**TRADING STRATEGY ROBUSTNESS ANALYSIS REPORT**

PREPARED BY

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# Background

This analysis focused on testing the robustness of five trading strategies. In this study, we aim to objectively evaluate the performance of these strategies across various market conditions. As the financial landscape shifts, understanding the reliability and effectiveness of different trading approaches is crucial for traders seeking to navigate markets successfully. The strategies below have been considered for robustness tests.

1. Bollinger Bands
2. Relative Strength Index (RSI)
3. Moving Average Convergence Divergence (MACD)
4. Simple Moving Average Crossover Strategy
5. Stochastic Oscillator

# Performance

## Trading Strategies

In this version of the report, the strategies have been tested on the ‘EUR/USD’ fiat currency pair, with data loaded from the Yahoo Finance (yfinance) API. The following criteria is applied:

* Currency pair – ‘EUR/USD’
* Period – 2 years
* Interval – 1 hour
* Start date - As a requirement in the yfinance API, we cannot fetch hourly data beyond 730 days. Therefore, we use start date that is 729 days from the current date
* End date – The current day’s date

### Strategy Datasets

This parent dataset loaded above is then sliced into two separate datasets:

* 'insample\_dataset' – This contains data from the start date to the date 365 days / 1 year ahead in the future
* 'outsample\_dataset' – This contains data from 1 day after the end date of the ‘*'insample\_dataset*'  to the current day’s date

### Strategy Setup

#### Bollinger Bands

The Bollinger Bands are created using the pandas ta library with the parameters below:

* Exponential Moving Average window of 60
* Standard Deviation of 2

A graph showing a line of stock

Description automatically generated with medium confidence

#### Relative Strength Index (RSI)

The RSI series is created using the pandas ta library with the parameters below,:

* RSI window of 14
* RSI scalar of 100
* Lower threshold of 30
* Upper threshold of 70

A graph showing a red line

Description automatically generated

#### Moving Average Convergence Divergence (MACD)

The MACD is generated using the pandas ta library with the parameters below,:

* Fast line of 12
* Slow line of 25
* Signal line of 5

A graph of red lines

Description automatically generated with medium confidence

#### Simple Moving Average Strategy Crossover

The SMA is generated using the pandas ta library with the parameters below:

* SMA short window length of 30
* SMA long window length of 30

A graph showing the value of a stock market

Description automatically generated

#### Stochastic Oscillator

The Stochastic Oscillator series is generated using the pandas ta library with the parameters below,:

* Fast line of 1
* Slow line of 3
* Smooth value of 3
* Offset of 0
* Lower threshold of 20
* Upper threshold of 80

A blue and red lines

Description automatically generated

## Backtesting and Cross Validation

### Backtesting.py Strategy Setup

To backtest our strategy, we use the python library **backtesting.py**.

First, we define a four indicator functions below, that will create the technical indicators to be used by the Strategy class:

1. **bands\_indicator**

Buy - If Closing Price crosses over the Upper Bollinger Band

Sell - If Closing Price crosses below the Lower Bollinger Band

1. **rsi\_indicator**

Buy - If RSI crosses over the Upper Threshold

Sell - If RSI crosses below the Lower Threshold

1. **macd\_indicator**

Buy - If MACD line crosses over the Signal Line

Sell - If MACD line crosses below the Signal Line

1. **sma\_indicator**

Buy - If Closing Price crosses over the SMA line

Sell = If Closing Price crosses below the SMA line

1. **stoch\_indicator**

Buy - If %K line crosses above the %D line, set our position to close because the price is predicted to drop

Sell - If %K line crosses below the %D line, enter a buy position because the price is predicted to increase

### Backtesting and validating a single currency pair EUR/USD

All backtests were run with cash of $10,000 and commission at 0.24% per trade

#### Bollinger Bands

**Results**

Result Value

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10135.4448976203

Final Equity 6422.168181221631

Sharpe Ratio 0.0

PnL $-3577.832

Return % -35.778%

Win Rate [%] 27.044%

Number of trades 159

**Close-to-Close Equity Lines**

**A graph with a line graph

Description automatically generated**

#### Relative Strength Index (RSI)

**Results**

RSI Backesting results with investment of 10000 and commission of 0.24%

Result Value

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10318.99836582594

Final Equity 5684.029825890044

Sharpe Ratio 0.0

PnL $-4315.97

Return % -43.16%

Win Rate [%] 23.316%

Number of trades 193

**Close-to-Close Equity Lines**

A graph with a line graph

Description automatically generated

#### Moving Average Convergence Divergence (MACD)

**Results**

MACD Backesting results with investment of 10000 and commission of 0.24%

Result Value

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10000.0

Final Equity 1966.3638600280174

Sharpe Ratio 0.0

PnL $-8033.636

Return % -80.336%

Win Rate [%] 18.82%

Number of trades 627

**Close-to-Close Equity Lines**

A graph with a red line

Description automatically generated

#### Simple Moving Average Strategy

**Results**

SMA Backesting results with investment of 10000 and commission of 0.24%

Result Value

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10000.0

Final Equity 9018.02921655096

Sharpe Ratio 0.0

PnL $-981.971

Return % -9.82%

Win Rate [%] 25.0%

Number of trades 76

**Close-to-Close Equity Lines**

**A graph with a line graph

Description automatically generated**

#### Stochastic Oscillator

**Results**

Stochastic Oscillator Backesting results with investment of 10000 and commission of 0.24%

Result Value

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 11489.206572299101

Final Equity 10357.437455777077

Sharpe Ratio 0.35303

PnL $357.437

Return % 3.574%

Win Rate [%] 50.0%

Number of trades 8

**Close-to-Close Equity Lines**

A graph with a red line

Description automatically generated

#### Insample Backtest Performance Summary

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicator** | **Final PnL** | **Number of Trades** | **Profitable** |
| MACD | 357 | 8 | Yes |
| SMA Crossover | -981 | 76 | No |
| Bollinger Bands | -3,577 | 159 | No |
| RSI | -4,315 | 193 | No |
| Stochastic Oscillator | -6,588 | 473 | No |

### Optimizing Backtest Hyperparameters for EUR/USD

To optimize this strategy, we take the instances of the Strategy classes created above and run the backtesting.py function optimize () on it.

#### Bollinger Bands

**Hyperparameter Ranges**

* Exponential Moving Average: Range 20 to 71 with a step value of 1
* Standard Deviation: Range 1 to 3 with a step value of 0.5

##### Optimized Backtest Results

Bollinger Bands Optimized Backesting Results

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10944.31382699768

Final Equity 10439.820269442676

Sharpe Ratio 0.41151

PnL $439.82

Return % 4.398%

Win Rate [%] 41.86%

Number of trades 43

**Close-to-Close Equity Lines**

**A graph with a line graph and numbers

Description automatically generated**

##### Cross Validation Results

**Optimization Heatmap for EUR/USD**

**A chart of different colors

Description automatically generated**

**Cross-validation Results Table**

Backesting optimized reults with investment of 10000 and commission of 1%

Result Value

---------------- -------------------------

Start Date 2022-12-05 00:00:00+00:00

End Date 2023-12-01 22:00:00+00:00

Peak Equity 10982.876085256585

Final Equity 9287.915450146686

Sharpe Ratio 0.0

PnL $-712.085

Return % -7.121%

Win Rate [%] 34.211%

Number of trades 38

**Cross-validation Close-to-Close Equity Lines**

**A graph showing a line graph

Description automatically generated**

#### RSI

**Hyperparameter Ranges**

* RSI window: In the range of 20 to 71 with a step value of 1
* RSI scalar: In the range of 5 to 50 with a step value of 5

**Optimized Backtest Results**

RSI Optimized Backesting Results

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 11662.776385172574

Final Equity 11326.978769644467

Sharpe Ratio 1.15946

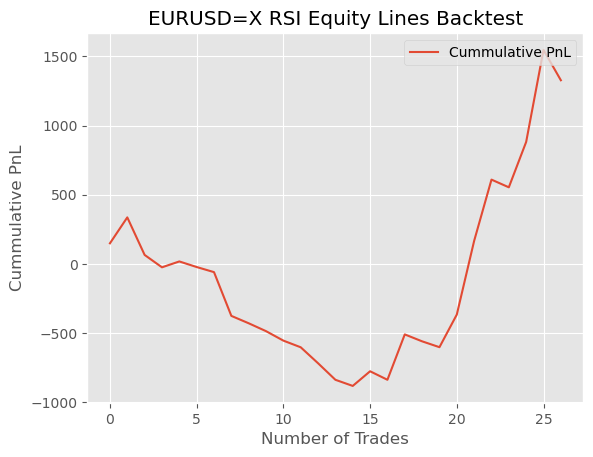
PnL $1326.979

Return % 13.27%

Win Rate [%] 37.037%

Number of trades 27

**Close-to-Close Equity Lines**

****

##### Cross Validation Results

**Optimization Heatmap for EUR/USD**

**A screenshot of a graph

Description automatically generated**

**Cross-validation Results Table**

Backesting optimized reults with investment of 10000 and commission of 1%

Result Value

---------------- -------------------------

Start Date 2022-12-05 00:00:00+00:00

End Date 2023-12-01 22:00:00+00:00

Peak Equity 11051.097857368095

Final Equity 10588.181074396143

Sharpe Ratio 0.75864

PnL $588.181

Return % 5.882%

Win Rate [%] 35.0%

Number of trades 20

**Cross-validation Close-to-Close Equity Lines**

**A graph with red line

Description automatically generated**

#### MACD

**Hyperparameter Ranges**

* MACD fast window: in the range of 10 to 30 with a step value of 2
* MACD slow window: in the range of 10 to 50 with a step value of 2
* MACD signal window: in the range of 5 to 20 with a step value of 1

**Optimized Backtest Results**

MACD Optimized Backesting Results

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10038.347850990294

Final Equity 6090.757344064357

Sharpe Ratio 0.0

PnL $-3909.243

Return % -39.092%

Win Rate [%] 26.316%

Number of trades 228

**Close-to-Close Equity Lines**

**A graph showing a number of trades

Description automatically generated**

##### Cross Validation Results

**Optimization Heatmap for EUR/USD**

**A chart of different colors

Description automatically generated with medium confidence**

**Cross-validation Results Table**

Backesting optimized reults with investment of 10000 and commission of 1%

Result Value

---------------- -------------------------

Start Date 2022-12-05 00:00:00+00:00

End Date 2023-12-01 22:00:00+00:00

Peak Equity 10003.346322757721

Final Equity 6044.868107915185

Sharpe Ratio 0.0

PnL $-3955.132

Return % -39.551%

Win Rate [%] 23.223%

Number of trades 211

**Cross-validation Close-to-Close Equity Lines**

**A graph showing a line graph

Description automatically generated with medium confidence**

#### SMA Crossover

**Hyperparameter Ranges**

* SMA short window: in the range of 10 to 50 with a step value of 5
* SMA short window: in the range of 50 to 200 with a step value of 5

**Optimized Backtest Results**

SMA Optimized Backesting Results

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 10007.37507589274

Final Equity 9895.859741315875

Sharpe Ratio 0.0

PnL $-104.14

Return % -1.041%

Win Rate [%] 27.711%

Number of trades 83

**Close-to-Close Equity Lines**

**A graph showing the number of trades

Description automatically generated**

##### Cross Validation Results

**Optimization Heatmap for EUR/USD**

**A chart of different colors

Description automatically generated with medium confidence**

**Cross-validation Results Table**

Backesting optimized reults with investment of 10000 and commission of 1%

Result Value

---------------- -------------------------

Start Date 2022-12-05 00:00:00+00:00

End Date 2023-12-01 22:00:00+00:00

Peak Equity 10014.065880002212

Final Equity 7187.209823538237

Sharpe Ratio 0.0

PnL $-2812.79

Return % -28.128%

Win Rate [%] 23.333%

Number of trades 90

**Cross-validation Close-to-Close Equity Lines**

**A graph with a line going up

Description automatically generated**

#### Stochastic Oscillator

**Hyperparameter Ranges**

* Slow window: 1
* Fast window: In the range of 1 to 3 with a step value of 1
* Smooth window: In the range of 1 to 3 with a step value of 1

**Optimized Backtest Results**

Stochastic Oscillator Optimized Backesting Results

---------------- -------------------------

Start Date 2021-12-03 00:00:00+00:00

End Date 2022-12-02 22:00:00+00:00

Peak Equity 11214.717336701891

Final Equity 9954.403920264222

Sharpe Ratio 0.0

PnL $-45.596

Return % -0.456%

Win Rate [%] 47.5%

Number of trades 40

**Close-to-Close Equity Lines**

**A graph with red line

Description automatically generated**

##### Cross Validation Results

**Cross-validation Results Table**

Backesting optimized results with investment of 10000 and commission of 1%

Result Value

---------------- -------------------------

Start Date 2022-12-05 00:00:00+00:00

End Date 2023-12-01 22:00:00+00:00

Peak Equity 10005.279791479494

Final Equity 9227.887282471575

Sharpe Ratio 0.0

PnL $-772.113

Return % -7.721%

Win Rate [%] 45.833%

Number of trades 24

**Cross-validation Close-to-Close Equity Lines**

**A graph with a line graph

Description automatically generated**

#### Outsample Cross-Validation Performance Summary (EUR/USD)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Indicator** | **Initial PnL** | **Optimized PnL** | **Cross-validation** | **Initial Parameters** | **Optimized Parameters** | **Performance** |
| Bollinger Bands | -3,577 | 439.82 | -712.085 | EMA Window 16  STD 2 | EMA Window 65  STD 3 | Improved |
| RSI | -4,315 | 1326.979 | 588.181 | Length 14  Scalar 100 | Length 33s  Scalar 100 | Improved |
| MACD | -6588 | -3909.243 | -3955.132 | Fast 12  Slow 25  Smooth 5 | Fast 28  Slow 48  Smooth 19 | Improved |
| SMA Crossover | -981 | -104.14 | -2812.79 | Short 30  Long 100 | Short 35  Long 80 | Lowered |
| Stochastic Oscillator | 357 | -45.596 | -772.113 | Fast 1  Slow 3  Smooth 3  Offset 0 | Fast 1  Slow 2  Smooth 2  Offset 0 | Lowered |

### Backtesting and validating multiple currency pairs

In this section, we apply the logic above to the list of nineteen currency pairs below:

#### Here is the list presented as a numbered word list:

#### 1. USDJPY=X

#### 2. GBPUSD=X

#### 3. AUDUSD=X

#### 4. USDCAD=X

#### 5. USDCHF=X

#### 6. EURGBP=X

#### 7. EURJPY=X

#### 8. GBPJPY=X

#### 9. EURCHF=X

#### 10. USDNOK=X

#### 11. USDCNY=X

#### 12. EURCAD=X

#### 13. USDHKD=X

#### 14. USDSGD=X

#### 15. USDKRW=X

#### 16. USDSGD=X

#### 17. EURAUD=X

#### 18. EURNZD=X

#### 19. GBPCHF=X

#### Multiple currency backtesting data

For each currency pair in the currency list, we download data with­­­ the following criteria from the yfinance API:

* Period – 2 years
* Interval – 1 hour
* Start date - As a requirement in the yfinance API, we cannot fetch hourly data beyond 730 days. Therefore, we use start date that is 729 days from the current date
* End date – The current day’s date

Each parent dataset is then sliced into two separate datasets:

* 'insample\_dataset' – This contains data from the start date to the date 365 days / 1 year ahead in the future
* 'outsample\_dataset' – This contains data from 1 day after the last date in the insample\_dataset  to the current day’s date

For each currency pair, the insample\_dataset is saved to a file in the insample directory, and 'outsample\_dataset' saved to the outsample directory.

##### Backtesting

To backtest, we iterate through the currency data files in the insampledirectory. For each iteration:

1. Run each strategy on the dataset with cash of $10,000 and commission at 0.24% per trade. The initial parameter values for each strategy are maintained.
2. Run the backtesting.py optimize () function during each iteration, and select the hyperparameters for that currency pair
3. Select and save all the backtesting statistics
4. Save the currency pair, backtest statistics and optimal parameters into the list bulk\_backtest\_results.
5. Write the list bulk\_backtest\_results to the file ‘**backtest\_metrics.csv’ for each strategy**

##### **Cross-validation**

To cross-validate, we iterate through the currency data files in the outsampledirectory. For each iteration:

1. Load the currency’s file from the insample directory, and select the optimal hyperparameters
2. Run each trading strategy on the datasetwith cash of $10,000 and commission at 0.24% per trade.
3. Select and save all the cross-validation statistics
4. Save the currency pair and cross-validation statistics into the list bulk\_validate\_results
5. Write the list bulk\_validate\_results to the file ‘validation\_metrics.csv’ **for each strategy**

#### Bulk backtesting and cross-validation results and findings

##### Performance Summary

Below is a ranked summary of the strategy performance for the 20 currency pairs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Strategy** | **# Improved Trades (In 20)** | **# Worsened Trades (In 20)** | **# Profitable Trades (In 20)** | **# Non-Profitable Trades (In 20)** | **Improved Ratios (In 20)** |
| RSI | 13 | 7 | 9 | 11 | 7 |
| Bollinger Bands | 19 | 1 | 4 | 16 | 5 |
| Stochastic Oscillator | 3 | 17 | 2 | 19 | 2 |
| MACD | 19 | 1 | 0 | 20 | 0 |
| SMA Crossover | 8 | 12 | 0 | 20 | 0 |

##### Detailed Performance

To determine the robustness of a strategy, I have considered the Final Equity generated for each currency pair, against an investment of $10,000 and commission of 0.24%.

For each strategy, three considerations below have been made using the backtest and cross-validation metrics to determine robustness:

1. Total number of profitable currency pair trades out of 20 currency pairs
2. Number of currency pair trades that show improved performance on backtesting versus on cross-validation. In this case, improved performance includes both going from making a loss to making a profit and making a lower loss on cross-validation. Therefore, a strategy that makes a bigger loss on cross-validation is considered to have a worse performance
3. The change in Sharpe, Sortino and Calmar ratios. For context, the below must be considered:
   1. **Sharpe Ratio** – This is a ratio of the return of an investment with its risk [7]. This ratio considers the overall volatility of an investment.[8] A higher Sharpe ratio is preferred.
   2. **Sortino Ratio** – This is a ratio of the downside risk or negative volatility of a trade. A Sortino risk of two and above is considered ideal [9]
   3. **Calmar Ratio** - This is a ratio of the return of an investment with its risk. This ratio focuses on the worst-case scenario through the maximum drawdown. [8] A higher Calmar ratio, is preferred.

##### Bollinger Bands

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Currency Pair** | **Initial PnL** | **Optimized PnL** | **Final Sharpe Ratio** | **Final Sortino Ratio** | **Final Calmar Ratio** | **Performance** | **Profitable** |
| EURUSD=X | 439.82 | -712.085 | 0 | 0 | 0 | Lowered | No |
| AUDUSD=X | -2826.48 | 53.44352 | 0.04646 | 0.065417 | 0.042148 | Improved | Yes |
| EURAUD=X | -1151.02 | -1059.48 | 0 | 0 | 0 | Improved | No |
| EURCAD=X | -3887.28 | -2414.5 | 0 | 0 | 0 | Improved | No |
| EURCHF=X | -3246.39 | -1218.22 | 0 | 0 | 0 | Improved | No |
| EURGBP=X | -3041.5 | 283.367 | 0.474868 | 0.68657 | 0.70168 | Improved | Yes |
| EURJPY=X | -4516.84 | 1766.528 | 1.454421 | 2.509794 | 3.152124 | Improved | Yes |
| EURNZD=X | -2251.48 | -783.981 | 0 | 0 | 0 | Improved | No |
| GBPCHF=X | -3213.3 | -1302.01 | 0 | 0 | 0 | Improved | No |
| GBPJPY=X | -4162.31 | -569.041 | 0 | 0 | 0 | Improved | No |
| GBPUSD=X | -4242.09 | -376.694 | 0 | 0 | 0 | Improved | No |
| USDCAD=X | -2751.5 | -411.442 | 0 | 0 | 0 | Improved | No |
| USDCHF=X | -4061.75 | -625.709 | 0 | 0 | 0 | Improved | No |
| USDCNY=X | -3231.48 | -1430.52 | 0 | 0 | 0 | Improved | No |
| USDHKD=X | -3774.41 | -1603.16 | 0 | 0 | 0 | Improved | No |
| USDJPY=X | -3987.38 | -1006.62 | 0 | 0 | 0 | Improved | No |
| USDKRW=X | -3230.92 | -1728.97 | 0 | 0 | 0 | Improved | No |
| USDNOK=X | -2691.77 | 663.1463 | 0.449165 | 0.70007 | 0.586914 | Improved | Yes |
| USDSGD=X | -3476.87 | -955.037 | 0 | 0 | 0 | Improved | No |

The Bollinger Bands indicator shows the second-best performance of the 5 strategies.

1. 19 of the 20 currency pairs show an improved performance on cross-validation. Although they are still making losses, the losses are lower than those incurred during backtesting. The one strategy that shows a worsened performance loses $712 dollars, which when compared to the other currency pairs’ final PnLs ranks among the lower losses made.
2. 4 of the 20 are profitable on cross-validation with positive ratios.

##### RSI

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Currency Pair** | **Initial PnL** | **Optimized PnL** | **Final Sharpe Ratio** | **Final Sortino Ratio** | **Final Calmar Ratio** | **Performance** | **Profitable** |
| EURUSD=X | 1326.979 | 588.181 | 0 | 0 | 0 | Lowered | Yes |
| AUDUSD=X | -3295.25 | 402.314 | 0.378576 | 0.552038 | 0.538607 | Improved | Yes |
| EURAUD=X | -2935.84 | 50.33214 | 0.051888 | 0.071244 | 0.052277 | Improved | Yes |
| EURCAD=X | -3146.24 | -490.393 | 0 | 0 | 0 | Improved | No |
| EURCHF=X | -3305.5 | 0 | nan | nan | nan | Improved | No |
| EURGBP=X | -2501.92 | -270.617 | 0 | 0 | 0 | Improved | Yes |
| EURJPY=X | -3475.07 | 90.83062 | 0.088502 | 0.121494 | 0.08953 | Improved | Yes |
| EURNZD=X | -1808.12 | -974.204 | 0 | 0 | 0 | Improved | No |
| GBPCHF=X | -3488.21 | 174.5158 | 0.311075 | 0.446034 | 0.326818 | Improved | Yes |
| GBPJPY=X | -3232.57 | -323.926 | 0 | 0 | 0 | Improved | No |
| GBPUSD=X | -3784.16 | -276.495 | 0 | 0 | 0 | Improved | No |
| USDCAD=X | -3021.99 | 0 | nan | nan | nan | Improved | No |
| USDCHF=X | -4302.64 | -479.844 | 0 | 0 | 0 | Improved | No |
| USDCNY=X | -4122.97 | -552.335 | 0 | 0 | 0 | Improved | No |
| USDHKD=X | -1808.83 | -204.608 | 0 | 0 | 0 | Improved | No |
| USDJPY=X | -4663.44 | 862.6549 | 0.76966 | 1.190809 | 1.188121 | Improved | Yes |
| USDKRW=X | -3644.12 | -115.551 | 0 | 0 | 0 | Improved | No |
| USDNOK=X | 1326.979 | 588.181 | 0.559252 | 0.831043 | 0.65424 | Lowered | Yes |
| USDSGD=X | -3295.25 | 402.314 | 0.009587 | 0.0128 | 0.008714 | Improved | Yes |

The RSI indicator shows the best performance of the 5 strategies.

1. 18 of the 20 currency pairs show an improved performance on cross-validation. Though this figure is lower than the 19 of 20 in the Bollinger Bands Strategy, RSI has 9 profitable currency-pair investments compared to the 4 for Bollinger Bands.
2. 2 currency pairs do not execute trades and require further checks

##### MACD

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Currency Pair** | **Initial PnL** | **Optimized PnL** | **Final Sharpe Ratio** | **Final Sortino Ratio** | **Final Calmar Ratio** | **Performance** | **Profitable** |
| EURUSD=X | -3909.243 | -3955.132 | 0 | 0 | 0 | Lowered | No |
| AUDUSD=X | -8108.45 | -4649.85 | 0 | 0 | 0 | Improved | No |
| EURAUD=X | -7330.94 | -6031.07 | 0 | 0 | 0 | Improved | No |
| EURCAD=X | -7760.71 | -5471.45 | 0 | 0 | 0 | Improved | No |
| EURCHF=X | -8266.69 | -5545.54 | 0 | 0 | 0 | Improved | No |
| EURGBP=X | -7666.37 | -5510.16 | 0 | 0 | 0 | Improved | No |
| EURJPY=X | -7459.28 | -4878.03 | 0 | 0 | 0 | Improved | No |
| EURNZD=X | -8057.12 | -5613.41 | 0 | 0 | 0 | Improved | No |
| GBPCHF=X | -8119.09 | -6502.73 | 0 | 0 | 0 | Improved | No |
| GBPJPY=X | -7091.97 | -4277.9 | 0 | 0 | 0 | Improved | No |
| GBPUSD=X | -7337.56 | -6177.05 | 0 | 0 | 0 | Improved | No |
| USDCAD=X | -7615.29 | -4770.58 | 0 | 0 | 0 | Improved | No |
| USDCHF=X | -8392.15 | -5458.53 | 0 | 0 | 0 | Improved | No |
| USDCNY=X | -6716.47 | -4474.94 | 0 | 0 | 0 | Improved | No |
| USDHKD=X | -8810.28 | -5728.63 | 0 | 0 | 0 | Improved | No |
| USDJPY=X | -7361.28 | -4710.64 | 0 | 0 | 0 | Improved | No |
| USDKRW=X | -6704.55 | -4085.68 | 0 | 0 | 0 | Improved | No |
| USDNOK=X | -7869.32 | -5239.09 | 0 | 0 | 0 | Improved | No |
| USDSGD=X | -8063.35 | -5610.3 | 0 | 0 | 0 | Improved | No |

The MACD indicator ranks fourth in performance out of the 5 strategies.

1. On cross-validation, all the currency pairs continue to make losses, though the losses are lower than those incurred on backtesting
2. The MACD makes significantly large losses, losing between 45% to 88% of the total investment, which shows poor performance.
3. No currency pairs show profitable investments

##### SMA Crossover

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Currency Pair** | **Initial PnL** | **Optimized PnL** | **Final Sharpe Ratio** | **Final Sortino Ratio** | **Final Calmar Ratio** | **Performance** | **Profitable** |
| EURUSD=X | -104.14 | -2812.79 | 0 | 0 | 0 | Lowered | No |
| AUDUSD=X | -2854.89 | -1471.43 | 0 | 0 | 0 | Improved | No |
| EURAUD=X | -2786.68 | -1241.19 | 0 | 0 | 0 | Improved | No |
| EURCAD=X | -664.903 | -1758.14 | 0 | 0 | 0 | Lowered | No |
| EURCHF=X | -1235.83 | -2111.13 | 0 | 0 | 0 | Lowered | No |
| EURGBP=X | -1285.09 | -1727.74 | 0 | 0 | 0 | Lowered | No |
| EURJPY=X | -349.544 | -2741.73 | 0 | 0 | 0 | Lowered | No |
| EURNZD=X | -2054.73 | -1753.68 | 0 | 0 | 0 | Improved | No |
| GBPCHF=X | -1269.04 | -1197.07 | 0 | 0 | 0 | Improved | No |
| GBPJPY=X | 756.7595 | -2895.06 | 0 | 0 | 0 | Lowered | No |
| GBPUSD=X | -1107.76 | -1276.43 | 0 | 0 | 0 | Lowered | No |
| USDCAD=X | -3304.9 | -1550.92 | 0 | 0 | 0 | Improved | No |
| USDCHF=X | -46.5606 | -2922.98 | 0 | 0 | 0 | Lowered | No |
| USDCNY=X | -1393.8 | -535.86 | 0 | 0 | 0 | Improved | No |
| USDHKD=X | -1820.5 | -727.463 | 0 | 0 | 0 | Improved | No |
| USDJPY=X | -427.023 | -1720.16 | 0 | 0 | 0 | Lowered | No |
| USDKRW=X | -844.876 | -1494.59 | 0 | 0 | 0 | Lowered | No |
| USDNOK=X | -2166.62 | -1449.03 | 0 | 0 | 0 | Improved | No |
| USDSGD=X | -654.526 | -1873.24 | 0 | 0 | 0 | Lowered | No |

The SMA Crossover indicator shows the worst performance out of the 5 strategies.

1. Though 8 of the currency pairs show an improved performance, none of the investments are profitable on cross-validation

##### Stochastic Oscillator

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Currency Pair** | **Initial PnL** | **Optimized PnL** | **Final Sharpe Ratio** | **Final Sortino Ratio** | **Final Calmar Ratio** | **Performance** | **Profitable** |
| EURUSD=X | -45.596 | -772.113 | 0 | 0 | 0 | Lowered | No |
| AUDUSD=X | -188.99 | -1674.85 | 0 | 0 | 0 | Lowered | No |
| EURAUD=X | -486.616 | -580.291 | 0 | 0 | 0 | Lowered | No |
| EURCAD=X | 333.7083 | -442.9 | 0 | 0 | 0 | Lowered | No |
| EURCHF=X | -693.174 | -1297.57 | 0 | 0 | 0 | Lowered | No |
| EURGBP=X | 0 | 378.8307 | 0.652283 | 1.017039 | 0.944213 | Improved | Yes |
| EURJPY=X | 624.2178 | -718.81 | 0 | 0 | 0 | Lowered | No |
| EURNZD=X | -463.564 | -685.189 | 0 | 0 | 0 | Lowered | No |
| GBPCHF=X | -619.715 | -652.059 | 0 | 0 | 0 | Lowered | No |
| GBPJPY=X | 637.2335 | -1162.22 | 0 | 0 | 0 | Lowered | No |
| GBPUSD=X | -547.035 | -534.656 | 0 | 0 | 0 | Improved | No |
| USDCAD=X | 456.1877 | -653.797 | 0 | 0 | 0 | Lowered | No |
| USDCHF=X | -164.771 | -1011.57 | 0 | 0 | 0 | Lowered | No |
| USDCNY=X | 20.74069 | -974.734 | 0 | 0 | 0 | Lowered | No |
| USDHKD=X | -365.552 | -1117.52 | 0 | 0 | 0 | Lowered | No |
| USDJPY=X | 1383.371 | -33.4917 | 0 | 0 | 0 | Lowered | No |
| USDKRW=X | -101.052 | -940.94 | 0 | 0 | 0 | Lowered | No |
| USDNOK=X | 0 | 203.2383 | 0.154295 | 0.236189 | 0.181256 | Improved | Yes |
| USDSGD=X | 392.7346 | -607.423 | 0 | 0 | 0 | Lowered | No |

The Stochastic Oscillator indicator ranks third out of the 5 strategies.

1. Though only 3 of the currency pair investments how an improved performance compared to the 8 for the SMA Crossover Strategy, two of the pairs are profitable on cross-validation, compared to the SMA Crossover Strategy which had none.
2. This indicator fails to generate the %K and %d series for the insample data when the fast value is not 1. The slow and smooth ranges used for hyper-parameterization are also low, between 1 and 3. This will be reviewed for improvement.

##### Conclusion

In conclusion, according to my findings Relative Strength Index (RSI) is the most robust trading strategy for hourly data.

## Costs and Backtesting Assumptions

1. The costs assumed for this backtest were an investment of $10,000 and commission of 0.24%
2. All trading activities were performed at the adjusted closing price at that day (retrieved from Yahoo finance)
3. Volume of each trading activities was unlimited

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