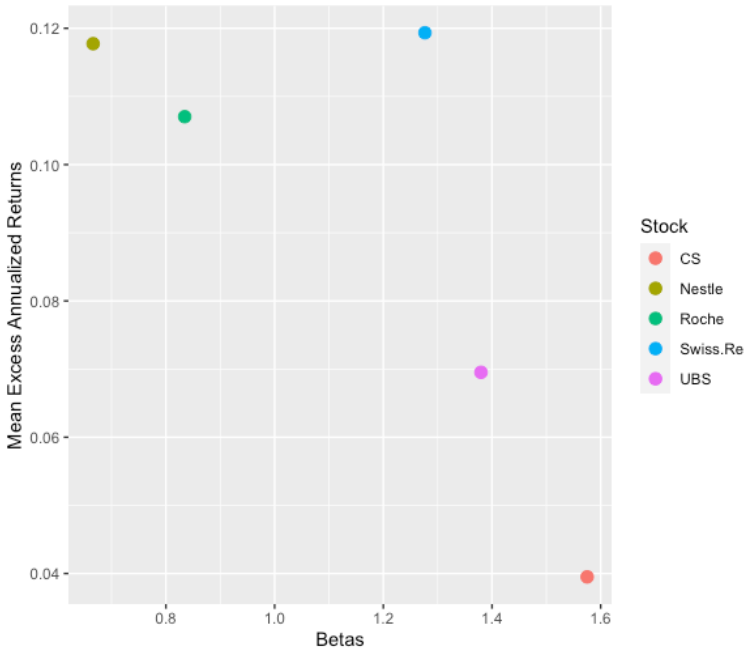
Theory *of* Finance

Solution Sheet for Problem Set 2

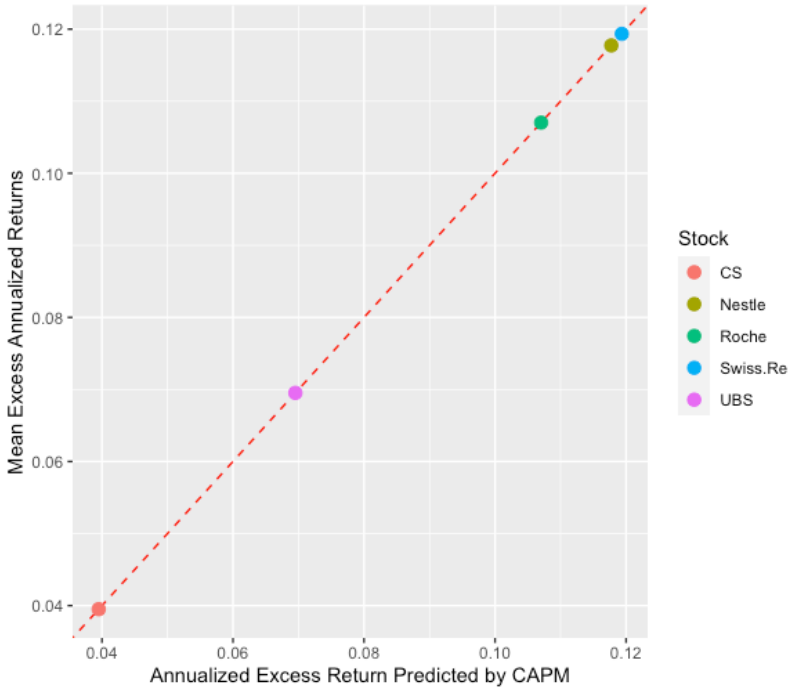
**CAPM & Risk Management**

Deadline: 15.11.2022

**Solved by: Sandro Gassner**

| Task | | Points Earned |
|---|---|---|
| **1. Betas, Covariances, and the CAPM**<br><br>a) Beta calculation and two plots featuring beta and predicted excess returns (10 points) | We calculated the following alphas and betas for the 5 stocks:<br><br>| Stock | Alphas | Betas |<br>\|---\|---\|---\|<br>\| CS \| -0.0087 \| 1.5750 \|<br>\| Nestle \| 0.0047 \| 0.6661 \|<br>\| Roche \| 0.0026 \| 0.8346 \|<br>\| Swiss.Re \| 0.0002 \| 1.2766 \|<br>\| UBS \| -0.0047 \| 1.3797 \|<br><br>The results are plotted in the following graph:<br><br>  <br><br><br>In the first graph we observe that every stock has a different beta, which measures the systematic risk of the stock compared to the market (in this exercise, SMI will reflect the market). Therefore, stocks with Betas >1 (<1) will move with more (less) momentum than the SMI. Additionally, we observe that the mean of the five betas is not equal to 1 which makes sense since the | |

SMI consists of Switzerland top 20 largest stocks. Only 5 stocks are in this exercise.
We noticed some negative correlation between beta and mean excess annualized return with Swiss.Re being off the downward sloping trend.




In the second graph, we observe a linear relationship between annualized excess return predicted by CAPM and mean excess annualized returns. Furthermore, we observe that the CAPM predicted returns are same as actual mean excess annualized returns. The mean of the predicted values in an OLS regression (in-sample) is always equal to the mean of the original values.

b) CAPM test (6 points)

| t-test for alpha = 0 | | |
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| **Stock** | **t-value** | **p-value** |
| CS | -2.3100 | 0.0217 |
| Nestle | 2.6000 | 0.0096 |
| Roche | 1.1200 | 0.2630 |
| Swiss.Re | 0.0643 | 0.9490 |
| UBS | -1.3900 | 0.1660 |

From the table above, we observe the p-value for each alpha. We note that in two cases the p-value is smaller than 0.05 which means that the null-hypthesis ($H_0$: $\alpha = 0$) is rejected for Nestlé and Credit Suisse at significance level of 5%. This means that

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| | the notion of CAPM does empirically not hold **in this setting** given the p-value of CS and Nestlé. | |
| c) Single Index model volatility and correlation estimation (6 points) | According to 4.4 from the lecture slides, we obtain the following formular to calculate the variance and covariance to derive standard deviation and correlation:<br>$\sigma_{ii} = \beta_i^2 \sigma_{mm} + \mathrm{Var}(\varepsilon_{it})$<br>$\sigma_{ij} = \beta_i \beta_j \sigma_{mm}$ when $i \neq j$,<br>Since there is no idiosyncratic risk the term $Var(\varepsilon_{it})$ can be dropped from the equation.<br>Standard deviation of the stock: 0.0483<br>We have calculated the following correlation coefficients:<br>**stock_j** / **corr_ij**: Nestle 0.6574; UBS 0.6975; CS 0.7065; Swiss.Re 0.6407; Roche 0.6557 | |
| d) Performance measure calculation (20 points) | We calculated the following <u>annualized</u> performance measures:<br>**Jensen's alpha**:<br>With the highest alpha out of the five stocks, Nestlé is suggested to possess the highest abnormal rate of return.<br>**Sharpe ratio:**<br>The Sharpe ratio suggests that Nestlé has the highest risk adjusted return relative to the risk-free rate. | |

| | Nestle | UBS | CS | Swiss.Re | Roche |
|---|---|---|---|---|---|
| jensens_alpha | 0.0569 | -0.0564 | -0.1043 | 0.0028 | 0.0309 |
| sharpe_ratio | 0.7635 | 0.2309 | 0.1164 | 0.3935 | 0.5524 |
| m2 | 0.0249 | -0.0561 | -0.0736 | -0.0314 | -0.0072 |
| appraisal_ratio | 0.4900 | -0.2615 | -0.4341 | 0.0121 | 0.2109 |
| information_ratio | 0.2087 | -0.0974 | -0.2025 | 0.1186 | 0.1061 |
| treynors_ratio | 0.1768 | 0.0504 | 0.0251 | 0.0935 | 0.1283 |
| t2 | 0.0855 | -0.0409 | -0.0662 | 0.0022 | 0.0370 |

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| | **M2:**<br>As Nestlé has the highest M^2 value, it's suggested that the risk adjusted return of Nestlé will be higher than the other stocks. This is also in line with the selection of Nestlé using the Sharpe ratio as the stock with the highest Sharpe ratio will also have the highest M^2 ratio.<br><br>**Appraisal ratio:**<br>According to the appraisal ratio, Nestlé is the stock of choice due to its highest average extra return per unit of extra volatility.<br><br>**Information ratio:**<br>As Nestlé has the highest Information ratio, Nestlé remains the stock of choice as it has the highest adjusted returns relative to the benchmark.<br><br>**Treynor's ratio:**<br>Looking at the Treynor's ratio, we observe that Nestlé has the highest Treynor's ratio, suggesting that the reward to risk ratio is highest.<br><br>**T2:**<br>As T2 and Treynor's ratio basically have the same ranking, Nestlé will be the stock of choice when looking at the T^2 ratio.<br><br>In line with all the performance metrices, we conclude that Nestlé is the stock of choice given by the reasoning above. | |
| e) Brief economic intuition on relation between beta and seven fundamental variables (14 points) | **Dividend payout (-):**<br>In regards of CAPM, dividend payment usually has no impact on the enterprise value as accumulating or distributing stocks/portfolios offer the same income. However, given information asymmetry between management and investors, dividend payout to earnings ratio is associated with the management outlook on the firm's future performance. Especially, when firms establish a policy of dividend stabilization, the management of companies with volatile earnings will want to choose a lower payout ratio. In simple terms, given a high dividend payout, we expect the managements outlook to be positive and less volatile (risky) compared to the market hence have a lower beta.<br><br>**Asset growth (+):**<br>Asset growth can be referred to as growth in company size, growth in profitability or growth in asset value. Essentially these growths are tied to an expanding balance sheet because of (but not limited to) the following factors: | |

1) Excessive earnings opportunity
2) Rate of returns exceed expected rate of returns
3) Payout policy that retains a higher portion of the earnings (less dividends)

While the 2 and the 3 can be explained in this exercise by the earnings variability or dividend payout, excessive earnings opportunity refers to companies venturing into new opportunities by investing e.g., in companies through acquisition. There are two narratives why this investment increases the risk:

1) The company expands into more unknown areas where earnings are more uncertain and volatile.
2) Following the excessive earnings opportunity, competition will eventually erode the market. Therefore, it is unsure how long the excessive earning will last.

Conclusively, these two reasonings are associated with an increase in risk thus a higher beta.

**Leverage (+):**
The leverage ratio of a company refers it's the ratio of debt to total assets. Having a high leverage therefore relates to a high debt ratio which essentially increases the systematic risk of the company reflected in its increased beta. In other words, having a high amount of debt increases the default risk as firms are burdened with interest and repayment.

**Liquidity (-):**
It's argued that liquid assets are less volatile/risky compared to illiquid assets. In extreme cases, highly liquid assets such as cash can be perceived as risk free. Therefore, a company with relative high liquid assets can be perceived as less risky than the market. Therefore, an increase in liquidity is associated with a lower systemic risk and therefore lower beta.

**Asset size (-):**
Generally, it is believed that larger firms are less risky than smaller companies. There are multiple empirical evidence supporting these statements:

1) Large companies are less likely to default on their debt compared to small companies.
2) As a result, large companies have better bond ratings
3) Large companies have less variation in their earnings (less volatile)

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| | Furthermore, large companies are also able to diversify their assets thus decrease their risk overall which eventually leads to a lower company beta.<br><br>**Earnings variability (+):**<br>As risk is essentially defined as volatility, increasing variability in earnings will increase the company's variance and risk compared to the market. Intuitively, variability in earnings causes the equity value to fluctuate therefore increase volatility compared to the market. Therefore, earnings variability is associated positively with the company's beta.<br><br>**Earnings beta (+):**<br>An earnings beta refers to the movement of earnings compared to the markets earning. Therefore, having a high earnings beta will cause the company's beta to also be high due to the simple fact that equity value is also volatile due to the sensitivity of the earnings compared to the market. | |
| **2. Risk Measures**<br><br>a) Calculation of risk measures (10 points) | We calculated the following annualized risk measures:<br><br>| | Nestle | UBS | CS | Swiss.Re | Roche |<br>|---|---|---|---|---|---|<br>| mean_absolute_deviation | 0.0348 | 0.0644 | 0.0729 | 0.0590 | 0.0438 |<br>| semi_std_deviation | 0.0319 | 0.0615 | 0.0704 | 0.0625 | 0.0393 |<br>| empirical_VaR | 0.0632 | 0.1300 | 0.1545 | 0.1090 | 0.0744 |<br>| empirical_exp_shotfall | 0.0871 | 0.1844 | 0.2253 | 0.1966 | 0.1083 | | |
| b) Evaluation of risk measures (6 points) | **Mean absolute deviation (MAD):**<br>From the table above we observe that Nestlé has the lowest MAD and CS the highest MAD. Therefore, given the MAD, we expect Nestlé to have the least amount of risk and CS the highest amount of risk.<br><br>**Semi-standard deviation:**<br>Given the semi-std deviation we perceive that Nestlé has the lowest downside risk compared to the other stock. Furthermore, we observe that CS has the highest downside risk compared to the other stocks.<br><br>**Empirical VaR:**<br>Looking at the VaR, we once again observe Nestlé to be the least risky and CS to be the riskiest stock out of the 5.<br><br>**Empirical exp shortfall:** | |

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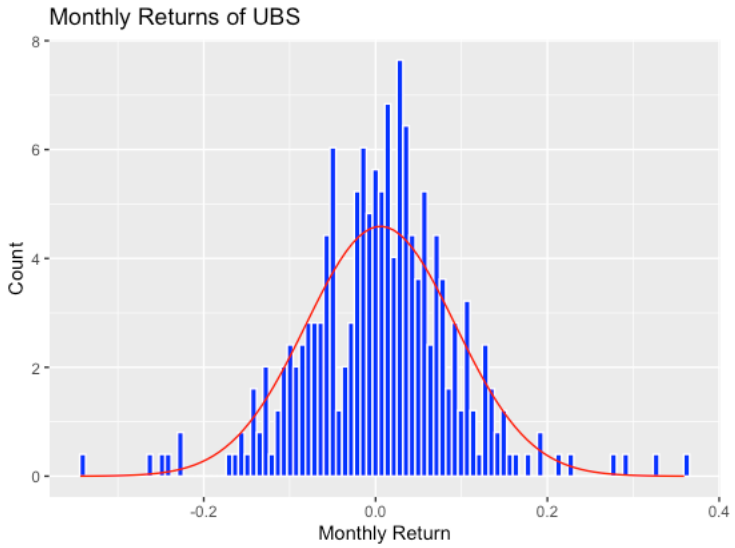
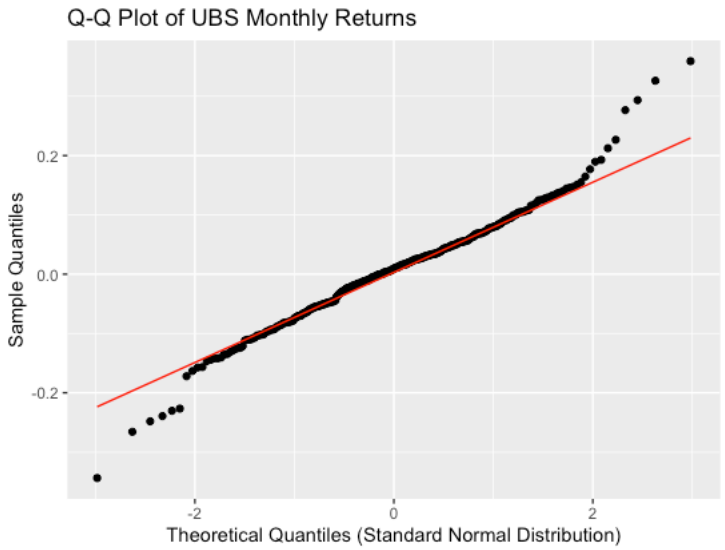
| | Assessing the shortfall, Nestlé shows the lowest shortfall risk thus is considered the least risky stock while CS is the riskiest stock.<br><br>In conclusion, Nestlé is the least risky asset while CS is the riskiest asset based on the aforementioned metrices. | |
| c) Histogram and Q-Q plot for UBS returns (10 points) |  <br>Given the graph, we observe that the return of UBS somewhat resembles a normal distribution given its bell shape. However, we also see from the graph that UBS has more returns centered around 0 and therefore a higher peak than a normal distribution. Additionally, we observe higher count of empirical return at the tails of the distribution thus indicating fat tails.<br><br>  <br>This graph additionally, shows how close UBS returns follows a normal distribution. The fact that the plot follows the linear | |

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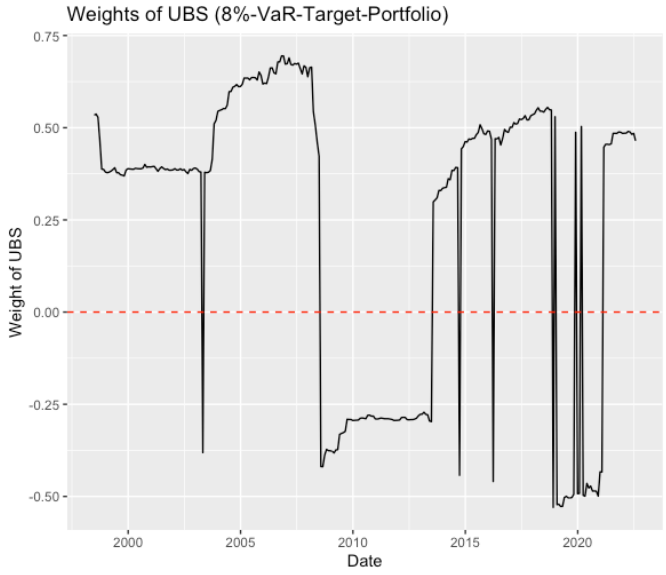
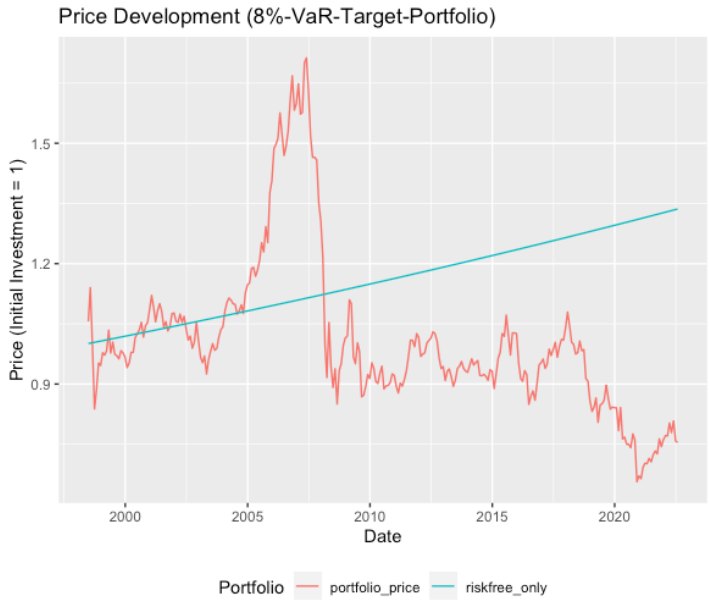
| | pattern in the middle indicates that the empirical returns follow a normal distribution closely. Nonetheless, we see strong deviation at the tails which relates to a heavy tailed distribution compared to normal distribution. This supports the notion before that the empirical distribution of returns from UBS seem to have fat tails.<br><br>Conclusively, calculating the VaR of UBS using a normal distribution would underestimate the VaR. | |
| **3. Risk Targeting**<br><br>a) Plots of value development and portfolio weights (12 points) | The portfolio VaR is given by the following formula:<br><br>$$\%VaR_p = \sqrt{\begin{matrix} w^2\%VaR_1^2 + (1-w)^2\%VaR_2^2 \\ +2w(1-w)\rho_{1,2}\%VaR_1\%VaR_2 \end{matrix}}$$<br>Since the covariance of the risk-free asset and UBS is zero, we can drop the second line within the square root.<br><br>We can rewrite this as<br><br>$$w = -\frac{VaR_p + \mu_{rf,t}}{\mu_{UBS,t} + c * \sigma_{UBS,t} - \mu_{rf,t}} \; for\; \mu_{UBS,t} \geq \mu_{rf,t}$$<br>and<br>$$w = -\frac{VaR_p + \mu_{rf,t}}{\mu_{UBS,t} - c * \sigma_{UBS,t} - \mu_{rf,t}} \; for\; \mu_{UBS,t} < \mu_{rf,t}$$<br><br>For the VaR at a 99% confidence level c equals -2.325. And the target $VaR_p$ equals 8%. The formula for the optimal weight of UBS (w) depends on the rolling expected mean. If the expected rolling mean of UBS is smaller than the risk-free rate, we would choose to short UBS (negative w) to obtain a VaR of 8%. Otherwise, the weight of UBS is positive.<br><br>Further, we inserted the estimated returns and standard deviations based on the last 5 years for each period. If we solve for w, we get the following weights for UBS in our 8%-VaR-target portfolio: | |




The price development of our portfolio with the corresponding weights of UBS since June 1998 can be seen in the following plot:




We also added the price development for only holding the risk-free asset over this time horizon for a comparison. Overall, holding the risk-free asset only would mean a higher portfolio price today. Nevertheless, there are times when the portfolio containing UBS significantly outperformed the risk-free asset only portfolio.

Finally, we computed the following portfolio statistics:

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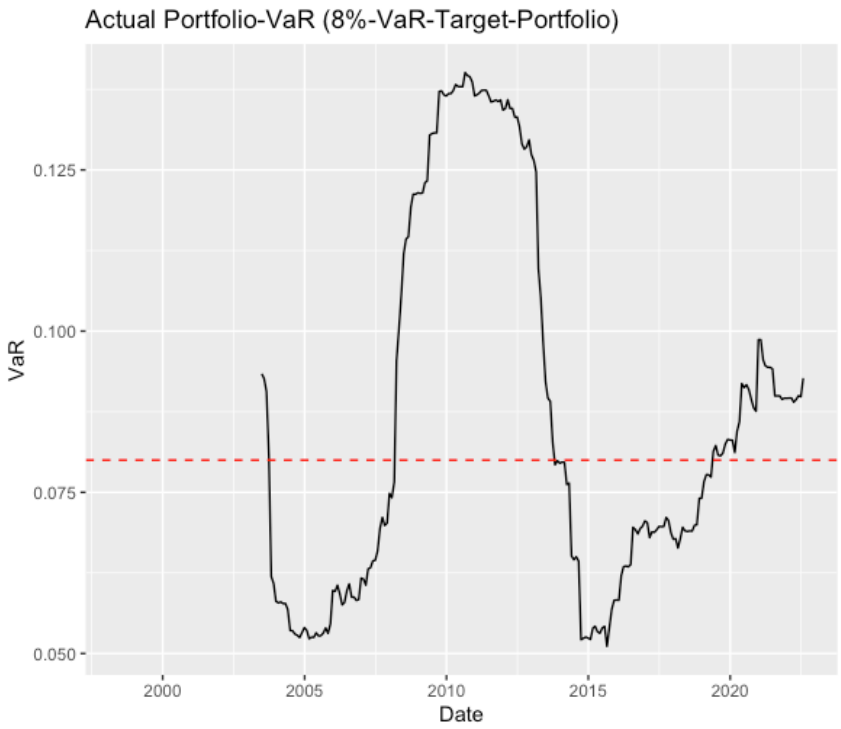
| | Annualized mean return: -0.1717%<br>Annualized standard deviation: 13.9511% | |
| b) Risk targeting evaluation (8 points) | We calculated the actual portfolio VaR of our trading strategy based on the portfolio returns of the last 5 years for each month. The results are plotted below:<br>  <br>From 230 months observed, the Portfolio-VaR exceeded the target of 8% in 110 months. As almost half of the months exceeded the VaR of 8%, the balancing strategy did not perform well. As mentioned in exercise 2c), using the theoretical VaR underestimates the risks as the return distribution are fat tailed compared to a normal distribution which caused the portfolio to exceed the theoretical risk target of 8% more often. | |