**Portfolio Risk Management Project**

**Mid-term report (Due 11:59pm 17/10/2021 Sunday, End of Week 9) – 15 marks**

Submit a midterm report **no longer than 10 pages single spaced** in the main report and include supporting information (graphs/tables) in the appendix.

1. You are encouraged to start working on this report earlier than Week 5 and it is better to do so. No deadline extension for this part since we already set it quite late.
2. **Question 1 (0.5 mark).** Again, the time point is the beginning of 2021 (December 31 2020). State your one-year investment goal **quantitatively.** The utility function is required to be a polynomial function moments of the portfolio return. For example, the easiest case is: U= E(R) – k \* [stderr(R)]^2, which means the utility is a simple formula of expected return minus k\*variance. You can add the third moment to highlight the downside risk. Conduct a simple exercise to calibrate the parameters of your utility function by the following procedure. In 2021, the long-term stock market return (market portfolio) is assumed to be 10% with annualized standard error of return at 18%. These are quite realistic numbers. The risk-free rate is assumed to be 1%. Suppose you only invest in market portfolio and risk-free asset. First, state you want to optimally invest how much proportion (e.g., 75%, 88%, 100% or even 120%) of your money into the market portfolio? Then you derive the value of k (or more parameters) that fits your optimal proportion. In this question, we assume that the weight must be 75%<w<125%. For real world mutual funds, they typically invest 90-100% into risky assets. Here, I allow for >100% so to allow you to choose an aggressive preference.
3. **Question 2 (5 marks).** Optimize your best mutual fund’s holdings using your objective function in Question 1 (keeping the same composition of stocks as the best mutual fund but adjusting only the weights). In other words, re-weight the portfolio of your best mutual. The new portfolio (including risk-free asset) should deliver better performance that maximizes your objective function. Grading for this question will be based on quantitative approaches only.
   1. You may focus on the top 30 stocks when your portfolio includes too many stocks.
   2. The requirement is only about investing in the same composition stocks of your best mutual fund. You don’t need to include new stocks. We assume the weight is the same throughout the sample period for simplicity.
   3. The optimization method is open. Given our mean-variance utility function, you may be able to derive closed-form formulas of your weights. You can explore techniques such as risk-parity optimization or mean-semi-variance optimization but for the sake of fairness of all groups, you are not to trouble the TAs for help on these advanced methods if you’re facing technical problems while implementing them. You can use gradient descent method, Newton Method, or even more complicated methods.
   4. To make the TA’s job easier, only Python is allowed. You need to submit your data and code so that the TA can replicate your analysis to get your answers.
   5. You can use any historical time-period for estimating the return and var-covariance matrix. You are also allowed to make reasonable adjustments. You can choose one of the following two methods. The default approach is the first one.
      1. Solution 1: you use the average return, sample variance, sample covariance in your sample period as the proxy of your forward-looking expected return, and expected var-covariance matrix. This is the simplest approach to help you understand this problem. But in case that your expected returns are mostly negative, you may need to try the advanced solution 2 for some of your stocks or all of your stocks.
      2. Solution 2:
         1. First, estimate the SML line of all of your portfolio firms with S&P500 being the market portfolio. That means using the individual firm’s daily return as DV and S&P500 daily return as IV for an OLS regression. You are allowed to use more advanced regression models if you learned how to do it from other modules.
         2. Second, given the estimated SML line of all firms, you can calculate the expected return of each firm by SML formula. This is also the predicted value of DV of your estimated OLS model.
         3. Third, construct the variance-covariance matrix from the SML formulas of your portfolio firms. You can assume your OLS residual term is uncorrelated with the S&P500 return.
   6. Numerically, it may be easier to solve the optimal portfolio when do the optimization directly with N+1 assets (N is the number of stocks, 1 is for the risk-free assets). The variance-covariance matrix has (N+1)\*(N+1) dimension.
   7. Let’s set the weight of each stock within the portfolio (including risk-free asset) as 0<=w<=25%.
4. **Question 3 (1.5 marks)**. Briefly discuss (1) the difference between new weights and the original weights. (2) whether your new portfolio weights make sense. If something looks wrong, discuss the potential problem to fix it. In other words, we will read your results, if we feel results problematic, then we expect you explain/discuss it. If you do not explain problematic results, you may lose points in this part.
5. **Question 4 (4 marks)**. Calculate the VaR (5%) and Expected Short-fall (5%) of 3 portfolios (best-performing, worst-performing, your own optimal portfolio) using the historical data by HS and Parametric (normal distribution) methods. For each portfolio, you should have 4 numbers calculated from **at least** previous 12 months of daily return data. You are allowed to use data with longer sample period.
6. **Question 5 (2 marks)** Compare your VaR predictions with the realized return and standard deviation of return in the first half of 2021 (up to 2021 Q2) by back testing methods covered in BT4016. Briefly discuss your results for all three portfolios (best fund, worst fund, and your optimized fund). Overall, which one of the 4 methods give you the best result?
7. **Question 6 (2 marks)** The time point is now shifted to the end of September 2021 (end of Week 8 of NUS Calendar). Discuss how you can adjust your “optimal portfolio” so it can outperform all other 14 chosen mutual funds in 2021 Q4.
   1. One difference between this portfolio and the earlier one is you can use the information in 2021 (historical data in 2021 and all updated news about Covid-19 developments). Collect some information to help you decide which stock to up weight or down weight.
   2. The other difference regarding optimization is: you can use your own forward-looking expected return and variance-covariance matrix. Justify your adjustment decision by some arguments.
   3. There is one more important requirement. Pick one stock that is most applicable by dividend discount model (paying dividends regularly, relatively large and stable). Collect some information about the current dividend, analysts forecast of next year’s dividend and growth of dividends. Then apply DDM to compute a theoretical valuation. Based on the market price on September 15 and your valuation, decide the new weight of this stock (subjectively is fine). One simple quantitative approach is to use new valuation price divided by real market price to calculate your expected return.
   4. Based on your new expected return and var-covariance of all stocks, derive a new optimal portfolio.