SOCIETY OF ACTUARIES
Enterprise Risk Management – Investment Extension

Exam ERM-INV

Date: Friday, April 27, 2018
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.

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Exam ERM-INV Front Cover

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. (*12 points*) You are a consultant hired by JDY Life, a publicly traded company that specializes in term life insurance. You are to assess JDY's risk related to fraudulent policyholder behavior.

In addition to its claims department, which investigates all claims, JDY employs a claims investigation unit (CIU) consisting of 10 regional investigators who are responsible for additional investigation of all claims with face values above $1,000,000.

The CEO of JDY wishes to incorporate the assessment of recent fraudulent behavior into the company's economic capital calculation, which is based on Solvency II requirements.

(a) (*2 points*) To acquire the data needed for your initial analysis, you meet with Bill, the Chief Investigator of the CIU, and Tom, the head of JDY's claims department. Bill and Tom use different criteria to identify fraudulent claims.

(i) Explain how the absence of a universal risk language may inhibit the effectiveness of a company's ERM framework.

(ii) Recommend effective risk management practices that should be adopted by JDY in order to ensure consistent reporting of fraudulent claims.

(b) (*6 points*) You decide that the fraudulent data from the CIU is most pertinent to your analysis. Bill provides you with the following data showing the number of fraudulent claims in each of the past 10 years as well as the aggregate loss amount associated with the claims.

Year	Total Number of Events	Total Loss Amount
2007	9	$11,400,000
2008	3	$3,500,000
2009	4	$6,700,000
2010	5	$10,200,000
2011	4	$5,500,000
2012	8	$10,400,000
2013	5	$10,600,000
2014	3	$8,200,000
2015	5	$5,200,000
2016	2	$17,100,000
10-year total	**48**	**$88,800,000**

1. Continued

JDY's current economic capital level is maintained at a level such that, in a given year, JDY will have no greater than a 0.5% chance of losses due to fraudulent claims exceeding capital held. You propose using the Actuarial Approach for modeling annual aggregate losses based on the data provided.

(i) Describe the three main components of an economic capital definition in the context of JDY.

(ii) Recommend an appropriate distribution for modeling JDY's frequency of fraudulent claims. Justify your response using the data provided.

(iii) Describe the key attributes of an appropriate distribution for modeling average loss amount for fraudulent claims for JDY.

Based on the proposed model, you perform 10,000 Monte Carlo simulations of future fraudulent claims activity and determine that the appropriate standalone economic capital is $35,700,000. JDY's CEO comments that the economic capital amount seems excessive, but is satisfied that the work is complete and the requirements of Solvency II are met.

(iv) Describe the requirements of the CEIOPS Use Test pertaining of the use of internal models for measuring economic capital that should be communicated to the CEO.

(v) Outline and explain the key considerations for incorporating fraudulent claims risk into JDY's aggregate economic capital framework.

Question 1 continued on the next page.

1. Continued

(c) (*4 points*) JDY is considering the following two options:

- Option 1: Purchase a new fraud monitoring system with the expected benefit of a 30% reduction in the frequency of payments made on fraudulent claims.

- Option 2: Increase CIU staffing and require enhanced investigation for all claims with face value in excess of $3,000,000. Enhanced investigation is expected to identify all fraudulent claims investigated.

You are provided the following list of five claims with face value in excess of $3,000,000 over the past 10 years.

Year	Total Loss Amount
2009	$3,300,000
2010	$4,000,000
2013	$5,000,000
2014	$6,000,000
2016	$15,000,000

(i) Calculate the current aggregate expected annual loss due to fraud risk using the Actuarial Approach. Show your work.

(ii) Determine the expected reduction in aggregate loss under each Option. Show your work.

(iii) Propose additional considerations, apart from reduced expected losses, that JDY should consider when evaluating its purchase decision.

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2. (*10 points*) You are an ERM actuary working for KTY, a toy manufacturer. KTY is interested in modeling the operational risk for economic capital purposes – specifically, the risk related to legal settlements resulting from consumer injuries due to its products. KTY is the smallest of the 20 major players in the market and only uses internal settlement data for risk modelling.

KTY data only includes total settlements from the past ten years:

Settlement year	Total settlement amount ($ thousands)
2007	1.0
2008	1,000.0
2009	6.0
2010	3.0
2011	5.0
2012	3.5
2013	6.0
2014	2.0
2015	10.0
2016	4.0
Total	**1,040.5**

(a) (*4 points*) KTY's economic capital level is set at CTE (99.8). KTY's CRO asks you to use a hybrid empirical/generalized Pareto model for total settlements.

You are given:

- $G_{s,k}(x) = 1 - \left(1 - \frac{kx}{s}\right)^{\frac{1}{k}}$ *for* $k \neq 0$
- $F^*(x) = \left[1 - F_n(u)\right] G_{s,k}(x-u) + F_n(u)$ *for* $x \geq u$
- k, s parameters are estimated using moment matching with KTY's internal data, where:
  - $s^* = 0.5\bar{x}(A+1)$
  - $k^* = 0.5(A-1)$
  - $A = \bar{x}^2 / (w - \bar{x}^2)$
- The threshold is set at the 70th percentile.

2. Continued

You are simulating 1,000 values resulting from the **entire** CDF and you are given the highest five numbers generated.

Rank	Simulated value
996	0.9903
997	0.9913
998	0.9928
999	0.9955
1000	0.9983

(i) Demonstrate that $k = -0.247$ and $s = 251$.

(ii) Calculate KTY's economic capital using the simulation results. Show your work.

(b) (*4 points*) You assess the precision of the estimated CTE using the asymptotic standard error formula.

(i) Calculate the Formula Standard Error (FSE) for CTE (99.8) using your result from part (a). Show your work.

Your department generated 99 additional samples using your model and provided the following results:

(in $ thousands)

	CTE (99.8)	FSE (CTE (99.8))
Maximum	7,711	4,339
Minimum	1,722	34
Average	3,178	822
Standard Deviation	939	n/a

You notice the variability of CTE (99.8) and FSE (CTE (99.8)) resulting from the simulation.

(ii) Describe how the variance verification process can be used to validate the FSE formula.

(iii) Recommend three improvements to reduce the variability of the CTE estimator in the simulation performed by your department.

Question 2 continued on the next page.

2. Continued

(c) (*2 points*) KTY received news that an industry peer recently paid a $100 million settlement. KTY's CRO is concerned that the capital level produced by your model grossly underestimates potential losses.

(i) Explain why the CRO's concern is appropriate.

(ii) Recommend how you would improve operational risk modeling to address the issue raised by the CRO.

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3. (*7 points*) XEN Life Insurance Company has the following risk appetite statement.

Measure	Capital at Risk (CaR)
Interpretation	The probability of a 30% reduction of available capital over one year is less than 0.5%.

XEN uses fixed income assets to back its liabilities. The table below shows the sensitivity to interest rate movements of XEN's liability and asset values.

(All values in $millions)

	Dollar Value change per 1bp change in interest rates		
	5 year	**10 year**	**20 year**
Liability	0.1	0.8	0.1
Asset	0.3	0.3	0.3

(a) (*4 points*) To estimate the interest rate CaR you are given the following stress scenario:

Interest Rate Scenario	**Change in Yield Curve**		
	5 year	**10 year**	**20 year**
99.5^{th} percentile	-1.5%	-2.2%	-2.0%

3. Continued

You are also given the following table of additional information related to XEN's capital position at 99.5th percentile.

(All values in $millions)

Available Capital	180
CaR without Diversification Benefits	
Non-market Risks	20
Interest Rate Risk	?
Equity Risk	15
Foreign Exchange (FX) Risk	5
Diversification Benefits	
Between Market and Non-Market Risks	10
Among Market Risks	5

(i) Determine whether the company is within its current risk appetite limit under this stress scenario. Show your work.

(ii) You noticed that the following stress scenario was once employed in the past.

Interest Rate Scenario	Change in Yield Curve		
	5 year	10 year	20 year
99.5th percentile	-2%	-2%	-2%

Describe the shortcomings of this stress scenario relative to the original scenario.

(b) (*3 points*) XEN's Chief Investment Officer has suggested rebalancing the asset portfolio by investing in equal proportions of the following asset classes to take advantage of current market conditions:

- 20-year U.S. Treasury zero coupon bonds
- 20-year Treasury bonds with coupons
- Interest-only strips on 20-year GNMA pass-throughs

(i) Critique the use of each of the proposed asset classes in the portfolio on the basis of:

I. Key rate duration
II. Adherence to risk appetite statement

(ii) Propose three alternative asset classes that would be appropriate to include in the rebalancing. Justify your selection.

4. (*7 points*) XYZ Company is an insurer writing catastrophe risk insurance.

(a) (*0.5 points*) XYZ is subject to a regulatory requirement to maintain the ratio of net written premium to Policyholders' Surplus (PHS) of no greater than 4:1. Additional sales do not impact PHS.

Shown below is information on XYZ (in $ millions):

Policyholders' Surplus (PHS)	20
Gross Premium	100

Recommend a quota share reinsurance agreement that allows XYZ to achieve a ratio of 4:1.

(b) (*5 points*) A natural disaster recently occurred, and all the major reinsurance companies in the market now have much lower capacity to write new business.

(i) Describe how each of the following three alternative reinsurance instruments could address this situation. Justify your response.

I. Catastrophe (cat) bond
II. Sidecar
III. Industry Loss Warranty (ILW)

(ii) Recommend the best option for XYZ. Justify your response.

XYZ decides to issue catastrophe (cat) bonds with an industry loss trigger.

(iii) Describe the risks to which investors of these bonds are exposed.

4. Continued

(c) (*1.5 points*) XYZ bears counterparty risk not only from its reinsurance agreements but also from derivative transactions with other financial institutions, one of which is PQR.

The table below shows the details of such transactions between XYZ and PQR valued at the end of the most recent valuation period. (MtM values are from the XYZ's point of view.)

Trades with positive MtM	+$8m
Trades with negative MtM	-$7m

Assume no recovery in an event of default of either party.

(i) Assess the impact on each company's balance sheet if neither one defaults.

(ii) Assess the impact of a netting agreement on XYZ's loss if PQR defaults.

(iii) Assess the impact of a netting agreement on PQR's loss if XYZ defaults.

5. (*12 points*) You have started working as a portfolio analyst at a large life insurance company, and are tasked with building the firm's first portfolio focused exclusively on small tech companies. Your company's practice is to ignore how each portfolio is correlated with other portfolios.

Your manager has given you the following targets for your own portfolio.

- σ_p is less than or equal to 14%
- Absolute Portfolio VaR(95) is less than or equal to 25% of the portfolio's total value
- The horizon period for measurement is one year

(a) (*2 points*) You are approached by two different small tech companies specializing in tablet production. Both companies are independently looking to expand their operations.

You are considering two assets with the following characteristics.

	Return	Sigma	Correlation
Asset A	20%	16%	0.60
Asset B	10%	12%	

You begin to look at how these two assets would fit within your portfolio by evaluating two initial asset allocation choices. You have been given 100,000 in initial seed money to build this portfolio.

	Asset A	Asset B
Choice 1	30,000	70,000
Choice 2	70,000	30,000

(i) Calculate σ_p for each choice. Show your work.

(ii) Evaluate whether the portfolio risk for each choice is within the specified targets.

5. Continued

(b) (*4 points*) You ultimately decide on a third choice (shown as "Original" below), hoping to emphasize Asset A's favorable return. After you make this investment, your manager asks you to determine the change in VaR that would result if $10,000 were transferred from Asset B to Asset A (shown as "Alternate" below).

Investment Choice	Asset A Allocation	Asset B Allocation	σ_p
Original	80,000	20,000	14.35%
Alternate	90,000	10,000	15.17%

(i) Calculate the change in Absolute Portfolio VaR for each investment choice using incremental VaR. Show your work.

(ii) Calculate the change in Absolute Portfolio VaR for each investment choice using marginal VaR. Show your work.

(iii) Assess whether marginal VaR or incremental VaR is more appropriate in evaluating the investment choices. Justify your response.

(iv) Propose which of the two investment choices (Original vs. Alternate) you would recommend to management. Justify your response.

(c) (*2 points*) A veteran colleague suggests that you try to find several assets that are not perfectly correlated to include in your portfolio, stating that adding more of such assets will always result in reducing σ_p.

Design an example disproving your colleague's statement.

(d) (*2 points*) Provide three reasons why your firm's practice of ignoring correlations among all investment portfolios may not be a good risk management practice.

Question 5 continued on the next page.

5. Continued

(e) (*2 points*) After raising concerns about your firm's practice of ignoring correlations among all investment portfolios, you have been tasked with preparing a descriptive report of the correlation between your two technology-related holdings and the firm's other large asset holdings (listed below).

I. **ABC Aviation** – a pioneer in high-end drone technology who has only recently become widely known. Seeking investors to help scale operations and bring its most successful prototype to retail stores by the end of the year.

II. **FGH Tax Advisory LLC** – a small consulting group which has specialized in helping state governments structure their tax policies. Seeking additional investment to fund the acquisition of a similar firm which specializes in consulting about federal taxation policy.

III. **UVW Manufacturing –** a small manufacturing company specializing in home door and entryway construction. Seeking investors to fund a major factory expansion to enable marketing to American consumers.

Provide qualitative observations, for each of the three firms, about the correlation between your two technology-related holdings and each firm in the event of a broad economic recession.

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6. (*12 points*) You are a risk analyst at ABC in the newly created ERM department and have been asked to review the management of liquidity risk. ABC has multiple initiatives in place to enhance their ERM function, but at this time the risk management framework at ABC is considered rudimentary.

You are given the following information about ABC.

ABC current balance sheet ($ millions)

Assets		**Liabilities**	
Short-term:		Short-term:	
Cash and Cash- equivalent	50	Lines of credit	50
Medium-term:		Medium-term:	
		Guaranteed-investment contracts (GICs)	50
Long-term		Long-term:	
Investment-grade securities	600	Traditional life policies- surrender charge: 50%	500
Private placements	300	Leases	300
Foreign investments	50	**Equity: Tier 1**	
		Ordinary shares	30
		Preferred shares- perpetuity	20
		Retained earnings	50
Total	1,000	**Total**	1,000

- ABC operates in North America.
- ABC's credit rating is AA. It desires to maintain it going forward.
- ABC dominates the markets where it operates, and transacts business with both a dedicated sales force as well as a network of brokers.
- No strategic expansion is envisioned but ABC will continue to develop its traditional insurance products.
- Not considered to be a Systemically Important Financial Institution (SIFI) at the moment.
- Risk management has focused on modeling market, credit, and insurance risks in the past.
- Stated investment policy: Buy and hold.

6. Continued

(a) (*1.5 points*)

(i) Describe the two primary components of liquidity risk.

(ii) Explain how the interaction of these components might impact the net liquidity position of ABC.

(b) (*4 points*) You've been asked to develop ABC's liquidity risk appetite statement.

(i) Describe four considerations you would take into account.

(ii) Outline an appropriate liquidity risk appetite statement for ABC.

(c) (*3 points*) ABC's ERM committee has identified the following scenarios that could affect liquidity at ABC. These scenarios were developed based on an analysis of past external events that have affected the industry in general, other companies similar to ABC, and the global economy.

(1) Credit risk: ABC credit risk downgrade from AA to B

(2) Catastrophic risk: A pandemic similar to the 1918 flu

(3) Systemic risk: Global financial crisis similar to that in 2008-2009, with high market decline and substantial credit losses

(4) Operational risk: Permanent negative impact on ABC's reputation

(5) Operational risk: Fraud in the distribution channel

(6) Business risk: Upcoming retirement of CFO with established succession plan

Assess the relevance of risks (4), (5), and (6) to ABC's liquidity position. Justify your answers.

(d) (*3.5 points*) For the risks (1), (2), and (3) listed in part (c):

(i) Assess the potential impact on ABC's cash flows.

(ii) Assess the interaction with the other risks currently modeled by ABC.

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

7. (*11 points*) ABC Insurance offers a managed volatility fund to its Variable Annuity policyholders. Currently the fund has $400 million invested assets, split equally between an equity portfolio and a government bond portfolio. The fund's overall volatility is managed relative to a risk budget, requiring rebalancing amongst the equity and bond portfolios as changes in the portfolio volatility change the fund's Value at Risk.

Recently, the equity portfolio became more diversified as the number of different companies held was increased to 50. This diversification has reduced the realized volatility of the equity portfolio but has made the current risk management process of the fund unwieldy. You have been asked to make enhancements to the fund's risk measurement process.

(a) (*3 points*) You first consider the covariance matrix used to determine the equity portfolio VaR.

(i) Determine the number of parameters that must be estimated using each of:

- the full model
- the diagonal model $R_i = \alpha_i + \beta_i R_M + \in_i$
- the beta model $R_i = \alpha_i + \beta_i R_M$

(ii) Explain each term in the diagonal model.

(iii) Recommend one of the models above. Justify your response.

The government bond portfolio consists of a $100 million 3-Year annual coupon bond and a $100 million 1-Year annual coupon bond. You have decided to map the bonds' cash flows to separate maturities. You are given the following information.

	Cash Flow (in millions)				Correlation Matrix		
Term (Year)	3-Year Bond	1-Year Bond	Discount Factor	Undiversified Individual VaR (95%)	1Y	2Y	3Y
1	$6	$104	0.96	4.5%	1.00	0.90	0.85
2	$6		0.90	5.0%	0.90	1.00	0.95
3	$106		0.84	6.0%	0.85	0.95	1.00

7. Continued

(b) (*4 points*) Calculate the 1-year VaR (95%) of the bond portfolio and round to nearest $million. Show your work.

After performing your VaR calculations for each of your Equity and Bond portfolios the risks can be summarized as follows:

Portfolio	Value (in millions)	Current Risk Exposure (in millions)
Equity	$200	$20
Bond	$200	Part (b) Result

The correlation between the equity and bond portfolios is 0.05.

(c) (*4 points*)

(i) Calculate the total risk of the whole fund. Show your work.

(ii) Calculate the value to be reallocated to each portfolio to achieve a total risk budget of $20 million. Show your work.

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

8. (*9 points*) You are an investment actuary at SLIC. The pension committee has asked you to review the normal policy asset allocation split between equity and fixed income for the SLIC Salaried Pension Plan (the Plan). Plan liabilities will be considered in your analysis as an asset class held short.

You construct a mean-variance optimization model to maximize the expected return of the Plan's surplus at a given level of surplus risk, i.e.,

$$Max(U_S) = R_S - \lambda\sigma_S^2$$

Extending the capital asset pricing model, you model asset index return betas relative to returns of a proxy Portfolio Q of global equity and fixed income indices with market capitalization weights. The Plan liabilities are mapped to a suitable portfolio of equity and bond indices. The underlying models for asset returns and liability returns are as follows:

$$R_A = R_F + \beta_A\mu_Q$$
$$R_L = R_F + \beta_L\mu_Q$$

The risk-free return is 1%, and the expected excess return of Portfolio Q is 10%.

The betas for the asset indices under consideration and the Plan liability portfolio are as follows:

Index	Beta
U.S. Equity	1.1
Foreign Equity	1.3
U.S. Bonds	0.4
Foreign Bonds	0.3
Plan Liabilities	0.6

(a) (*1 point*) Calculate the expected return for each of the four asset indices and the Plan liabilities. Show your work.

8. Continued

The optimization model starts with an initial allocation to each of the four asset indices as follows:

Index	MV($millions)	Initial Allocation
U.S. Equity		25%
Foreign Equity		25%
U.S. Bonds		25%
Foreign Bonds		25%
Total Assets	730	100%
Total Liabilities	948	130%
Surplus	-218	

You consider three alternative formulas to calculate the expected surplus return in your model's objective function as follows:

I. $R_S = \dfrac{S_1 - S_0}{S_0}$

II. $R_{S(L)} = \dfrac{S_1 - S_0}{L_0}$

III. $R_{S\left(\frac{A}{L}\right)} = \dfrac{A_1 / L_1}{A_0 / L_0}$

(b) (*3 points*)

(i) Calculate the return on surplus under the initial asset allocation using each of the three alternative formulas and your expected returns from part (a). Show your work.

(ii) You proceed to model surplus returns using formula II.

Explain the shortcomings of the other two methods relative to formula II.

Question 8 continued on the next page.

8. Continued

You note that the surplus return model can be decomposed into a risk-free return on surplus and a surplus beta return.

(c) (*2.5 points*)

(i) Derive an expression for surplus beta in terms of an asset beta, β_A and a liability beta, β_L.

(ii) Explain what surplus beta risk represents.

(d) (*2.5 points*) The surplus risk model in your analysis may be represented as:

$$\sigma_S^2 = \beta_S^2 \sigma_Q^2$$

(i) Determine the relationship of asset portfolio beta β_A to the liability portfolio beta β_L that would be required to produce the lowest-risk, minimum surplus variance on the surplus efficient frontier. Show your work.

(ii) Explain the implications of the result in (i) for the beta for any optimal normal asset allocation solution for the Plan to the pension committee.

****END OF EXAMINATION****

USE THIS PAGE FOR YOUR SCRATCH WORK

USE THIS PAGE FOR YOUR SCRATCH WORK