

QF621 Quantitative Trading Strategies

Pairs Trading: Application of Machine Learning and GARCH Model in the Foreign Exchange Market

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CONTENT

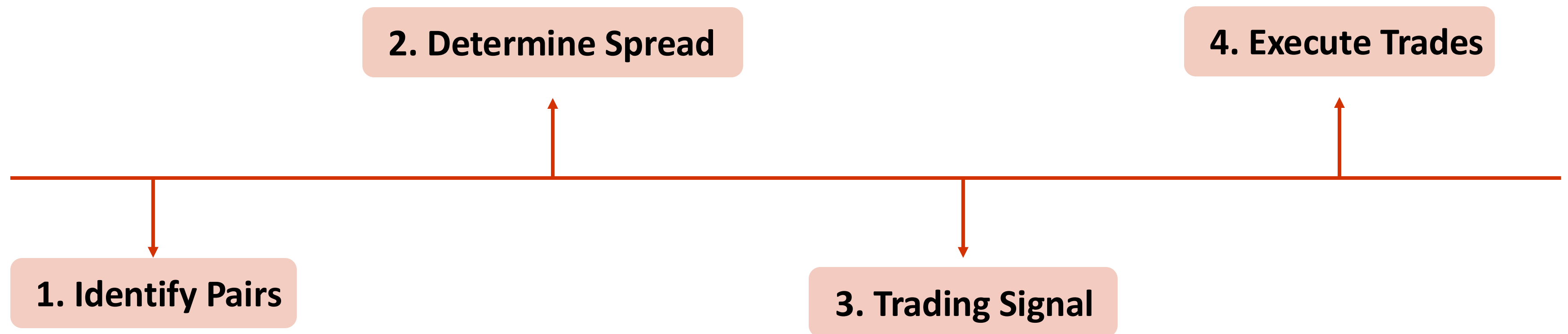
- 1 Introduction
- 2 Pairs Selection
- 3 Trading Signal
- 4 Back-testing Result
- 5 Conclusion

INTRODUCTION

Pairs Trading in Forex

- Simultaneous long and short positions in two correlated currency pairs.
- Profits from the ***relative price movements*** rather than absolute price levels.
- ***Exploits*** mean reversion in correlated currency pairs.

Steps



Project Overview

Data Source

- 35 historical Forex rates sourced from Yahoo Finance.
- Time frame: From 2014.01.01 to 2024.05.25

Pairs Selection

Method

Introduction

Pure PCA Analysis	<ul style="list-style-type: none">• A dimensionality reduction technique that transforms a large set of variables into a smaller one that still contains most of the information.• It identifies the directions (principal components) in which the data varies the most.
PCA + OPTICS Clustering	<ul style="list-style-type: none">• Combine PCA with OPTICS to leverage the strengths of both techniques for finding trading pairs.• OPTICS is a clustering algorithm that identifies clusters with varying densities, which helps in finding groups of assets that behave similarly.

Project Overview

Pairs Selection

Method	Suitable for	Advantages
Pure PCA Analysis	<ul style="list-style-type: none">Markets with <i>high volatility</i>Markets with significant <i>linear</i> relationshipsMarkets with <i>large data scales</i>	<ul style="list-style-type: none">Effectively captures the <i>primary directions</i> of variance
PCA + OPTICS Clustering	<ul style="list-style-type: none"><i>Diversified</i> markets<i>Complex</i> markets with significant <i>nonlinear</i> relationshipsMarkets with <i>strong local correlations</i>	<ul style="list-style-type: none">Identifies intricate market structuresUncovers <i>potential</i> trading opportunities

Project Overview

Trading Signal

Method

Introduction

Traditional Methods

- Often involves *simple statistical techniques* to identify deviations from historical relationships between asset prices.

GARCH

- To model and *forecast time-varying volatility* in financial time series.

Project Overview

Trading Signal

Method

Suitable for

Advantages

Traditional Methods

- Markets with *stable* volatility patterns
- Markets with *fewer data points*

- *Simple* and *easy* to implement
- *Quick* computation
- *Less* computational intensive

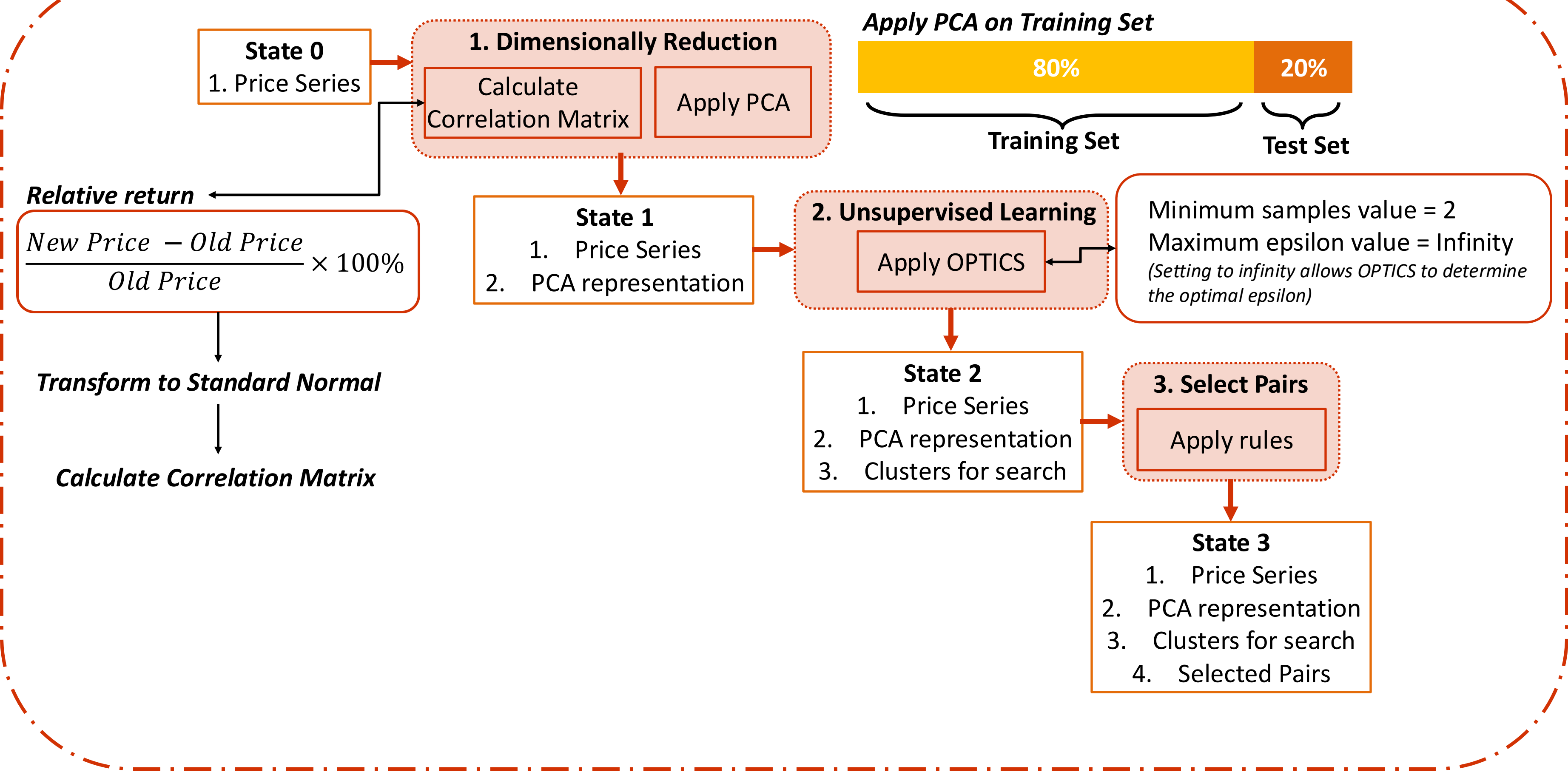
GARCH

- Markets with *high and variable* volatility
- Markets with *large* datasets and *high-frequency* data
- Markets where *capturing volatility is crucial*

- Models time-varying volatility *explicitly*
- *More accurate* spread estimation under conditions
- Provides a *more realistic* measure of risk

PAIRS SELECTION

PCA and OPTICS



Check for Cointegration & Stationarity

Step 2 ***Log-Transform the Prices***

- To stabilize variance and convert multiplicative relationships into additive relationships.

Step 4 ***Perform Engle-Granger Cointegration Test***

- Reject if p-value > 0.5.

Step 1 ***Identify the Most Influential Assets***

- Identify the assets with the highest and lowest absolute loading in the principal component.

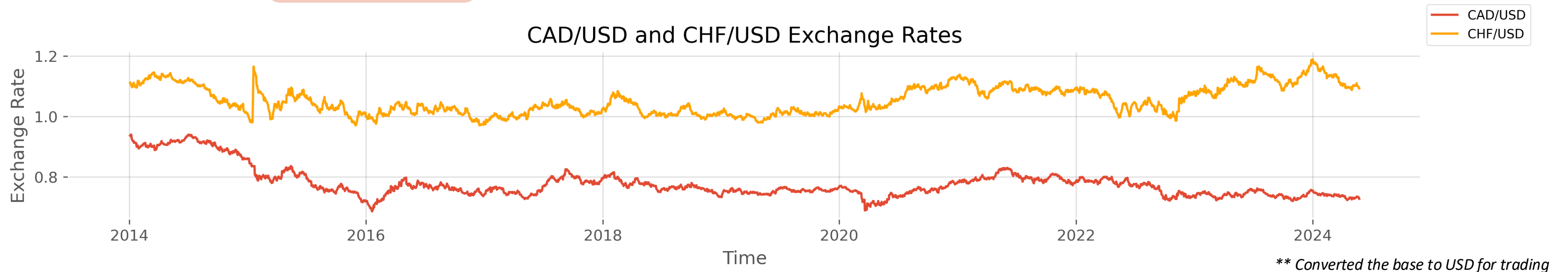
Step 3 ***Perform OLS Regression***

Step 5 ***Perform ADF Test for Stationarity***

- Performed on the residuals.
- Reject if p-value > 0.5.

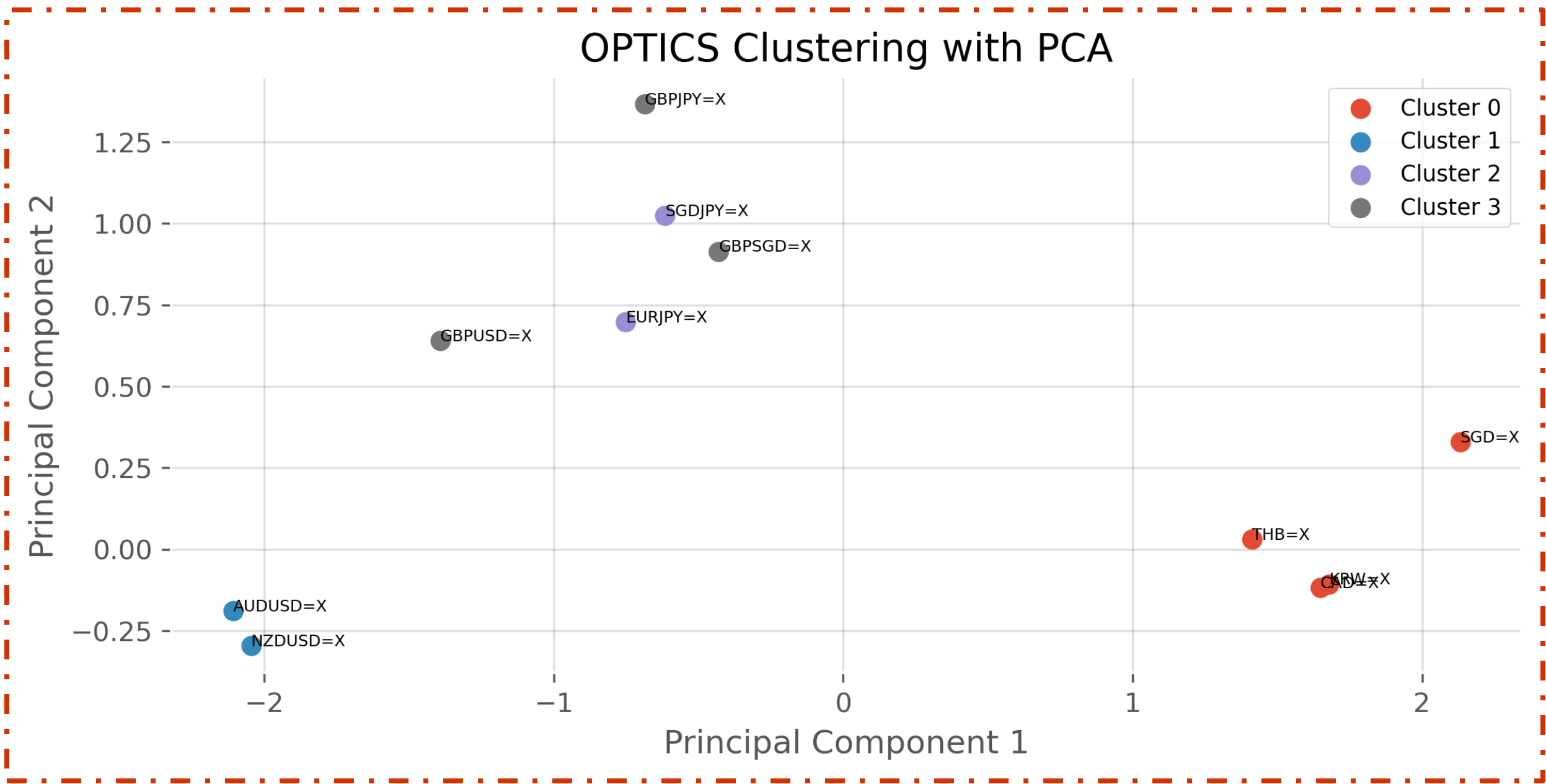
PCA Results**CAD=X and CHF = X**

(US Dollar / Canadian Dollar and US Dollar / Swiss Franc)

**Economic Intuition**

- **Different Economic Drivers:**
 1. **CAD = X** : Heavily influenced by the *commodity market*, particularly oil.
 2. **CHF = X**: Often considered a *safe-haven currency*.
- **Correlation and Diversification:**
 1. **Correlation**: Low correlation (*0.3160*) due to the different economic factors.
 - Opportunity for pairs trading, as the spread between them might offer mean-reverting characteristics.
 2. **Diversification**: The trader can potentially hedge against *sector-specific risks*.

PCA + OPTICS Results



List of Noisy Points:

SGDMYR=X, EURSGD=X, SGDHKD=X, SGDIDR=X, SGDCNY=X, SGDTHB=X, SGDINR=X, SGDKRW=X, AUDSGD=X, NZDSGD=X, JPY=X, HKD=X, MYR=X, INR=X, CNY=X, PHP=X, IDR=X, CHF=X, MXN=X, VND=X, EURGBP=X, EURSEK=X, EURCHF=X, EURHUF=X

Cluster	Currency
0	SGD = X
	THB = X
	KRW = X
	CAD = X
1	AUDUSD = X
	NZDUSD = X
2	SGDJPY = X
	EURJPY = X
3	GBPSGD = X
	GBPJPY = X
	GBPUSD = X

Total11 pairs

PCA + OPTICS Results

Cluster	Currency
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0	SGD = X
	THB = X
	KRW = X
	CAD = X

Based on *USD pairings*, with significant trade relations with the US and influences from US economic data.

1	AUDUSD = X
	NZDUSD = X

Due to *geographic proximity* and *similar economic structures*, heavily influenced by commodities and USD.

2	SGDJPY = X
	EURJPY = X

Based on the common involvement of the *Japanese Yen*, influenced by its safe-haven status and interest rate differentials.

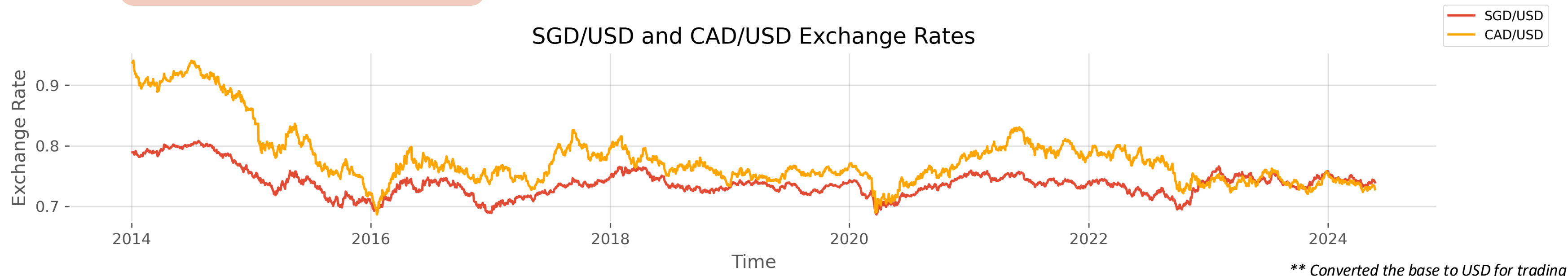
3	GBPSGD = X
	GBPJPY = X
	GBPUSD = X

Due to the common involvement of the *British Pound*, reflecting its global economic influence and diverse economic links.

Economic Explanation for the Clusters

PCA + OPTICS Results**SGD=X and CAD = X**

(US Dollar / Singapore Dollar and US Dollar / Canadian Dollar)

**Economic Intuition**➤ **Economic Divergence:**

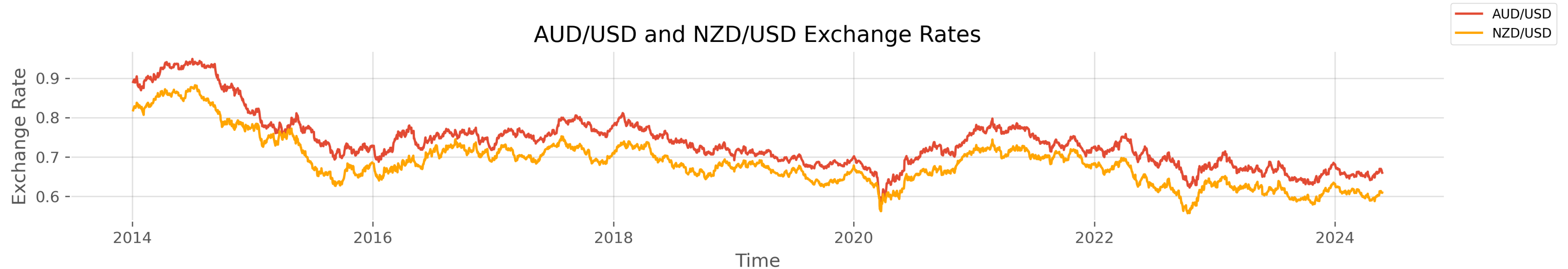
1. **SGD:** A highly developed and open economy, heavily reliant on **trade** and **services**.
2. **CAD:** Heavily influenced by the **commodity market**, particularly oil.

➤ **Interest Rate Differentials:**

1. **SGD:** MAS uses the **exchange rate** as the main tool of monetary policy rather than interest rates.
 - Interest rates in Singapore are influenced by **global interest rates** and the **domestic economy's performance**.
2. **CAD:** Bank of Canada's **interest rate decisions** directly impact the CAD.
 - Higher interest rates in Canada attract foreign investment, strengthening the CAD, while lower rates can weaken it.

PCA + OPTICS Results**AUDUSD=X and NZDUSD = X**

(Australian Dollar / US Dollar and New Zealand Dollar / US Dollar)

**Economic Intuition**➤ **Economic Structures:**

1. **Australia:** A *diverse economy* with key sectors including mining, agriculture, services, and manufacturing.
2. **New Zealand:** A *smaller, open economy* heavily reliant on agriculture and dairy products.

➤ **Geopolitical Factors:**

- Both countries have relatively *stable* political environments, but they can be affected by global geopolitical events that impact trade, commodity prices, and investor sentiment.

TRADING SIGNAL

Traditional Method

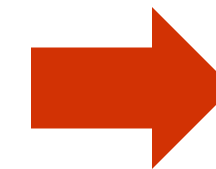
1 Generate Spread Series

From OLS Regression

Intercept	Coefficient
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$$MSPREAD = Y_t - (a + bX_t)$$

Log price series of 2 assets



Decentralization

2 Calculation of Mean and Standard Deviation

$$\mu = \frac{1}{N} \sum_{t=1}^N MSPREAD_t$$
$$\sigma = \sqrt{\frac{1}{N} \sum_{t=1}^N (MSPREAD_t - \mu)^2}$$

3 Construction of Trading Signals

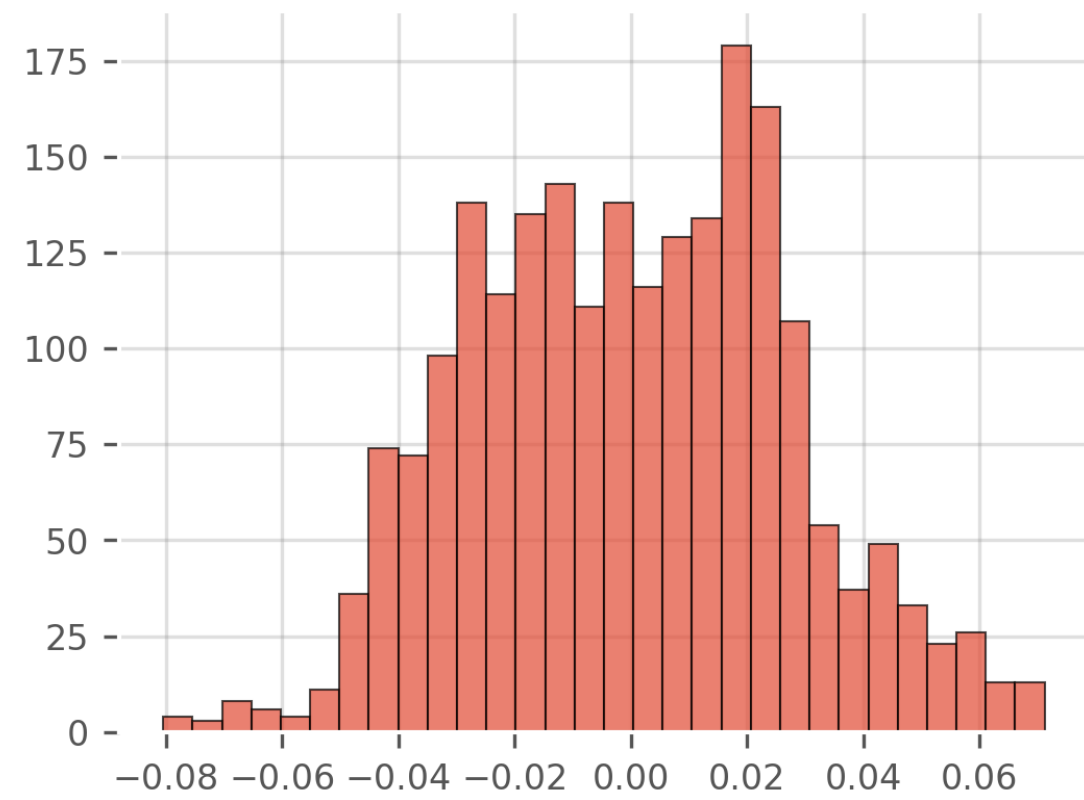
$$\text{Buy Signal} = MSPREAD_t < \mu - k\sigma$$
$$\text{Sell Signal} = MSPREAD_t > \mu + k\sigma$$

In our project, we set $k = 1$.

Traditional Method

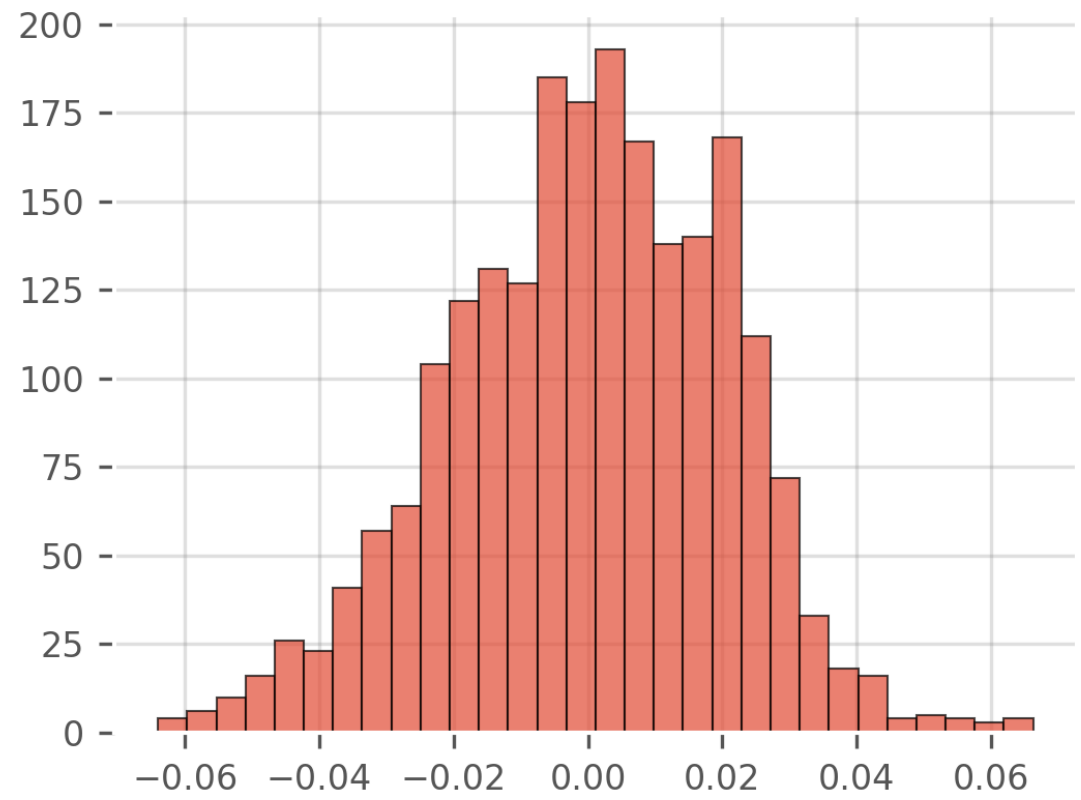
Descriptive Statistics of Decentralized Spread Series

SGD = X and CAD = X



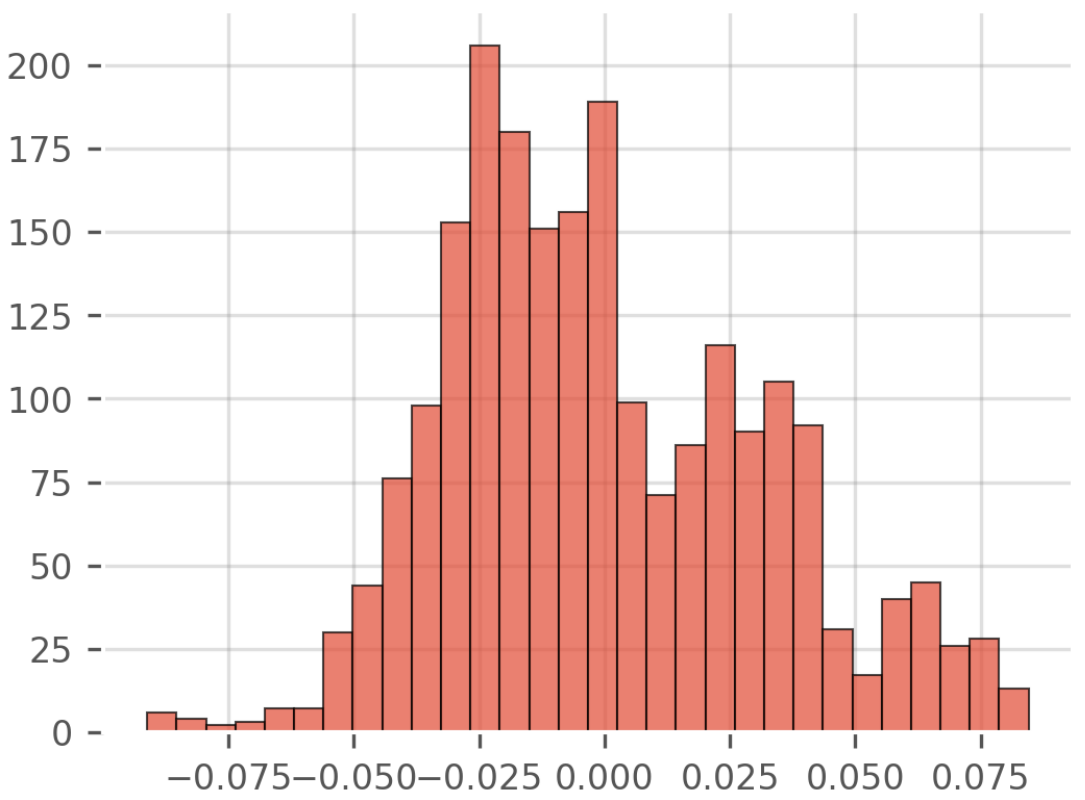
Mean = 0
Std. Dev. = 0.0272
Skewness = 0.0584
Kurtosis = 2.5515
Jarque-Bera Stats. : 19.4320
P-value (JB Test): 0

AUDUSD = X and NZDUSD = X



Mean = 0
Std. Dev. = 0.0205
Skewness = -0.1962
Kurtosis = 2.9459
Jarque-Bera Stats. : 14.1902
P-value (JB Test): 0.0008

CAD = X and CHF = X



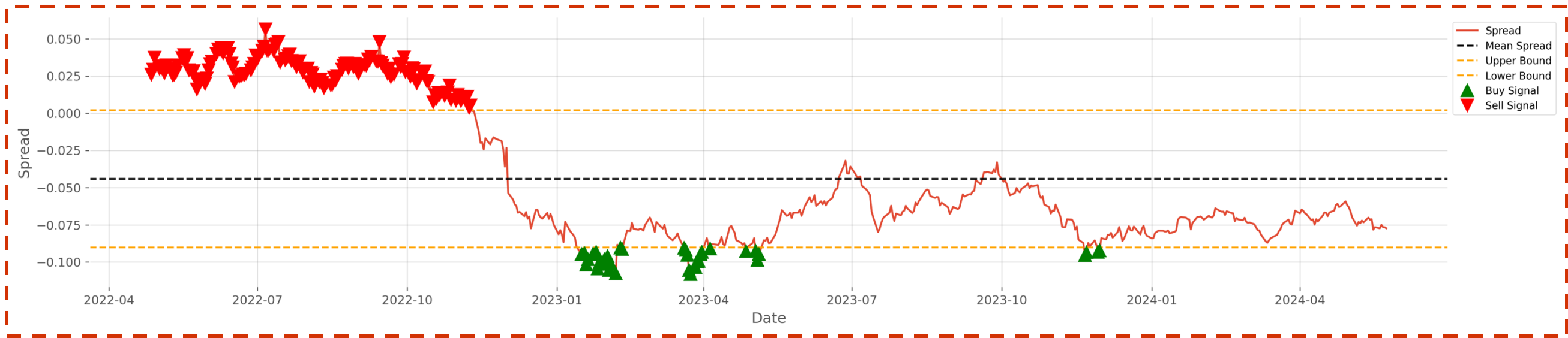
Mean = 0
Std. Dev. = 0.0318
Skewness = 0.4245
Kurtosis = 2.7480
Jarque-Bera Stats. : 70.9398
P-value (JB Test): 0.0000

Traditional Method

Construction of Trading Signals

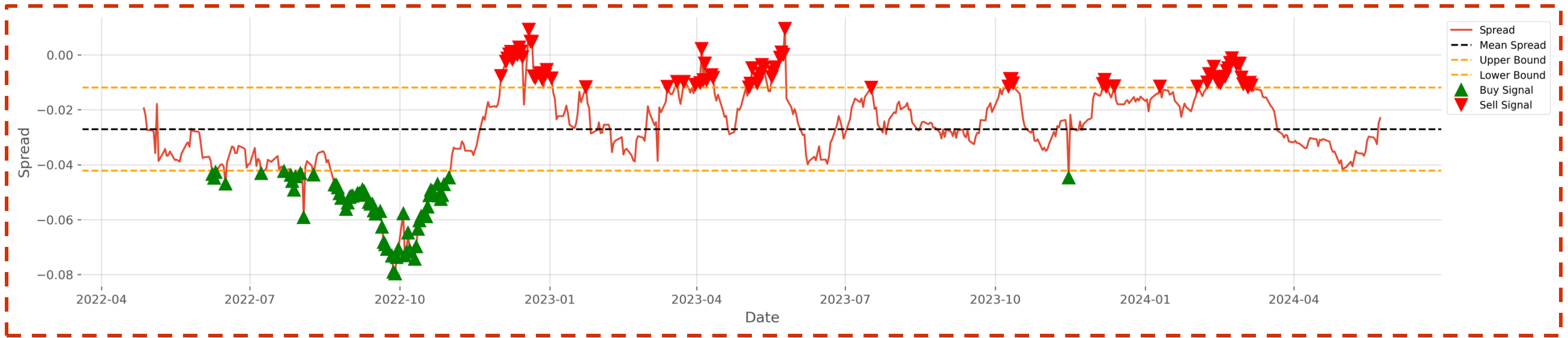
SGD = X and CAD = X

Holding: 365
Sell: 141
Buy: 37



AUDUSD = X and NZDUSD = X

Holding: 400
Sell: 78
Buy: 65



CAD = X and CHF = X

Holding: 316
Sell: 140
Buy: 87



GARCH Model Method

1 Generate Spread Series

2 Fitting an AR Model

$$MSPREAD_t = c + \sum_{i=1}^p \phi_i MSPREAD_{t-1} + \epsilon_t$$

3 Fitting a GARCH Model

$$\epsilon_t = \alpha_0 + \sum_{i=1}^q \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2$$

4 Construction of Trading Signals

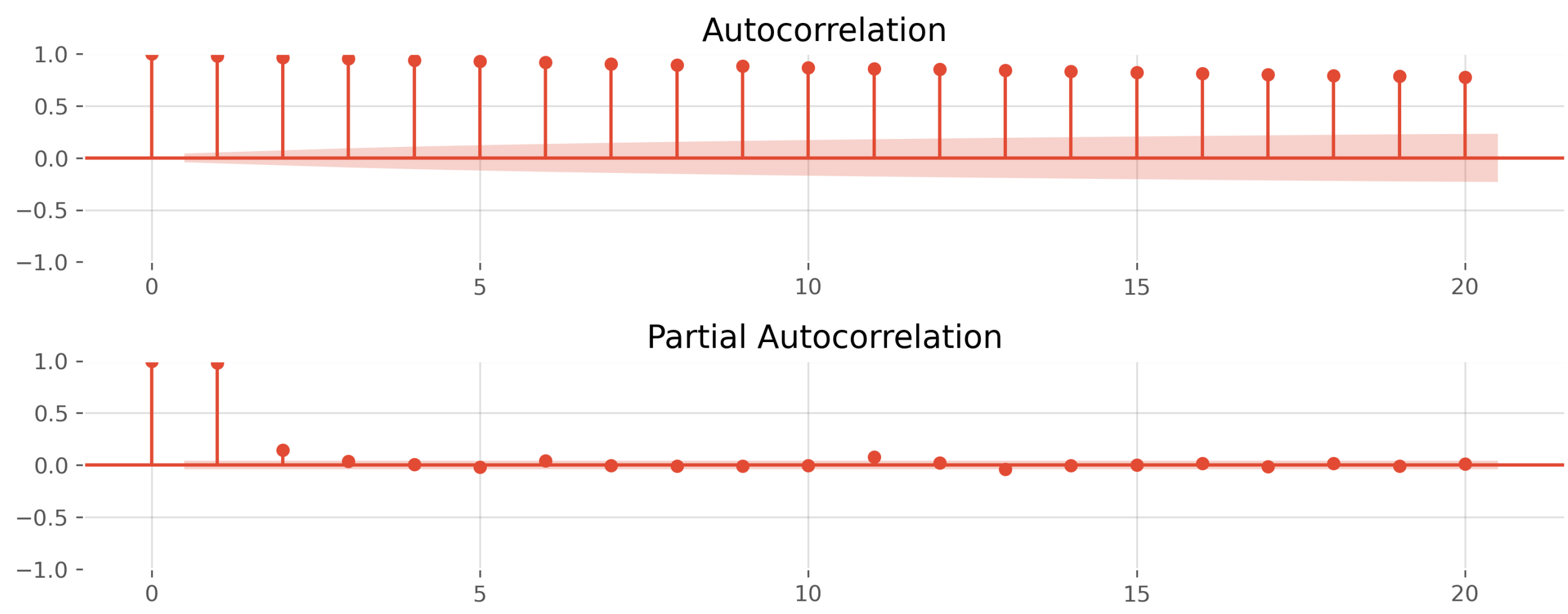
$$\text{Buy Signal} = MSPREAD_t < -k\sigma$$

$$\text{Sell Signal} = MSPREAD_t > k\sigma$$

In our project, we set $k = 1$.

GARCH Model Method

Autocorrelation Test (All the pairs have the same results.)



PACF

Significant spikes at lags 1 and 2 and then fluctuates around zero.

ACF

A slow decay.

} ***AR(2)***

GARCH Model Method

ARCH-Lagrange Multiplier Test

- To indicate evidence of heteroskedasticity in the residuals of the GARCH(1,1) model.
 - P-value > 0.05 : Homoskedasticity
 - P-value < 0.05 : Heteroskedasticity

SGD=X and CAD=X

Lagrange Multiplier Test Statistic: 24.1818
p-value: 0.0071

AUDUSD = X and NZDUSD = X

Lagrange Multiplier Test Statistic: 30.9759
p-value: 0.0006

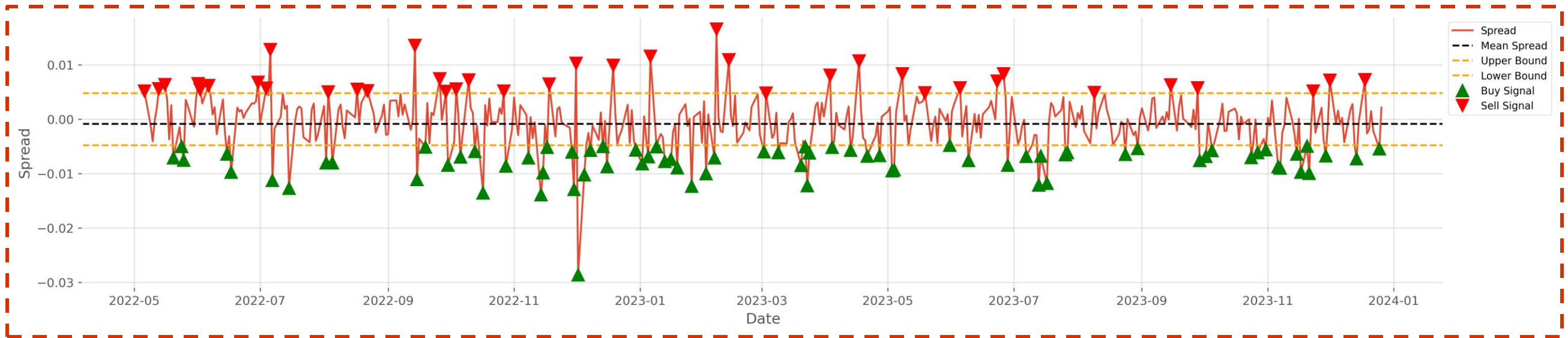
CAD = X and CHF = X

Lagrange Multiplier Test Statistic: 42.6111
p-value: 0.0

 ***Heteroskedasticity***

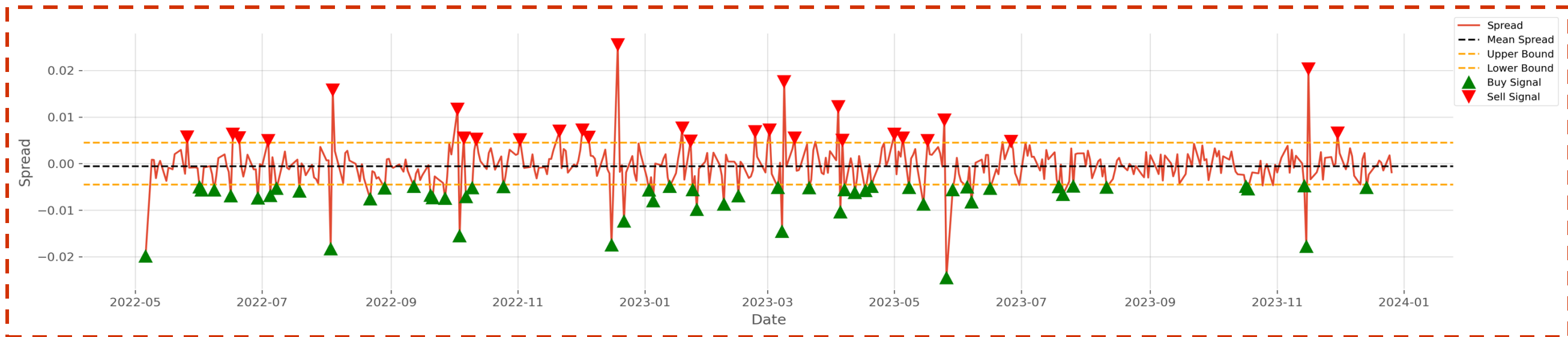
SGD = X and CAD = X

Holding: 315
Sell: 38
Buy: 75



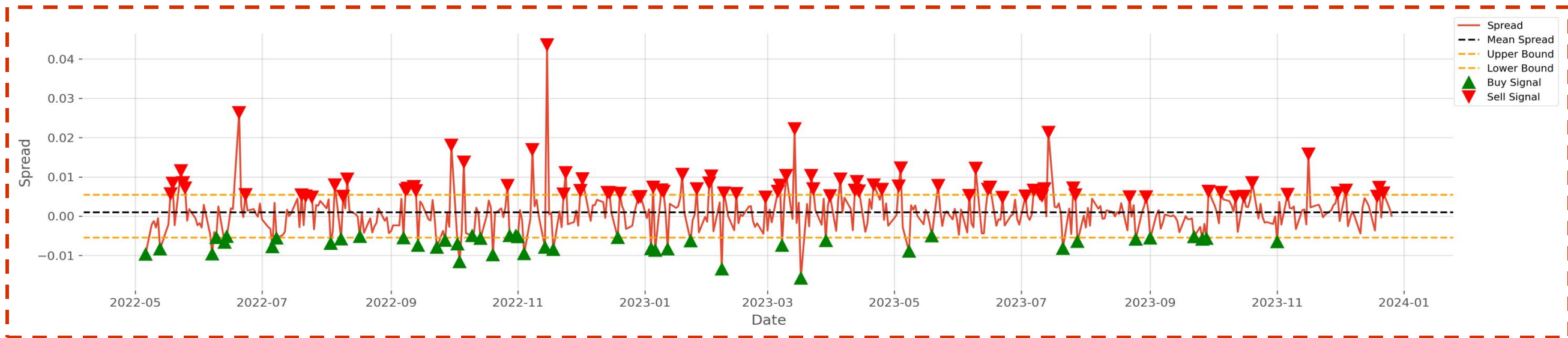
AUDUSD = X and NZDUSD = X

Holding: 347
Sell: 28
Buy: 53



CAD = X and CHF = X

Holding: 299
Sell: 84
Buy: 45



BACK-TESTING RESULT

Back Testing Metrics

Cumulative Return

Sharpe Ratio

Sortino Ratio

Max Drawdown (%)

Cumulative of daily return

$$\sqrt{252} \times \frac{\text{Average Value of Daily Return}}{\text{Standard Deviation of Daily Return}}$$

$$\sqrt{252} \times \frac{\text{Average value of daily return}}{\frac{\sum \text{Daily Return}^2}{\sqrt{\text{Number of Days}}}}$$

$$\max \left(\frac{\text{Maximum Drawdown (\$)}}{\text{Cumulative Maximum portfolio value}} \times 100\% \right)$$

****Assume initial capital = 100,000**

Methods	Pairs	Cumulative Return	Sharpe Ratio	Sortino Ratio	Maximum Drawdown (%)
Traditional	SGD = X and CAD = X	6,011.54	0.51	0.05	-37.85
	AUDUSD = X and NZDUSD = X	57,878.88	1.08	0.11	-0.66
	CAD = X and CHF = X	1,108.41	-0.14	-0.01	-0.95
GARCH Model	SGD = X and CAD = X	84,053.84	6.32	0.98	-0.18
	AUDUSD = X and NZDUSD = X	90,915.98	4.80	0.95	-0.03
	CAD = X and CHF = X	46,785.76	6.31	0.99	-0.22

CONCLUSION



THANK YOU

Call Now.
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