Algorithmic Trading, COMP0051, 2022/23

Coursework 2. Cohort 2022/23. This assignment is worth 60% of the overall mark.

All reports will be checked for plagiarism and plagiarism cases will be thoroughly investigated, do not include non-original material (text, images, tables) without clearly stating the source.

Standard and non-standard calculators are permitted

1. **Time Series Prep [30 Points]**

   (a) Download S&P 500 ETF (called *SPDR* or Spider, ticker SPY Equity[1]) at end-of-day prices for the period of time between 1 Jan 2014 to 31 December 2019. Download the Effective Fed Funds Rate (EFFR Index) [2] as the risk-free rate. Adjust annual risk-free rate to make it a daily rate, i.e., $r_t^f = EFFR(t) \cdot dc$, where dc is a day-count. You can use $dc \approx (1/252)$.

   A unit of SPDR will cost p_t at time t, which we have to finance at the risk-free rate. The daily excess return per unit of SPDR reads,

   $$r_t^e = \frac{\Delta p_t}{p_t} - r_t^f.$$

   (b) Plot the SPDR return time series, the EFFR, and the excess return per unit of SPDR, starting from $t = 0$ corresponding to 1 Jan 2014.

2. **Trading Strategies [45 Points]**

   Definition. In a leveraged strategy, the (leveraged) *book size* is the available capital times the leverage amount. By a leveraged strategy we mean a sequence $\{\theta_t\}_{t=1}^T$ of dollar values of SPDR which can be long or short such that

   $$|\theta_t| \leq V_t \cdot L$$

   where V_t is the total value of the holdings, and L is the leverage.

   (a) Define three leveraged trading strategies for the SPDR with initial capital $V_0 = \$200,000$. For all strategies, set the leverage $L = 5$. Use the first 70% of days as

[1] https://finance.yahoo.com/quote/SPY/

[2] https://www.newyorkfed.org/markets/reference-rates/effr

training set and the remaining 30% as test set. The daily trading PnL, which we define as the excess return of each strategy $\{\theta_t\}_{t=1}^T$, is given by the equation:

$$\Delta V_t = \big(\frac{\Delta p_t}{p_t} - r_t^f\big)\theta_t$$

where θ_t is the dollar value of SPDR held at time t (i.e., $\theta_t = \text{units}(t) \times p_t$).

(b) Plot the position of the strategies θ_t together with the upper and lower bounds $[-V_t \cdot L, V_t \cdot L]$. Calculate the turnover in dollar value traded over time

$$\text{Turnover}_{\text{dollars}} = \sum_0^T |\Delta\theta_t|.$$

Additionally calculate the turnover in number of units traded over time

$$\text{Turnover}_{\text{units}} = \sum_0^T \big|\frac{\theta_{t+1}}{p_{t+1}} - \frac{\theta_t}{p_t}\big|$$

(c) Create a total PnL series for the strategies, where we assume that unused capital will be put in a money-market and grow at the same risk-free rate, i.e., the value of your account changes by the trading PnL (ΔV) and the change in the growth of the money-market capital account (ΔV^{cap}).

$$\begin{aligned} V_{t+1}^{total} - V_t^{total} &= \Delta V_t^{total} \\ &= \Delta V_t + \Delta V_t^{cap} \\ &= \big(\frac{\Delta p_t}{p_t} - r_t^f\big)\theta_t \; + \; (V_t^{total} - M_t) r_t^f \end{aligned}$$

where $M_t = \frac{|\theta_t|}{L}$ is the total margin used and V_0 was as above. Plot ΔV_t, ΔV_t^{cap}, and ΔV_t^{total} and plot their accumulated values (i.e., cumsum() of each).

3. **Performance Indicators [25 Points]**

(a) Define the excess return of a trading strategy as the daily trading PnL, $PnL_t = \Delta V_t$. Use this quantity to compute the Sharpe Ratio (SR), Sortino Ratio, Maximum Drawdown and the Calmar ratio of your strategies. For each of them provide two independent measurements: one within the training set and one within the test set.

(b) Plot the average excess returns of the strategies in the test set versus their standard deviations, include the SPDR average excess return and its standard deviation. Can you identify a linear combination of trading strategies with an higher Sharpe Ratio than the original ones?

(c) Plot the Drawdown chart over time for all of the strategies separately

$$DD_t = \max_{s \leq t}[PnL_s] - PnL_t$$

and plot the historic rolling 90-day volatility of the underlying asset (p_t) on each chart.

(d) Discuss the Drawdown chart. When are the biggest drawdowns? Are they related to the historic volatility? Could you see safer strategies involving using more or less margin based on the underlying market volatility?

Written report A single written report in pdf (around 10 pages) structured into:

- Introduction
- Methodology
- Results
- Discussion
- Bibliography

will need to be submitted to Moodle before the deadline of 30/03/2023.

Coding and Editing Students are allowed to use any programming language and any editing software for the report. For transparency, the code will need to be uploaded as well (you can choose your preferred format).

Marking The marking will be based on the following criteria:

- Clarity of presentation and explanations;
- Justification of the methodology, i.e. the trading strategies;

- Validity of results;
- Consistency of language and mathematical notation;
- Critical interpretation of results.