ACTL2111/5102 2024 Term 1 Excel Assignment

Deadline: 10 April 2024 at 5pm sharp

Jackson is a fresh actuarial graduate who just started his first full time job in a reputable insurance company in Sydney on 1 January 2024. Upon the start of his job, Jackson also decided to make an investment for a deposit to purchase his first home in 10 years time. Jackson has an awareness of investments of different types, including stocks, bonds, and some other risky asset Y. He has asked you to analyze his investment strategies.

To help you with your analyses, Jackson has provided you with all necessary information. In particular:

a. **Salary**: Jackson's salary can be decomposed into three components (all after income tax):
   - An annual base salary of \$60,000 and it will increase by 6% every year at the beginning of each year. He receives his salary monthly on the last day of each month (i.e., the first payment will be on 31 January 2024).
   - A sign-on bonus of \$20,000, paid with his first salary.
   - Performance bonus paid at the end of each year. His bonus in year t, B_t is calculated using the following formula
   $$B_t = 0.15A_t \cdot I_t \cdot \exp(-1/t),$$
   where A_t is his base salary for year t, and I_t is a Bernoulli random variable with success probability $p = 0.8$.

b. **Savings**: Jackson is very keen on saving as much as possible for his deposit, so he has decided that each month when he receives his salary, he will put 30% of it to his investment portfolio.

c. **Investment options**: Jackson is specifically interested in 3 types of investments:
   - Option 1: 100% technology portfolio.
   - Option 2: 60% corporate bonds and 40% Vanguard Australian Shares Index Fund (ASX code: VAS).
   - Option 3: Initially 100% in the risky asset Y.

   For example, in Option 2, Jackson will use 30% of his salary to invest 60% in corporate bonds and 40% in VAS every month.

d. **Technology portfolio**:
   - Jackson builds his own portfolio using three US stocks, Apple Inc (AAPL), Tesla Inc (TSLA), and Microsoft Corp (MSFT). He calculates the monthly expected returns R_1, R_2, R_3 and standard deviations $\sigma_1, \sigma_2, \sigma_3$ for the three stocks respectively (see below for hints). He then decides the weight for each stock by maximizing
   $$\boldsymbol{w}^\top \boldsymbol{R} - \boldsymbol{w}^\top \boldsymbol{\Sigma} \boldsymbol{w}, \tag{1}$$
   with respect to $\boldsymbol{w} = (w_1, w_2, w_3)^\top$. Here, $\boldsymbol{w}$ is a vector with w_i being the percentage of total investment he puts in stock i, with $w_i \geq 0$ for $i = 1, 2, 3$. Moreover, $\boldsymbol{R} = (R_1, R_2, R_3)^\top$; and $\boldsymbol{\Sigma}$ is the covariance matrix for the returns.
   - After 8 years, he will rebalance his portfolio by adding Nvidia Corp (NVDA) (with expected return R_4 and standard deviation σ_4) to his investment. The rebalancing is done such he maximizes
   $$\tilde{\boldsymbol{w}}^\top \boldsymbol{R}^* - \tilde{\boldsymbol{w}}^\top \boldsymbol{\Sigma}^* \tilde{\boldsymbol{w}}, \tag{2}$$
   with respect to $\tilde{\boldsymbol{w}} = (\tilde{w}_1, \tilde{w}_2, \tilde{w}_3, \tilde{w}_4)^\top$. Here, $\tilde{\boldsymbol{w}}$ is a vector with $\tilde{w}_i$ being the percentage of total investment he puts in stock i, with $\tilde{w}_i \geq 0$ for $i = 1, 2, 3, 4$; $\boldsymbol{R}^* = (R_1, R_2, R_3, R_4)^\top$; and $\boldsymbol{\Sigma}^*$ is the covariance matrix for the returns (now including NVDA).

— After determining the weights, he invests in this carefully designed portfolio. He projects the future returns to be **normally distributed**. The mean and variance for the first eight years are $\boldsymbol{w}^\top \boldsymbol{R}$ and $\boldsymbol{w}^\top \boldsymbol{\Sigma} \boldsymbol{w}$, respectively; and for the last two years are $\tilde{\boldsymbol{w}}^\top \boldsymbol{R}^*$ and $\tilde{\boldsymbol{w}}^\top \boldsymbol{\Sigma}^* \tilde{\boldsymbol{w}}$, respectively.

e. **Corporate bond**: To chase high returns, Jackson ruthlessly invests in a junk bond.
   — This junk bond provides a 6% return per month.
   — However, there is large risk associated as the firm's condition may deteriorate over the years. We use levels 1, 2, 3 to represent the firm's financial conditions.
      — The firm starts in level 1.
      — Level 1: The firm is healthy. In the next month, it may reside in level 1 (with probability 0.97) or go to level 2 (with probability 0.03).
      — Level 2: The firm is experiencing distress. In the next month, it may reside in level 2 (with probability 0.98) or go to level 3 (with probability 0.02).
      — Level 3: The firm bankrupts.
   — The investments are assumed not to be impacted when the firm is in levels 1 and 2. Jackson immediately loses 70% of invested amount in the junk bond when the firm jumps to level 3.
   — When the firm bankrupts, Jackson finds another similar firm to invest the remaining value (as well as the future investments), so the returns and risks he faces remains the same.

f. **VAS return**: The log return of VAS are assumed to be **normally distributed** with parameters calculated using historical data, see below for instructions.

g. **The risky asset** Y:
   — For every year, the risky asset Y generates a return that is either
      — 90% nominal annually, compounded monthly (with probability 0.6)
      — 36% nominal annually, compounded monthly (with probability 0.2)
      — -6% nominal annually, compounded monthly (with probability 0.2)
   — Y is subject to downside risks (market crashes), where the time between each market crash follows an exponential distribution with mean 1.5 years. Once the crash happens, the total value invested in Y decreases by 10% immediately.
   — Jackson becomes more prudent following market crashes, and put 10% less in Y (until 0% in Y) for the following months. He puts the reduced amount away in the bank and earn 1% effective annually.
   — For example, if the second crash occurs in the 30th month, Jackson will adjust his investment strategy starting from the 31st month. He will use 30% of his salary to invest 80% (1-2×10%) in Y, and put 20% in the bank.

h. **Costs and fees**: Jackson is not too concerned with costs, fees and taxes at this stage so you do not need to consider them in your analyses.

Tasks:

1. Calculate exactly (i.e., without using simulation)
   — the probability that Jackson's total performance bonus (nominal amount) will be no less than $90,000.
   — the probability it is no more than $10,000.

2. Create a table that presents Jackson's income (base and bonus) and the investment amount for each month over the next 10 years (from the first payment on 31 January 2024 to the payment on 31 December 2033). For this and following tasks we assume that Jackson receives his performance bonuses in years 2, 4, 6, and 9.

3. Calculate the values for R_1, R_2, R_3, R_4, σ_1, σ_2, σ_3, σ_4. Then, calculate the portfolio weights $\boldsymbol{w}$ and $\tilde{\boldsymbol{w}}$.

   — Note For this and following tasks, you need to use historical data on Yahoo Finance, with tickers AAPL, TSLA, MSFT, NVDA, VAS.AX for Apple, Tesla, Microsoft, Nvidia and VAS, respectively. The data used for analyses is monthly **adjusted close price** for the 5 year period from 2019 to 2024. On Yahoo Finance, you will need to select **monthly** data for the period from 31 January 2019 to 1 January 2024 then download this data for further analyses.

4. Now, suppose we want to maximize $\boldsymbol{w}^\top \boldsymbol{R} - q \cdot \boldsymbol{w}^\top \boldsymbol{\Sigma} \boldsymbol{w}$ with respect to $\boldsymbol{w}$ and $\tilde{\boldsymbol{w}}^\top \boldsymbol{R}^* - q \cdot \tilde{\boldsymbol{w}}^\top \boldsymbol{\Sigma}^* \tilde{\boldsymbol{w}}$ with respect to $\tilde{\boldsymbol{w}}$, instead. Change the value of q to be 10, 100, then 1,000. Briefly explain what you observe. (**Do NOT use results from this question to answer the remaining parts.**)

5. Calculate the return and variance for the two portfolios (original and rebalanced). Then simulate 100 trajectories of the portfolio he invests in for the period from 1 February 2024 to 31 December 2033, assuming that each monthly return is normally distributed with the mean and standard deviation calculated from question 3 above. Note that each trajectory is a sample path of simulated monthly returns with 1 simulated value per month for the 10 year period.

   — Note: For this question, you should calculate the **return**, rather than the **log return** defined in question 6 below.

6. Calculate the monthly log return of VAS using historical data available on Yahoo Finance, and hence, calculate the mean and standard deviation of the monthly log returns.

   — Note: The log return of stock a for the m-th month is defined as

$$r_{a,m} = \ln\left(\frac{\text{adjusted close price of asset } a \text{ for the } m\text{-th month}}{\text{adjusted close price of asset } a \text{ for the } (m-1)\text{-th month}}\right).$$

7. Simulate 100 trajectories for the monthly log returns of VAS for the period from 1 February 2024 to 31 December 2033, assuming that each monthly log return is normally distributed with the mean and standard deviation calculated in the previous step.

8. Calculate the accumulated value for the three investment options given at the end of December 2033. For each of the options you will have 100 accumulated value simulations. Plot the accumulated values from each of the 3 options on the same histogram and provide summary statistics for each of the three options.

9. Provide a brief recommendation to Jackson, with a summary of your findings (max 250 words). This should be placed in a separate sheet within the same EXCEL file.

10. Comment on any limitations encountered in your analysis, and provide some potential improvements that can be made.

Hint for risky asset Y: For the jumps, you may want to simulate a series of exponential random variables for the jump times. You may round the jump times to the nearest 1/12th for simplicity.

Assignment submission procedure and guidelines

Students are reminded that the work they submit must be their own. Assignments must be submitted via the Turnitin submission box that is available on the course Moodle website. Turnitin reports on any similarities between their own cohort's assignments, and also with regard to other sources (such as the internet or all assignments submitted all around the world via Turnitin). More information is available at: [click]. Please read this page, as we will assume that you are familiar with its content. As long as the due date is still future, you can resubmit your work and then the previous version of your assignment will be replaced by the new version (graders are only able to download and grade the newest version of the submission).

The file you submit for the assignment must be a **single Excel file**. Once you have uploaded your Excel file, you should download it from the system to confirm that it is the correct file and a valid file that can be opened. This is to make sure that the file in the system is not a corrupted file or an incomplete file, which may happen if students have created multiple versions of the file when writing the assignments or when there is internet connection problem when the file is being uploaded.

Students are reminded of the risk that technical issues may delay or even prevent their submission (such as internet issues, power outage, computer breakdowns). Students should then consider either submitting their assignment from the university internet network or **allow enough time (at least 24 hours is recommended) between their submission and the due time.** The Turnitin module will not let you submit a late report. **No paper copy will be either accepted or graded.**

Please note that the School of Risk and Actuarial Studies will apply the following policy on **late assignments**:

Late submission will incur a penalty of 5% per day or part thereof (including weekends) from the due date and time (e.g. 0 day 15 minute = 5% penalty; 2 days 21 hours = 15% penalty). An assessment will not be accepted after 5 days (120 hours) of the original deadline unless special consideration has been approved. An assignment is considered late if the required format (sinlge Excel file in this case) has not been submitted on time; or where an assignment has been submitted on time but the student requests to replace the assignment with a newer version after the deadline.

Students who are late must submit their assessment item to the LIC via e-mail at eric.cheung@unsw.edu.au. The LIC will then forward the documents to the graders. The date and time of reception of the e-mail determines the submission time for the purposes of calculating the penalty.

If a student is unable to complete the assignment at all or would like to apply for an extension due to illness or other extraordinary circumstances beyond the student's control, the student can consider applying for special consideration which is centrally managed by the university. Please refer to the online course outline for details. See also [click].

In the unlikely event of a technical problem, the full document must be submitted to the LIC before the due time by e-mail, with explanations about why the student was not able to submit on time. In principle, this assignment will not be marked. It is only in exceptional circumstances (e.g. Moodle breakdown) where the assignment was submitted before the due time by e-mail that it may be marked—and this only if a valid reason is established (and the LIC has the discretion in deciding whether a given reason is valid).

Plagiarism awareness

Students are reminded that the work they submit must be their own. While we have no problem with students discussing assignment problems if they wish, the material students submit for assessment must be their own. In particular, this means that any code you present are from your own computer, which you **yourself** developed, without any reference to any other student's work.

While some small elements of code are likely to be similar, big patches of identical code (even with different variable names, layout, or comments—Turnitin picks this up) *will* be considered as plagiarism. The best strategy to avoid any problem is *not* to share bits and pieces of code with other student outside your group.

Note however that you are allowed to use any Excel files that were made available during the course (either from the lectures or developed in the lab tutorials). You don't need to reference them formally, and this will *not* be considered as plagiarism.

Students should make sure they understand what plagiarism is—cases of plagiarism have a very high probability of being discovered. For issues of collective work, having different persons marking the assignment does not decrease this probability. For more information on plagiarism, see [click].

Students may consult the "Write well; Learn deeply" website and consult the resources provided there. In particular, all students should do the quiz about plagiarism to make sure they know how to avoid any issue. For instance, did you know that sharing any part of your work with other students (outside your group) before the deadline is already considered as plagiarism? [1]

Assessment criteria

Please see the file "Rubric".

[1] Yes, that's right, just sending it, even if the third party promises not to copy, is already plagiarism in the UNSW policy!