QF621 Quantitative Trading Strategies

Foreign Exchange Quantitative Trading

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1 Abstract

Our project aims to develop a sophisticated quantitative trading strategy within the foreign exchange market. This project capitalizes on the unique advantages of FOREX, such as minimal idiosyncratic and country risks, high liquidity, and the inherent allowance for leveraging and short selling and high Asset Under Management (AUM) capability. We have selected the following 9 FOREX pairs: **USDJPY, USDEUR, USDGBP, USDAUD, USDCAD, USDCHF, USDNZD, USDSGD, USDZAR**.

The strategy encompasses a diverse range of currency pairs, including majors, minors, and those sensitive to commodity prices or with diverse geographical influences, to ensure a well-rounded approach to risk management. The methodology incorporates **trend-following logic** based on rolling windows, **risk-based techniques** focusing on risk-adjusted returns, and a dynamic portfolio-level money management system using VaR metrics to detect and adapt to potential regime changes.

Our portfolio formation strategy is multifaceted, utilizing back-testing to refine behaviors across various sub-strategy portfolios, with a focus on achieving a high Sharpe ratio and low PnL correlation. The formation includes **equal weighting, Sharpe-adjusted, risk-adjusted, and nomination-based weighting schemes**, with provisions for cash reserves. A key component is the **2-Strike VaR risk control mechanism**, which employs both stop-loss and potential overloading on specific strategies to achieve higher returns manage risk effectively. The trading strategies include allocation techniques for **Maximizing return and Minimizing volatility, Pairs trading and Relative Strength Index (RSI)**.

The project aims to construct a robust portfolio that aligns with the objectives of hedge funds, emphasizing a high Sharpe ratio in-sample strategy, low correlation, strategic weighting, and stringent risk controls.

2 FOREX Advantages

Firstly, the FOREX market offers minimal idiosyncratic risk. The foreign exchange transactions involve the exchange of two currencies, naturally diversifies the risks specific to assets or companies. Moreover, trading in various pairs can further diversifying the unsystematic risks.

Secondly, the FOREX market also provides minimal country risk. The global nature of the transactions allows investors to reduce their dependence on the economic or political conditions of a single country. This geographical diversity helps investors construct more robust investment portfolios, thereby reducing risks associated with specific countries.

Thirdly, Liquidity risk is effectively controlled in the FOREX market as well. As the largest and most active financial market globally, with daily trading volumes reaching several trillions of dollars, the FOREX market offers investors extremely high liquidity, ensuring the immediacy of transactions and the stability of prices.

Besides, an increased capacity for assets under management (AUM) is another significant advantage of the FOREX market. Due to the depth and breadth of the market, even large-scale capital inflows or outflows do not significantly impact market prices, providing an ideal operating environment for large investment institutions.

In addition, the FOREX market allows short selling, which provides investors with more trading flexibility and market opportunities. Whether the market is rising or falling, investors have the opportunity to generate returns.

Finally, the use of leverage is another key characteristic of the FOREX market. Investors only need to pay a small fraction of the margin to conduct larger-scale transactions, which to some extent magnifies the potential investment returns and also increases risk. However, proper risk management and strategy application can effectively control this risk.

In summary, the advantages of the FOREX market lie in its global nature, high liquidity, flexibility, and the capacity to accommodate large-scale capital. These characteristics make the FOREX market an ideal choice for investors seeking global diversified investment and risk management.

3 FOREX Pairs and Data Preprocessing

3.1 Major and Minor currencies

Major currencies typically include currencies with larger global economic volumes, such as the US dollar, euro, pound sterling, and Japanese yen. In contrast, minor currencies are other currencies typically have smaller trading volumes relative to major currencies, representing the scale risk factors in FOREX trading pairs.

3.2 Commodities-sensitive currencies

These currencies may be influenced by fluctuations in specific commodity prices, such as oil and other major commodities, representing the idiosyncratic risk in FOREX trading pairs.

3.3 Geographically diverse currencies

Currencies from different countries and regions, represent the country risk factors in FOREX trading pairs, as their values may be influenced by economic, political, and geopolitical factors specific to those countries.

3.4 Our approach and data selection

We introduced price data for FOREX trading pairs, specifically with the **US dollar as the base currency**. We used the variables pre and post to select the time range of interest. This means we can specify the period according to specific needs to select the data of interest. We calculated the number of missing values in each trading pair. Subsequently, we filled in the missing values to ensure data integrity. Finally, we extracted the processed data as training data for subsequent analysis and modeling use.

The data was cleaned with a cut-off date set at 2007-01-01. The **in-sample evaluation period spans from 2010-01-01 to 2020-01-01**, followed by the **out-of-sample testing period from 2020-01-01 to 2024-02-29**. These delineations ensure a thorough assessment and validation of the strategies within the specified timeframes.

4 Methodology

4.1 Trend-following logic

We will observe price trends over certain rolling windows and attempt to capture any existing trends. By adopting this approach, we can better adapt to market changes and formulate trading strategies based on current price trends.

4.2 Risk-based techniques

Our strategy will consider risk-adjusted returns and Value-at-Risk (VaR) metrics. This means that we will not only focus on returns but also consider risk factors. We will use risk-adjusted metrics to assess the expected returns of our portfolio given a certain level of risk and utilize VaR metrics to measure the maximum potential loss our portfolio may face.

4.3 Higher-level portfolio management

We will employ higher-level portfolio management techniques to identify potential regime changes or failures in portfolio strategies, and to retire such strategies effectively. By closely monitoring market changes and adjusting our portfolio strategies we can better protect the value of our portfolio and achieve robust long-term returns.

5 Key aspects of Portfolio Formation

First of all, exploring the behaviors of different sub formations based on back-testing results to, focusing on increasing Sharpe ratios and reducing the correlation between profits and losses. This helps understand the risk-adjusted performance of each sub strategy and provides a basis for constructing a more robust investment portfolio.

Also, we will adopt various scheme strategies such as equal weighting, Sharpe-adjusted weighting, risk-adjusted weighting, and nomination weighting (which may reserve cash portions) for strategy formation on the portfolio. These strategies balance risk and return based on different objectives and preferences.

Lastly, implementing 2-strike Value-at-Risk (VaR) risk control involves setting overloading levels and stop losses, which helps manage portfolio risk exposure across different market environments, ensuring its resilience under various market conditions. Such risk control strategies safeguard the portfolio from extreme fluctuations and ensure long-term stability and growth.

6 Strategies

6.1 Allocation Max Return and Min Volatility

When allocating for maximum return or minimum volatility, in order to maximize the utilization of market dynamics and value differentials during the asset allocation process to achieve better investment returns and risk control, we consider the following three points:

- **Momentum Long Short:** Momentum effect is a common phenomenon in the market, where assets with higher momentum tend to continue rising while those with lower momentum may continue falling. Therefore, by simultaneously establishing long positions in assets with high momentum and short positions in assets with low momentum, we can capitalize on this trend to generate returns.
- **Size Long Short:** There often exists long-term value differentials between assets of different sizes. Typically, large-cap assets have more stable performance and higher valuations, while small-cap assets may have higher growth potential and lower valuations. Hence, by simultaneously establishing long positions in large-cap assets and short positions in small-cap assets, we can exploit this size effect to achieve better investment returns.
- **Efficiency Frontier Algorithm, Minimum Inverse Sharpe, Minimum Portfolio Standard Deviation:** The purpose of these algorithms and methods is to optimize the configuration of the investment portfolio to maximize returns and minimize risk.

The efficiency frontier algorithm helps identify the portfolio with the highest returns related to all combination of totally 9 FOREX assets, while the minimum inverse Sharpe identifies max expected return portfolio and minimum portfolio standard deviation methods help identifies minimize volatility of the investment portfolio, thereby enhancing investment stability. Considering these factors comprehensively allows investors to more fully consider the dynamic characteristics and risk factors of the market when allocating for maximum return or minimum volatility, thus achieving better investment performance.

Allocation Max Return

ylf_1 In Sample PERFORMANCE	
Daily annualized sharpe	0.650196
Average annual returns %	9.924048
Total returns %	102.548493
Max drawdown %	-23.849357
%VaRld 1% - para	2.197805
%VaRld 1% - hist	2.365217
%VaRld 5% - para	1.542431
%VaRld 5% - hist	1.383993
Stressed %return during Covid19	0.000000
Stressed %return during Dec18	5.148855
Stressed %return during Fall2015	-2.074963
Stressed %return during Oct14	-0.538661
Stressed %return during Aug2013	0.671847

Allocation Min Vol

ylf_2 In Sample PERFORMANCE	
Daily annualized sharpe	0.386489
Average annual returns %	2.544307
Total returns %	26.291171
Max drawdown %	-14.962448
%VaRld 1% - para	0.954820
%VaRld 1% - hist	0.987635
%VaRld 5% - para	0.672152
%VaRld 5% - hist	0.556455
Stressed %return during Covid19	0.000000
Stressed %return during Dec18	-0.255934
Stressed %return during Fall2015	4.677173
Stressed %return during Oct14	1.062601
Stressed %return during Aug2013	0.612943

6.1.1 Max Return Portfolio

We encompass a robust portfolio management approach, structured around several key methodologies:

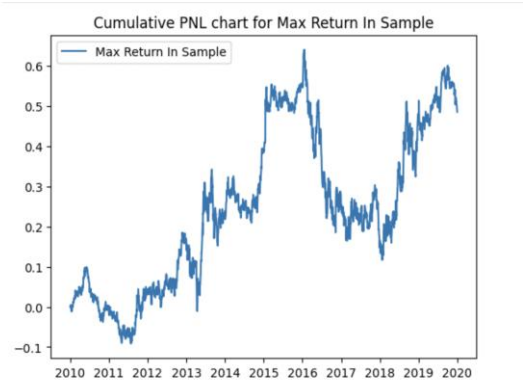
Date tag generation: This process involves generating a series of date tags to define the timeframe for training data and strategy backtesting. These date tags are instrumental in systematically assessing portfolio performance over different time periods.

Risk assessment: We calculated both parametric and historical Value at Risk (VaR) metrics, these metrics offer insights into the potential losses that the portfolio may incur under different confidence levels, thereby facilitating risk management.

Portfolio optimization: Utilize fine-tuning method on rolling windows as well as other possible hyperparameters we try to balance the relevance and effectiveness, constructing portfolios aimed at maximizing returns. By minimizing the ratio of risk to returns, the function determines the optimal allocation ratios for assets within the portfolio, enhancing portfolio performance.

Performance evaluation: Evaluate the portfolio performance using various metrics, including the Sharpe ratio, annualized returns, and maximum drawdown. Visualizing the cumulative returns curve aids in comprehensively assessing the portfolio's performance and identifying areas for improvement.

By constructing the portfolio with maximum returns, one can identify the investment strategy that maximizes expected returns in each market environment, thus providing valuable insights for actual investment decisions.



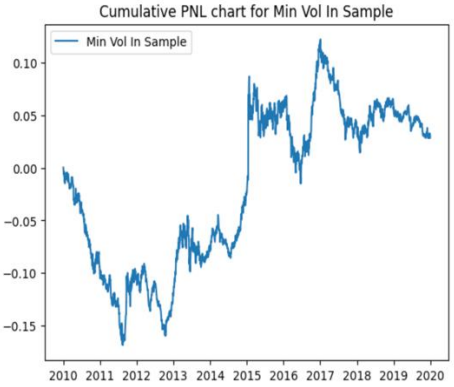
Out[24]:

Max Return In Sample PERFORMANCE	
Daily annualized sharpe	0.286675
Average annual returns %	4.701885
Total returns %	48.586149
Max drawdown %	-52.412033
%VaR1d 1% - para	2.385373
%VaR1d 1% - hist	2.552929
%VaR1d 5% - para	1.681122
%VaR1d 5% - hist	1.603215
Stressed %return during Covid19	0.000000
Stressed %return during Dec18	8.852464
Stressed %return during Fall2015	-1.035352
Stressed %return during Oct14	-2.662219
Stressed %return during Aug2013	3.826006

6.1.2 Minimum Volatility Portfolio

We construct a minimum volatility portfolio and calculate the weights, expected annualized return, and volatility of the portfolio. Generate a training data time range with specified parameters and constructs a minimum volatility portfolio using the portfolio built, then evaluates its performance. After that we construct a minimum volatility portfolio in-sample and evaluates its performance.

By constructing a minimum volatility portfolio, it identifies an investment strategy with the lowest volatility in market environment, thereby reducing portfolio risk and enhancing investment efficiency.



Out[30]:

Min Vol In Sample PERFORMANCE	
Daily annualized sharpe	0.049276
Average annual returns %	0.275878
Total returns %	2.850744
Max drawdown %	-16.864363
%VaR1d 1% - para	0.819529
%VaR1d 1% - hist	0.899802
%VaR1d 5% - para	0.579131
%VaR1d 5% - hist	0.513133
Stressed %return during Covid19	0.000000
Stressed %return during Dec18	0.102675
Stressed %return during Fall2015	0.938755
Stressed %return during Oct14	0.822120
Stressed %return during Aug2013	0.516352

6.2 Pairs Trading

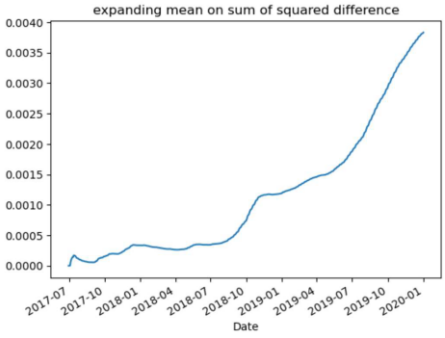
Similarity Measurement: In Pairs Trading, the first step is to determine the "tradability" between two financial assets. This is typically achieved through statistical analysis methods such as **cointegration testing** or **2nd momentum difference measurements**. Cointegration testing is used to determine whether there is a long-term stable relationship between the prices of two assets, while the sum of squared difference measuring on tradability on similarity characters. Through these methods, the tradability between the two assets can be quantified, providing a basis for subsequent trading strategies.

Spread Trading: Once the two assets has been determined, the next step is to execute

a spread trading strategy. The spread refers to the difference in prices between two assets, and spread trading involves trading based on this difference. Typically, investors will simultaneously establish long positions and short positions, and trade when price fluctuations cause the spread to deviate from its long-term average. When the spread narrows, investors sell long positions and buy short positions, and vice versa. Through this approach, investors can profit from changes in the spread.

De-coupling Detection: In Pairs Trading, the relationship between assets is not always stable and may change due to various factors such as market risks, macroeconomic factors, etc. Therefore, de-pairing detection is necessary to identify and address changes in the relationship between assets. De-pairing detection typically involves monitoring and analyzing market data, as well as dynamically adjusting between assets. Once changes in the relationship between assets are detected, investors need to adjust their trading strategies promptly to adapt to the new market environment.

Conclusion: In this strategy, we **short the spread** when it deviates by two standard deviations (two sigma) from its mean, indicating a potential reversion to the mean. To manage risk, we **set stop-loss orders** to cut losses if the spread widens beyond three standard deviations (three sigma). Conversely, traders may **take profit** when the spread narrows to one standard deviation (one sigma) from the mean, capturing the expected mean reversion profit. By doing this, statistically, we have higher chance of winning than losing with 1 to 1 risk reward ratio if the pair is to hold.
Our current Pairs trading begins with a measure of similarity, typically computed as the sum of squared differences between the prices of two assets. However, in some cases, pairs may lose their similarity over time due to changing market condition. When this occurs, we engage in a process known as de-pairing, where they discontinue trading a particular pair and seek out new pairs.



6.3 Relative Strength Index (RSI)

This strategy involves calculating the RSI indicator for each forex pair, a high RSI (>70) indicate potential overbought conditions and oversold (RSI < 30) conditions in the market.

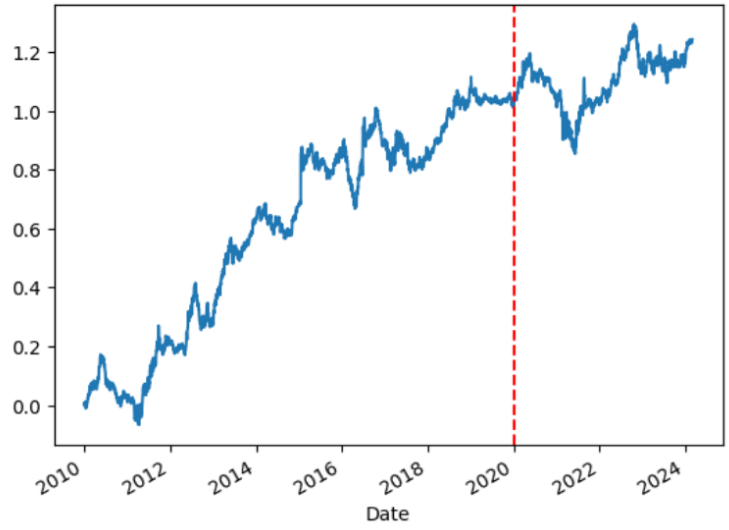
In the in-sample analysis, the RSI is computed using varying window lengths, ranging from 10 to 100 for each forex. By comparing the Sharpe ratio among the forex pairs, USDCAD, USDCHF and USDZAR achieved the highest Sharpe ratios.

In the out-of-sample test, the RSI strategy was applied to above three forex pairs using the optimal window lengths identified in the in-sample analysis. While the Sharpe ratios for USDCHF and USDZAR remained robust, USDCAD failed to generate trading signals. This was attributed to the use of a longer window length of 75, which may lead to the RSI values become over smooth. Hence, this strategy may fail to capture short term market fluctuations effectively.

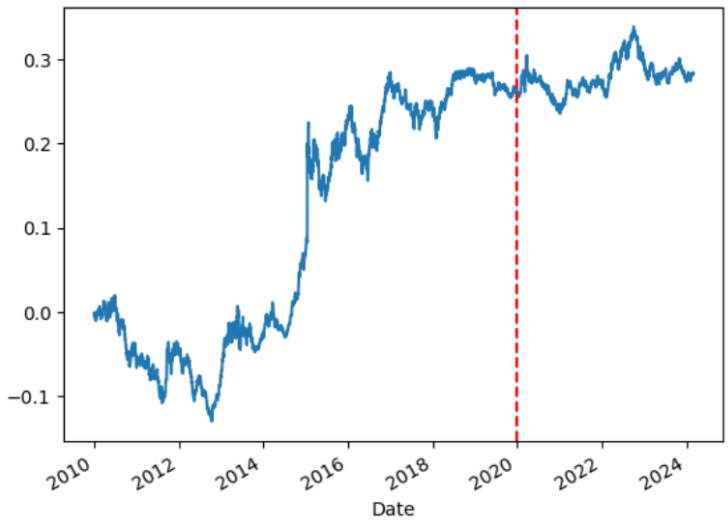
7 Strategy Composition

7.1 Portfolio Strategy Loading: without risk management

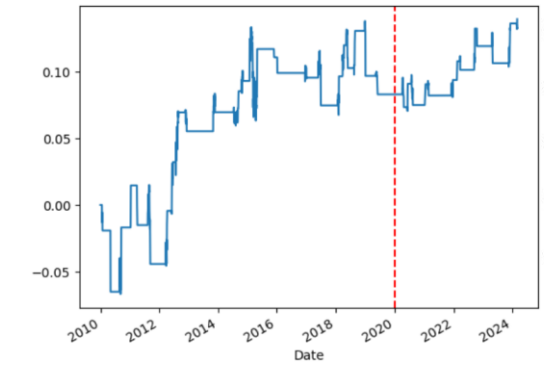
Max Return PnL:

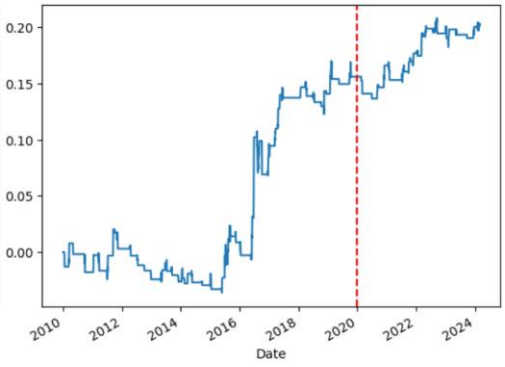


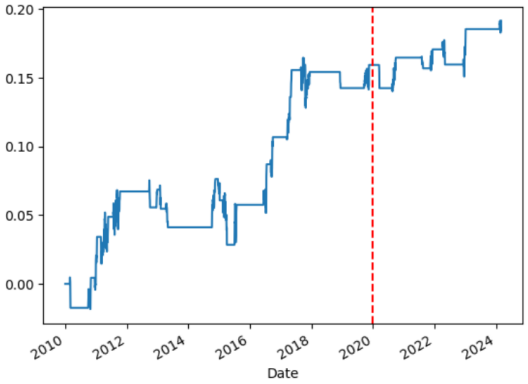
Min Volatility PnL:

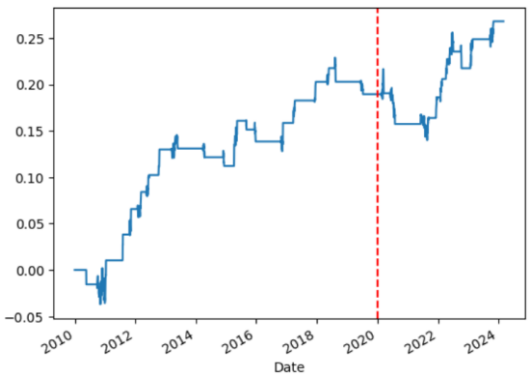


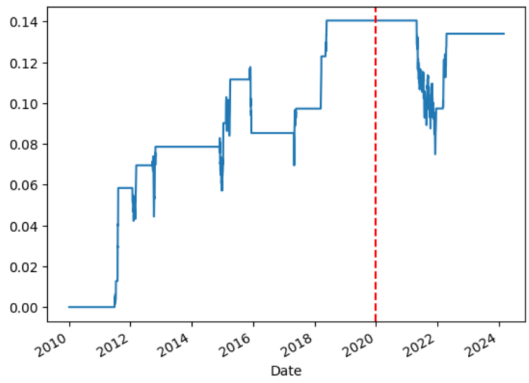
Pairing Trading:

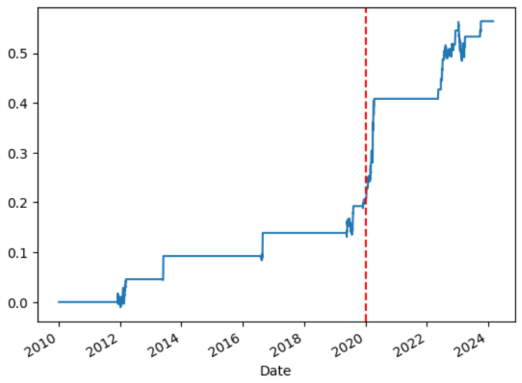


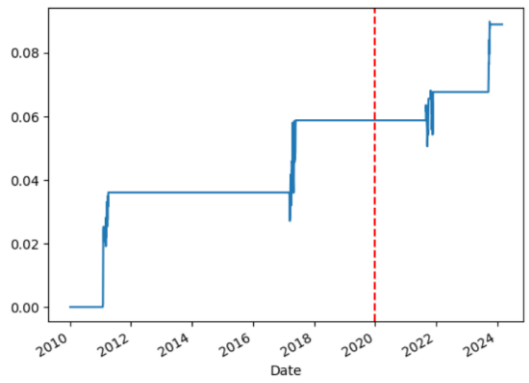


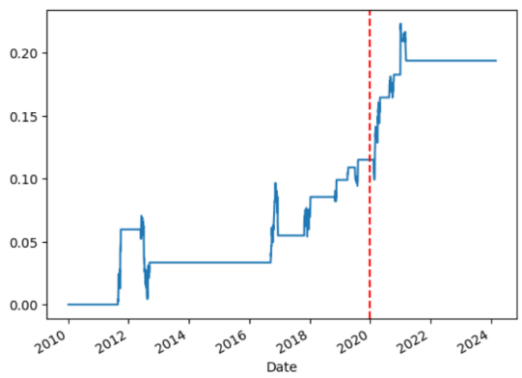


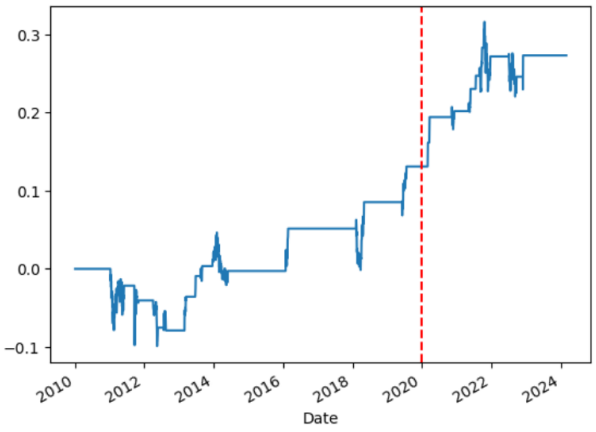




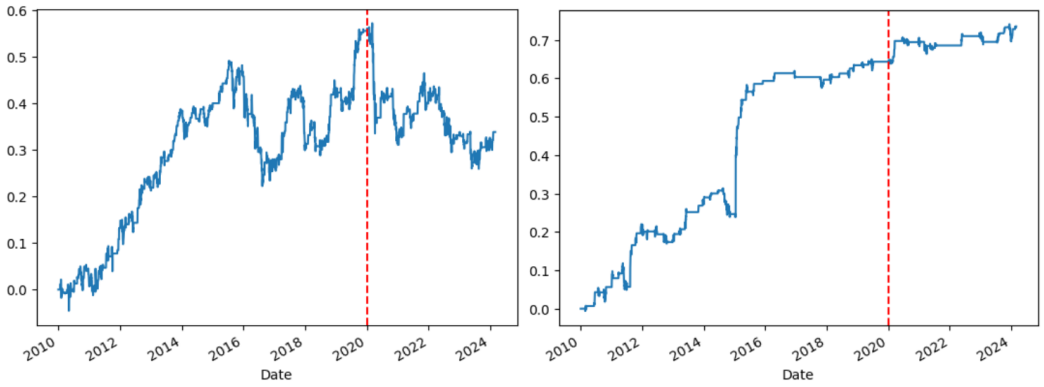








RSI:



7.2 Strategy Weightage

The determination of strategy weights is a crucial step in portfolio construction.

In the first step, we establish strategy PnL metrics based on in-sample performance, allowing for a better understanding of each strategy's historical performance.

In the second step, we utilize Sharpe ratios and correlation matrices to select the most promising portfolio strategies. These metrics help assess the balance between risk and return of each strategy, aiding in the selection of suitable strategy combinations.

Subsequently, we employ different portfolio weightage methods to further test on out-of-sample data. These methods include equal weightage, Sharpe-adjusted weightage, risk-adjusted weightage, and nomination weightage, which can reserve cash portions to cope with market fluctuations. By comprehensively considering these various weightage methods, we can more thoroughly evaluate the performance of different strategy combinations in future market environments and make corresponding adjustments and decisions.

Manual Selection of Portfolio Strategies:

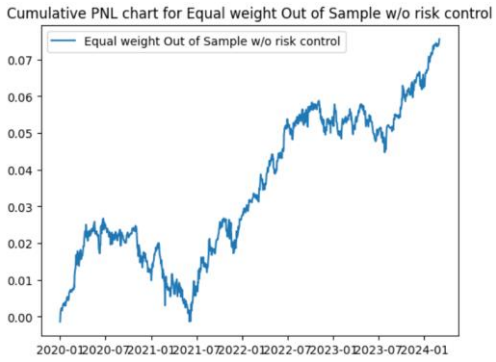
By selecting specific portfolio strategies using predefined keys and extracting corresponding portfolios for further analysis. These strategies are chosen based on

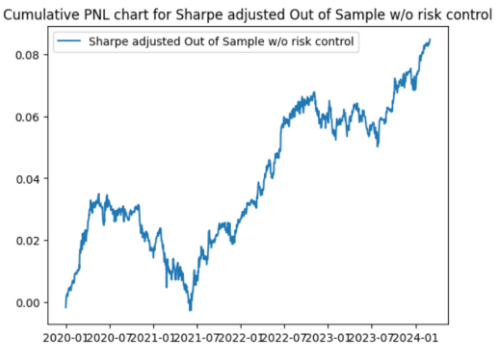
external information not seen by models, say during the British exiting EU, we may hold on any pairs involving EUR or GBP, which serves as a basis for strategic composition and allocation decisions.

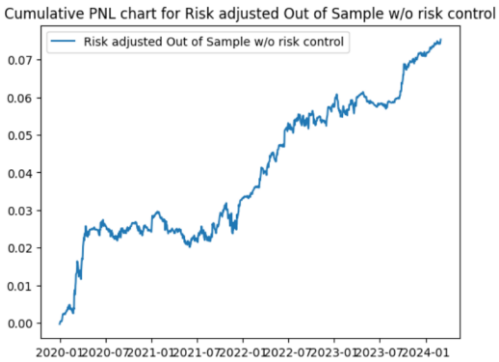
Next, we conduct correlation analysis to understand the relationships between the selected portfolios and the entire in-sample portfolio. This analysis provides insights into how the performance of each strategy correlates with others and with the overall portfolio. Performance metrics, including the Sharpe ratio and Value at Risk (VaR), are calculated for each selected strategy to assess their risk-return profiles. These metrics help evaluate the effectiveness and risk exposure of each strategy, informing the allocation decision-making process.

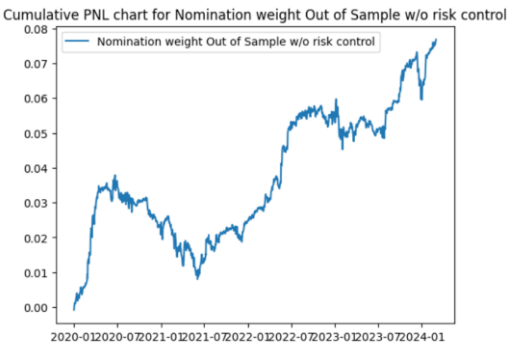
We then assign weightages to the selected strategies using different portfolio weighting scheme. These weightages determine the allocation of assets within the portfolio, aiming to optimize risk-adjusted returns. Following weightage assignment, portfolios are constructed by combining selected strategies with their respective weightages for out-of-sample testing. This step involves creating portfolios based on the allocation determined in the previous steps, preparing them for evaluation in a real-world context.

Finally, we evaluate the performance of the constructed portfolios using metrics like Sharpe ratio, cumulative returns, and drawdowns to determine their effectiveness and suitability for real-world investment scenarios. This evaluation helps validate the chosen allocation and composition strategies, ensuring they align with the desired investment objectives.









7.3 Final Portfolio

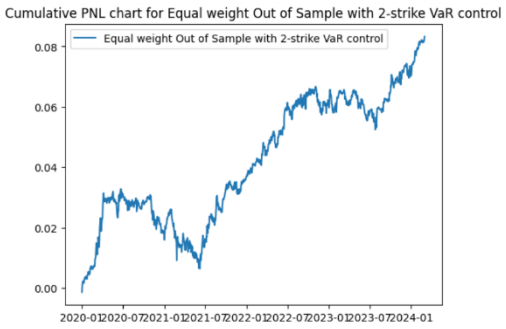
We outline a risk management strategy termed **"2-strike" Value at Risk (VaR) control**, aiming to mitigate downside risk in out-of-sample investment portfolios. The approach involves adjusting portfolio allocations when losses surpass a predetermined threshold, indicating a deviation from risk tolerance levels.

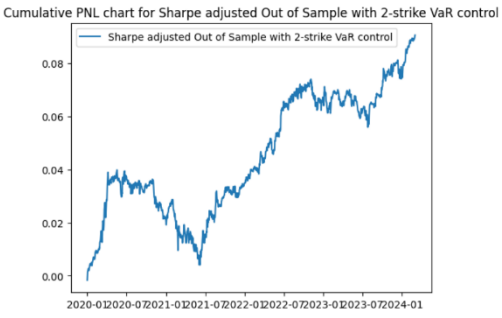
Initially, the process iterates through selected portfolio strategies, applying the 2-strike VaR control mechanism. This mechanism adjusts portfolio positions based on **specified VaR thresholds** and predefined rebalance dates, effectively managing downside risk. Following the risk control adjustments, the revised portfolio positions and their corresponding weights are organized into separate data structures.

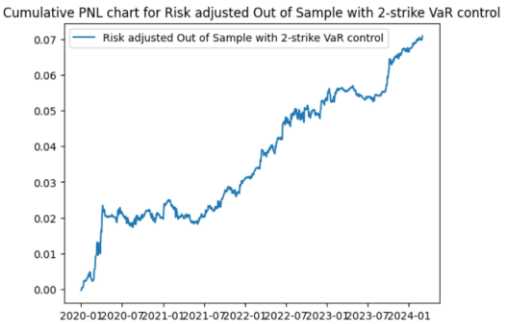
Subsequently, the performance of these adjusted portfolios under 2-strike VaR control is evaluated to assess their effectiveness in managing risk while preserving performance. Evaluation metrics such as **cumulative returns**, **Sharpe ratio**, and **drawdowns** are calculated for the adjusted portfolios to gauge their performance. This evaluation provides insights into how well the 2-strike VaR control mechanism maintains risk levels while optimizing returns.

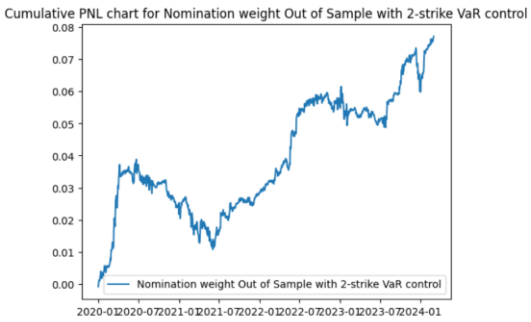
Moreover, the impact of the risk control mechanism on portfolio asset allocation was shown by plotting the portfolio weights under 2-strike control for each strategy. This visualization aids in understanding how risk management adjustments influence portfolio composition.

Overall, the objective of this section is to enhance risk management for out-of-sample investment portfolios by implementing the 2-strike VaR control mechanism. The aim is to ensure that portfolios adhere to predefined risk thresholds while maximizing returns and minimizing downside risk.

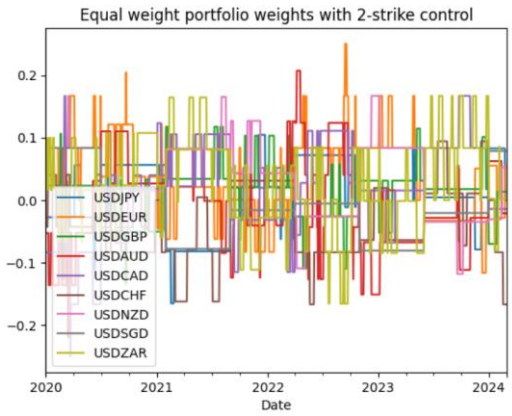


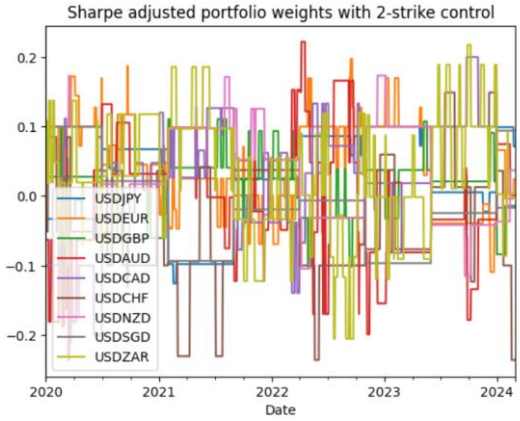


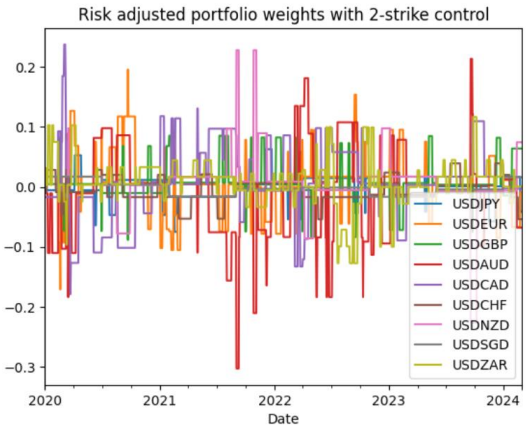


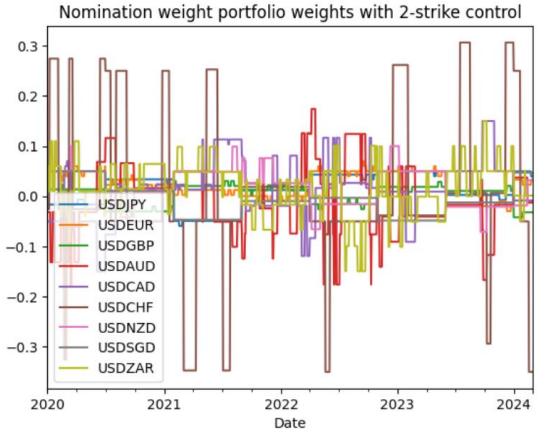


Portfolio Weightage with 2-strike control:









Performance summary:

	Risk Adjust	Equal Weight	Sharpe Adjust
Annualized Sharpe	1.840116	1.102058	1.035989
Avg. Annual return	1.641620%	1.928202%	2.096704%
Total return	7.087630%	8.324936%	9.052438%
Max Drawdown	-0.683249%	-2.642975%	-3.571785%
VaR 1% para	0.124284%	0.248869%	0.288406%
VaR 1% hist	0.143352%	0.274199%	0.300047%
VaR 5% para	0.085967%	0.173722%	0.201481%
VaR 5% hist	0.071380%	0.169162%	0.195653%
Stressed period Covid19	0.415027%	0.414853%	0.477848%