NEOMA BUSINESS SCHOOL
REIMS · ROUEN · PARIS

Introduction to Python with application to Finance

Group Project

Groupe Members:

Bao Chau DUONG

Sonia NKHAILA

Part A: EUR/USD exchange rate and Ornstein-Uhlenbeck mean reversion process

Question 1

After downloading the daily EUR/USD exchange rate from 2010 January to 2023 October from Yahoo Finance, and, following the instructions we came up with the code entitled “Question 1”.

While making the code we had to consider what datas to take from the historical values and what we wanted to see in our visual conclusion knowing that the goal of the code was of course to see if the full sample of datas of the EUR/USD exchange rate exhibits the mean reversion feature.

We used the OLS model:

$$\Delta X_t = \propto + \beta \Delta X_{t-1} + \epsilon_t$$

We decided to keep the closing rates and the date as meaningful parameters for our test. And, to display the time series regression ΔX_t over time to see the daily returns over time to identify trends, outliers, or patterns that may not be immediately apparent in numerical results as usually do in econometrics.

Runing the code, we’ve made with the help of python dedicated websites, our classes and ChatGPT, our analysis suggests that the EUR/USD exchange rate exhibits a mean reversion feature over the full sample period from January 2010 to October 2023.

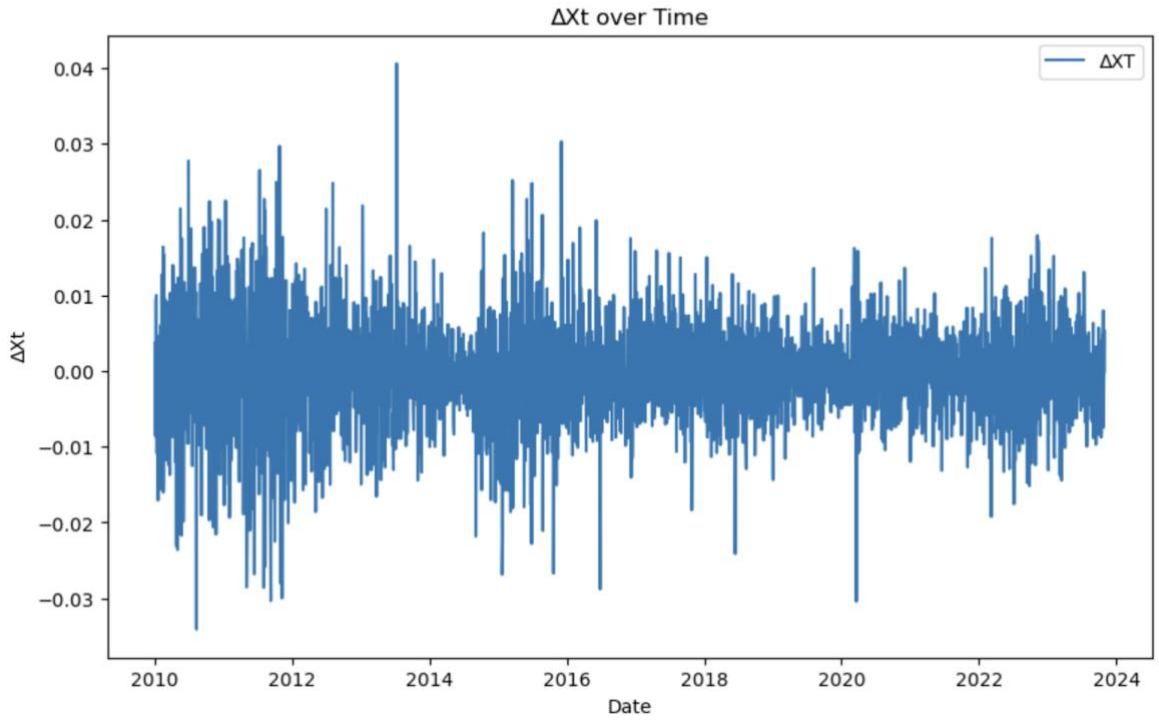
We found out that from:

- Alpha (α): 0.0025
  This shows the intercept term from the regression, representing the average change in the exchange rate when the previous period's rate is zero.
- Beta (β): -0.0021
  This is the coefficient of the lagged exchange rate, indicating a negative relationship between the current change and the previous rate. A negative beta suggests mean reversion.
- Long-run mean (μ): 1.1481
  This is the calculated long-run average to which the exchange rate is expected to revert. It's computed as $-\alpha/\beta$.
- Speed of mean reversion (θ): 0.0021
  This indicates how quickly the exchange rate reverts to the long-run mean. It's calculated as $-\beta$.
- T-statistic of Beta: -2.2026
  This is the t-statistic of the beta coefficient, used to determine if beta is statistically significantly different from zero.
- Mean Reversion Feature: Yes
  The data exhibits mean reversion features since $\alpha > 0$ and $\beta < 0$.
- Beta Statistically Significant: Yes
  The beta is statistically significant as the t-statistic is less than the critical value of -1.

The negative and statistically significant beta coefficient indicates that the exchange rate tends to revert to a long-term mean.

Now looking at our graphic:

```
α: 0.002461251149061979, β: -0.0021438279336089532, μ: 1.1480637557132072, θ: 0.0021438279336089532
The data exhibits mean reversion feature.
T-statistic (-2.2025732070779123) is statistically significant.
```



We can see some higher spikes in 2011, 2013 as well as 2020 but nothing significant especially considering that we stay between -0.03 and 0.04.

Question 2

We want to construct a dynamic trading strategy to estimate the mean reversion model for a past estimation window of 80 trading days and for a critical value of -1 just like the first question.

The code is “Question 2”.

For that, we keep our OLS model implementing a mean-reversion strategy by estimating a linear regression model in a moving estimation window. For the visualization we chose to display the growth of the initial investment and the cumulative strategy return over time to assess the performance of a trading strategy and gaining insights into its behavior throughout different market conditions.

For the parameters:

- The estimated alpha of -0.0001 indicates that the mean daily return of the EURUSD exchange rate is slightly negative. This is consistent with the notion that the exchange rate tends to mean-revert to its long-term average.

- The estimated beta of -0.0381 indicates that the returns are negatively correlated with the lagged returns, further supporting the mean reversion hypothesis.

- The mean t-statistic for beta of -0.3474 suggests that the relationship between the lagged returns and daily returns is not statistically significant. This means that the negative correlation between the returns is weak and may not be reliable for predicting future returns.

For the performance metrics, we chose the Sharpe ratio, the maximum drawdown, the calmar ratio as well as the skewness and volatility, this choice comes from reading some of the state of art and papers on what is relevant to our analysis.

Our results:

- The Sharpe Ratio of 0.3496 indicates that the strategy has generated a risk-adjusted return of 34.96% per year. This is a decent return, considering the relatively low volatility of the strategy.

- The maximum drawdown of 0.0764 indicates that the strategy has experienced a decline of 7.64% from its peak to the trough of its cumulative returns. This is a moderate drawdown, suggesting that the strategy has been relatively resilient to market downturns.

- The Calmar Ratio of 4.574 is a relatively high value, indicating that the strategy has generated a return of 4.574 times the average drawdown. This suggests that the strategy has been able to generate substantial returns while managing risk effectively.

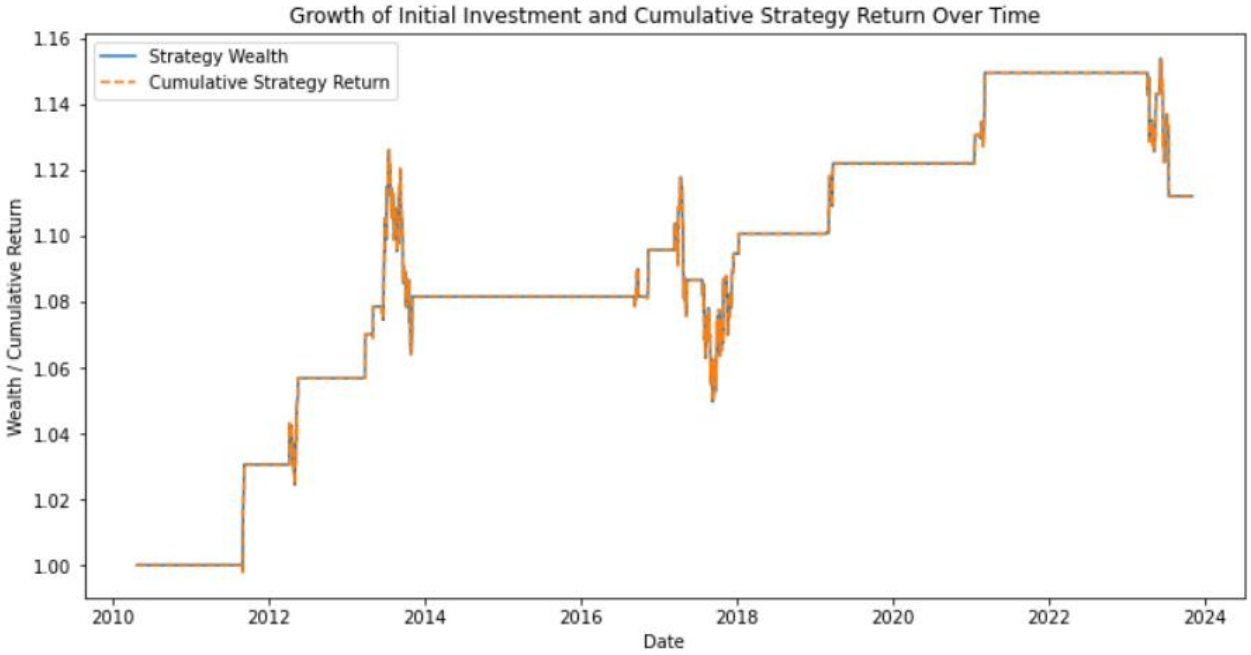
- The skewness of 0.4697 indicates that the strategy returns are positively skewed, meaning that they are more likely to be positive than negative. This is consistent with the positive final cumulative return and suggests that the strategy has not generated excessive losses.

- The standard deviation of 0.0014 indicates that the strategy returns are very low in volatility. This is a positive sign, as it suggests that the strategy is relatively immune to market fluctuations.

- The downside deviation of 0.0028 indicates that the negative portion of the strategy returns is also relatively low in volatility. This further reinforces the notion that the strategy is not prone to excessive losses.

The final cumulative return of 1.1120 indicates that the strategy has generated a total return of 111.20% over the evaluation period. This is a significant positive return, suggesting that the strategy has been profitable overall. While the relatively low maximum drawdown and Calmar Ratio suggest that the strategy may not be suitable for highly risk-averse investors, it could be a viable option for traders seeking to profit from short-term EURUSD trading opportunities. We think we can push it further with more datas maybe the interventions and weights of the trading on those days.

Here's how our visual datas looks:



Part B: Improvement of the strategy's performance

Question 3

To improve the strategy performance, we decided to use another mean reversion approach which is the GARCH (1,1) model using the paper **"Mean reversion Models of financial markets"** by Eric Hillebrand as an inspiration and to understand perfectly how the model could be used in the strategy performance.

The (GARCH) model, particularly the GARCH(1,1) model, is a statistical model used to capture volatility clustering in financial time series data. The model is expressed as follows:

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

With $\sigma_t^2 the$ conditional variance at time t; ω The constant term or intercept, representing the long − term average of the conditional variance; α The coefficient associated with the lagged squared returns ε_{t-1}^2 and β The coefficient associated with the lagged conditional variance σ_{t-1}^2 representing the persistence of past conditional variance in the current period.

We've also added the notion of volatility which is essential for a portfolio strategy performance. To improve even more the strategy, we've also added the calculation of the Hurst Exponent which is a measure of the long-term memory of a time series like the one we have.

The code is "Question 3".

From the datas we get:

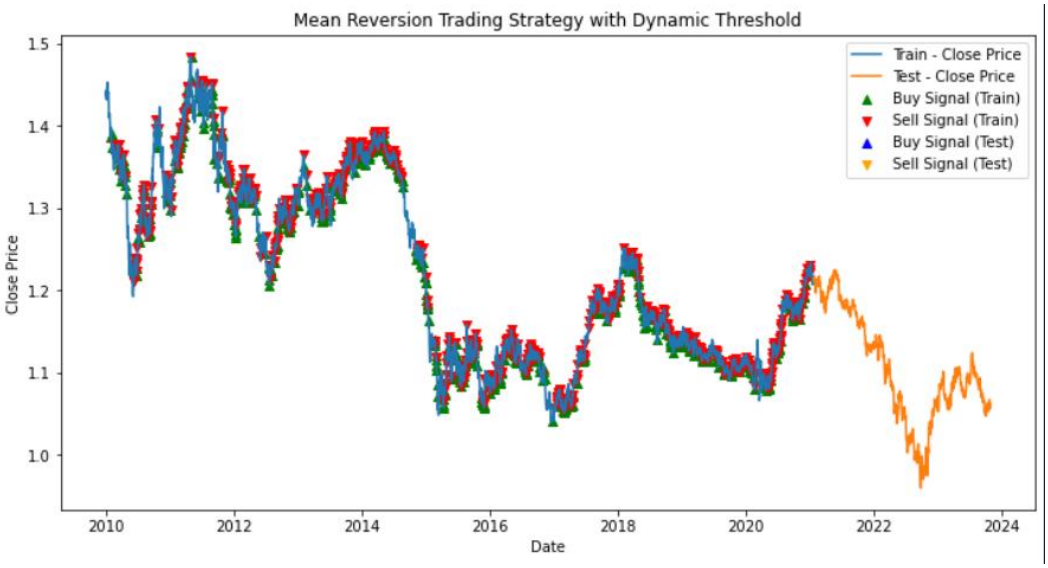
- Hurst exponent is 0.5305522942144956 which suggests a random walk behavior.
- Sharpe Ratio is 0.12600930048348544 which indicates a positive return relative to the risk-free rate.
- The Maximum Drawdown is -0.21479020373821556 which represents the maximum loss from a peak to a trough of a portfolio before a new peak is attained.
- The Cumulative Return is 1.0719096833768678 which is the cumulative growth of the investment over the analyzed period.
- The negative log-likelihood is a measure used in the optimization process of the model It starts at a very high value (1.8126400434866e+13), indicating a poor fit and, after several iterations, it converges to a lower value (2218.3859778892274), suggesting an improved fit.

The optimization process successfully converged, and the model results suggest positive cumulative returns, albeit with a relatively low Sharpe Ratio and a notable drawdown.

For the the graphic:

- The plot shows the closing prices of the financial instrument under consideration, differentiating between the training and testing periods.
- The buy and sell signals are marked on the plot, indicating points where the strategy would initiate trading actions based on mean reversion principles.
- The green and red markers represent buy and sell signals during the training period,
- The blue and orange markers indicate corresponding signals during the testing period.
- The dynamic threshold, adjusted based on recent market conditions, is also visualized, influencing the strategy's decision to enter or exit trades.

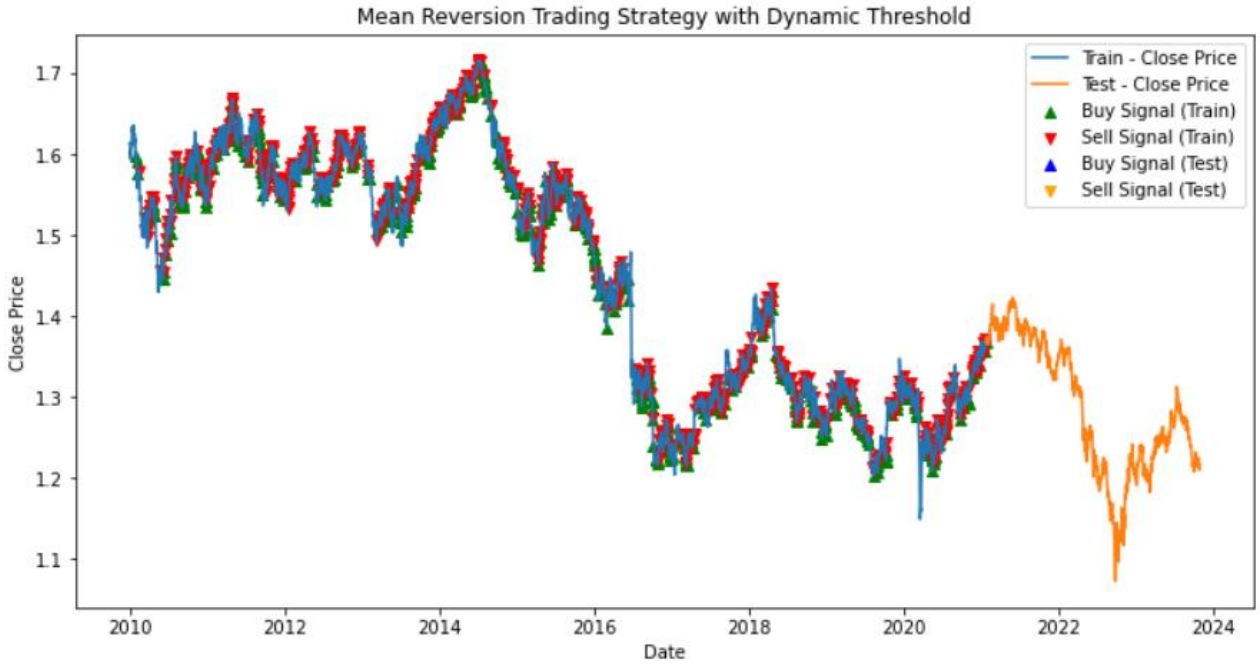
This dynamic threshold reflects the adaptive nature of the strategy, responding to changes in market volatility. Overall, the visualization allows for a clear understanding of how the mean reversion strategy responds to price movements and adjusts its trading decisions dynamically in different market conditions.



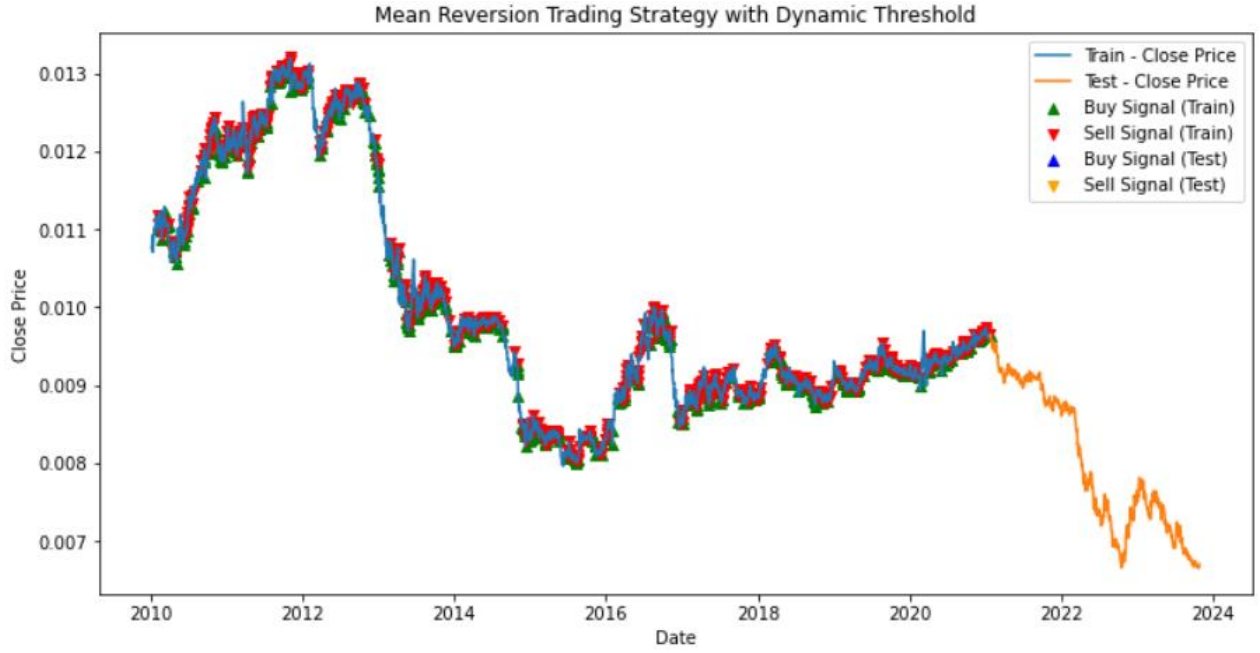
Question 4

For this last question we started by downloading the additional EUR/GBP, GBP/USD, JPY/USD.

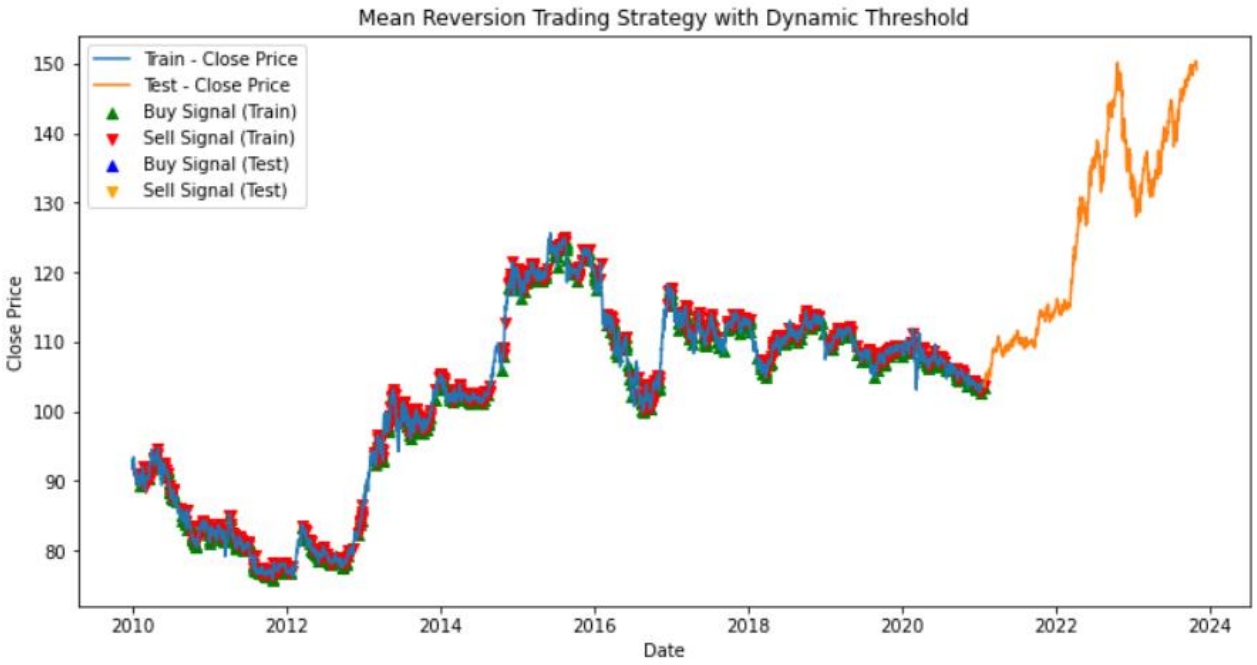
EUR/GBP



GBP/USD



JPY/USD



This strategy does work for every pair by carefully taking the same types of datas so the date and the closing rates. We then looked up multiple methods to modify the strategy to jointly trade multiple currency pairs and approaching a real portfolio strategy. We decided to start back from the GARCH (1,1) model.

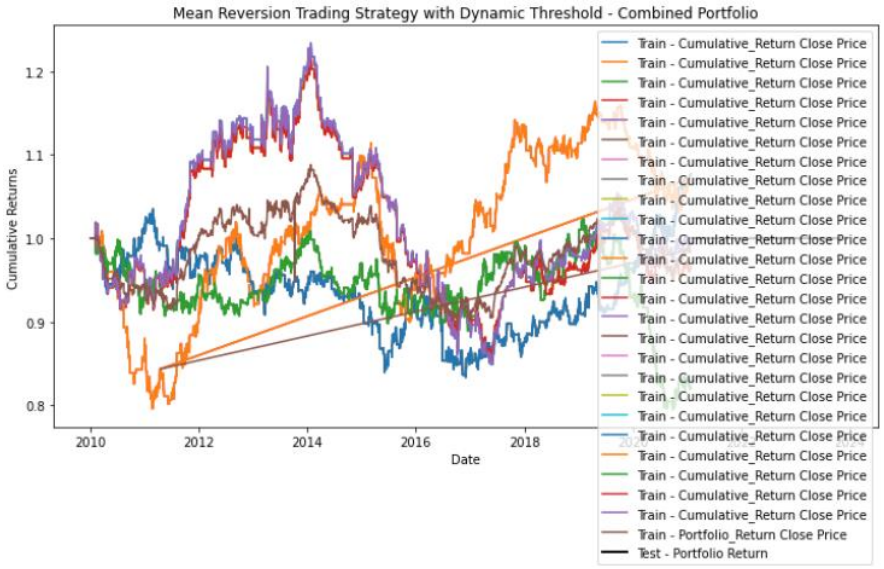
The code is “Question 4”.

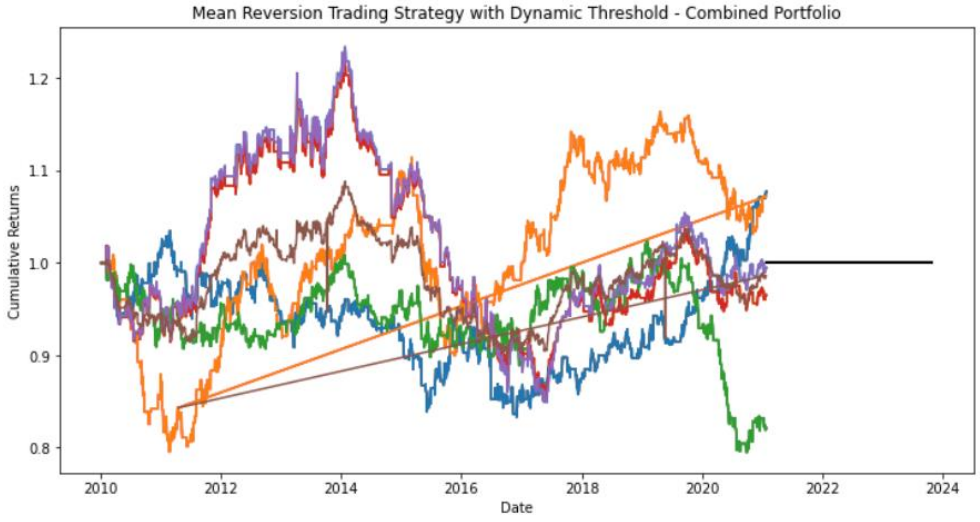
The optimization results for each currency pair's GARCH(1,1) model are displayed, showing the convergence process during parameter estimation. The negative log-likelihood function (Neg. LLF) decreases with each iteration, indicating the optimization algorithm's progress. The "Optimization terminated successfully" message confirms that the optimization reached a satisfactory solution.

We find:

- Sharpe Ratio is 368.57 which indicates a positive return relative to the risk-free rate.
- The Maximum Drawdown is -0.2453 which represents the maximum loss from a peak to a trough of a portfolio before a new peak is attained.
- The Cumulative Return is 0.8432 which is the total percentage return achieved by the portfolio over the entire period. In this context, the portfolio achieved a cumulative return of approximately 84.32%.

For the graph we have a line plot represents the cumulative returns during the training period for each currency pair. The testing period – Portfolio return represents the cumulative returns of the combined portfolio during the testing period.
The visual representation of the mean reversion strategy reveals distinctive performance trajectories for individual currency pairs during the training period, with variations in cumulative returns reflecting the strategy's efficacy across diverse pairs. The testing period – Portfolio in the testing period encapsulates the collective performance of the combined portfolio, serving as a comprehensive metric for assessing the overall success of the strategy when applied concurrently to various currency pairs. This comparative analysis aims to gauge the strategy's effectiveness in fostering a robust and diversified portfolio, thereby enhancing risk-adjusted returns across multiple assets.





We would like to try different GARCH models or other volatility models to capture the underlying volatility dynamics more accurately or to consider transaction costs in the simulation to make the strategy more realistic if we had more time.