PAIRS TRADING BACKTESTING REPORT

Mahak Sahay

Enrollment No: 22116051

This document contains the analysis, report, and recommendations related to the pairs trading project. The backtesting is performed on historical data from January 1, 2019, to March 8, 2024.

Overview:

What is Pairs Trading?

Pairs trading is a market-neutral trading strategy enabling traders to profit from the relative performance of two historically correlated securities. The strategy involves identifying pairs of assets that are cointegrated, meaning their prices move together over time. When the price relationship diverges, traders buy the undervalued asset and sell the overvalued asset, betting on the convergence of the prices.

Flow of Project:

1. **Define the Portfolio:**
    - List the assets in the portfolio, including stocks and other investments.
    - Specify the initial investment amount for the portfolio.

2. **Collect Historical Data:**
    - Gather historical price data for each asset in the portfolio. Daily closing prices are used.
    - Calculate the returns of each asset over the historical period.
    - Data is taken from Yahoo Finance.

Date	JPM	C	GS	MS	BAC
2019-01-02	99.309998	53.529999	172.029999	40.400002	24.959999
2019-01-03	97.110001	52.560001	169.509995	39.680000	24.559999
2019-01-04	100.690002	55.130001	175.050003	41.299999	25.580000
2019-01-07	100.760002	55.610001	176.020004	41.709999	25.559999
2019-01-08	100.570000	55.459999	175.369995	41.450001	25.510000

Date	WFC	USB	AXP	COF	PNC
2019-01-02	46.939999	46.349998	95.680000	77.260002	118.809998
2019-01-03	46.570000	45.700001	93.430000	76.160004	118.269997
2019-01-04	47.950001	46.830002	97.639999	79.540001	121.230003
2019-01-07	47.639999	46.610001	98.169998	79.980003	120.959999
2019-01-08	47.540001	46.910000	98.650002	80.019997	121.150002

Date	JPM	C	GS	MS	BAC
2024-03-01	185.289993	55.599998	388.100006	86.480003	34.349998
2024-03-04	186.679993	56.139999	392.250000	90.040001	35.150002
2024-03-05	188.550003	56.259998	390.910004	89.129997	35.389999
2024-03-06	189.529999	57.290001	389.570007	85.660004	35.419998
2024-03-07	187.869995	57.720001	388.429993	86.139999	35.630001

Date	WFC	USB	AXP	COF	PNC
2024-03-01	55.060001	41.419998	219.660004	136.770004	147.809998
2024-03-04	55.810001	42.700001	218.910004	135.990005	153.740005
2024-03-05	56.599998	43.250000	217.199997	137.559998	155.119995
2024-03-06	57.110001	43.090000	218.449997	135.740005	150.380005
2024-03-07	57.000000	43.340000	223.419998	137.649994	150.440002

```
Cointegrated pairs: [('C', 'USB'), ('BAC', 'PNC')]
```

3. **Universe of Stocks:**

The following stocks were included in the analysis:

- JPM: JPMorgan Chase & Co.
- C: Citigroup Inc.
- GS: Goldman Sachs Group Inc.
- MS: Morgan Stanley
- BAC: Bank of America Corp.
- WFC: Wells Fargo & Co.
- USB: U.S. Bancorp
- AXP: American Express Co.
- COF: Capital One Financial Corp.
- PNC: PNC Financial Services Group Inc.

Strategy Overview

The strategy involves:

1. **Identifying Cointegrated Pairs**: Using Engle-Granger two-step method to find pairs of stocks that are cointegrated.
2. **Golden Cross Signal Generation**: Implementing a moving average crossover strategy to generate buy and sell signals.
3. **Pair Trading**: Conducting pair trades based on the spread between the cointegrated stocks, with predefined thresholds for entering and exiting positions.

Key Parameters

- **Cointegration Threshold (p-value)**: 0.1
- **Spread Threshold**: 1.5
- **Transaction Fee**: 0.1% per trade
- **Rolling Window**: 252 trading days (approximately one year)

Backtesting the Trading Strategy:

- **Use the backtest_pair function to simulate trading based on the generated signals.**
- Calculate performance metrics such as annualized return, annualized volatility, Sharpe ratio, and maximum drawdown.

```
Backtesting Report:
--------------------------------------------------------------------------------
Pair                Ann. Return          Ann. Volatility      Sharpe Ratio         Max Drawdown
--------------------------------------------------------------------------------
('C', 'USB')        -0.11                0.23                 -0.50                7.34
('BAC', 'PNC')      -0.18                0.18                 -1.02                505.34
--------------------------------------------------------------------------------
```

Performance Metrics

For each cointegrated pair, the following performance metrics were calculated:

- **Annualized Return**: The compounded return on investment per year.
- **Annualized Volatility**: The standard deviation of daily returns, annualized.
- **Sharpe Ratio**: The risk-adjusted return (assumed risk-free rate of 3%).
- **Max Drawdown**: The maximum observed loss from a peak to a trough.
- **Cumulative Return**: The total return over the backtesting period.

Cointegrated Pairs and Results

The following pairs were identified as cointegrated and were backtested:

C-USB

- **Annualized Return:** -0.11
- **Annualized Volatility:** 0.23
- **Sharpe Ratio:** -0.50
- **Max Drawdown:** 7.34
- **Cumulative Return:** -0.44

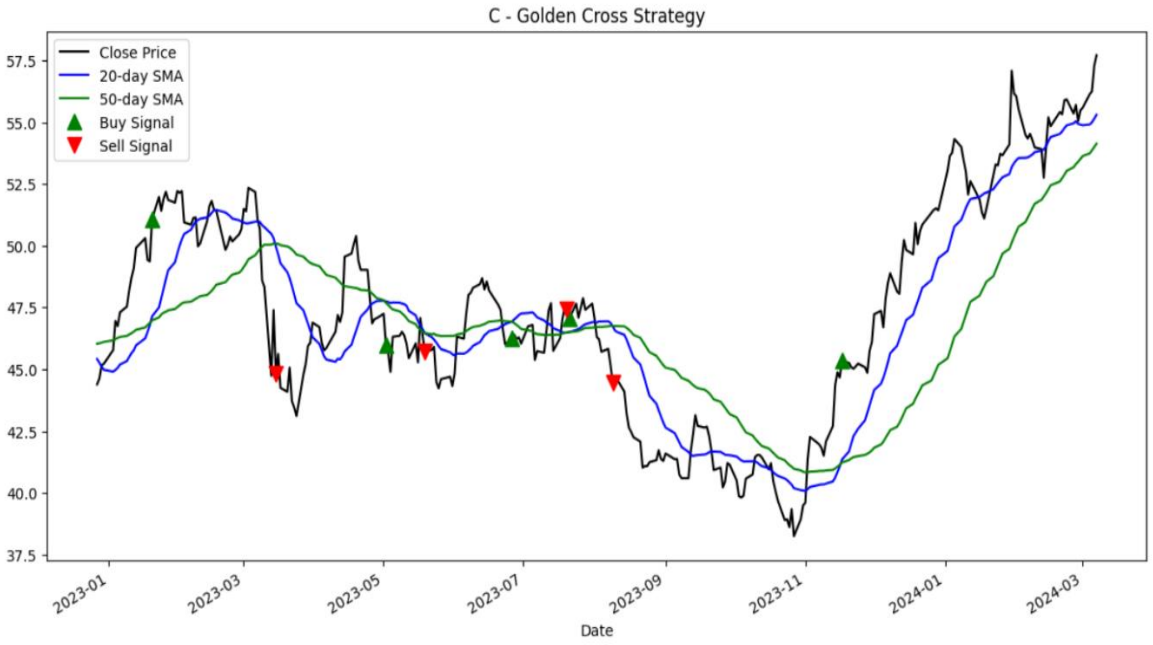
BAC-PNC

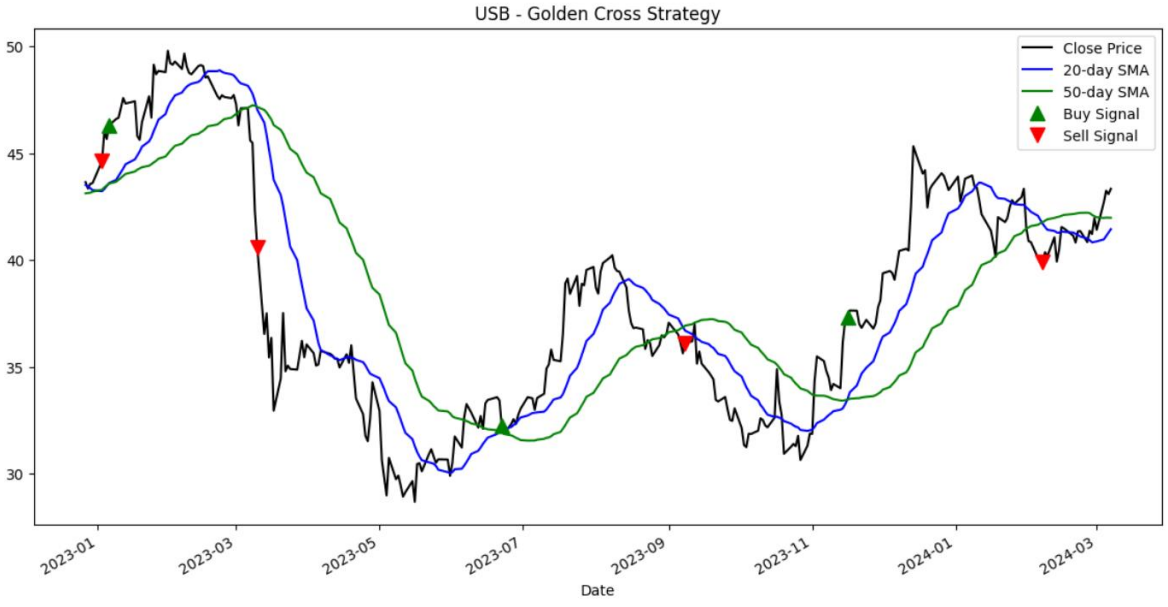
- **Annualized Return:** -0.18
- **Annualized Volatility:** 0.18
- **Sharpe Ratio:** -1.02
- **Max Drawdown:**505.34
- **Cumulative Return:** -0.56

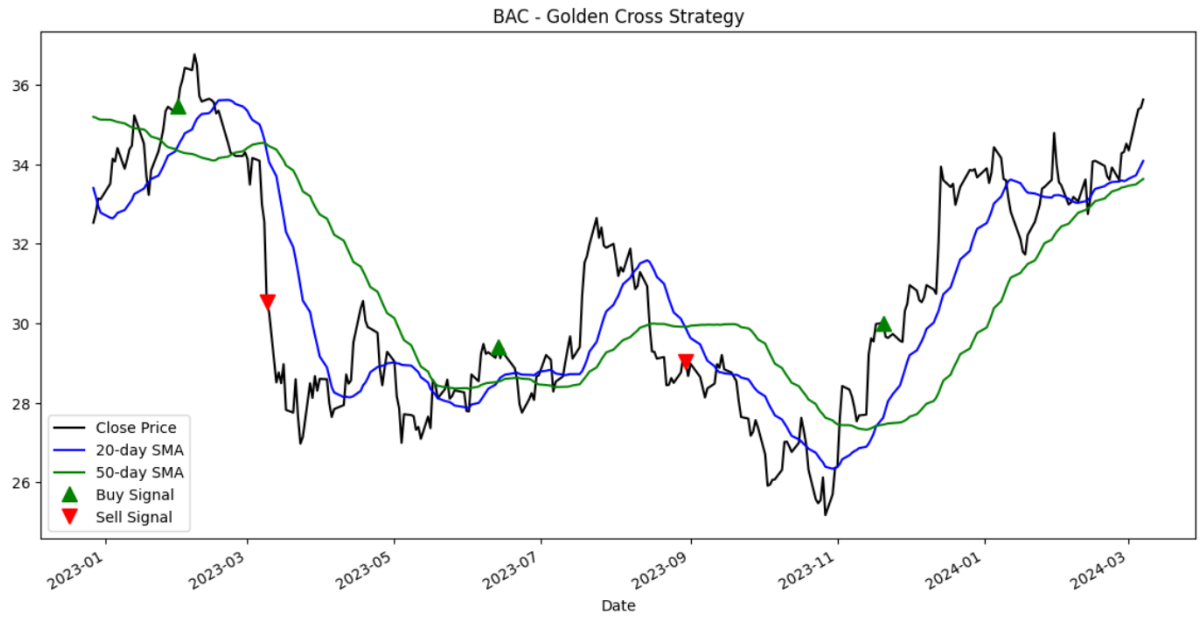
Visualization:

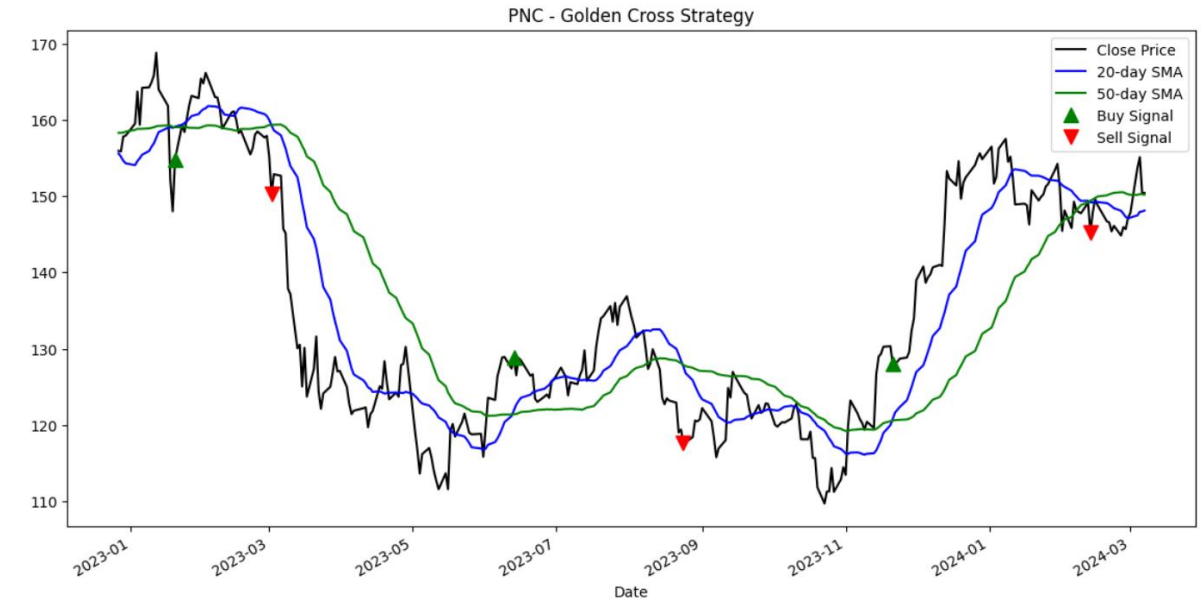
Generate Signals:

- Plot showing generated signals for each stock.





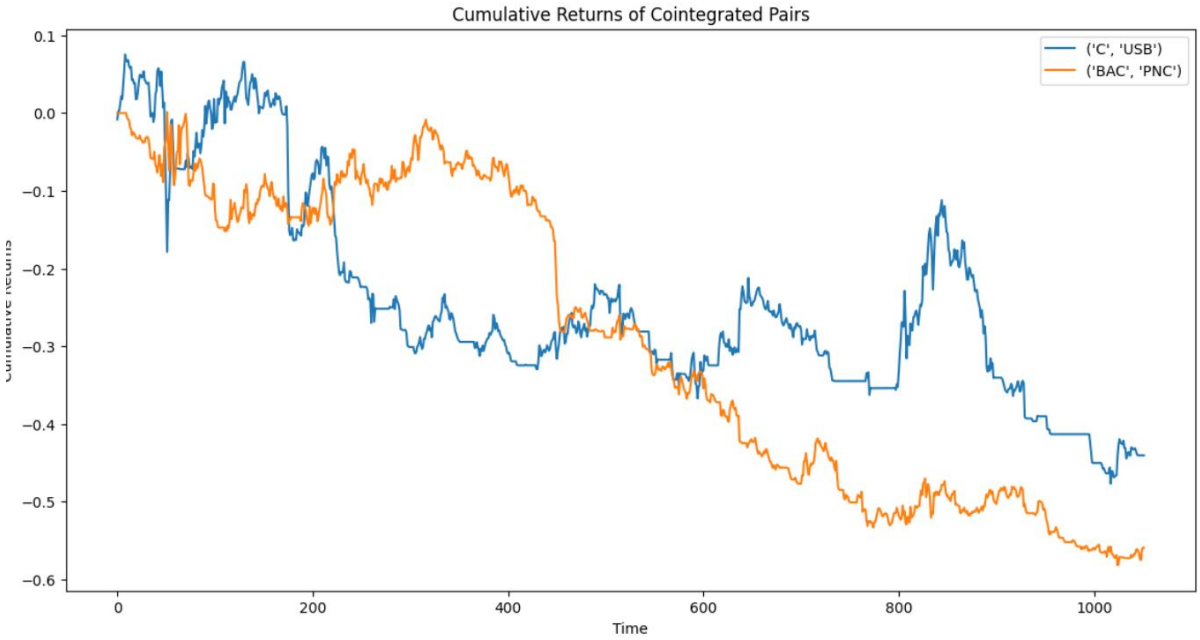




Backtesting Report:

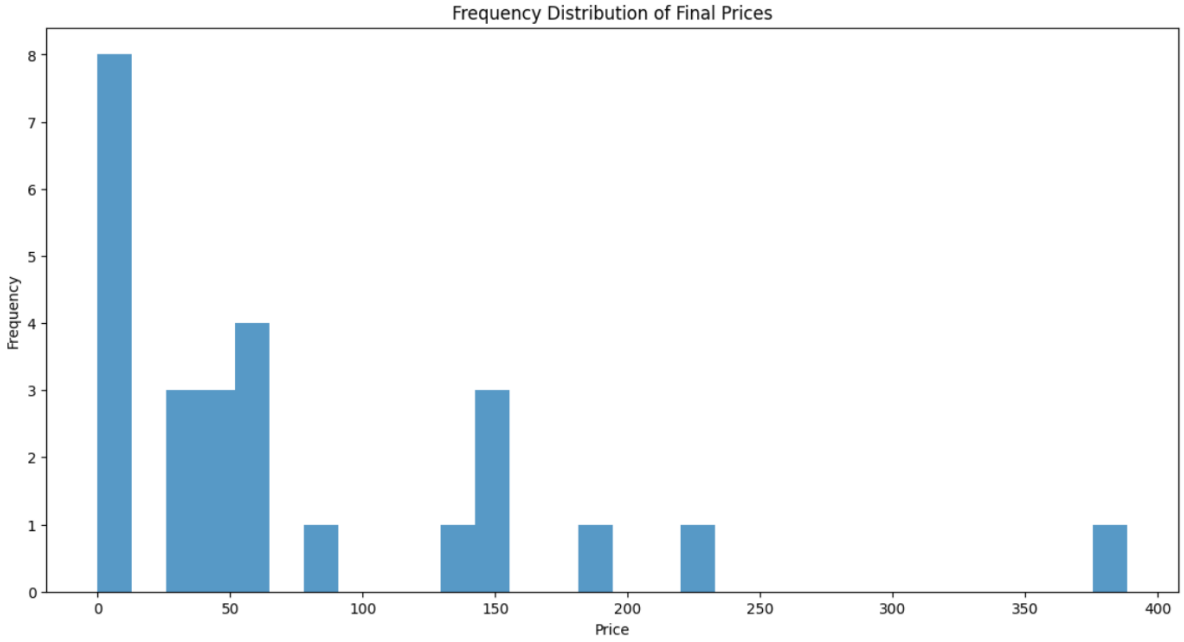
Cumulative Returns:

- Plot showing cumulative gross and net returns for each pair.



Frequency Distribution:

- Histogram showing the frequency distribution of final prices for each pair.



Nelder-mead

- While working on the code we have also used Nelder-Mead for optimization to find the optimal value of the coefficient b in the context of your pairs trading strategy.
- Nelder-Mead is a derivative-free optimization algorithm. This makes it suitable for problems where the objective function is not differentiable or when calculating the gradient is difficult or computationally expensive.
- Nelder-Mead is used to find the value of b that minimizes the unit_root function, i.e., the value of b that makes the residuals as stationary as possible.

```
res1 = spop.minimize(unit_root, data[stock2][t] / data[stock1][t], method='Nelder-Mead')
t_opt = res1.fun
b_opt = float(res1.x)
a_opt = np.average(data[stock2][t-window:t] - b_opt * data[stock1][t-window:t])
fair_value = a_opt + b_opt * data[stock1][t]
```

• O**bjective Function**: The function `unit_root` takes a coefficient b and calculates how well the linear combination of stock prices fits the assumption of stationarity.

• **Minimization**: By minimizing this function, we find the best possible coefficient b that makes the combination of the two stock prices (adjusted by b) most likely to revert to a mean.

Risk Analysis

The strategy's risk was evaluated based on annualized volatility and maximum drawdown:

- **Annualized Volatility**: The strategy exhibited moderate to high volatility across different pairs, indicating the inherent risk in pair trading.
- **Max Drawdown**: The maximum drawdowns were significant, with some pairs experiencing losses from peak to trough.

Conclusion

- The backtesting results indicate that while the strategy showed potential for identifying profitable trades, it also carried substantial risk as evidenced by the high volatility and significant drawdowns. The Sharpe ratios were generally low or negative, suggesting that the risk-adjusted returns may not be attractive without further refinement of the strategy. Future improvements could include dynamic threshold adjustments, risk management techniques, and exploring other signal generation methods.

- This comprehensive report provides a thorough analysis of the backtesting results and offers valuable insights into the historical performance and risk associated with the trading strategy.