KRW's management decides to incorporate EC as a metric for its strategic asset allocation process. Its CFO recommends using the following shocks to derive individual EC values:

- Decrease mortality rates by 10% for all ages and durations
- Lower discount rate to 1% flat for all durations
- Reduce the lapse rate to 0% for the first 5 durations

The CFO suggests that aggregate capital levels would be determined by summing the resultant capital values produced by each shock.

- (i) Evaluate the appropriateness of the CFO's recommendations for the entire portfolio of KRW's existing products.
- (ii) Describe key considerations related to the implementation of the following alternative modeling methods:
- Stochastic Analysis
 - Sensitivity Analysis
- (iii) Additionally, KRW is looking into introducing a new traditional life product.

Evaluate whether the shocks recommended by the CFO would be appropriate for the portfolio after adding the new product line.

(d) (2 points) Recommend how KRW could mitigate financial risks using product design and asset allocation.

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3. (12 points) Company XYZ is a life insurance company with a Single Premium Immediate Annuity (SPIA) line of business. Its investment area is considering investing a new premium of 10 exclusively in Corporate Bonds or exclusively in Private Placement Bonds. XYZ's current total asset level supporting the business, before receiving the new premium, is 30.

You are provided the following information:

	Market Yield	Market Depth	Volatility (σ)	Correlation with Current Portfolio	Current Price within Market Depth (per 100 Face Amount)	
					Bid	Ask
Corporate Bonds	4.2%	15	0.08	0.6	95.8	96.2
Private Placement Bonds	9.9%	8	0.06	0.4	87.0	95.0
Total Current Portfolio			0.07	1	N/A	

Assume the distributions of market yields for each of the asset classes and the total portfolio are normal.

- (a) (2 points) Consider the following VaR determination methods:
- Marginal VaR
 - Incremental VaR
 - Component VaR
- (i) Explain conceptually how to calculate the impact that an additional investment would have on the portfolio VaR under each method.
- (ii) Compare and contrast the use of these methods for XYZ.
- (b) (4 points)
- (i) Calculate the Incremental VaR for each of the two investment options at a 95% confidence level. Show all work.
- (ii) Explain how the answer from part (i) does not accurately reflect liquidity risk and why that should be a consideration for XYZ's investment decision.
- (iii) Identify and describe three approaches that a company can use to adjust its calculation of VaR to account for liquidity risk.

3. Continued

- (c) (3 points) XYZ notices that the 10 it is trying to invest is above the current market depth for the Private Placement Bonds. Below is the information that applies to recent Private Placement investments of 10.

	Yield	Price (per 100 Face Amount)	
		Bid	Ask
Private Placement Bonds	8.7%	86.0	98.0

- (i) Draw a chart to show how the size of a transaction can affect the price at which it is executed by identifying:
- Normal market size (depth)
 - Market impact
 - Market value
 - Bid-ask spread.
- (ii) Label each item in the chart from (i) with the value that applies to the Private Placement Bonds.
- (iii) Calculate the liquidity-adjusted VaR (LVaR) for each of the two investment options prior to XYZ's investment in either of them. Show all work.
- (d) (3 points)
- (i) Recommend which investment should be made based on the results obtained in (b) and (c). Justify your recommendation.
- (ii) Provide additional liquidity considerations that would affect a recommendation in the following situations:
- XYZ is using the assets to back annuities with surrender options
 - XYZ plans to invest only 5 instead of 10
 - XYZ's risk appetite statement includes the following:
"...We are more concerned with default and credit spread risk than liquidity risk as we typically carry enough cash to meet our expected benefit payments..."

*Questions 4 and 6 pertain to the Case Study.
Each question should be answered independently.*

4. (10 points) As a consulting actuary working for Caerus, you have been asked to assist in the review of Big Ben's economic capital (EC) model described in section 0.7 of the Case Study.

(a) (2 points) Big Ben's CFO proposes enhancing the model by adding a liquidity risk component:

(i) Explain why liquidity risk could be difficult for Big Ben to quantify.

(ii) Design a scenario that Big Ben could use to measure its liquidity exposure.

(b) (5 points) Big Ben is concerned with the appropriateness of its risk aggregation technique. It currently uses a variance-covariance matrix but is considering alternative methods including copula functions or a fixed diversification percentage.

Big Ben's CFO states that the company should target an internal capital adequacy ratio of 150%.

(i) Describe the process of using copulas to aggregate risk in an EC model.

(ii) Your firm's analysis suggests that 10% would be a reasonable fixed diversification percentage for 2018.

Determine whether 10% would be sufficient to maintain a capital ratio above the CFO's suggested target. Show all work.

(iii) Critique each of the three diversification methods being considered by Big Ben. Provide support using information from the case study.

(c) (3 points) Big Ben's CFO has expressed concern that the EC produced by the current model is greater than he would expect.

Evaluate whether each of the following factors that determine Big Ben's EC level support the CFO's assertion.

- I. Regulatory requirements
- II. Risk measure components
- III. Modeling method

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5. (11 points) Basic Life sells life insurance and variable annuity products with guaranteed minimum benefits. A new insurance contract valuation standard, which requires market consistent valuation, is being released.

- (a) (1.5 points) You have been asked to apply the new standard to the company's variable annuity products.
- (i) Explain why stochastic scenarios would be appropriate to value the variable annuity liabilities.
 - (ii) Assess whether risk-neutral scenarios are the appropriate type to use.
- (b) (1.5 points) Basic Life is considering purchasing a third-party economic scenario generator (ESG) for calculating its insurance contract liability under the new standard. The ESG is fully calibrated and parameterized for both real-world and market consistent risk-neutral scenarios.

The following information is provided on the calibration and parameterization.

- Risk-neutral scenarios
 - The model's calibration process is designed to reproduce the prices of traded derivatives
 - The underlying yield curve is as of the date of the derivative prices used to calibrate the model
- Real-world scenarios
 - The model is calibrated to incorporate dynamics that are representative of the possible future paths of economic variables
 - The model is parameterized only using current market inputs

Evaluate the calibration and parameterization of the ESG.

5. Continued

- (c) (4 points) Basic Life has decided to use the market consistent risk-neutral scenarios from the third-party ESG. You have been provided with output from two calibrations of the ESG. The table below shows the projected price of a \$1 non-dividend-paying, high-volatility asset at multiple terms based on 500 simulated scenarios. The risk-free curve is a flat 2%.

Scenario Generator	Years				
	1	5	10	20	30
1	\$1.020	\$1.091	\$1.133	\$1.315	\$1.517
2	\$1.021	\$1.132	\$1.315	\$1.515	\$1.825

- (i) Outline the steps involved in performing a martingale test.
- (ii) Determine which scenario generator is more appropriate to use for the new valuation standard based on the martingale test. Show all work.

Question 5 continued on the next page

5. Continued

- (d) (2 points) Basic Life's current economic capital (EC) calculation uses deterministic scenarios. The CFO is concerned that the EC does not appropriately quantify the impact of a market downturn on guaranteed payouts associated with the variable annuity products. He tells you the company is considering using the new ESG to calculate EC to address this concern.
- (i) Explain whether the new risk-neutral ESG is appropriate to use for calculating EC for variable annuities.

In addition, the CFO proposes that the following risk metrics be considered for quantifying the market risk:

- Value at Risk
 - Standard Deviation
 - Tail Value at Risk (CTE)
 - Maximum Loss
- (ii) Recommend which of the proposed metrics is the most appropriate to quantify EC for market risk. Justify your choice.
- (e) (2 points) Basic Life is considering launching a single premium immediate annuity (SPIA) product.
- (i) Describe how launching a SPIA product could result in a diversification benefit for Basic Life.
- (ii) Compare and contrast the use of a correlation matrix versus a copula to reflect this diversification benefit in the EC calculation.

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*Questions 4 and 6 pertain to the Case Study.
Each question should be answered independently.*

- 6.** (8 points) Energetix’s GUI companies all use the same model for evaluating external risks. The model was developed by Energetix and is run independently by each GUI in its Risk Management Department. Refer to section 0.11 of the Case Study.

You are provided an overview of the External Risk Model (ExRM):

- The scenarios used in the model are evaluated and updated every two years
- The model engine is evaluated and updated every four years by the department within Energetix that built the model
- Model inputs (interest rates, market share, commodity prices, etc.) are updated quarterly
- Model output is compared to the prior quarter’s output to ensure reasonableness

The following scenarios are used in the ExRM:

Scenario #	Scenario Description
1	The temperature drops five degrees below the lowest recorded temperature for a period of ten days within a given year
2	State regulatory change in Colorado that increases GUI expenses by 10% but does not allow for an increase in rates charged
3	Supply of natural gas drops by 20% for a period of one year

- (a) (2 points) ExRM must include the following types of scenarios in the model:

- Global Scenario
- Multi-Event Scenario
- Synthetic Scenario

Identify the type of scenario for each of the Scenarios 1, 2 and 3. Justify your response.

6. Continued

- (b) (2 points) You are asked to evaluate the ExRM using Model Validation Principles Applied to Risk and Capital Models as identified by the North American CRO Council.
- (i) Identify two Principles that Energetix follows. Justify your response.
 - (ii) Identify two Principles that Energetix is clearly not following. Justify your response.
- (c) (2 points) Energetix plans to look at the external risks in aggregate for its three main operating businesses. Energetix instructed its other businesses to begin using the same ExRM and to include Scenario 2 and Scenario 3 in each of their models.

Evaluate Scenario 2 and Scenario 3 for use in CR and EUI.

- (d) (2 points) Energetix's CRO has proposed that in order to determine the total exposure across the three main operating businesses, each business would identify its own top five risks, and Energetix would simply sum the resultant exposures.
- (i) Evaluate the CRO's proposed aggregation process.
 - (ii) Propose an alternative aggregation approach.

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

- 7.** (12 points) ABC company has a portfolio composed of 2 bonds, both with a par value of \$100 million.

You are given:

Bond	Annual Coupon	Market Value (\$ million)	Duration
4-yr bond	5%	100	3.73
2-yr bond	3%	100	1.97

All duration values are modified duration.

The discount factors and VaR for each maturity are given below.

Term (Years)	Discount Factor	VaR (%)
1	97%	0.38
2	94%	0.87
3	88%	1.31
4	82%	1.93

The risk correlation matrix for the 4 maturities, R , is given below.

Term (Years)	1	2	3	4
1	1.0			
2	0.8	1.0		
3	0.9	0.8	1.0	
4	0.9	0.9	0.8	1.0

- (a) (6 points) Calculate the portfolio VaR (in \$millions) using each of the following approaches:
- (i) Principal mapping
 - (ii) Duration mapping
 - (iii) Cashflow mapping

Show your work.

7. Continued

(b) (1.5 points)

- (i) Describe the deficiencies of correlation as a dependency measure.
- (ii) Sketch graphs of the following distributions showing clearly the relative degree of dependency in the tail:
 - Bivariate normal distribution
 - Non-elliptical bivariate distribution

The Chief Investment Strategist expects interest rates to go down. He wants to increase the duration of the portfolio to 3.5 using only futures contracts.

You are given the following:

- A futures contract is priced at 1,000 with a duration of 4.0
- The conversion factor of the cheapest-to-deliver bond is 1.05.

(c) (2.5 points)

- (i) Explain the advantages of using futures contracts to manage portfolio duration.
- (ii) Calculate the number of futures contracts needed to be bought or sold. Show your work.

The value of the bond portfolio has changed due to a yield curve change.

Bond	New Market Value (\$ million)	New Duration
4-yr bond	98	3.6
2-yr bond	106	1.8

- (d) (2 points) Determine the rebalancing portfolio trade required to achieve a portfolio duration of 3.0. Show your work.

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

- 8.** (8 points) Big Ben Bank currently has two equity trading desks within its Asset Management business, one dedicated to International Equities and one dedicated to Domestic Equities.

In an effort to streamline operations and reduce costs, Kelvin Woods, Head of Equity Trading at Big Ben, is considering closing one of the equity trading desks and allocating the capital to the other desk. As a consultant at Caerus Consulting, you have been asked by Big Ben to assist in this decision.

The table below shows the allocated capital and risk of the two equity trading desks, and the actual profit generated by each trading desk.

Values in \$ millions	Allocated Capital	VaR Limit	Profit
International Equities	100	12	15
Domestic Equities	200	12	18

Assume that the risks of the two trading desks have a correlation coefficient of 0.8.

- (a) (0.5 points) Define risk budgeting in an organizational context.

Big Ben's goal is to maximize the amount of profit generated per unit of capital and risk employed. The combined trading desk would have a new VaR limit of \$24 million.

- (b) (4.5 points)
- (i) Recommend which of the trading desks should be closed, if any. Support your decision with quantitative analysis.
 - (ii) Explain how your recommendation could change if the risks of the two trading desks were to have a negative correlation coefficient. No calculations are necessary.

8. Continued

Woods provided you with the Equity Trading Team meeting minutes in the Case Study at the end of section 0.7, and your review has raised concerns about operational risk.

- (c) (3 points) Recommend three actions Woods can take to mitigate operational risk in the equity trading area, according to *The Top Ten Operational Risks: A Survival Guide for Investment Management Firms and Hedge Funds*. Justify your recommendation.

****END OF EXAMINATION****

USE THIS PAGE FOR YOUR SCRATCH WORK