1. This is an **individual** assessment. You MUST produce and submit your own work. You MUST view and sign the student declaration form.
2. Dataset: same company data and sample period as the one you have studied in Case Study Part I
3. **Submission Deadline: 12th AUgust**
4. **A submission link for each 'Member' number will be available from Moodle**
5. **IMPORTANT.** There are TWO problems. Each worth 35 points. Nominate (choose) ONE of the problems that will be fully marked. Your 30% of the marks will be based on this problem. The remaining 5% will be based on your 'reasonable' attempt at the remaining problem.
   - Reasonable will be judged based on your general understanding of what needs to be done, and your understanding of the methodology and the theory and application. But we will NOT FULLY CHECK THE CODES AND THE COMPUTATIONS. Theoretical results will be checked.

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6. **Total marks**: **<u>70</u>**. This score will be weighted **35%** for your total grade (30% for the nominated problem, 5% for the other).

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7. Attach your PYTHON code and output as Appendix.

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8. Show all the necessary derivations of the analytical results. Your discussion and answers should be to the point.

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9. No need to include the Python output in the answers. Only report the information required to answer the specific questions. The Python code and output should be put at the end as an Appendix.

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GOOD LUCK!

Problem I. Computing application [Total 35 marks allocated as shown below]

In this application you will use daily data on your company returns together with the S&P500 returns over the same sample period as in PART I.

A. Set your in-sample or learning period to start from the first observation up to and including February 28th 2020. Denote this sample size T_1. Set the forecast (evaluation) period to be the remaining observations from March 1st, 2020 to the last observation. There are $T - T_1$ observations in this forecast period. Use the following methods to choose and estimate suitable forecasting models using the in-sample data only:

(i) Naive (Random walk model)

(ii) A Reg-AR(1): a regression with the lag 1 market index return added to a an AR(1) model for your company return.

(iii) A CAPM Model for the excess returns on your company stock.

(1) **[3 Marks]** Report and discuss the estimates from each model specification above.

(2) **[5 Marks]** Generate moving origin (also knows as static forecasts) horizon 1-day forecasts for each observation in the forecast sample (the remaining $T - T_1$ of the sample) from all methods above. Assess the accuracy of these forecasting methods using plots, RMSFE and RMAFE.

Recall. The Root-mean-square-forecast-error (RMSFE) and the Root-mean-absolute-forecast-error (RMAFE):

$$\text{RMSFE} = \sqrt{\frac{1}{h}\sum_{s=T_1}^{T-1} (\text{fe}_{s,s+1})^2},$$

$$\text{RMAFE} = \sqrt{\frac{1}{h}\sum_{s=T_1}^{T-1} |\text{fe}_{s,s+1}|}$$

where $h = T - T_1$, T the sample size, and T_1 is the last observation in the training sample. Here the last 25% observations make the hold out sample $T_1 + 1$ to T. The forecast error is the difference between the value of the return at time $(s + 1)$ and its forecast $y_{s+1|s}$ made at time s.

$$\text{fe}_{s+1,s} = y_{s+1} - y_{s+1|s}, \text{ where } s = T_1, \cdots, T - 1.$$

B. Given the Reg-AR(1) model in (A) for your company asset return series, assume Gaussian errors and fit the following conditional volatility models: (i) GARCH(1,1), (ii) GJR-GARCH(1,1) and (iii) EGARCH(1,0) using the first T_1 of sample data.

(1) **[7 Marks]** Report the variance equations estimates and draw the news impact curves (NIC) from the three conditional volatility models above. Comment on the shapes of the NICs.

(2) **[6 Marks]** Using a forecast origin of day T_1, generate h-step-ahead forecasts of volatility, for $h = T_1 + 1, \cdots, T$, and for the volatility models (i), (ii) and (iii) in B. Comment and compare the plots of these volatility forecasts.

(3) **[4 Marks]** Using a forecast origin of day T_1, generate h-step-ahead forecasts of volatility, for $h = T_1 + 1, \cdots, T$, for the exponentially weighted moving average (EWMA) model with $1 - \lambda = 0.94$. Add the forecast series to your plot in B.(2). Compare the EWMA volatility forecasts series with the three forecast series in B.(2).

C. Conditional volatility is unobservable which makes a direct comparison between forecasted volatility and actual volatility impossible. GARCH forecasts can be evaluated using observable proxies for conditional volatility.

(1) **[5 Marks]** Generate 1-step-ahead forecasts of volatility using two proxies: (1) sample standard deviation (all previous data) $s(\text{all past data})$, (2) sample standard deviation using the previous 25 observations $s(25)$. Add all these forecasts to your plot from B.(3).

(2) **[5 Marks]** Assess the accuracy of each model's forecasts using volatility proxies 1 and 2. Which models did best overall? Did the proxies agree on which were the best models over the whole data period and especially around financial periods?

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Problem II [Total of 35 marks allocated as shown below]

Suppose that your company returns, denoted $\{y_t\}$, are generated by the following process:

$$
\begin{aligned}
y_t &= \phi_0 + \phi_1 y_{t-1} + \delta\sigma_{t-1} + \epsilon_t + \theta_1\epsilon_{t-2} + \theta_2\epsilon_{t-4}, \quad \text{where, } |\phi_1| < 1,\ |\theta_1| + |\theta_2| < 1,\\
\epsilon_t|\mathcal{F}_{t-1} &\sim \mathrm{WN}(0, \sigma_t^2),\\
\sigma_t^2 &= \alpha_0 + \alpha\epsilon_{t-1}^2 + \gamma\epsilon_{t-1}^2 I_{t-1} + \beta\sigma_{t-1}^2\\
\alpha_0 > 0&, \quad \alpha > 0,\ \beta > 0,\ \gamma > 0,\ \alpha + \beta + \frac{1}{2}\gamma < 1,
\end{aligned}
$$

where $\mathcal{F}_{t-1}$ denotes information available at time $t-1$. I_{t-1} is a binary random variable: $I_{t-1} = 1$ if $\epsilon_{t-1} < 0$, and $I_{t-1} = 0$ if $\epsilon_{t-1} \geq 0$. Divide the sample data, $1, \cdots, T$ into an estimation sample, $1, \cdots, T_1$ and an evaluation sample $T_1 + 1, \cdots, T$. We are interested in comparing models pre- and post- Covid19. To do so, let T_1 be the observation corresponding to February 28th 2020.

A. **[4 marks]** Estimate the model above for your returns series, using the sample $t = 1, \cdots, T_1$.

B. **[3 marks]** Comment on the role of the GARCH component in the mean equation and its effect on the unconditional mean and variance of the returns.

C. **[4 marks]** Using the estimation results, compute a dynamic h-step ahead forecast for y_{T_1+h} and $\sigma^2_{T_1+h}$. Place a 95% forecast interval around the point forecast of y_{T_1+h}, for $h = 1, \cdots, T - T_1$. Plot the forecasts and their forecast bands.

D. **[4 marks]** Using the estimation results, compute the static (one-step ahead) forecast for y_{t+1} and σ^2_{t+1} over the evaluation period $t = T_1 + 1, \cdots, T$. Place a 95% forecast interval around these point forecasts. Plot the forecasts and their forecast bands.

E. **[4 marks]** Explain why the static and the dynamic forecasts differ? Do you see any mean reversion in these forecasts. Explain!

F. Consider the Exponential GARCH model:

$$
\begin{aligned}
\ln(\sigma_t^2) &= \omega + \alpha_1|z_{t-1}| + \gamma z_{t-1} + \beta\ln(\sigma_{t-1}^2),\\
-1 < \beta < 1&, \quad z_{t-1} = \epsilon_{t-1}/\sigma_{t-1}.
\end{aligned}
$$

(i) **[4 marks]** Repeat the estimation in (A.) of the model but now with the EGARCH specification above for conditional volatility.

(ii) **[5 marks]** As a market analyst, you are interested in measuring how long news travel and stay in the returns process and thus in the financial market. To understand this, you compute the Half-life time for both the GJR and the EGARCH. In your analysis, how long before the Covid19 negative shock, that hit the market on March 1st, 2020, dies out or at least halves its effect?

G. **[7 marks]** Suppose a portfolio manager holds a position of ten million dollars ($\$10m$) in the market portfolio given by your company stock. Calculate and plot the daily empirical 99% Conditional-Value-at-Risk of this portfolio for $T_1 + 1, \cdots, T$ for both GJR and EGARCH. Comment on the differences between these two series of VaRs and how the two have evolved over time since March 1st, 2020.

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