QFI Investment Risk Management Exam

Exam QFIIRM

Date: Friday, November 3, 2023

INSTRUCTIONS TO CANDIDATES

General Instructions

1. This examination has 9 questions numbered 1 through 9 with a total of 60 points.

   The points for each question are indicated at the beginning of the question.

2. 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 provided in this document.

Written-Answer Instructions

1. Each question part or subpart should be answered either in the Word document or the Excel file as directed. Graders will only look at work in the indicated file.

   a) In the Word document, answers should be entered in the box marked ANSWER. The box will expand as lines of text are added. There is no need to use special characters or subscripts (though they may be used). For example, β_1 can be typed as beta_1 (and ^ used to indicate a superscript).

   b) In the Excel document formulas should be entered. Performing calculations on scratch paper or with a calculator and then entering the answer in the cell will not earn full credit. Formatting of cells or rounding is not required for credit.

   c) Individual exams may provide additional directions that apply throughout the exam or to individual items.

2. The answer should be confined to the question as set.

3. Prior to uploading your Word and Excel files, each file should be saved and renamed with your five-digit candidate number in the filename.

4. The Word and Excel files that contain your answers must be uploaded before the five-minute upload period expires.

Navigation Instructions

Open the Navigation Pane to jump to questions.

Press Ctrl+F, or click View > Navigation Pane:
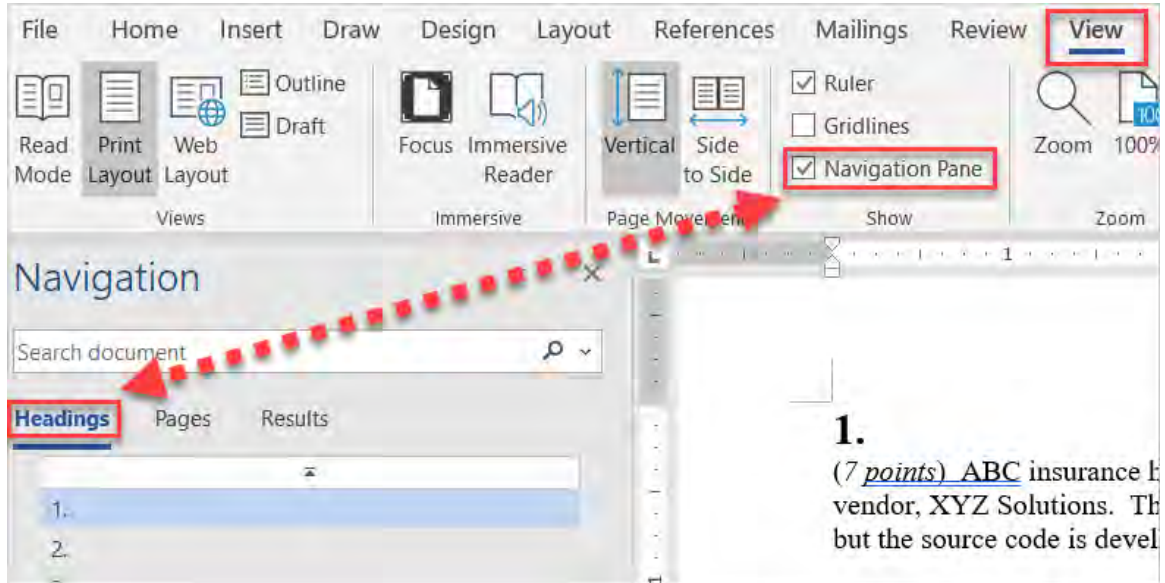
1.

(*9 points*) You are working as an actuary in a market risk team for a large insurance company. The chief risk officer (CRO) has asked you to conduct a survey to identify equity risk exposure of the company. You have designed a standardized, one-time questionnaire and distributed it to the following participants:

      (i)   Junior staff within the market risk team

      (ii)   Senior investment and risk officers of the company

      (iii)   Independent consultants that are experts in risk management

(a)   (*1 point*)

      (i)   (*0.5 points*) Identify two risk identification techniques that would be the most suitable to use with the above participants.

> ANSWER:

      (ii)   (*0.5 points*) Assess the approach of using a standardized, one-time questionnaire with the above participants.

> ANSWER:

1.   Continued

In the survey, the independent consultant points out the need to strengthen the company's modeling capability and is proposing to use either an independent lognormal process (ILN) or GARCH (1,1) to model the monthly returns of the Equity Index (EI).

(b)   (*2 points*)

(i)   (*1 point*) List four important stylized facts about equity price movements.

ANSWER:

(ii)   (*0.5 points*) Evaluate how well ILN addresses these four facts.

ANSWER:

(iii)   (*0.5 points*) Evaluate how well GARCH addresses these four facts.

ANSWER:

Because of recent inflation, the equity market is experiencing high volatility. You are interested in quantitatively assessing the probability that EI will experience a significant decline in the next month.

After reviewing the comments in the survey, you decide to implement a GARCH (1,1) model for the EI monthly log-returns. The junior staff provides you with the following parameters calibrated based on the historical data.

$\mu = 0.003$,
$a_0 = 6.5 \times 10^{-4}, a_1 = 0.1, b = 0.6$
$\sigma_0^2 = 0.0036$

The EI value at time t = 0 is 400, and the EI value at time t = -1 was 450.

1. Continued

(c)   (*3 points*)

   (i)   (*0.5 points*) Explain whether you should use the risk-neutral or real-world measure for this calculation.

   > ANSWER:

   (ii)   (*1 point*) Calculate the probability that the EI will drop by more than 20% in a month.

   > *The response for this part is to be provided in the Excel spreadsheet.*

   (iii)   (*1 point*) Calculate the number of months after which the expected variance will equal the long-term variance (within 6 decimals).

   > *The response for this part is to be provided in the Excel spreadsheet.*

   After reviewing, you realize that the junior staff made a mistake in his calibration, and the correct parameters should be $a_1 = 0.15$, $b = 0.75$.

   (iv)   (*0.5 points*) Describe qualitatively how these new parameters will impact the results of the model.

   > ANSWER:

In addition to the monthly log returns, you would like to model the quarterly, semi-annual and the annual log returns as well. The junior staff responds that this can be done by simply scaling up the parameters of your model based on the time factors.

(d)   (*0.5 points*) Critique the junior staff's suggestion.

   > ANSWER:

1. Continued

The CRO is interested in evaluating market-consistent prices of future cash flows while retaining the same variance process as your model.

(e)   (*1.5 points*) Propose an equivalent process that addresses the CRO's needs and describe its distribution in terms of your model's parameters.

(Equation is not required. A detailed explanation of the process would suffice.)

ANSWER:

The CRO is concerned that your model does not adequately address the leverage effect, where higher volatility clusters are observed in market crashes or failures.

(f)   (*1 point*) Revise the GARCH model to address the CRO's concern and justify your response.

ANSWER:

2.

(*8 points*) You are a risk manager at an insurance company. The Chief Risk Officer (CRO) is particularly interested in modeling market risk (risk factor X_1) and credit default risk (risk factor X_2). The CRO suggests rank correlation because he believes that correlation is not an appropriate dependency measure.

(a)   (*2 points*) Critique the CRO's statement: "correlation is not an appropriate dependency measure".

> ANSWER:

(b)   (*1 point*) Describe these two types of relationships.

> (i)   (*0.5 points*) Concordant

>> ANSWER:

> (ii)   (*0.5 points*) Discordant

>> ANSWER:

You have gathered historical data for ten periods.

Time	X_1	X_2
1	2.1%	-0.5%
2	10.2%	2.0%
3	20.1%	7.8%
4	-4.4%	-1.8%
5	19.7%	3.8%
6	5.5%	1.0%
7	-7.5%	2.4%
8	10.6%	0.0%
9	30.4%	-1.9%
10	-1.7%	0.5%

2. Continued

(c)   (*3 points*) Calculate three types of correlation of X_1 and X_2

   (i)   (*1 point*) Pearson's

   > *The response for this part is to be provided in the Excel spreadsheet.*

   (ii)   (*1 point*) Spearman's rank

   > *The response for this part is to be provided in the Excel spreadsheet.*

   (iii)   (*1 point*) Kendall's rank

   > *The response for this part is to be provided in the Excel spreadsheet.*

(d)   (*1 point*) Describe the advantages and disadvantages of rank correlation.

   ANSWER:

The CRO wants to know more about the effect of the recessionary cycle to the correlation of two factors. A risk analyst suggests using a copula approach.

(e)   (*1 point*) Explain the advantages of the copula approach to model the tail risk.

   ANSWER:

3.

(*4 points*) ABC company has a portfolio consisting of two bonds with exposures, $C_1 = 10$ and $C_2 = 20$.

Their default probabilities are estimated to be $P_1 = 0.2$ and $P_2 = 0.1$.

You are asked to develop a credit-risk model for modeling the default loss of the portfolio:

$$L = c_1 \, \mathbb{I}_{\mathcal{D}_1} + c_2 \mathbb{I}_{\mathcal{D}_2},$$

where $\mathbb{I}_{\mathcal{D}_i}$ is the default indicator which is equal to one if the ith bond defaults before time T, $i = 1,2$.

Assume that $\mathbb{I}_{\mathcal{D}_1}$ and $\mathbb{I}_{\mathcal{D}_2}$ are independent

(a)   (*1 point*) Calculate the 97.5% VaR of L.

> *The response for this part is to be provided in the Excel spreadsheet.*

After your manager reviewed your model, a concern was raised over the independence assumed between the default events. She recommends you use the threshold approach to model the default dependence. Specifically, for $i = 1,2$, let y_i be the state variable underlying the ith bond, which admits the following form:

$$y_i = \sqrt{\rho} \, G + \sqrt{1 - \rho} \, \epsilon_i,$$

where G and ϵ_i are independently distributed standard normal. The state variables are connected to default events via

$$\begin{cases} \mathbb{I}_{\mathcal{D}_i} = 1, & if \ y_i \leq \Phi^{-1}(p_i), \\ \mathbb{I}_{\mathcal{D}_i} = 0, & if \ y_i > \Phi^{-1}(p_i). \end{cases}$$

3. Continued

The following table outlines the bivariate standard normal CDF $\Phi_2(x, y; \rho = 0.5)$ evaluated at various points (x, y).

x	y	$\Phi_2(x, y; \rho = 0.5)$
-0.84162	-1.28155	0.05150
0.84162	-1.28155	0.09737
-0.84162	1.28155	0.19737
0.84162	1.28155	0.75150

(b) (*2 points*) Recalculate the 97.5% VaR of L, using the threshold model approach.

The response for this part is to be provided in the Excel spreadsheet.

(c) (*1 point*) Describe the difference between the VaR values based on the independence model and the threshold model.

ANSWER:

4.

(*8 points*) You have applied for a model governance position at an actuarial software and consulting firm. Interviewers are in discussions with you on various topics related to model risk and model governance.

The first interviewer asks about model risk and model governance.

(a) (*1 point*)

(i) (*0.5 points*) Identify the two main sources of model risk.

ANSWER:

(ii) (*0.5 points*) List the main purposes of model governance.

ANSWER:

The second interviewer states: "Some of the companies we work with are small with limited resources; we work with these companies to develop proxy models that can deliver the needed results with the resources available."

(b) (*1.5 points*)

(i) (*1 point*) List four methods for constructing proxy models.

ANSWER:

(ii) (*0.5 points*) Identify two risks of using proxy models.

ANSWER:

4. Continued

The interviewer notes that client companies are very concerned about estimating parameters, in particular, understanding the parameter risk of their models.

(c)   (*3 points*)

(i)   (*1 point*) Explain the conditions when standard errors can be used to estimate parameter uncertainty.

ANSWER:

(ii)   (*0.5 points*) Describe the key advantage of Bayesian methods over MLE for assessing parameter uncertainty.

ANSWER:

(iii)   (*1.5 points*) Describe the steps to simulate values from the predictive distribution using the Markov Chain Monte-Carlo (MCMC) algorithm given a prior p and likelihood function L.

ANSWER:

Another interviewer describes a new model being developed of real-world exchange rates between US Dollars (USD) and an emerging-market nation Buranda outside of North America with currency BUR. The model is to be used to decide investment returns of held-to-maturity pension plan assets.

- The model uses a weekly projection time-step.
- Model USD/BUR performance is benchmarked to long-established FX models for USD/Canadian dollars and USD/Mexican pesos.
- The model parameters require at least 10 years of data to fully calibrate. Buranda was part of a larger neighboring nation until 8 years ago; due to their shared history, that nation's historical exchange rate with USD is used when USD/BUR is unavailable.

(d)   (*1 point*) Critique the appropriateness of the model characteristics above.

ANSWER:

4. Continued

Finally, the last interviewer notes that behavioral biases may negatively influence decision-making processes and risks analyses, particularly during the information processing step.

(e)   (*1.5 points*) Define the following behavioral biases:

(i)   (*0.5 points*) Confirmation Bias

ANSWER:

(ii)   (*0.5 points*) Framing Bias

ANSWER:

(iii)   (*0.5 points*) Anchoring Bias

ANSWER:

5.

(*9 points*) A commercial airline has hired you as an external consultant to help evaluate its operations based on your financial risk management experience.

You are first asked to provide insights on the company's established practices compared with the financial sector. The following are examples of these practices:

1. All employees, regardless of experience, must reference approved procedures for critical operational phases.
2. Every vital primary system has an independent, alternate backup system in case of failure/malfunction. Secondary systems are also used to cross-check primary systems.
3. Frequent periodic training is required for all employees, tailored to their function(s).
4. Crew radio communications acknowledge instructions received by repeating them back.

(a)   (*1 point*) Identify which "Top Ten" operational risk is addressed by each practice.

ANSWER:

5. **Continued**

You are asked to analyze the normality assumption for the distribution of flight times, which is used to determine how much fuel to hold, as excess and insufficient fuel both have costs. A sample of historical flight data for a route between City A and City B has been provided to you.

(b) (*4 points*)

(i) (*1 point*) Calculate the 90% VaR roundtrip flight time from City A to City B assuming a normal distribution with its mean and standard deviation estimated from the sample data presented in Excel spreadsheet.

The response for this part is to be provided in the Excel spreadsheet.

(ii) (*1 point*) Calculate the smoothed empirical 90% VaR of the roundtrip flight time.

The response for this part is to be provided in the Excel spreadsheet.

(iii) (*0.5 points*) Explain whether one-sided or two-sided hypothesis testing is more appropriate for testing the 90% VaR.

ANSWER:

(iv) (*1 point*) Calculate significance level (p-value) for which the normal distribution approximation of the 90% VaR roundtrip flight time would be rejected based on the provided sample data. Use a one or two sided test depending on your answer from part (iii).

The response for this part is to be provided in the Excel spreadsheet.

(v) (*0.5 points*) Determine whether approximating total flight time with a normal distribution is reasonable for this data.

ANSWER:

5. Continued

For a separate route, you are asked to compare the expected costs of holding excess fuel with expected costs of insufficient fuel. You are provided the following details:

- The route between City C and City D can be approximated by a normal distribution with a mean of 300 minutes and standard deviation of 3 minutes.
- The airline will incur $1M in additional costs for every minute of insufficient fuel necessary for the roundtrip flight.
- The airline with incur costs of an unknown amount $X per minute for each minute of flight-time with excess fuel held.
- The company policy is to hold exactly enough fuel for the 90% VaR roundtrip flight time.

(c)   (*2.5 points*) For roundtrip flight from City C to City D,

   (i)   (*1 point*) Calculate the expected costs due to insufficient fuel per roundtrip flight.

The response for this part is to be provided in the Excel spreadsheet.

   (ii)   (*1 point*) Calculate the expected minutes holding excess fuel per roundtrip flight.

The response for this part is to be provided in the Excel spreadsheet.

   (iii)   (*0.5 points*) Determine the largest value of X such that the additional cost of carrying extra fuel is worth the financial risk of insufficient fuel costs on average.

The response for this part is to be provided in the Excel spreadsheet.

5. **Continued**

The airline is concerned about the future cost to purchase fuel for this route. Their economists predict that there is a 1 in 5 chance fuel costs will exceed $8 per gallon. You are told that fuel is used at a rate of 60 gallons per minute.

(d)   (*1.5 points*)

   (i)   (*0.5 points*) Explain whether a fractal or a Gaussian distribution is more appropriate to model fuel costs.

   > ANSWER:

   (ii)   (*1 point*) Calculate the likelihood that the average roundtrip fuel cost between C and D will exceed $288k under either a fractal distribution with alpha (exponent) of 3 or Gaussian with mean of $1.98/gal, depending on which was recommended in part d(i).

   The response for this part is to be provided in the Excel spreadsheet.

6.

(*7 points*) You are an analyst at a small company offering financial services to various companies. You have been asked to evaluate solutions to provide to:

- Big Company, a well-established company
- New Company, a newcomer in the industry

Market Interest Rate (MIR) is the standard reference rate for making variable loans. The current MIR is 3.5%. Risk free rate is zero. Both companies want to minimize interest rate risk.

The bank has offered one fixed rate loan and one variable rate loan to each of the companies to fund their projects:

Type of loan	Fixed rate	Variable rate
Big Company	5%	MIR + 150bp
New Company	6%	MIR + 275bp

You discussed with the CFOs of both companies about their projects and gathered the following information:

Company	Big Company	New Company
Project cost	$10 million	$5 million
Expected project cashflow	$750,000 annually	Returns follow: If successful (50% chance), MIR + 275bp of project cost annually, If not successful (50% chance), MIR + 175bp of project cost annually.
Preferred type of loan	Fixed rate	None of the loans is suitable.

(a)   (*1 point*) Explain why neither loan offered by the bank is suitable for New Company based on the current MIR.

ANSWER:

6. **Continued**

You realize that bringing these two clients together may be advantageous to everyone. Your company charges each company 2.5bp for these services.

(b)   (*1 point*) Determine the total savings of two companies that could be realized through a swap arrangement in basis points, based on the rates given. (Remember to remove the service fee.)

> *The response for this part is to be provided in the Excel spreadsheet.*

You are developing a strategy to fund both projects, which will include loans to be taken by each company and a swap arrangement that will benefit both companies.

(c)   (*2.5 points*) Determine:

    (i)   (*1 point*) The loans to be taken by each company.

> ANSWER:

    (ii)   (*1.5 points*) The notional amounts of the swap and, all the swap parameters and their possible ranges.

> ANSWER:

You expect that:

- MIR will increase 10bp a year for the next 10 years.
- New Company's project will be successful if MIR is 4% or above and not successful if MIR is below 4%.

(d)   (*2 points*) Determine the following cash flows (if applicable) for Big Company, New Company, and your company, based on your expectations.

    (i)   The projects

    (ii)   The loans

    (iii)   The swap that you proposed

    (iv)   The swap service fee/income

    (v)   The net cash flows

> *The response for this part is to be provided in the Excel spreadsheet.*

6. Continued

(e)   (*0.5 points*) Explain why the companies may prefer to work directly with a larger swap broker instead of your company.

ANSWER:

7.

(*5 points*) You work as a financial analyst for a car dealer, Company XYZ. On October 1, 2007, your company lost a lawsuit and must pay $100 million in 9 months. To pay the lawsuit, the company decided to sell one of its warehouses to raise cash.

Company ABC offers to buy the warehouse for $95 million and deliver the payment in cash in 6 months.

(a)   (*0.5 point*) Identify the risks that Company XYZ is facing after losing the lawsuit.

> ANSWER:

Your coworker, upon learning that the warehouse was bought a year ago at a cost of $90 million, made the following statement.

"We can make a profit of $5 million from selling the warehouse. I guess the lawsuit wasn't that bad after all!"

(b)   (*1 point*) Describe the bias held by the coworker and the issue associated with the bias.

> ANSWER:

Your company decided to enter into a Eurodollar futures contract with expiration on April 1, 2008 to hedge interest rate risk. The underlying instrument is 3-month LIBOR. The company will buy 100 contracts, each with notional value of $1 million.

The price of a 90-day Eurodollar futures contract expiring on April 1, 2008 is $95.39.

(c)   (*1 point*) Determine the minimum bid price your company should accept from Company ABC that will allow the company to pay the lawsuit, ignoring interest earned between April 1 and July 1, 2008.

> *The response for this part is to be provided in the Excel spreadsheet.*

7. Continued

It is now April 1, 2008. Your firm has sold the warehouse at the minimum bid price 6 months ago while hedging the interest rate risk. The firm has now received the proceeds from Company ABC and the 100 futures contracts. The 90-day LIBOR rate is now 3.7088%. The price of the futures contract is currently $97.2912.

(d)   (*1.5 point*)

    (i)   (*0.5 point*) Calculate the profit or loss of the futures contract.

> *The response for this part is to be provided in the Excel spreadsheet.*

    (ii)   (*1 point*) Assess whether your firm will be able to pay the lawsuit on July 1, 2008.

> *The response for this part is to be provided in the Excel spreadsheet.*

Your coworker notices that the amount available to pay the lawsuit is not exactly $100 million, even though interest rate risk had been hedged using futures.

(e)   (*1 point*)

    (i)   (*0.5 point*) Identify the shortcoming of hedging with futures that is referred to by your coworker.

> ANSWER:

    (ii)   (*0.5 point*) Explain one method to overcome this shortcoming.

> ANSWER:

8.

(*5 points*) You are an ALM actuary at an investment management firm for small insurers. You facilitate communications between your firm's asset managers and the small insurers. In return for your firm's business, the broker that your firm works with provides valuable research services and subsidizes asset managers' business travel expenses.

(a)   (*1 point*) Critique the above arrangement.

> ANSWER:

One of the small insurers has a book of fixed indexed annuity products that requires trading options. You are not familiar with either the products or the options involved. However, you trust your asset managers and have informed the client that their assets are being managed as the client desires.

(b)   (*1.5 points*)

(i)   (*0.5 point*) Identify any unethical behavior in this scenario.

> ANSWER:

(ii)   (*1 point*) Recommend three possible remedial actions.

> ANSWER:

One of the asset managers is participating in an IPO and calls the firm's four largest clients to offer each of them 25% of the total shares allocated to your firm. You notice that most clients are excluded from the offer.

(c)   (*1.5 points*) Critique the asset manager's actions regarding the IPO.

> ANSWER:

8. **Continued**

The asset manager plans to approach a local insurance company as a prospective client. You are asked to prepare a presentation with the following approach:

- Selecting the current clients with the highest 3-year average of investment returns, regardless of which years that period spans.
- Showing the names of the clients to demonstrate your company's strength and the trust that was built over years with those big clients.
- Calculating investment returns before the deduction of fees since your company charges higher fees than other companies and this would help your company look more competitive.

(d)   (*1 point*) Identify any unethical behavior in using the above approach.

ANSWER:

9.

(*5 points*) Paula is an internal auditor at a company that has provided wealth management services to clients for over 10 years, primarily via investment accounts that focus on equity funds.

Paula learns that a pension fund accounts for one third of the assets under management. Because of the dominant position, the pension fund receives enhanced services, for which they pay a premium, such as investment research publications and enhanced treatment on investment recommendations and IPOs.

(a)   (*1 point*) Assess whether the company should continue providing the enhanced service to the pension fund.

> ANSWER:

Paula discovers that one of the traders purchased 50,000 shares of stock X and 2,000 call options for their personal trading account, as traders regularly disclose their personal investments. Shortly thereafter, that trader used $50 million from one of the fund's accounts to purchase more than 1 million shares of stock X.

(b)   (*1.5 points*) Assess the actions of the trader.

> ANSWER:

9. Continued

Paula reads the marketing brochure for the company's mid-cap growth strategy fund and finds the data supporting the performance metrics that the company provides to all current and prospective clients. The average composite return is the only performance metric provided.

The company claims that it has systematically overperformed compared to the S&P 500.

Supporting Data

	($m)	Years		
		1	**2**	**3**
Client A	Beginning of Year Assets	200	203	terminated
	Investment Income	10	10	
	Unrealized Capital Gains	-5	-8	
	Fees collected	-2	-2	
	Annual Return [*]	5.00%	4.93%	N/A
Client B	Beginning of Year Assets	100	103	105
	Investment Income	6	6	8
	Unrealized Capital Gains	-2	-3	0
	Fees collected	-1	-1	-1
	Annual Return [*]	6.00%	5.83%	7.62%
Client C	Beginning of Year Assets	80	83	86
	Investment Income	5	5	7
	Unrealized Capital Gains	-1	-1	-1
	Fees collected	-1	-1	-1
	Annual Return [*]	6.25%	6.02%	8.14%

(*): Annual return = Investment Income/ Beginning of Year Assets.

Performance Metric

Average composite return	6.13%	5.92%	7.88%
S&P 500	5.50%	5.00%	7.00%

9. Continued

(c)   (*2.5 points*) Critique:

(i)   (*2 points*) The methodology used to calculate the performance metric of the fund.

ANSWER:

(ii)   (*0.5 points*) The claim made by the company in its marketing brochure.

ANSWER:

END OF EXAMINATION