COMP0051 Algorithmic Trading
Coursework 2 - SPTL

1. Introduction

This report presents a comprehensive implementation and analysis of trading strategies using the SPDR Portfolio Long Term Treasury ETF (SPTL) as the main investment vehicle, contrasted against the Effective Federal Funds Rate (EFFR) as a risk-free rate benchmark. This study spans a critical period from January 1, 2014, to December 31, 2019, a timeframe notable for its economic fluctuations and pivotal market events, thus providing a rich dataset for analysis.

This investigation employs three distinct leveraged trading strategies: Simple Moving Average (SMA) Crossover, Bollinger Bands, and Overnight Trading. SMA Crossover provides a straightforward method that spots trends in the market, Bollinger Bands use price volatility to create a range and guide us on when to make a move, Overnight Trading takes advantage of the patterns between the close of one day and the opening of the next. These three strategies were picked due to their difference in terms of implementation, as well as their overall trading activity throughout the time series, providing a broad view of different trading strategies. Our goal is to evaluate which strategies might offer the best returns, considering their risks and rewards.

The report is structured as follows: We begin by detailing the steps taken to ready and prepare the raw data for our analysis, we then define our three leveraged trading strategies and how they are implemented with the dataset. In the results section we will present a comparative quantitative look at the outcomes of each strategy, using different graphs, visuals, and performance metrics to highlight key points, as well as provide quantitative analysis to present the findings of this report.

2. Methodology

2.1 Preprocessing Data

To gather the dataset required for our analysis, the SPTL fund data was downloaded from yfinance for the period from 1 January 2014 to 31 December 2019, the specific columns concerned here are Adjusted Close, Close, and Open. Adjusted Close refers to the adjusted end-of-day prices for the fund, we use this price for the first two strategies as it accounts for any corporate actions such as dividends, stock splits, and rights offerings that may affect the stock price, providing a more accurate reflection of the fund's value over time. The Open and Close prices are used just for the Overnight trading strategy.

The EFFR was downloaded over the same period as the annual risk-free rate:

$$r_t^f = EFFR(t) \times dc$$

We adjust the annual EFFR to get the daily risk-free rate r_t^f at time *t*, where $dc \approx \frac{1}{252}$ is a day count approximation for the number of trading days per year. Now that we have the daily risk-free rate, we can use it to calculate the daily excess return per unit of SPTL:

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

It can be attained by taking the percentage change in the Adjusted Closing price $\frac{\Delta p_t}{p_t}$ and subtracting it with the daily risk-free rate.

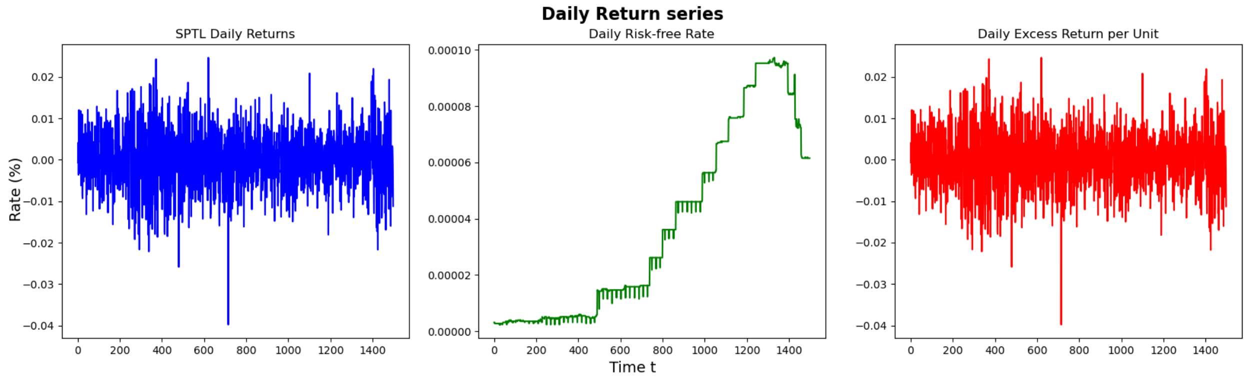

Figure 1: Daily Rate of Change for SPTL and Risk-Free Rate, and excess return

These graphs provide a picture of the investment performance of SPTL relative to the risk-free rate, as well as the risk-adjusted excess returns that could justify investing in SPTL over risk-free securities.

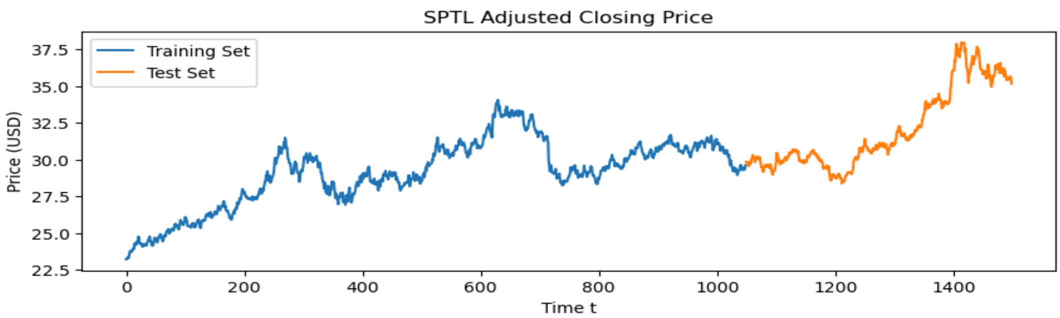

Figure 2: Train/Test split for SPTL Adj Close Price

Figure 3: Train/Test split for SPTL Daily Excess Return

To develop and backtest our trading strategies, we divided the data into training and test sets, using the first 70% of days as the training set and the remaining 30% as the test set. This division enables the training of our models using historical data and the assessment of their effectiveness on unseen data, offering insights into their capacity to adapt to upcoming market trends.

2.2 Simple Moving Average (SMA) Crossover

The SMA Crossover strategy is a widely used technical trading method that signals potential entry and exit points for a trade based on the crossing of two moving averages — a shorter-period SMA and a longer-period SMA. The shorter SMA has fewer periods and is thus more sensitive to recent price changes, while the longer SMA has more periods, rendering it less sensitive and more indicative of long-term trends.

The key signal for this strategy lies in the crossover of the two SMA's, serving as a signal for potential entry or exit points. When the short SMA crosses above the long SMA, this signals an emerging bullish trend and presents a potential buy opportunity. On the other hand, when the long SMA crosses below the short SMA, this may signify the end of an uptrend and the start of a bearish trend, suggesting a potential sell-off or short-selling opportunity.

Steps to implement the SMA Crossover strategy:
1) First we need to select appropriate time periods for the short and long SMAs. Common selections include 50 days and 200 days, respectively, but these may vary depending on trading style and objectives. As our test set does not have a huge amount of data (450 days) we decided to opt for 25 days and 100 days respectively.

2) Calculate the SMAs for the selected time periods using historical Adjusted Price data.

3) Monitor the two SMAs on a price chart, identifying the points where they intersect. These crossover points are where decisions are made regarding entry and exit positions.

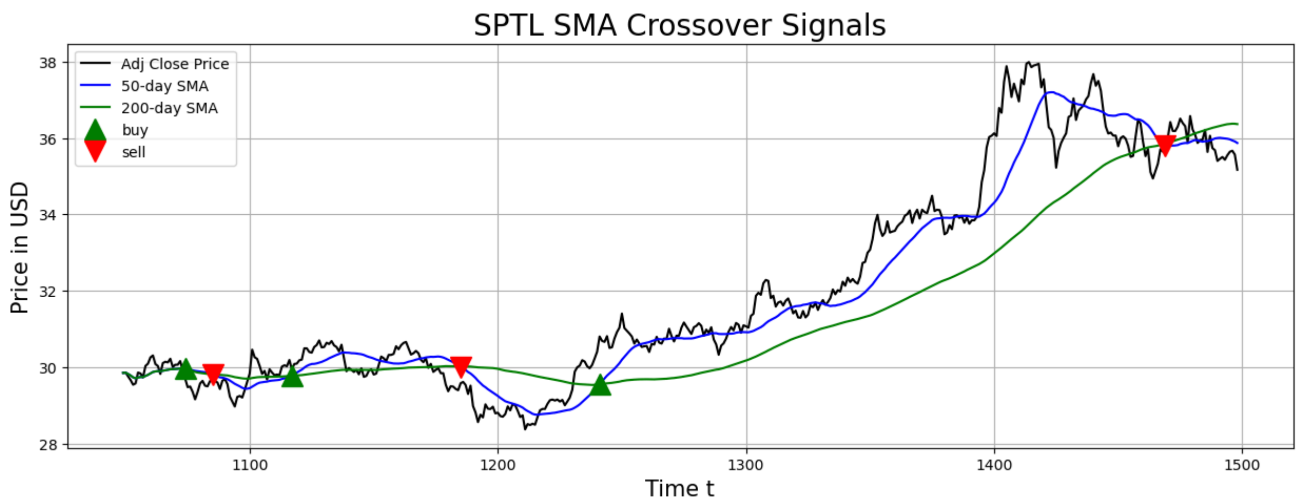

Figure 4: Buy and Sell signals for SMA Crossover strategy for SPTL test set

2.3 Bolinger Bands

The Bollinger Bands strategy is a versatile technical analysis tool developed by John Bollinger in the 1980s, it employs statistical charting to characterize the prices and volatility of a commodity over time. The strategy involves using a set of trendlines plotted two standard deviations (positively and negatively) away from an SMA of a security's price.

This strategy helps in identifying overbought or oversold conditions in the market. The bands widen during periods of increased volatility and contract when market volatility decreases, providing visual insights into the market state. When the price moves closer to the upper band, the market is becoming overbought, and when the price reaches the lower band, the market is becoming oversold.

Steps to implement the Bollinger Bands strategy:
1) Calculate the middle band (the SMA) over a set number of periods (usually 20). Then, calculate the upper and lower bands using the standard deviation of the price from the SMA.

2) Enter a position when the price breaks through the upper or lower band, suggesting a continuation or reversal might be imminent. Consider exiting a position when the price reaches the opposite band or exhibits signs of reversal.

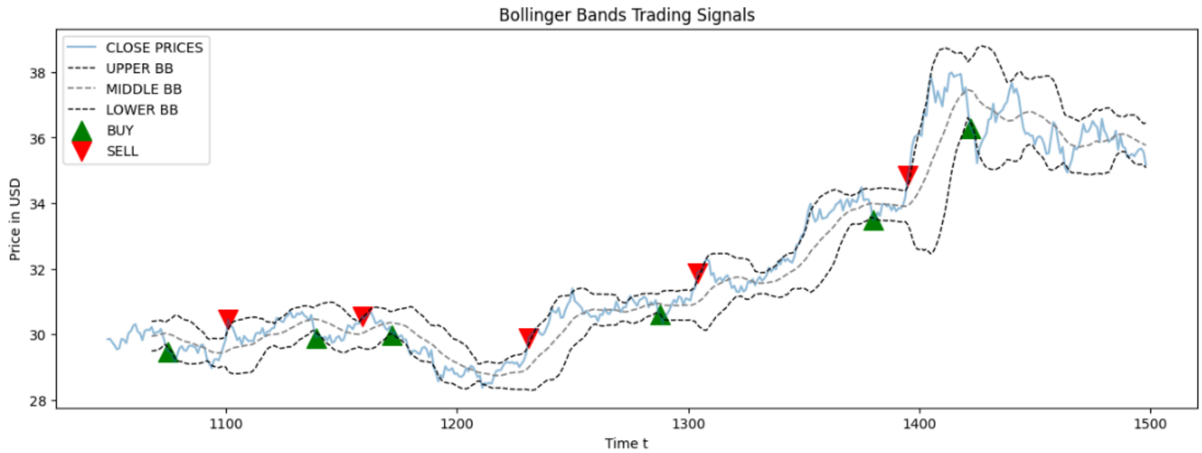

Figure 5: Buy and Sell signals for Bollinger Bands strategy for SPTL test set

2.4 Overnight Trading

The overnight trading strategy capitalizes on the tendency of asset prices to experience distinct patterns of behaviour during the close of one trading day and the opening of the next. This strategy operates under the premise that securities often exhibit different performance characteristics during the night compared to the daytime trading session.

As it is a straightforward strategy, the execution involves taking a position just before the market closes under the expectation that there will be a favourable overnight price move. The position is then sold soon after the market opens the next day, aiming to capitalize on any positive overnight price gap.

3. Results

3.1 Strategy Positions

Figure 6: Position θ_t plotted against time t, along with upper and lower bounds

Figure 6 highlights the position of the strategies with respect to the leveraged upper and lower bounds. The Overnight trading strategy walks along the maximum bound for the time period while SMA Crossover and Bollinger Bands demonstrate a more balanced approach reflecting the lower number of buying and selling signals.

3.2 Turnover

Turnover refers to the volume of assets bought or sold over a particular period. Turnover in dollars measures the total value of securities traded, providing insight into the monetary scale of trading activity. On the other hand, turnover in units counts the actual number of securities traded, irrespective of their individual price. Together, turnover in dollars and units provides a comprehensive picture of trading behaviour, revealing how often assets change hands and the value of those transactions.

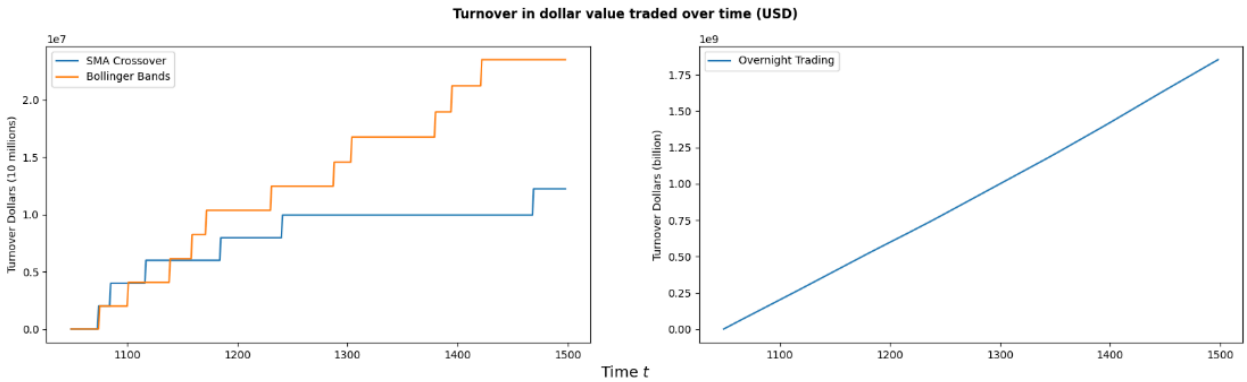

Figure 7: Turnover dollars for SMA and Bollinger (left), Overnight (right)

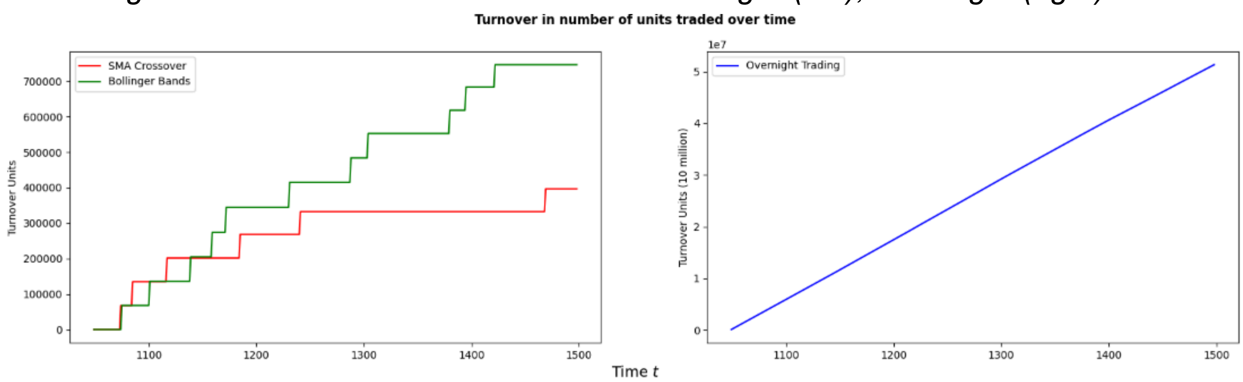

Figure 8: Turnover units for SMA and Bollinger (left), Overnight (right)

	SMA Crossover	Bollinger Bands	Overnight
Turnover Dollars	12,234,550	23,516,150	1,854,395,864
Turnover Units	396344	746322	51317016

Figure 9: Total turnover dollars and units for three trading strategies

We can see that the Overnight trading strategy yields the highest turnover values in both dollars and units, followed by the Bollinger Bands, then the SMA Crossover. High turnover suggests that the strategy is more actively managed and is therefore more capable of capturing market inefficiencies as opposed to more passive strategies, however, the high frequency of trading could incur high transaction costs in a real-world setting.

While the SMA Crossover strategy doesn't have a high overall turnover, the majority of its signals are within the first half of the time period, this could be due to trend shifts visible by the crossing of the two moving averages. The Bollinger Bands strategy sees high turnover when prices touch or breach the bands, indicating moments of high volatility.

3.3 Profit and Loss Series

In the quantitative analysis of trading strategies, the Total Profit and Loss (PnL) series provides an encompassing view of a strategy's performance. Not only does it account for the gains and losses derived directly from trading activities but also includes the returns from the capital not actively employed in trades, which in this case was allocated to a risk-free asset like a money market account.

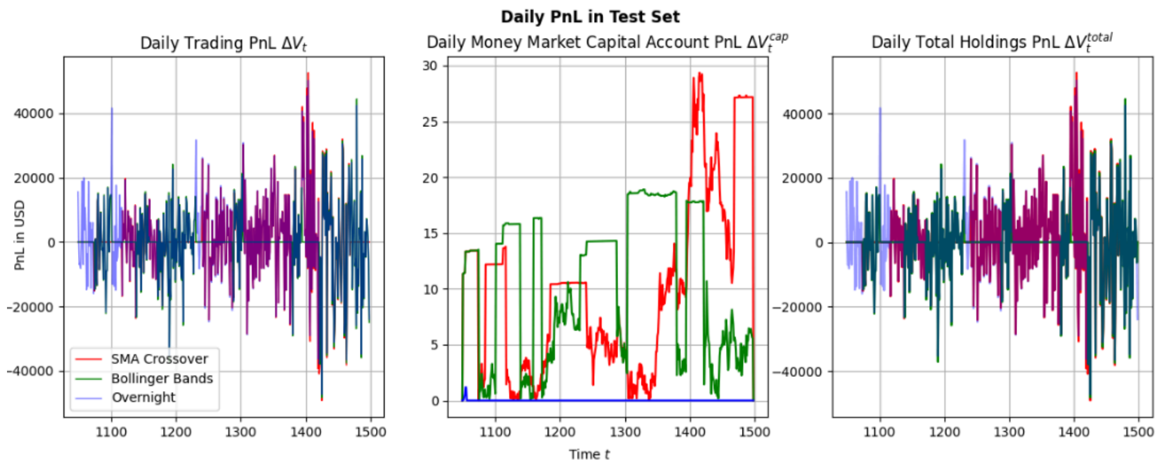

Figure 10: Daily Profit and Loss series for the test set

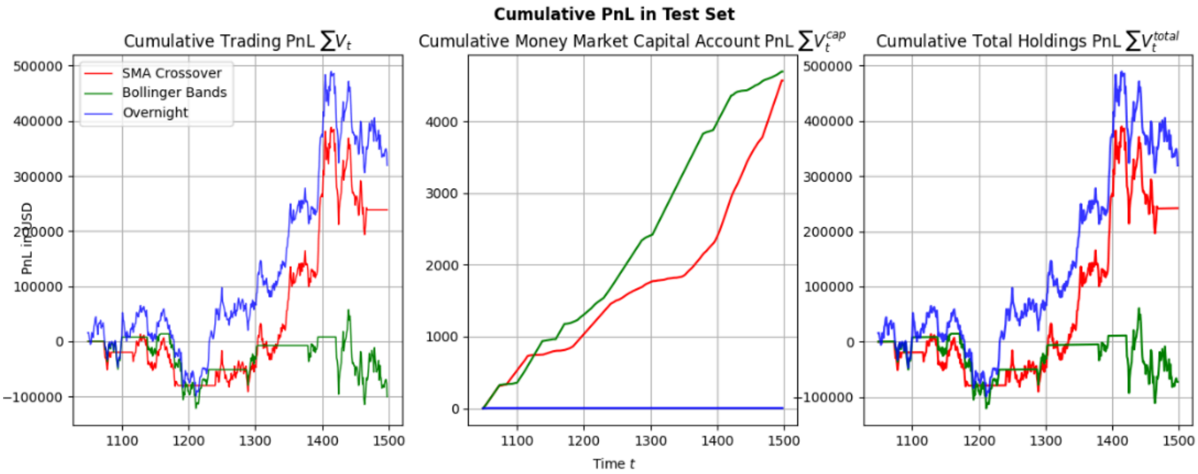

Figure 11: Cumulative Profit and Loss series for the test set

The variability in Figure 10 demonstrates the day-to-day risks and rewards associated with each strategy, the frequency and amplitude of the bars provide insights into the strategies' volatility and potential drawdown risks. By aggregating the daily values, Figure 11 paints a picture of the overall strategy performance over time. Steeper slopes indicate periods of stronger performance, while plateaus or declines suggest stagnation or losses. As the majority of the capital was actively employed in trade, the money-market capital account does not have a big effect on the total holdings. We can see that the Overnight trading strategy yielded the highest returns, nearing $500,000 at one point, while the Bollinger Bands strategy actually yielded a loss at the end of nearly $100,000.

As leverage was used in these strategies, it's crucial to consider the impact of funding costs, particularly when these costs increase. An increase in the funding rate would diminish the total PnL by increasing the cost of holding positions. If funding costs rose by 150%, the increased expenses would reduce the profitability of any leveraged position, potentially turning otherwise profitable strategies unprofitable, especially if the trading gains do not sufficiently outpace the funding costs. An increase of 150% would imply that for each unit of time t, the PnL will decrease additionally by 1.5 times the funding cost rate.

3.4 Performance Indicators

Performance indicators are another layer in the evaluation process, serving as quantitative measures to assess the performance of trading strategies and compare them against benchmarks or alternative approaches. These indicators encapsulate various aspects of performance, including profitability, risk management, consistency, and efficiency, offering a comprehensive view of the strategy's effectiveness. The four key indicators are the Sharpe Ratio, Sortino Ratio, Maximum Drawdown, and Calmar Ratio.

	SMA Crossover		Bollinger Bands		Overnight	
Dataset	**Test**	**Train**	**Test**	**Train**	**Test**	**Train**
Sharpe Ratio	0.697	0.735	-0.359	-0.375	0.82	0.424
Sortino Ratio	0.868	1.000	-0.348	-0.299	1.27	0.624
Max Drawdown (%)	-19.97	-35.25	-20.37	-20.65	-185.17	-43.38
Calmar Ratio	26.52	-72.456	-10.963	-15.304	3.831	-61.815

Figure 12: Table of performance indicators for all strategies in test and training set

Sharpe Ratio

Developed by William F. Sharpe in 1966, the Sharpe Ratio is a widely used performance indicator in finance that measures the risk-adjusted return of an investment or trading strategy, it compares the excess return of an investment to the volatility of its returns. “A Sharpe of 1 is considered acceptable, while a Sharpe of 1.5 or higher is preferrable. A Sharpe Ratio below 1 means the portfolio’s risk adjusted return is less than its volatility, and the investor is risking more than they are earning.” (Fowls, 2023)

Sharpe Ratio = (Portfolio return — Risk-free rate) / Portfolio volatility

For SMA Crossover, the Sharpe Ratio decreases slightly from training to test, suggesting a dip in performance under live conditions. Conversely, the Bollinger Bands strategy exhibits a consistently negative Sharpe Ratio, indicating that it fails to earn returns over the risk-free rate in both datasets. The Overnight strategy outperforms in the test set with a higher Sharpe Ratio, signalling better risk-adjusted returns when compared to the other strategies.

Sortino Ratio

The Sortino Ratio is a variation of the Sharpe Ratio, focusing specifically on downside risk, it measures the return of an investment per unit of downside risk. Unlike the Sharpe Ratio, which considers all volatility, the Sortino Ratio only considers the volatility of returns below a defined threshold, which in our case, is when the excess return < 0.

Sortino Ratio = (Portfolio return — Risk-Free Rate) / Downside portfolio volatility

The Sortino Ratio presents a similar trend for SMA Crossover, with a high value in the training set that diminishes in the test set but still outperforms Bollinger Bands, which remains negative in both sets. The Overnight strategy offers the highest Sortino Ratio in the test set, suggesting an effective management of downside risk while achieving better returns.

Maximum Drawdown

The Max Drawdown is a measure of the largest peak-to-trough decline in the value of a trading strategy over a specific period, it quantifies the worst loss experienced before a new peak is reached. Max Drawdown is essential for understanding the potential risk and loss exposure of an investment, a smaller Max Drawdown indicates lower risk and greater capital preservation.

$$\text{Max Drawdown} = (\text{Trough Value} - \text{Peak Value}) / \text{Peak Value}$$

The SMA Crossover shows a significant improvement in drawdown moving to the test set, whereas the Bollinger Bands show consistency in both sets, albeit with significant potential losses. However, the Overnight strategy indicates a substantial risk in the test set with a dramatic increase in maximum drawdown, signalling potential vulnerability to large losses.

Calmar Ratio

The Calmar Ratio is an indicator that evaluates the risk-adjusted return of an investment or strategy by comparing its average annualized return to its maximum drawdown, it can be seen as a combination of the previous 3 metrics. A higher Calmar Ratio indicates better risk-adjusted returns, with higher returns relative to the magnitude of drawdowns, reflecting improved capital efficiency and risk management.

$$\text{Calmar Ratio} = \text{Annual Rate of Return} / \text{Max Drawdown}$$

The SMA Crossover's positive Calmar Ratio in the test set suggests that the strategy has beneficial risk-adjusted returns, despite a substantial drop from the training set. Bollinger Bands' negative Calmar Ratio, raises concerns about its effectiveness. The Overnight strategy, while displaying a positive ratio in the test set, shows a dramatic decrease from the training set, questioning the stability of its returns due to the reduction of the amount of data.

Rolling Sharpe Ratio

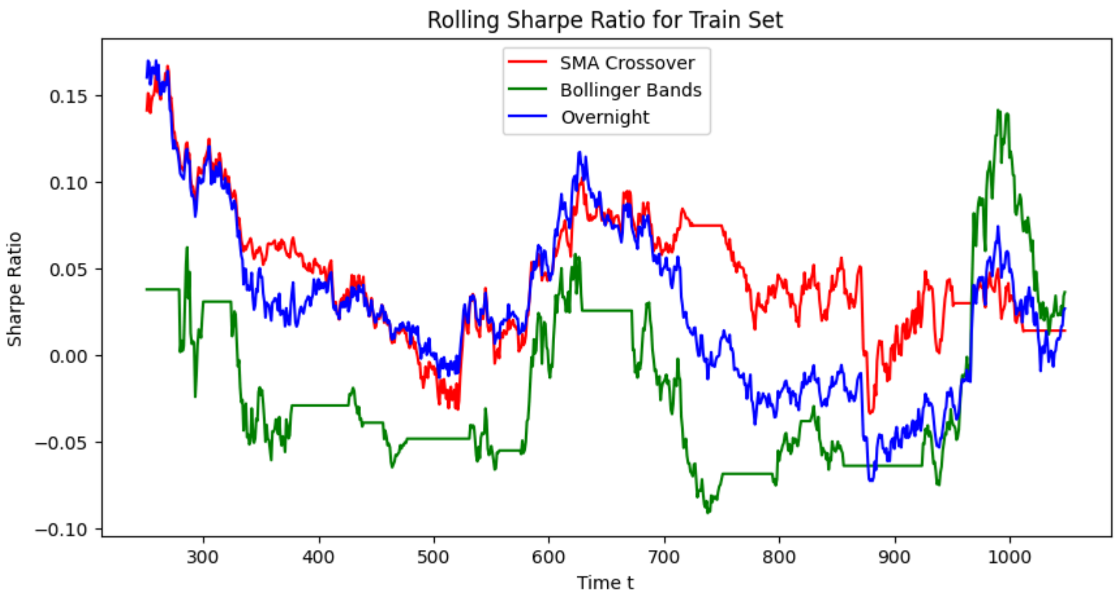

Figure 13: Rolling Sharpe ratio for 3 strategies in train set

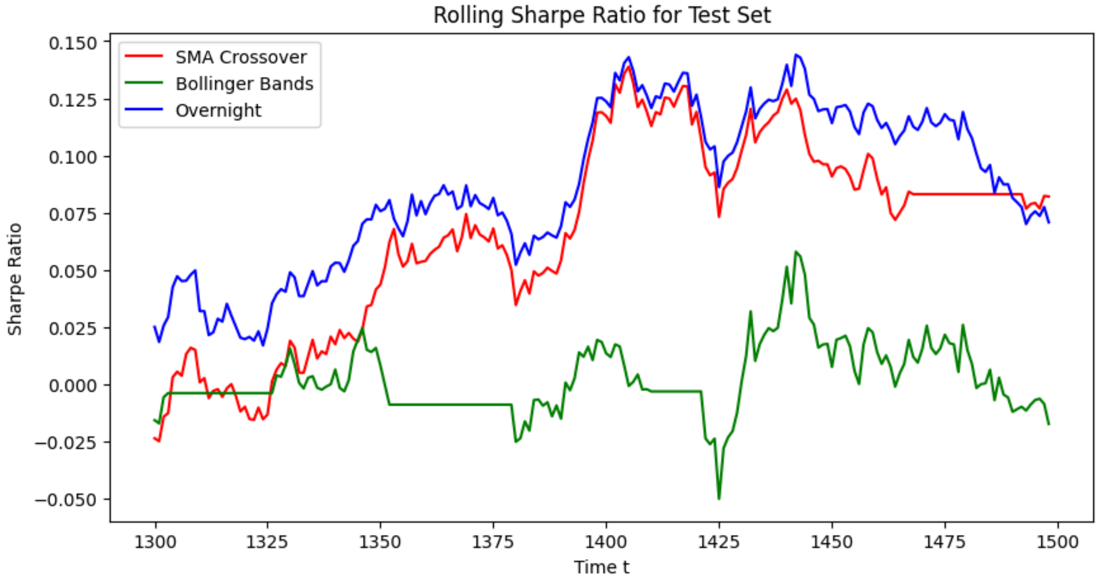

Figure 14: Rolling Sharpe ratio for 3 strategies in test set

All strategies exhibit fluctuations in their Sharpe Ratios over time, having high and low ratios in both the training and test set, with no specific pattern emerging. The SMA Crossover and Bollinger Bands strategies move in a somewhat correlated fashion, with their Sharpe Ratios often rising and falling together. This could suggest that both strategies may be responding similarly to market conditions or due to both strategies relying on moving averages as their mechanic. The Overnight strategy's Sharpe Ratio appears more volatile and generally trends lower than in the training set, suggesting a possible overfitting to the training data or a change in market dynamics not captured by the model.

Various methods can be employed to prevent unwanted changes in the Sharpe Ratio when moving from the training set to the test set. One of which is using cross-validation techniques specific to time-series data, like walk-forward analysis or rolling windows, to ensure the strategy is not overfitting and is stable across various market conditions. We can also train the strategy on data from different market regimes to ensure it does not become too tailored to a specific type of market condition. Another method is to implement strict risk management rules to limit losses during periods when the strategy underperforms, such as stop-loss orders or reducing leverage during high-volatility periods.

3.5 Drawdown Charts

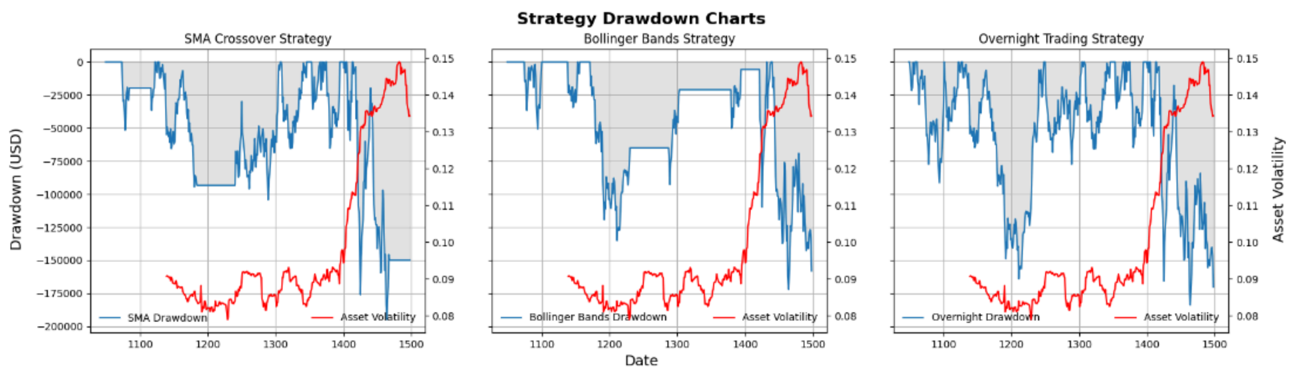

Figure 15: Drawdown chart over time for all strategies (gray/blue), historic rolling 90-day volatility of SPTL (red)

Drawdown charts are crucial tools for assessing the risk of trading strategies. They visually represent the decline from a portfolio's peak to its trough over a given period, offering a sense of the potential losses an investor might experience. These charts are particularly informative for understanding the magnitude and duration of losses during strategy implementation. Frequent or deep drawdowns can indicate a higher-risk strategy, which may not be suitable for all investors, and the duration of a drawdown, until a new peak is reached, can affect an investor's ability to stick to a strategy.

Biggest Drawdowns
The biggest drawdown for all three strategies happens towards the end of the time series at around t=1450, the drawdown going as low as 190,000 for the SMA Crossover strategy. The Overnight strategy also has another big drawdown around t=1200, as well as smaller drawdowns deeper than the other strategies throughout the time period.

Relation to Historic Volatility
Typically, higher asset volatility is associated with larger drawdowns due to greater price swings, and in our case, this is evident from t=1400 to t=1500 for all three strategies. However, the asset volatility is relatively low from the start up until t=1400 despite some pretty deep drawdowns at certain periods.

Safer Strategies and Margin Use
Safer strategies could involve reducing the leverage as lowering the leverage used during periods of high volatility could result in smaller drawdowns since the potential losses are less amplified. Adjusting the position size based on the current market volatility, increasing positions when volatility is low and decreasing them when volatility is high.

4. Bibliography

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