COMP 0051 Algorithmic trading coursework 2

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1   Introduction

SPTL ETF is designed to measure the performance of public obligations of the U.S. Treasury that have a remaining maturity of 10 years or more. This project introduces three trading strategies applied to SPTL price time series spanning from January 2014 to December 2019: Trend following, Mean reversion and Auto regressive modelling.

The Effective Fed Funds rate (EFFR) is used as risk free rate. The following graphs plots the daily EFFR rate and SPTL's daily excess return comparing to EFFR. The daily excess return of SPTL is the additional return beyond risk-free rate,which is mean reverting and more volatile at the start with some extreme values. EFFR rate experiences an upward trend until falling towards the end of the time period.
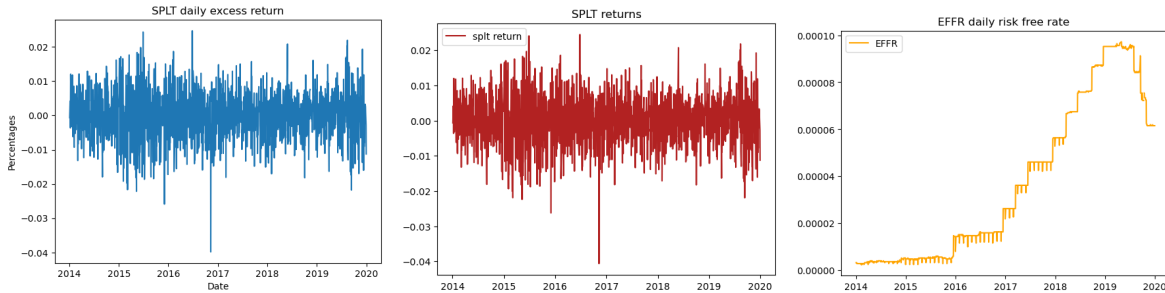

Figure 1: Comparison of SPTL return time series, EFFR and excess return of SPLT

2   Methodology

The leveraged trading strategies follows a static constrain that the traded dollar values has to be smaller or equal to the initial leverage book size (V0*L). In this case, the constrain is $ 2,000,000. This forces the strategy to unwind some holding of SPTL and put it into cash account if a price rise causes total value of holdings rise above $ 2,000,000 (vise versa for shorting). This constrain is adapted in all three trading strategies.

2.1   Trend Following

Trend following is the most known algorithmic trading style and is proven to be profitable for more than 200 years. Trend following aims to profit from the directional movement of asset prices by identifying and following established trends. It assumes that prices will continue to move in the same direction as the prevailing trend.

To implement a trend following strategy for SPTL, a rolling 30 days moving average is used as a indicator. For each trading day, the average of Today's and previous 29 days' closing price are calculated and stored as moving average. It is then used to compare with today's price. If moving average is higher than price, it is a indication that price might increase so the strategy longs SPTL. If moving average is lower than price, the price might decrease therefore short SPTL.

While in long position, the strategy exits and sells all its holding of SPTL when the moving average is smaller or equal to price. While shorting, the strategy exits when price is higher or equal to moving average.

This strategy uses all of it cash below constrain to complete buy orders. To implement constrain, the strategy checks its holding value every trading day and unwind excessive holdings to save in the cash account.

Fine tuning:

Based on this core strategy, different parameters are tested and fine tuned within the training set. Moving average with window size of 5, 30,60 and 120 provides substantially different result with window sizes of 5 and 30 perform the best. Window size of 30 is chosen for the final trend following strategy as it strikes a balance

between the short-term volatility captured by shorter moving averages and the long-term trends indicated by longer moving averages. A threshold of earlier exiting while longing (exit when moving average is smaller than 1.01* price) is added to the strategy as 30 days moving average can be less robust to changes in prices. As a comparison, a version using long term and short term moving averages cross sections as indication is developed but performs less well than using price time series.

Figure 2: Positions and Turn overs of trend following strategy

As presented in figure 2, the dollar value positions of trend following strategy is bounded by V0*L. The negative positions presents shorting. During the development, unit holding of shorting SPTL is set to be negative to differentiate against longing. This strategy executes frequently.

The 5 days moving average of turn over plots shows the changes in dollar value and unit traded over time. Dollar value turn over is higher during day 100 to 170, day 220 to 300 and day 380 to 420. Comparing with the 5 days rolling volatility of SPTL prices(red line), theses high turn over days all have high or increasing price volatility. It can be concluded that higher price volatility causes higher turn overs. The nature of this trend following strategy is to long or short while price deviates from its mean , therefore a more volatile prices trigger more order executions, leading to higher turn overs. Momentum tends to perform when volatility is high and has positive skewed return. The unit traded over time is affected by the price and constrain ,therefore is less representative.
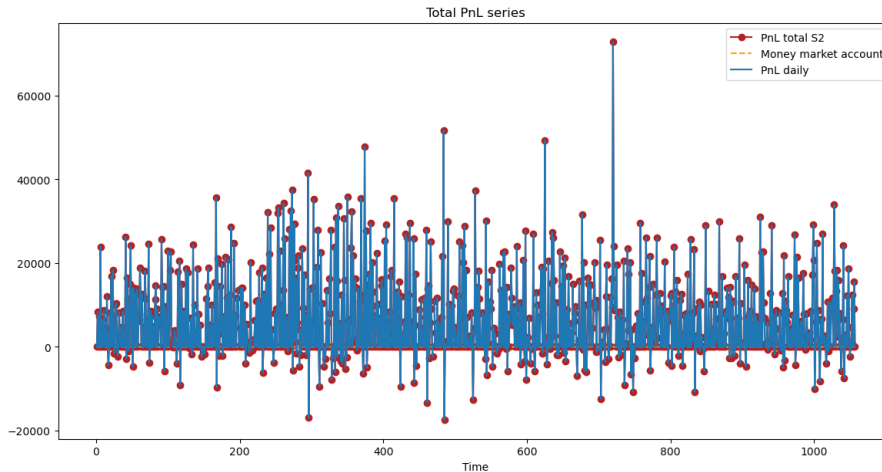

Figure 3: Total PnL series, daily PnL series and money market capital account -Trend following

Figure 3 shows the total and daily PnL series. It performs well with mostly positive dollar returns. The money market account is not visible on total PnL graph due to it being insignificant comparing to daily PnLs. In the separate money market plot, we can see a upward trending with cumulative return of 120. The cumulative sum of total and daily PnL shows linearly increasing trend, indicating promising strategy return.At the end of 450 days, the trend following strategy makes a cumulative excess return of over $ 2,500,000.
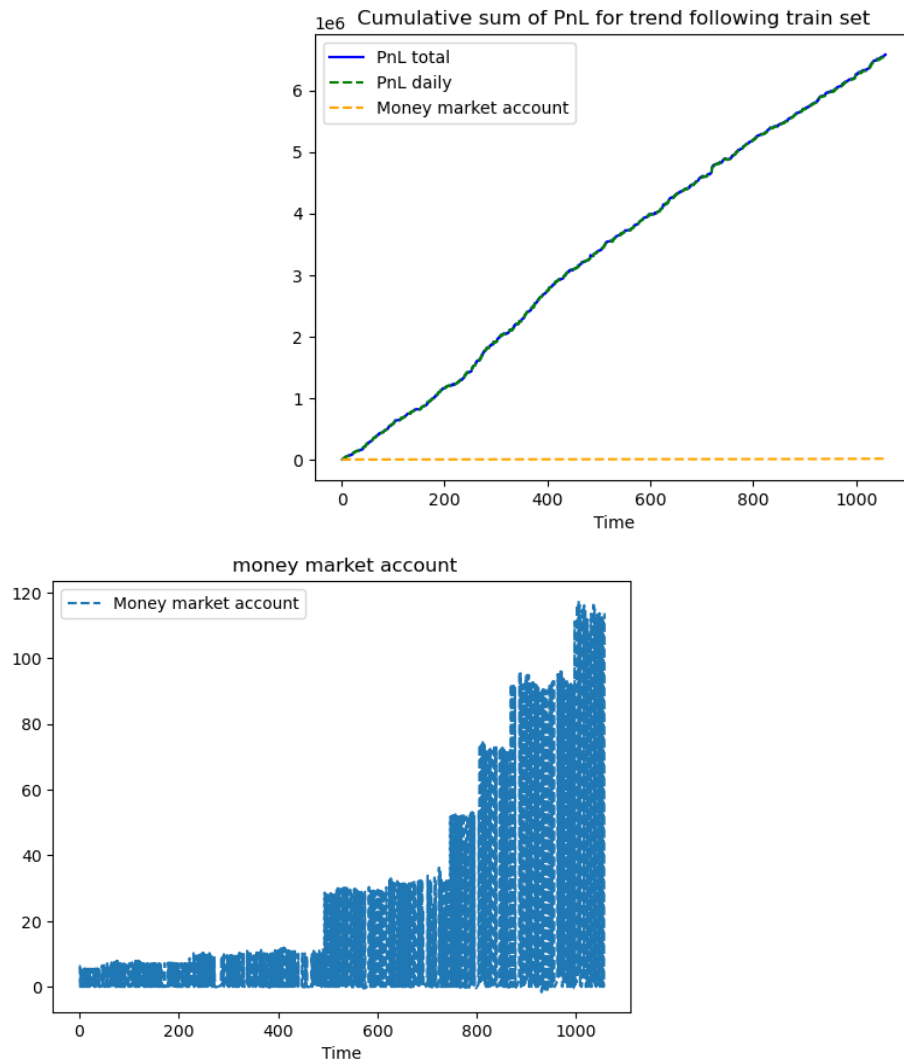

Figure 4: PnLs and money market account

The trend following strategy is only leveraged once due to its constant constrain. If the funding cost increase by 150 %, that will give a funding cost around 0.0002. When the funding cost increase, it can increase the difficulty for leveraging since putting money in money market can also yield a good return and it makes it more difficult for strategy to gain excess return. However due to the fact that this trend following strategy over perform risk free rate largely, a increase of 150% will not change the strategy.

2.2 Mean Reversion

Mean reversion utilises the tendency of asset prices to move back towards their long-term average or historical mean after prices deviate significantly from their average levels, either above or below experiencing periods of divergence.

However, It is easy to observe that the SPTL price is trending and not mean reverting.This can be proved by the success of the previous trend following strategy. Therefore, instead of using price as a indicator this strategy uses the return of price as a indicator. Return is highly mean reverting making it a suitable strategy to used on SPTL.

The core mean reversion strategy is to measure the extreme short term moving average of the return of SPTL. When moving average is above a threshold, assume the return is going to drop and short SPTL. When moving average is below a threshold, assume the price is going to increase and long SPTL. To capture the fast changing returns pattern, a moving average of window size of two is used. It is essential for mean reversion strategy to find a correct threshold. After testing within the training set, absolute value of 0.0125 is set to be the buy threshold while sell threshold is 0.002 for long and 0 for short. This is a relatively high threshold, aiming to increase the chance of mean reverting in sacrifice of trading frequency.
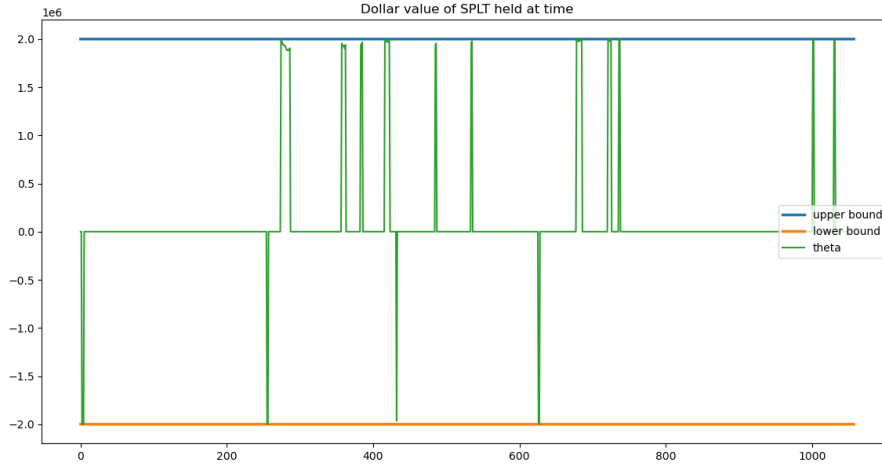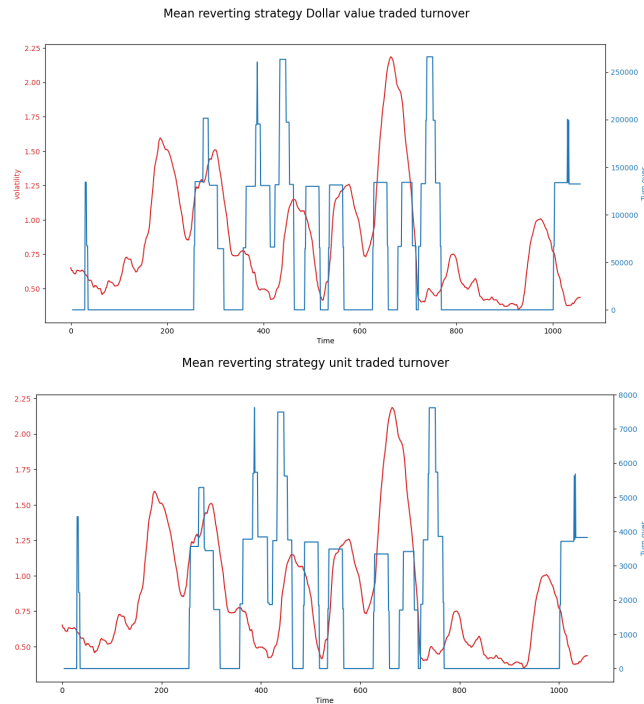

Figure 5: Positions of Mean reverting strategy

Figure 6: 30 days moving average of unit and dollar turn overs - Mean reversion

The dollar value holding follows the constrain. The mean reverting strategy executed 15 orders in total in

the training set, a significantly less number of trade than the trend following strategy. This is because of the high threshold set to ensure higher possibility of mean reverting.

This strategy has higher turn overs during high volatility period: day 150 to 300 and day 600 to 800. The nature of mean reversion aim to capitalise on short-term deviations from mean. During periods of high volatility, the frequency and magnitude of price movements tend to increase, leading to more opportunities for mean reversion trades.
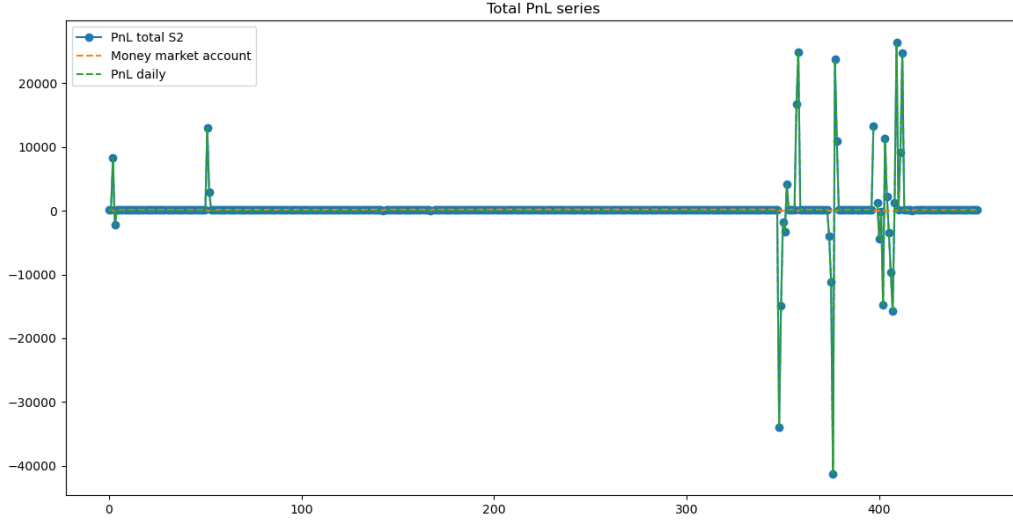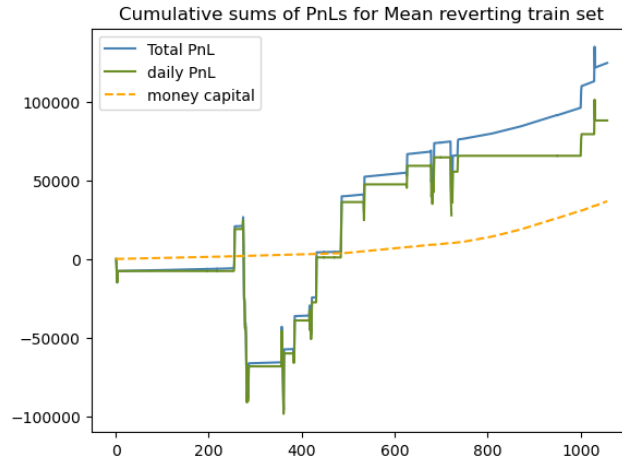

Figure 7: Total PnL series, daily PnL series and money market capital account -Mean Reversion

Total PnL series provides straightforward presentation of effectiveness of this strategy. Although only executed small amount of trade, there are still few significant negative values. The cumulative PnL chart shows that the daily PnL is overtaken by the money market account from day 150 onwards.

If the funding cost increases, there is a higher chance that this strategy would have negative excess return due to its under performing PnL. Therefore one should abandon mean reversion strategy and put all cash in money market if it is increase to 150%

The mean reversion strategy is proven to be less fit to SPLT. One of the possible reasons for not fit is that market conditions can change, leading to shifts in trends and volatility. In trending or momentum-driven EFTs like SPTL, mean reversion strategies fails to capture sustained price movements, resulting in losses. Another possible reason is that the mean reverting property may not persist over all time frames. Mean-reverting behaviour over short-term horizons can change over longer periods. Mean reversion strategies fails to adapt to the specific characteristics of the SPTL.

2.3 Auto regressive prediction

An Auto regressive model models and predicts future values of a time series where a stock's current value depends linearly on its past values and a stochastic error term. An AR model can be expressed as :

$X_t = c + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \ldots + \phi_p X_{t-p} + \varepsilon_t$

where $\phi_1, \phi_2...$ are the autoregressive parameters

In evaluating whether an AR model is suitable for modelling SPTL, it's crucial to recognise the presence of auto correlation in the SPTL data. Auto correlation indicates the degree of correlation between observations of SPTL at different time points. Figure 8 shows SPTL has a strong lag(1) auto correlation and it is suitable to model with an AR model.
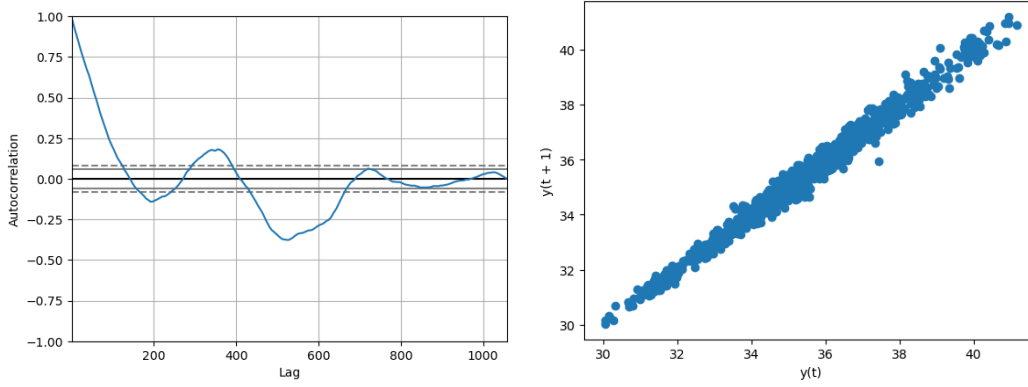

Figure 8: Autocorrelation tests

The AR strategy involves using AR models to predicts next trading day's price value based on historical prices of every past trading days in train set. The mean error of prediction is 0.059. A threshold of 0.01 is added to model, if the prediction is higher than 1.01* current price, the strategy longs and if prediction is lower than 0.99*current price the strategy shorts.
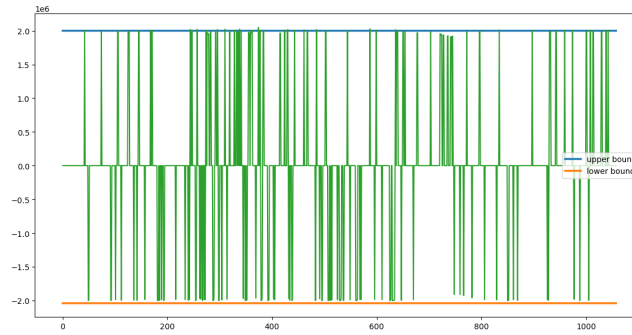

Figure 9: Dollar value positions of AR trading strategy

The dollar value position shows that AR strategy follows the leverage constrains. It has higher trade executions than mean revesion but lower than trend following
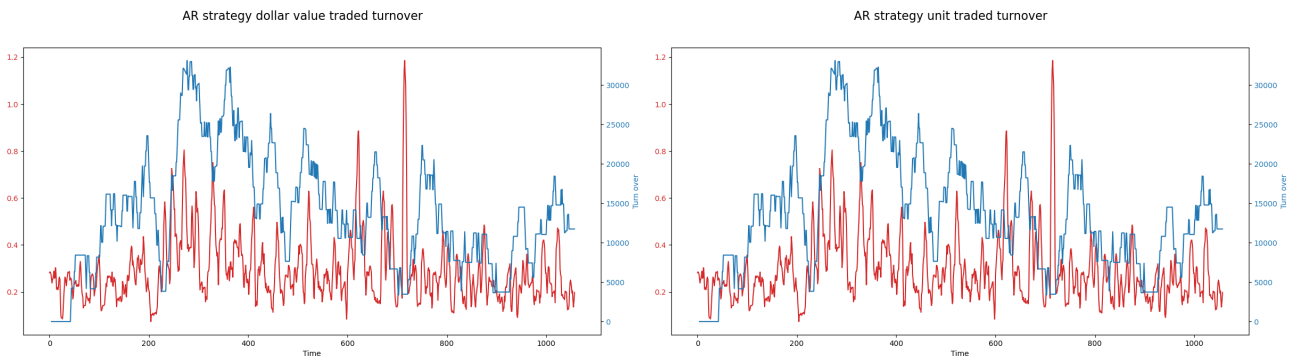

Figure 10: 30 days moving average of unit and dollar turn overs - AR

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Through the turn over plots, It is obvious that the number of turn over is highly correlated to the volatility. It also has highest correlation comparing to the other two strategies. The turn over is higher during day 200 to 400.
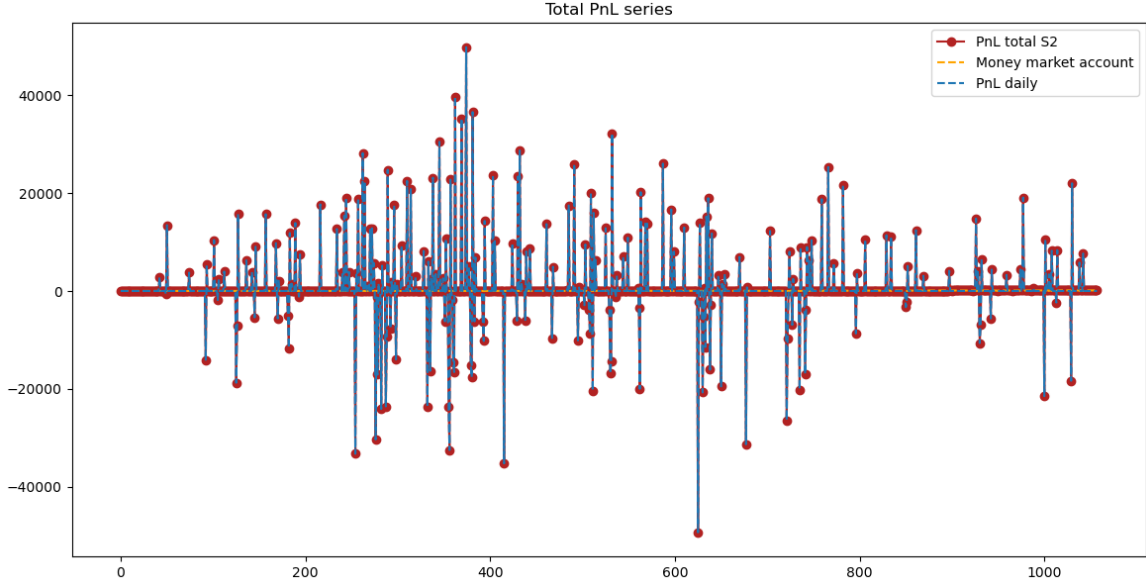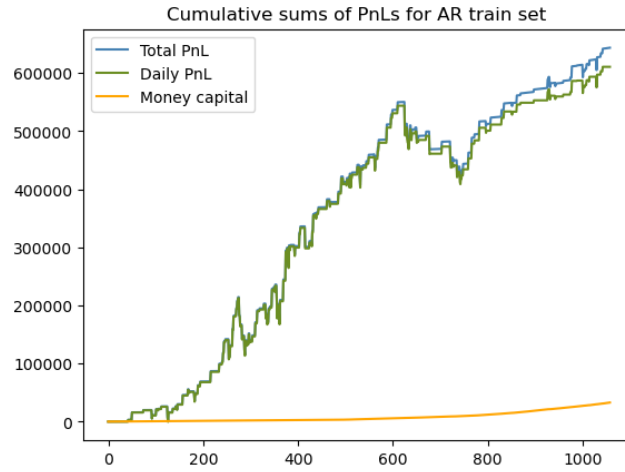

Figure 11: Total PnL series, daily PnL series and money market capital account -AR

The total PnL for AR model shows a high number of positive excess returns. However, a few negative excess returns are also present. The cumulative daily and total PnL shows a linear upward trend with a cumulative excessive return of $600,000 in 1000 days which validates the profitability of the AR strategy. If the funding cost increases, it will not affect AR strategy too much as the daily PnL is significantly more profitable than money market account.

Overall, the AR strategy performs better than mean reversion strategy but fall short of trend following. By fine tuning threshold and experimenting with AR model with lower error, AR strategy has a high potential to be used in trading SPTL.
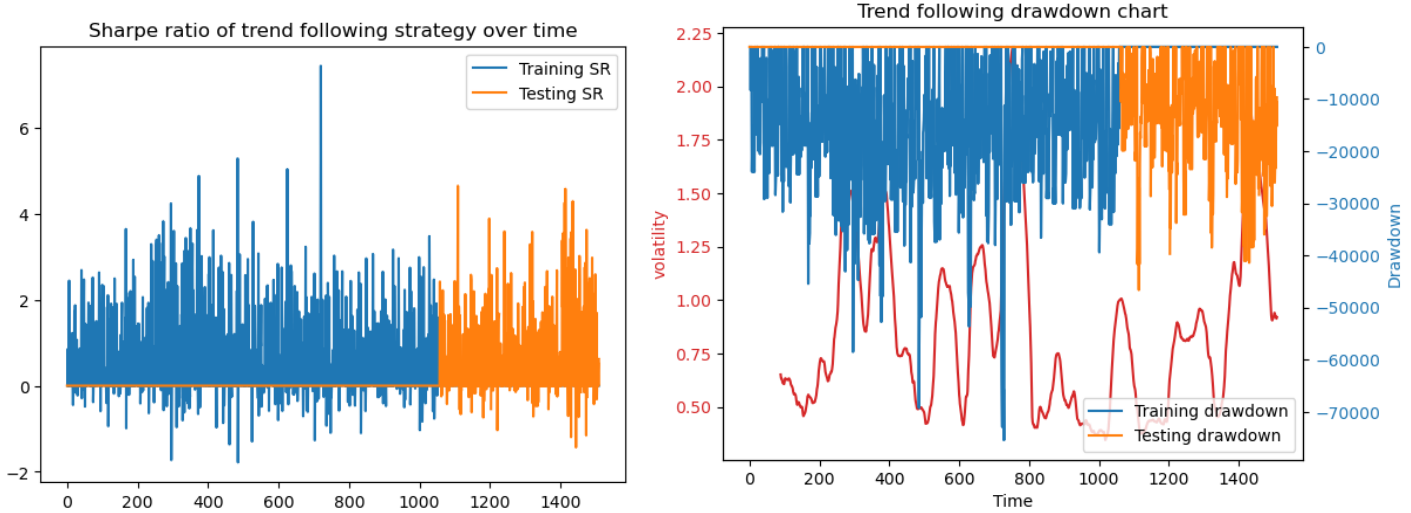
3 Results

Performance				
Trading strategy	Sharpe Ratio	Sortino Ratio	Maximum Drawdown	Calmar Ratio
Trend following Train set	0.638	3.583	90320.	1.240
Trend following Test set	0.644	4.423	54507	1.309
Mean Reversion Train set	0.024	0.036	68475	1.78
Mean Reversion Test set	0.019	0.026	67712	2.56
Auto Regression Train set	0.087	0.141	99150	1.99
Auto Regression Test set	0.028	1.480	82957	2.106

The performance result is the mean value of ratios. Sharpe Ratio is the risk adjusted return, Sortino ratio is the downside risk adjusted return, the maximum drown down measures maximum losses and Calmar ratio is maximum draw down adjusted return.

Overall, trend following strategy out perform the other two with test set Sharpe ratio of 0.644. It also has high Sortino ratio of 3.583 and 4.423 for train and test set respectfully,indicating the trend following strategy produces superior higher returns per unit of downside volatility compared to the risk-free rate.

Mean reversion and Auto regressive strategy 's performance test result shows that they produces only slightly higher risk adjusted return than the risk free rate,with Sharpe ratio of 0.019 and 0.028 only. The AR strategy produces highest maximum draw down among three strategies, introduces highest possible loss.
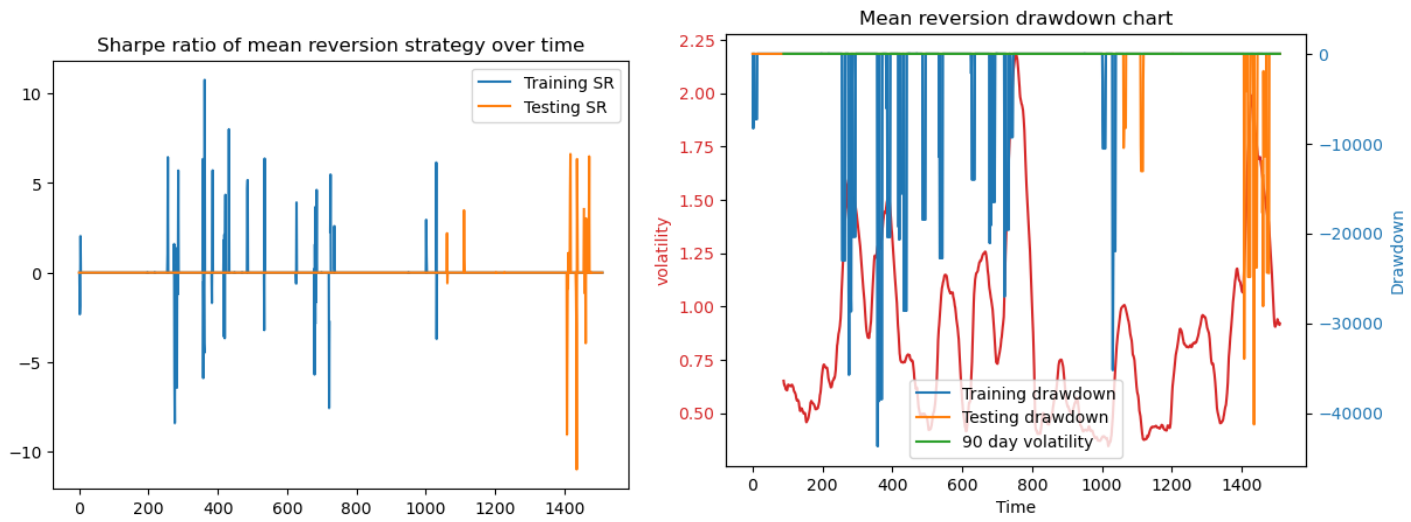

The trend following strategy's rolling Sharpe ratio of training and testing set remains similar levels with the testing set Sharpe ratio having less negative Sharpe ratio.

However for both Mean reversion and Auto regressive strategy, Sharpe ratio of test set is noticeably lower and has more negative Sharpe ratio than training set.

This can be caused by overfitting during developing the strategy model or a significant change in Market Conditions.One method to tackle over fitting is to validate the strategy using out-of-sample testing or cross-validation techniques to ensure it generalises well to new data. This might require acquiring additional data points
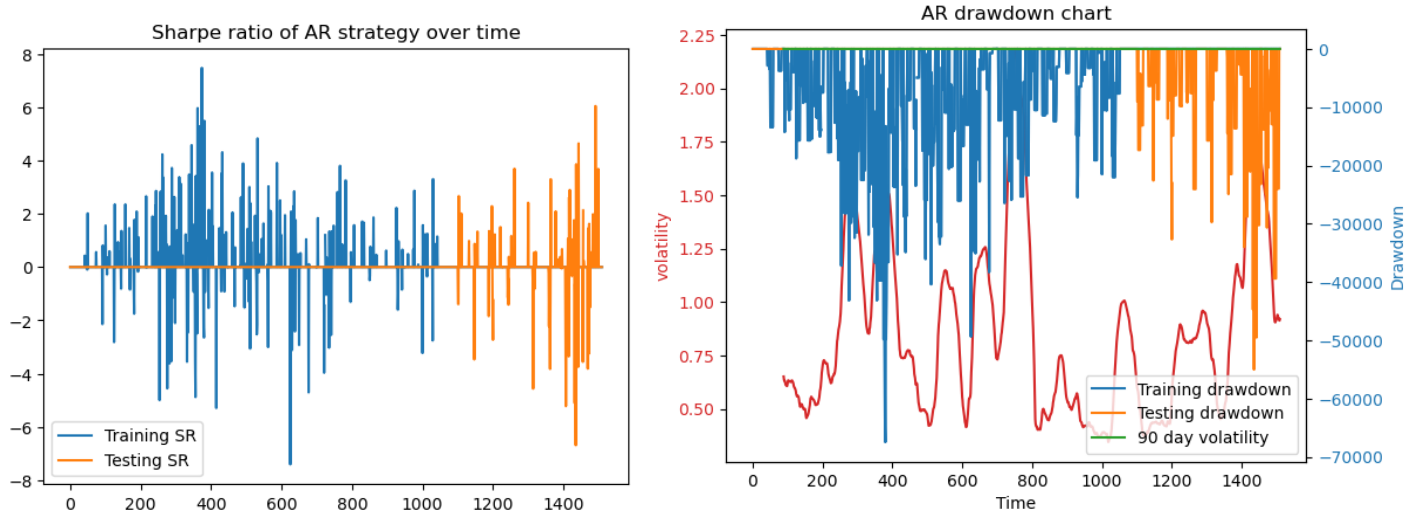
To deal with changing market conditions, a more robust strategy that puts more weight on current data can be particularly useful for capturing short-term trends and reacting more quickly to changes in market condition. Exponential Moving Averages or weighted moving averages can be implemented instead if moving averages, especially for mean reversion strategy.

Sharpe ratio of mean reversion strategy over time

Mean reversion drawdown chart

By observing the draw down charts it can conclude that the test set has similar level of draw downs as of train set. The trend following has in general lowest draw downs.

The biggest draw downs across 3 different strategies are the same time period: day 400,600,750 and 1400. It is related to historical volatility as the days with high draw downs all have high volatility of over 1.5(red line). A high draw down meaning high potential maximum loss.

A safety strategy can be developed using this property: use less margin when the market is highly volatile to reduce the risks of having large losses. Invest more margin when the market is less volatile and safer.

Sharpe ratio of AR strategy over time

AR drawdown chart

4   Discussion

Over all, only trend following strategies provides satisfying performance.

For future development, mean reversion should be discarded as it is already proved unfit to SPTL.

The trend following strategies implemented use simple moving averages and does not consider changing the margin use each time submitting a buy order. By adapting a exponential moving average that gives higher weight to current value might improve the ability of the trend following strategy. Implementation of a strategy to variate the margin cash use when submitting buy order according to volatility and risk free rate will be beneficial.

For development of AR strategy, one possibility is to predict more than one day's value and make decision based on all predictable future period.

5 Bibliography

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