# Vol Trade v.1

## Investment Strategy Testing Summary

**Vol Trade v.1** strategy is a swing trading technique based on **volatility contraction** and **range extension** in the direction of the prevailing trend. In its long version, it combines **a trend filter** (close above the long-term moving average) with the condition that **short-term volatility** falls to **a fraction of long-term volatility** and **remains there for a set number of sessions. After such a period of low volatility, a strong bullish candle** (the largest since the contraction began) generates a signal, which simultaneously sets **a new local high.**

The strategy **does not use stop loss orders;** the exit occurs when **short-term volatility exceeds long-term volatility** (volatility regime shift).

Although the strategy's logic seems sound, **it fails the Monte Carlo test.** This means the strategy loses its profitability and generates significantly larger drawdowns when tested under suboptimal conditions. Therefore, **it is not recommended for use in real-world trading.**

Our goal is to have a strategy that remains **profitable and effective across a wide range of parameters,** because the market is a volatile organism, and optimal parameters can change over time. **I can't** emphasize enough that for **a strategy to work** in real-world conditions, it must also perform under **suboptimal parameters** and **conditions.** In short, **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly capture the problem of many optimizations:

***"I've never seen a strategy that didn't work in backtests."***

**We don't know the future,** we don't know future market conditions, but if we know that our strategy **has historically generated acceptable results** in various market conditions and across various parameter ranges, then we are **one step ahead of other** market participants.

# Contents

# Step 1: Formulate an investment strategy

**Vol Trade v.1** strategy joins **an ongoing trend** when the market transitions from **a low-volatility regime** to **an impulse.** The trend context is confirmed by **a long-term moving average** – long positions are only considered when the price closes **above** this average. The preparatory condition is **sustained short-term volatility below the long-term level** for **several sessions.** The breakout is confirmed by **a candle with the largest range since the contraction,** which establishes **a new local extreme** and closes in the direction of the prevailing trend. Entry is made **at the open of the following day.**

Exiting the position occurs **only** when **the volatility regime changes** – **short-term volatility above long-term.** The lack of a stop loss emphasizes the need for conservative position sizing and consistent exposure management.

**The strategy uses:**

- **Trend Filter (SMA Long)** – selection of direction according to the dominant movement;
- **Variation ratio** – VolShort/VolLong ≤ threshold for a specified number of sessions (contraction);
- **Range expansion + extreme** – the signal candle is the widest since the beginning of the contraction and establishes a local high;
- **Entry T+1** – opening a position at the start of the next session;
- **Regime Change Reach** – close when short-term volatility ≥ long-term volatility.

**Characteristics – strengths and weaknesses:**

- **Quantitative, simple rules** (trend, contraction, breakout) – facilitate automation and testing;
- **Entry after confirmation –** reducing "false starts" typical of catching traffic early;
- **Lack of stop loss increases the risk of drawdowns and gaps** – strict control of position size is necessary;
- **Selectivity** – the required maintenance of contractions may limit the number of transactions;
- **Sensitivity to the definition of variability** – parameter sensitivity analysis recommended.

**Vol Trade v.1 strategy,** while simple, provides **a solid foundation for building algorithmic portfolios.** However, it requires **discipline and strict adherence to risk management methods.**

## Step 2: Determine investment principles

Below is **the pseudocode** for the **Vol Trade v.1 strategy** on daily data:

1. **Calculating Indicators:**
    a. **XXX-MALong –** XXX day moving average closing price.
    b. **XXX-VolLong** – XXX day variability (sum of squared deviations).
    c. **YY-VolShort** – YY day variability (sum of squared deviations).
    d. **WW-VolRatio** – VolShort/VolLong variability ratio below WW%.
    e. **ZZ-HighestHigh** – ZZ daily highest high.
    f. **ZZ-MaxRange** – maximum daily range (high−low) in the last ZZ sessions.
2. **Generating Entry Signals – Long Position:**
    a. **Trend:** closing price above MALong.
    b. **Volatility contraction:** for ZZ of subsequent VolShort/VolLong sessions below WW%.
    c. **Extension and extremum:** today's price range (high-low) is greater than MaxRange and today's high forms the highest high since ZZ days (HighestHigh) and today's candle is bullish.
    d. **Entry:** Once the conditions are met, a long position is opened at the opening of the next session.
3. **Generating Output Signals:**
    a. **Volatility regime change:** close all positions at the opening of the next session when VolShort > VolLong.
4. **Daily Monitoring:**
    a. Calculate MALong, VolShort, VolLong, VolRatio, HighestHigh and MaxRange every day.
    b. The system verifies entry/exit conditions and sets appropriate orders for the opening of the next session; it monitors the volatility regime.
5. **Additional Notes:**
    a. **No Short Positions:** The strategy focuses solely on long positions in an uptrend.
    b. **Financial Instruments:** For the purposes of this test, **long positions** on **stock indices, bonds, gold** and **the dollar index were used.**

**The above rules are described in a way that allows them to be directly converted into a script in the chosen testing platform, which ensures the accuracy of the historical simulation and the reliability of the test results.**

The tests are carried out assuming that the risk of one position is **1.0% of the total capital,** with **a hypothetical stop loss order located 2 x ATR (40 days)** away from the position opening point.

## Step 3: Pre-test your investment strategy

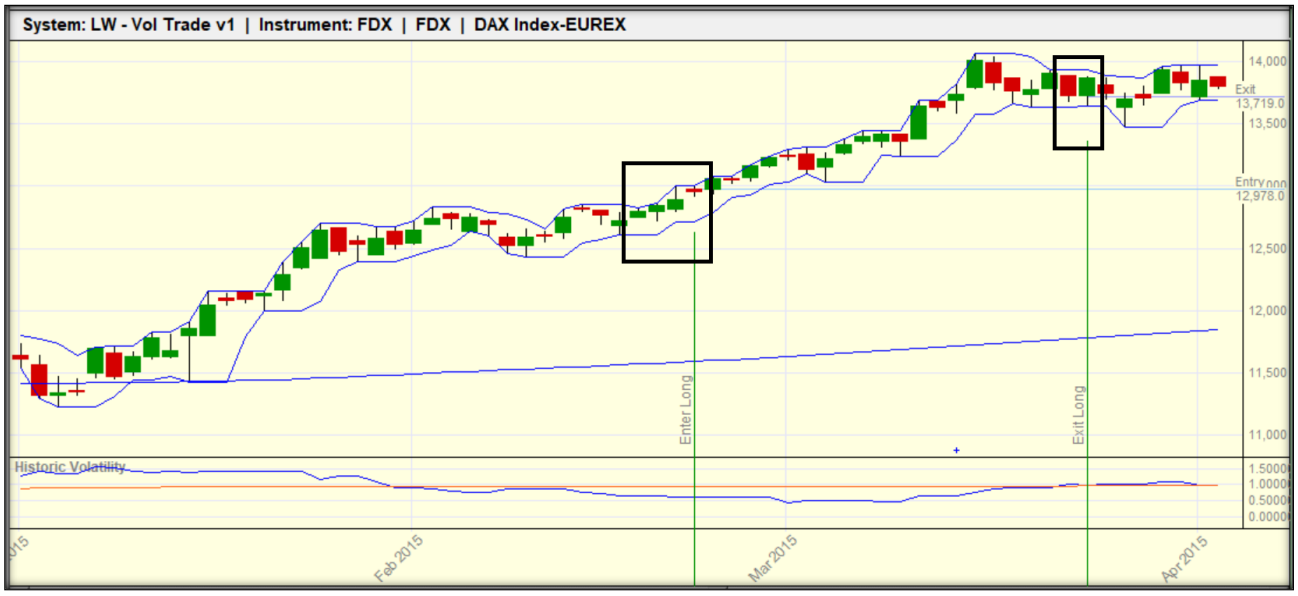
Below are some purchase and sale transactions that allow you to verify the following aspects:

- **Correctness of generated signals;**
- **Direction of opening a position;**
- **Moment of opening the position;**
- **The opening price of the position;**
- **Moment of closing the position;**
- **Closing price of the position;**
- **Compliance of the transaction with the theoretical assumptions of the investment strategy.**

At this stage, **it doesn't matter** whether the trades are **profitable,** what **instrument was used,** or whether they occurred **recently** or **in the distant past.** The key is **to verify that the trades are generated correctly** and in line with the assumptions described in the previous step.

**The first transaction was made on a DAX futures contract.** At the end of February 2015, prices remained in **an uptrend** (price above the long-term average), and **short-term volatility remained below long-term volatility for several sessions ("Historic Volatility" panel). During this time, a volatility contraction** was formed (the first three candles in the left-hand rectangle; **short-term volatility remains below 80% of long-term volatility). A buy signal requires that after such a period of low volatility, a breakout candle** appears (the widest since the beginning of the contraction), which simultaneously **establishes a new local high.** This condition was met (the third candle in the left-hand rectangle), which **generated a signal to open a long position.** According to the strategy's rules, **the position was open at the opening of the next session** (fourth candle in the rectangle on the left). The strategy **does not use stop loss orders. The system worked correctly.**

The strategy calls for **an exit when short-term volatility exceeds long-term volatility.** This signal appeared at the end of March 2015 (the first candle in the right-hand rectangle), so the position was closed at the opening of the next session (the second candle in the right-hand rectangle). **The system worked correctly.**




Once we are sure that the transactions are generated correctly, we can proceed to the first test of the strategy on the full **in-sample data set.** These tests are conducted on **baseline parameters** that, in my opinion, should align with the strategy's stated goals.

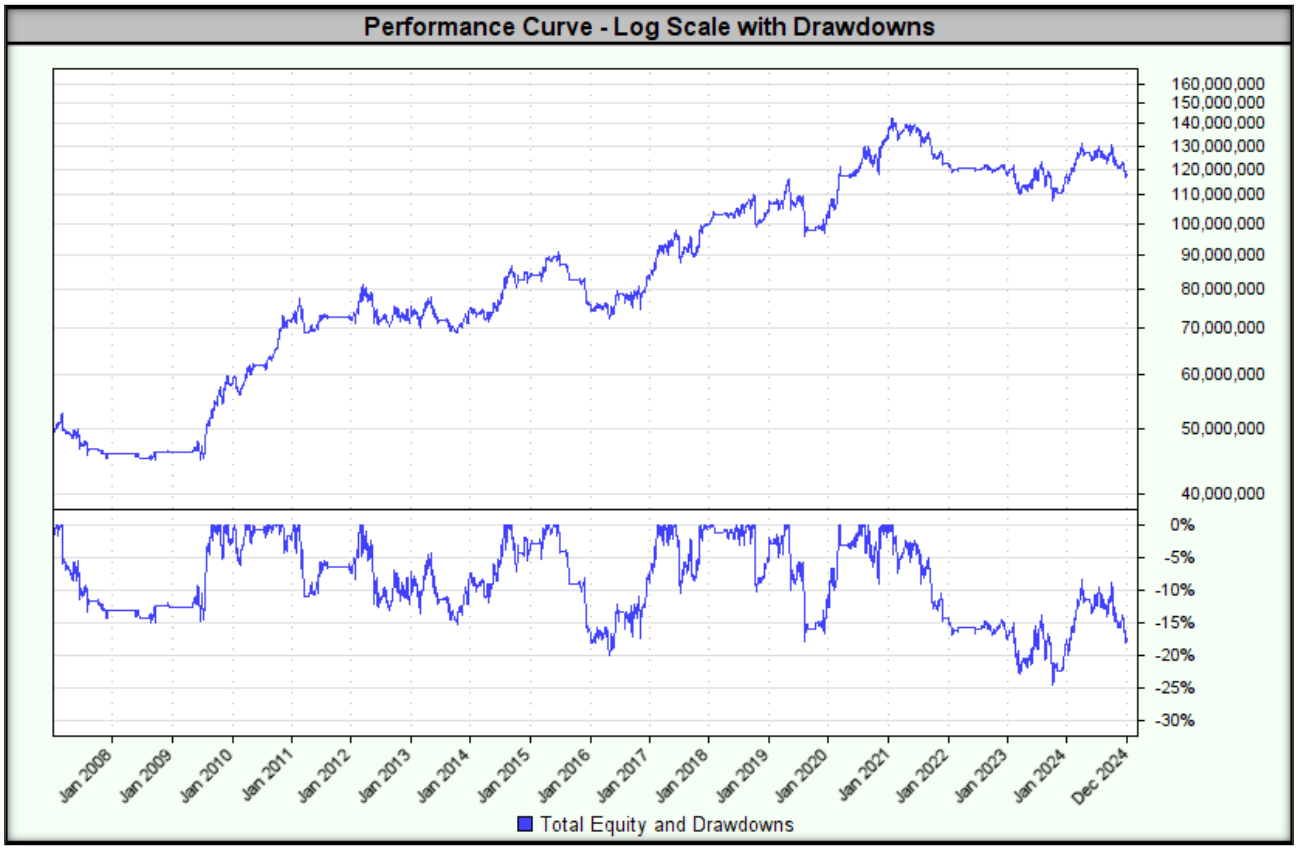
First, **we reject strategies that linearly lose capital.** If a strategy exhibits this pattern, it's a clear signal that any parameter optimization is pointless.

Our basic expectation is that the strategy generates **positive results,** even if they are at a low level.

Tested base parameters:

- **MALong –** 200-day moving average closing price.
- **VolLong** – 200-day volatility (sum of squared deviations).
- **VolShort** – 15-day volatility (sum of squared deviations).
- **VolRatio** – the variability ratio: VolShort/VolLong is at most 80%.
- **Volatility contraction:** for 3 consecutive VolShort/VolLong sessions it is at most 80%.
- **HighestHigh** – 3 day highest high.
- **MaxRange** – maximum daily range (High−Low) in the last 3 sessions.
- **How to open a position** – once the conditions are met, a long position is opened at the opening of the next session.
- **Stop loss** – lack.
- **Closing a position** – all positions are closed at the opening of the next session when VolShort > VolLong.
- **Position size** – corresponding to a risk of 1.0% of the total capital, with a hypothetical stop loss order located 2 x ATR (40 days) away from the position opening point.
- **Direction of position** – only long positions (buy).

The test result is shown below.




| Indicators/Measures | Concluding a transaction at the opening price |
|---|---|
| CAGR% | 4.9% |
| MAR Ratio | 0.20 |
| RAR% | 6.2% |
| R-Cubed | 0.15 |
| Robust Sharpe Ratio | 0.59 |
| Max Drawdown | 24.5% |
| Wins | 53.7% |
| Losses | 46.3% |
| Average Win% | 1.83% |
| Average Loss% | 1.40% |
| Win/Loss Ratio | 1.30 |
| Average Trade Duration (days) | 67 |
| Percent Profit Factor | 1.51 |
| SQN | - |
| Number of transactions | 296 |

In summary, the system is working properly and generating signals as expected. Furthermore, tests on the baseline parameters yielded satisfactory results. We can now move on to the most interesting stage of creating an investment strategy – **optimization.**

# Step 4: Optimizing and assessing the stability of the investment strategy

**This stage of strategy development and testing** is **crucial** because it determines how **effective** the strategy will be in **real-world conditions. I cannot** emphasize enough that for **a strategy to work** in real-world conditions, it must also perform under **suboptimal parameters** and **conditions.** In short, **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly capture the problem of many optimizations:

***"I've never seen a strategy that didn't work in backtests."***

**My goal is not** to find **optimal parameter values** – **my goal** is to find **a wide range of parameters** for which the strategy will generate **acceptable results. We don't know the future,** we don't know future market conditions, but if we know that our strategy **has historically generated acceptable results** in various market conditions and across various parameter ranges, then we are **one step ahead of other** market participants.

What **parameters to choose** for the next period is the topic of consideration in **Step 5, "Walk-Forward Analysis",** but before we get to that, **we need to know** whether our strategy is even **stable.**

## 1. Stability across a wide range of optimized parameters

This version of **the Vol Trade v.1 strategy utilizes the Grid Search** method **to optimize parameters.** This method **fully optimizes all specified parameters by creating a wide range of possible combinations.** Our goal is to find **parameter ranges** that **will keep the strategy stable (robust),** allowing us to assess its suitability in real-world market conditions.

**The key criterion for assessing stability is that all test results must demonstrate a positive MAR, and the maximum drawdown must not exceed 250% of the drawdown for the result with the highest MAR.** If any test produces a negative MAR, or if the drawdown exceeds 250% of the drawdown for the result with the highest MAR, the strategy is rejected entirely.

In the first step, we test the stability of the parameters on **in-sample data.** To do this, we define **ranges of** parameter values so that **the ratio of the highest to lowest value of the range is at least 150%.**

In the tested strategy, the ranges defined in this way are:

- **VolShort:** range **11-17 days (step: 1);**
- **MALong & VolLong:** range **135-200 days (step: 5);**
- **VolRatio:** range **70%-90% (step: 2.5 pp);**
- **Volatility Contraction & HighestHigh & MaxRange: 2-3 days** range **(step: 1).**

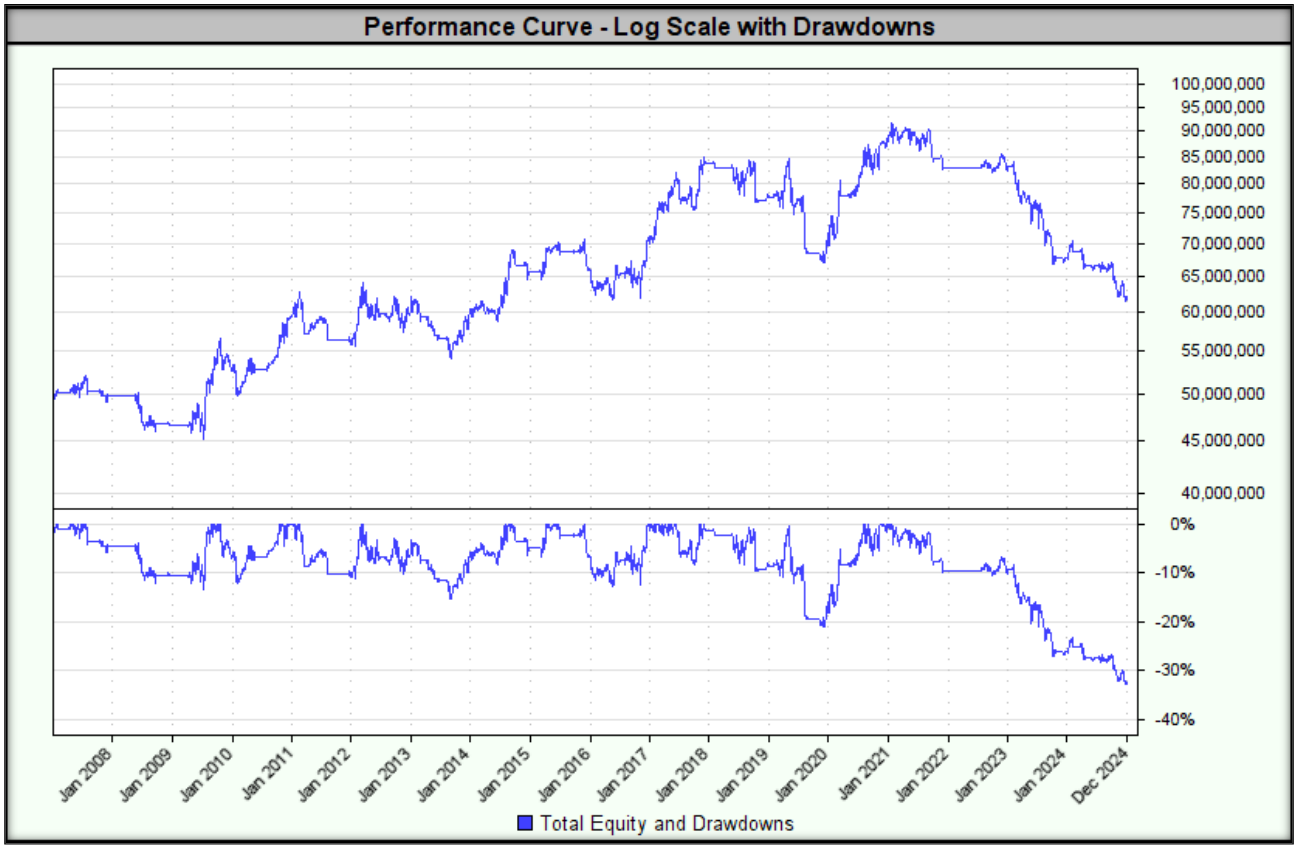
**The lowest MAR value of 0.06** was achieved for the following parameters:

- **VolShort:** 17 days;
- **MALong & VolLong:** 140 days;
- **VolRatio:** 75%;

- **Volatility Contraction & HighestHigh & MaxRange:** 3 days.

| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 1536 | 17 | 140 | 75.0% | 3 | $61,761,295.59 | 1.18% | 0.04 | 0.17 | 0.10 | 32.8% |
| 1518 | 17 | 135 | 75.0% | 3 | $64,239,917.99 | 1.40% | 0.04 | 0.20 | 0.13 | 31.8% |
| 1730 | 17 | 195 | 70.0% | 3 | $64,126,749.81 | 1.39% | 0.04 | 0.19 | 0.12 | 31.3% |
| 1604 | 17 | 160 | 70.0% | 3 | $61,873,957.38 | 1.19% | 0.05 | 0.17 | 0.12 | 25.5% |
| 1534 | 17 | 140 | 72.5% | 3 | $66,947,271.24 | 1.63% | 0.05 | 0.22 | 0.14 | 33.9% |
| 1712 | 17 | 190 | 70.0% | 3 | $66,878,700.83 | 1.63% | 0.05 | 0.21 | 0.13 | 33.0% |
| 1588 | 17 | 155 | 72.5% | 3 | $66,489,908.74 | 1.60% | 0.05 | 0.21 | 0.15 | 30.8% |
| 1748 | 17 | 200 | 70.0% | 3 | $66,633,022.84 | 1.61% | 0.06 | 0.21 | 0.14 | 28.6% |
| 1732 | 17 | 195 | 72.5% | 3 | $67,019,228.24 | 1.64% | 0.06 | 0.21 | 0.14 | 28.5% |
| 1694 | 17 | 185 | 70.0% | 3 | $70,019,828.47 | 1.89% | 0.06 | 0.24 | 0.15 | 31.9% |
| 1622 | 17 | 165 | 70.0% | 3 | $64,853,920.48 | 1.46% | 0.06 | 0.20 | 0.14 | 23.8% |
| 1606 | 17 | 160 | 72.5% | 3 | $69,047,726.54 | 1.81% | 0.06 | 0.23 | 0.16 | 29.4% |

Below is a graph of the equity curve for **the strategy with the lowest MAR.**



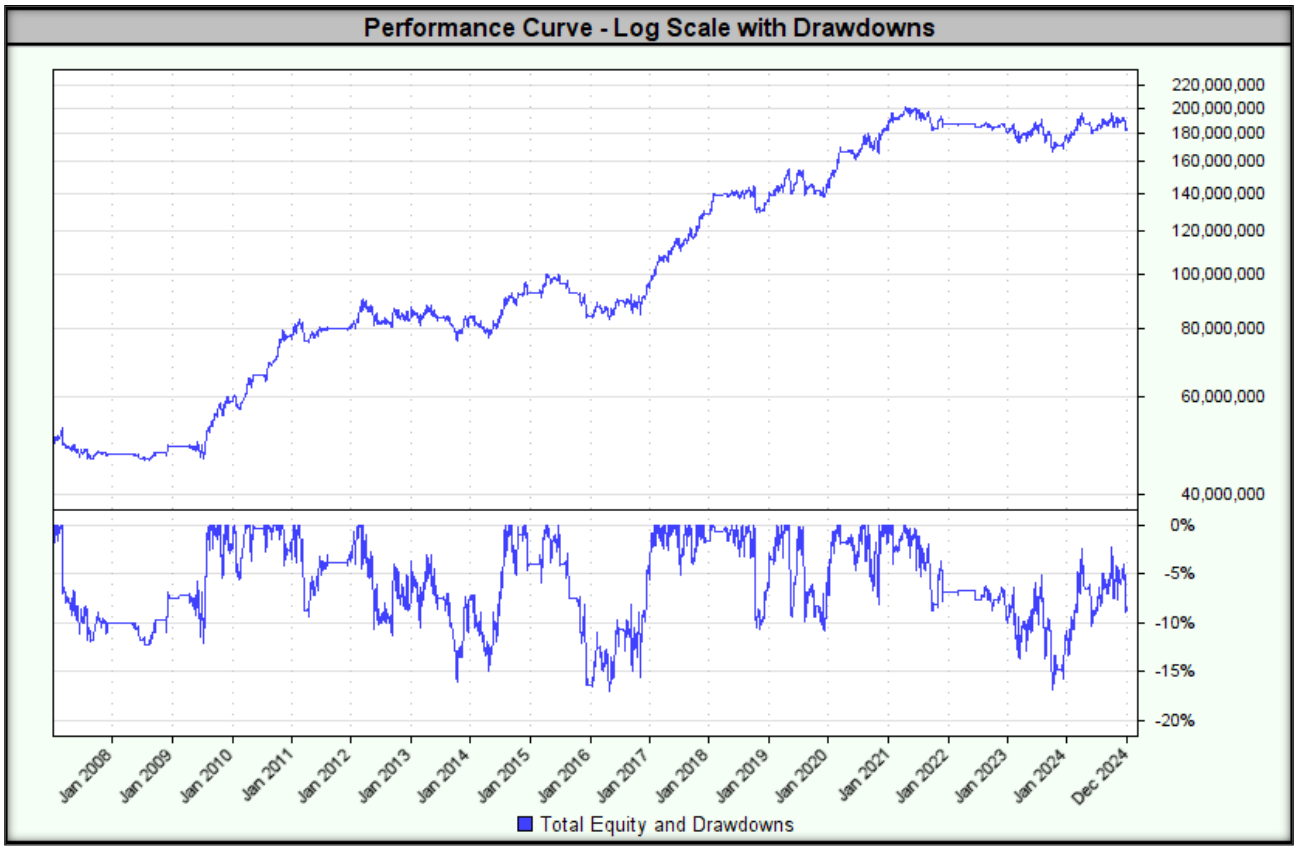

**The highest MAR value of 0.44** was achieved for the following parameters:

- **VolShort:** 11 days;
- **MALong & VolLong:** 200 days;
- **VolRatio:** 80%;
- **Volatility Contraction & HighestHigh & MaxRange:** 2 days.

**The highest MAR value** was accompanied by **a drawdown of 17.0%.**

| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 243 | 11 | 200 | 80.0% | 2 | $182,852,932.14 | 7.47% | 0.44 | 0.77 | 0.58 | 17.0% |
| 169 | 11 | 180 | 77.5% | 2 | $172,611,841.73 | 7.13% | 0.41 | 0.73 | 0.56 | 17.2% |
| 225 | 11 | 195 | 80.0% | 2 | $177,492,426.34 | 7.29% | 0.41 | 0.75 | 0.58 | 17.7% |
| 203 | 11 | 190 | 75.0% | 2 | $148,643,056.10 | 6.24% | 0.40 | 0.68 | 0.53 | 15.6% |
| 207 | 11 | 190 | 80.0% | 2 | $182,017,790.73 | 7.44% | 0.40 | 0.75 | 0.60 | 18.8% |
| 936 | 14 | 180 | 90.0% | 3 | $176,438,717.52 | 7.26% | 0.39 | 0.71 | 0.57 | 18.5% |
| 189 | 11 | 185 | 80.0% | 2 | $172,790,509.06 | 7.13% | 0.39 | 0.71 | 0.58 | 18.3% |
| 221 | 11 | 195 | 75.0% | 2 | $146,868,774.26 | 6.17% | 0.39 | 0.68 | 0.52 | 15.9% |
| 737 | 13 | 195 | 90.0% | 2 | $203,336,977.99 | 8.11% | 0.39 | 0.77 | 0.63 | 20.9% |
| 1205 | 15 | 185 | 90.0% | 2 | $205,708,747.20 | 8.18% | 0.39 | 0.76 | 0.60 | 21.2% |
| 953 | 14 | 185 | 90.0% | 2 | $192,791,094.47 | 7.79% | 0.39 | 0.73 | 0.63 | 20.2% |
| 1241 | 15 | 195 | 90.0% | 2 | $190,661,080.19 | 7.72% | 0.38 | 0.72 | 0.59 | 20.1% |

Below is a graph of the equity curve for **the strategy with the highest MAR.**



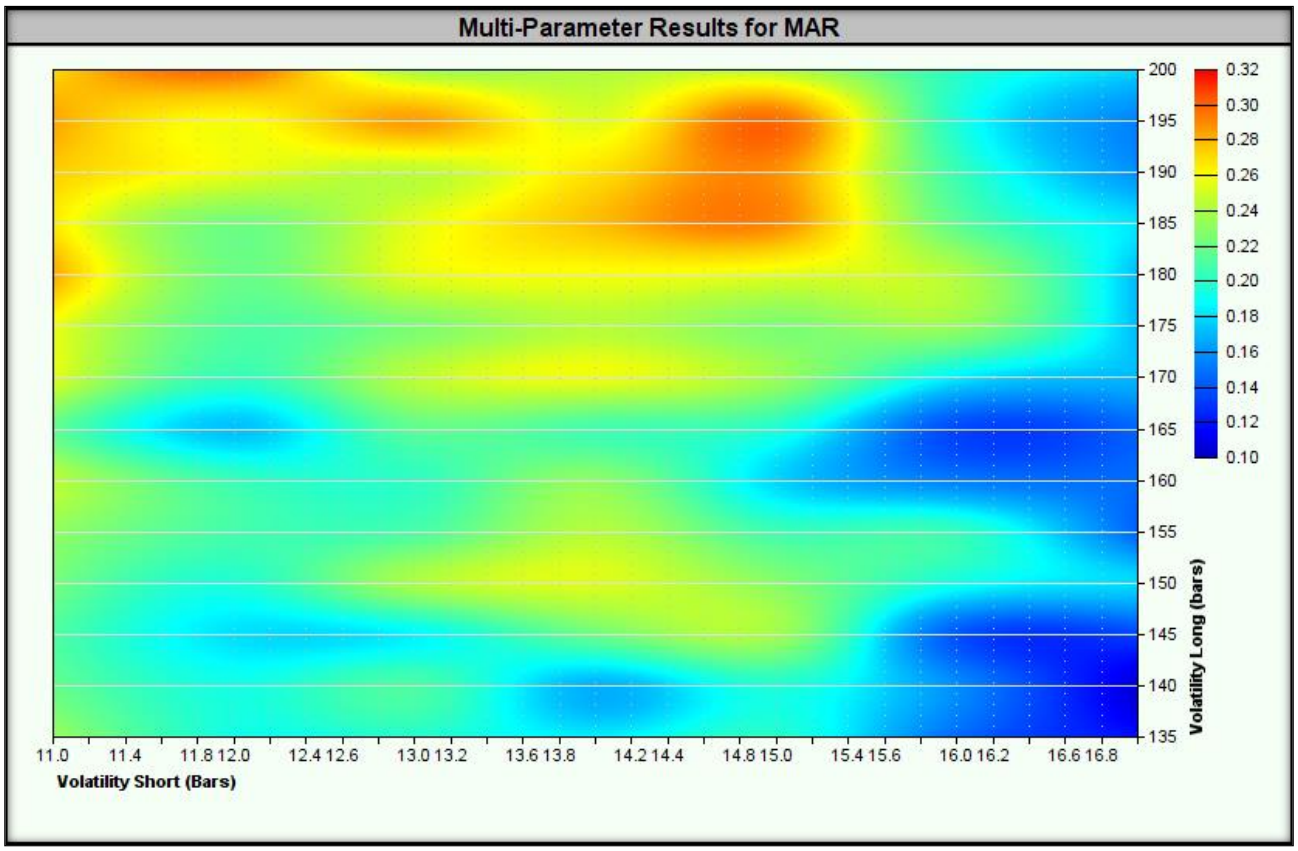

For all combinations of tested parameter ranges, **the highest drawdown was 33.9%.**

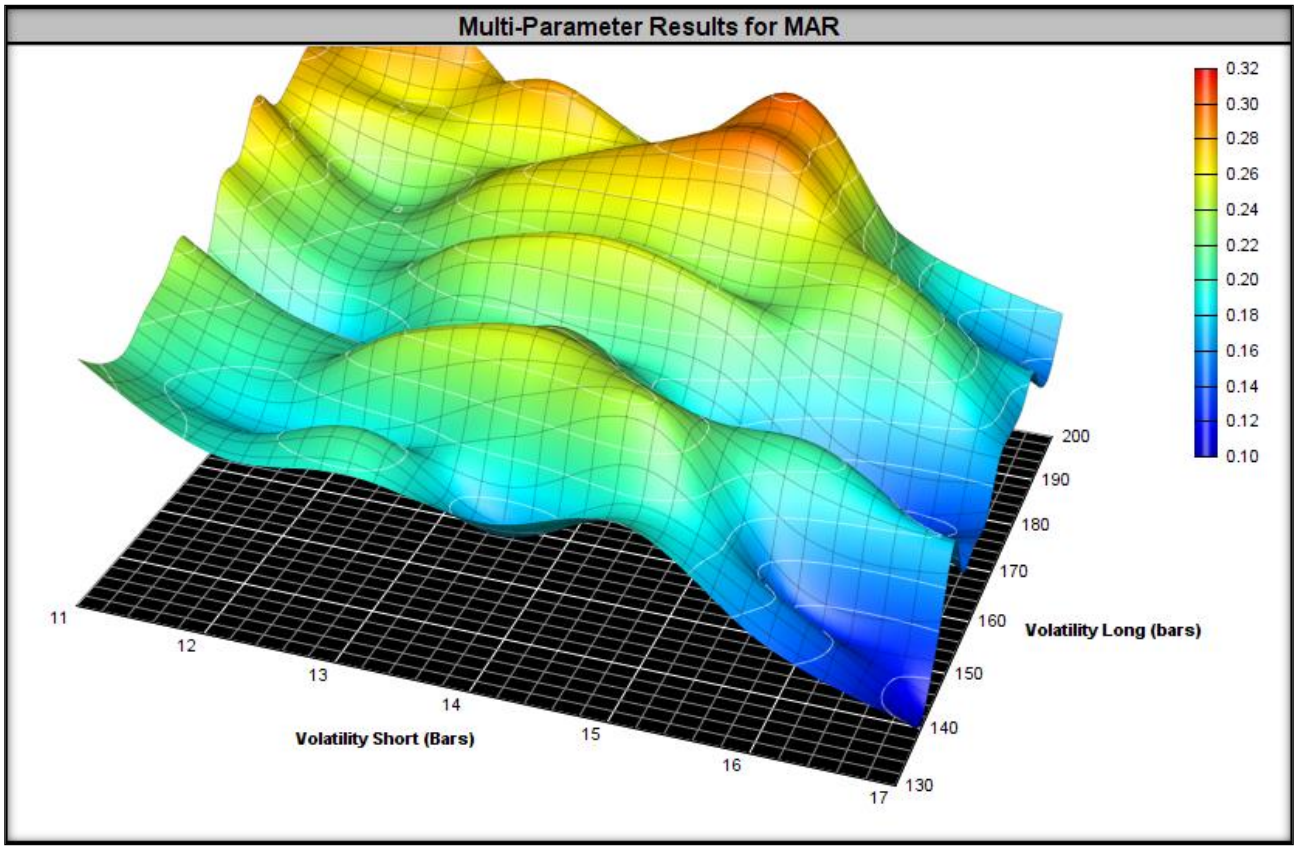
| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 1655 | 17 | 170 | 90.0% | 2 | $139,142,276.76 | 5.85% | 0.18 | 0.54 | 0.43 | 32.5% |
| 53 | 11 | 145 | 90.0% | 2 | $167,621,648.71 | 6.95% | 0.21 | 0.70 | 0.57 | 32.6% |
| 1536 | 17 | 140 | 75.0% | 3 | $61,761,295.59 | 1.18% | 0.04 | 0.17 | 0.10 | 32.8% |
| 1313 | 16 | 145 | 90.0% | 2 | $135,797,059.37 | 5.71% | 0.17 | 0.55 | 0.43 | 32.9% |
| 1535 | 17 | 140 | 75.0% | 2 | $78,052,725.18 | 2.51% | 0.08 | 0.29 | 0.22 | 33.0% |
| 1712 | 17 | 190 | 70.0% | 3 | $66,878,700.83 | 1.63% | 0.05 | 0.21 | 0.13 | 33.0% |
| 36 | 11 | 140 | 90.0% | 3 | $133,893,269.88 | 5.63% | 0.17 | 0.59 | 0.43 | 33.2% |
| 54 | 11 | 145 | 90.0% | 3 | $129,136,685.75 | 5.41% | 0.16 | 0.56 | 0.43 | 33.4% |
| 35 | 11 | 140 | 90.0% | 2 | $167,104,476.95 | 6.93% | 0.21 | 0.70 | 0.57 | 33.5% |
| 1533 | 17 | 140 | 72.5% | 2 | $81,232,449.58 | 2.73% | 0.08 | 0.33 | 0.23 | 33.6% |
| 1517 | 17 | 135 | 75.0% | 2 | $85,070,499.24 | 3.00% | 0.09 | 0.34 | 0.25 | 33.7% |
| 1534 | 17 | 140 | 72.5% | 3 | $66,947,271.24 | 1.63% | 0.05 | 0.22 | 0.14 | 33.9% |

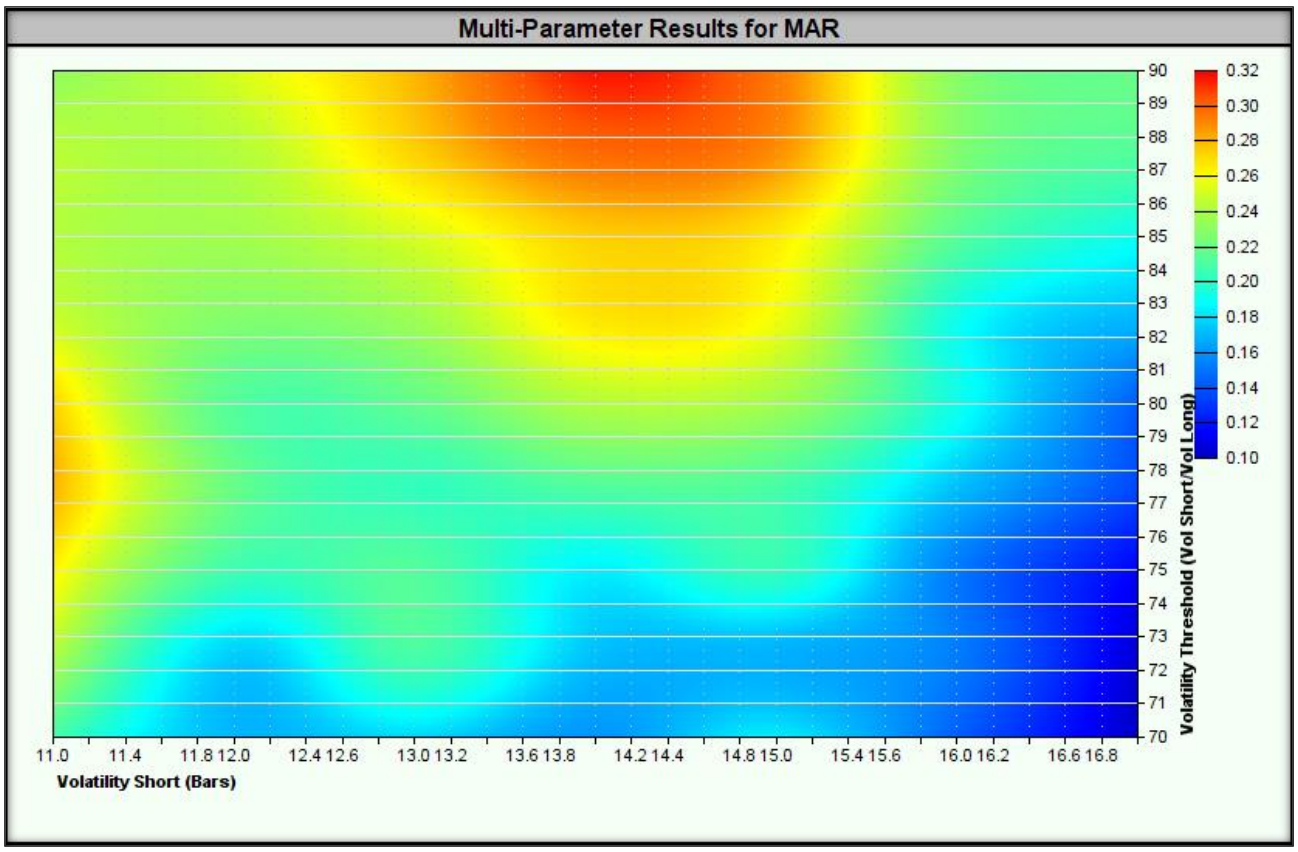
**In summary,** the strategy **passed the stability test** over a wide range of optimized parameters on in-sample data because:

- **All test results showed a positive MAR value** – which indicates the stability of the strategy in various market conditions.
- **The maximum drawdown did not exceed 250% of the drawdown value** for the result with the highest MAR (**33.9% vs. 17.0%)** – which means an acceptable risk of deep capital drawdowns.

**Heatmaps for the tested ranges** are shown below.




Multi-Parameter Results for MAR
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
11
12
13
14
15
16
17
Volatility Short (Bars)
200
190
180
170
160
150
140
130
Volatility Long (bars)


Multi-Parameter Results for MAR
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
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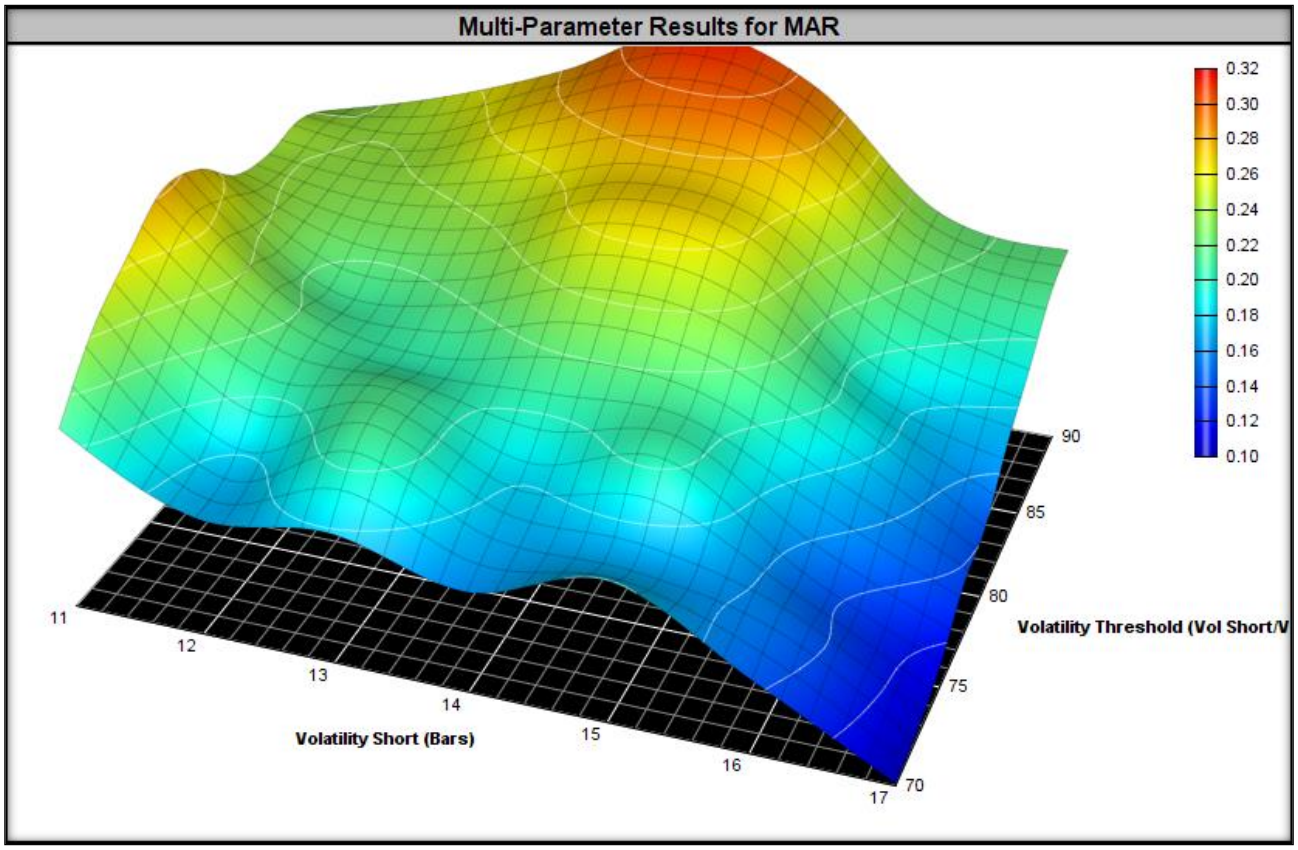
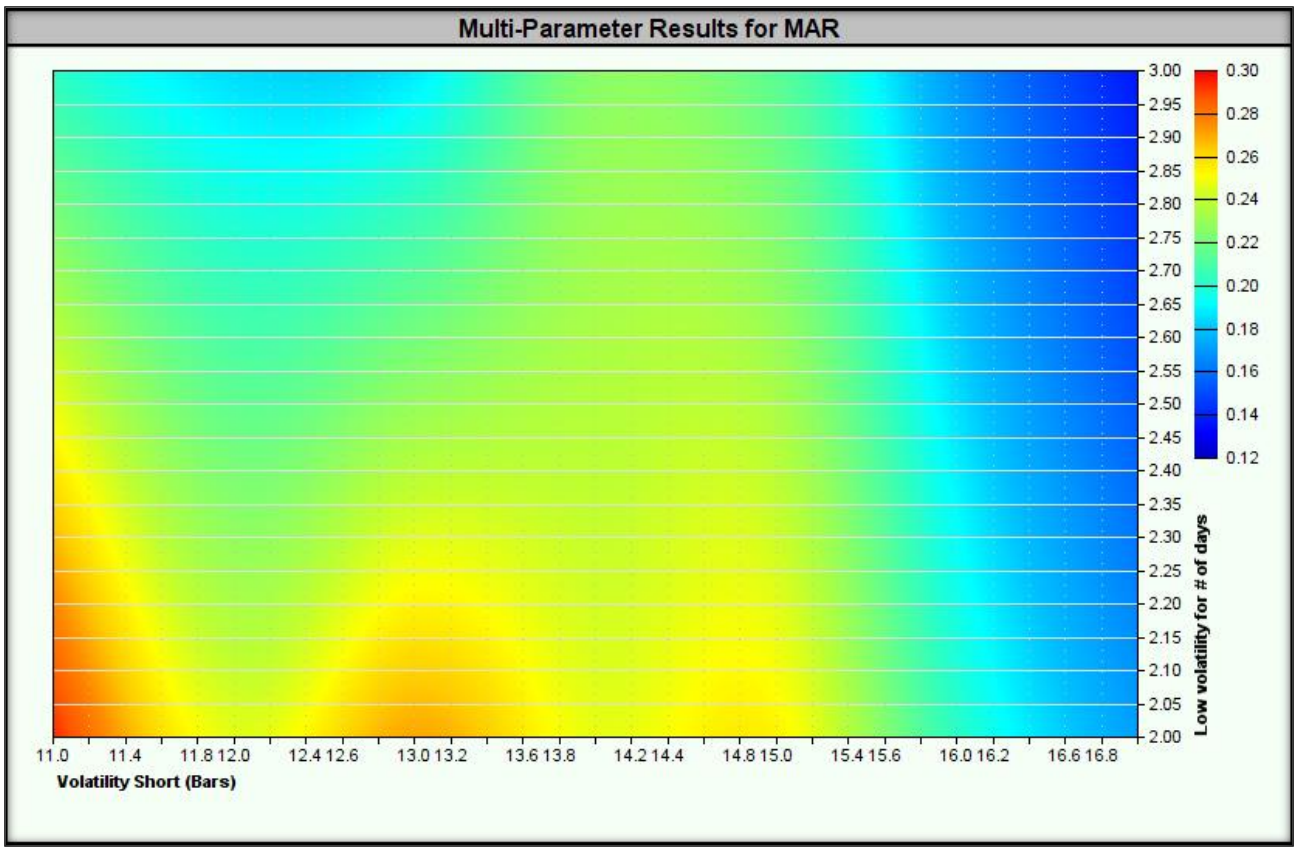
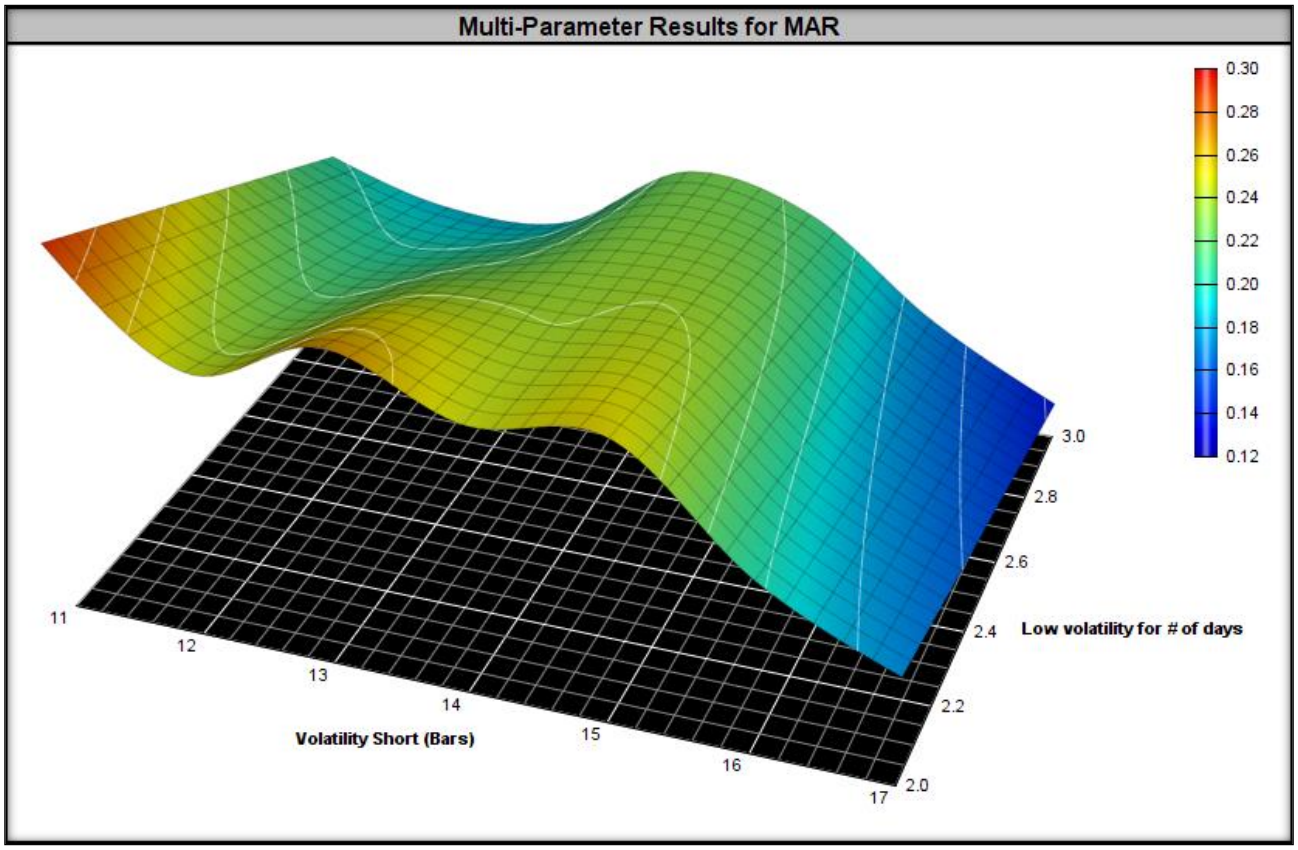
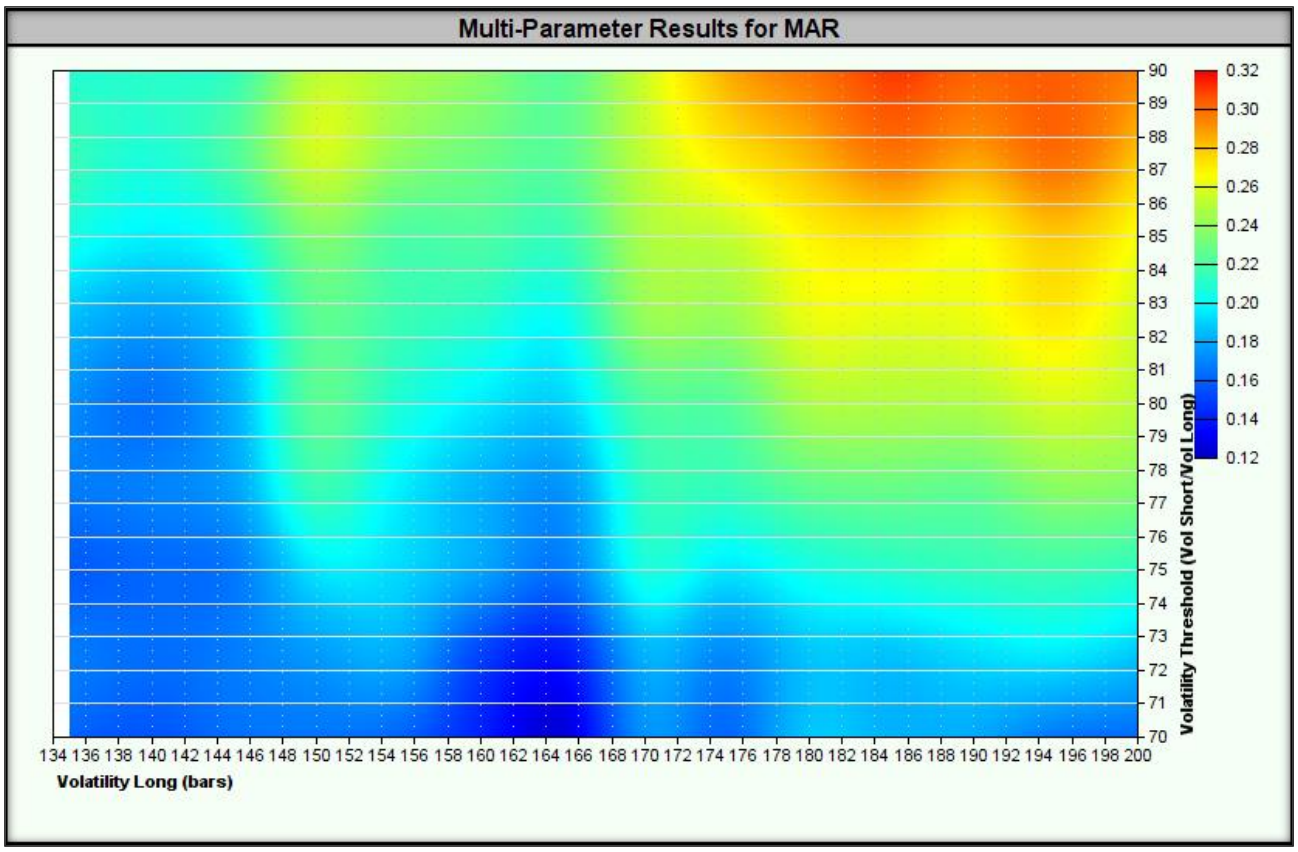
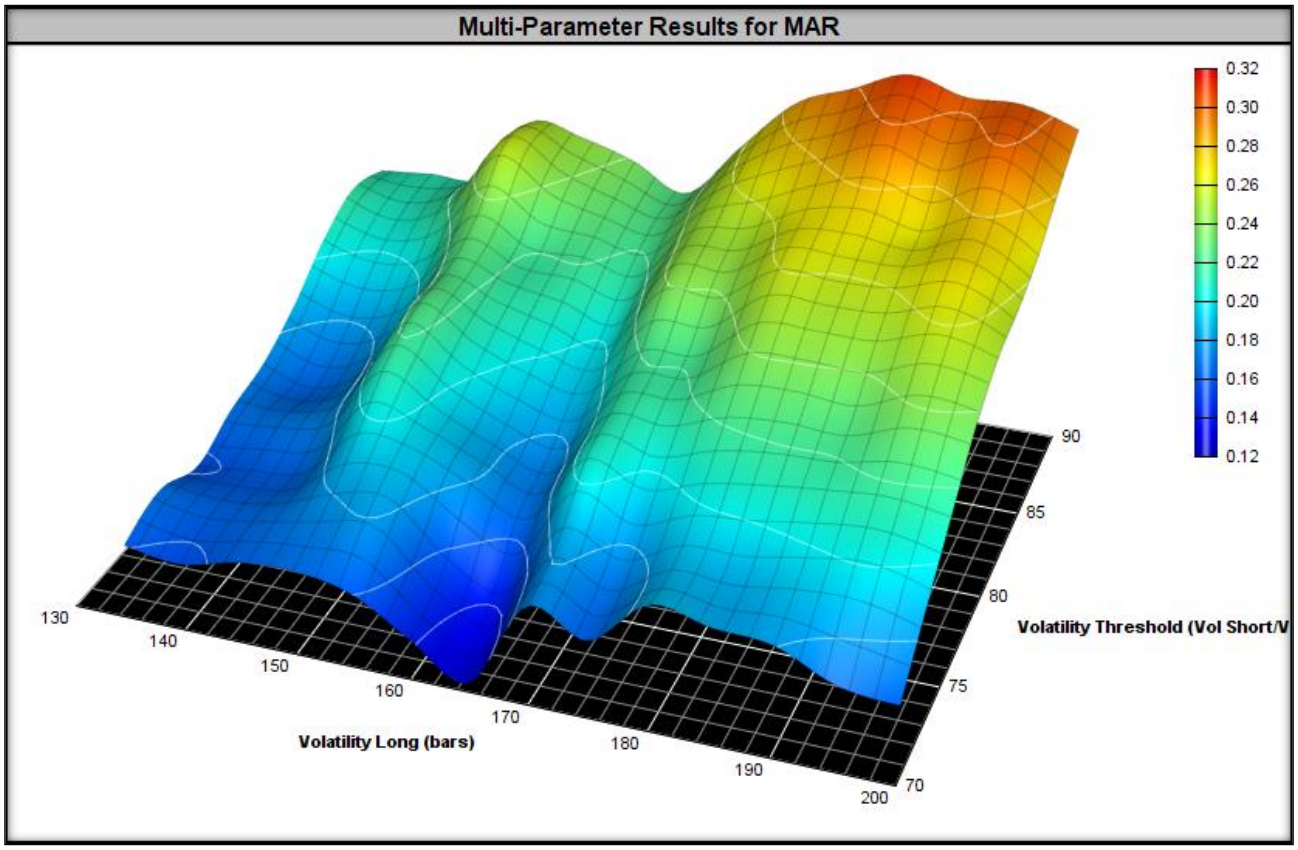
71
70
Volatility Threshold (Vol Short/Vol Long)
11.0
11.4
11.8 12.0
12.4 12.6
13.0 13.2
13.6 13.8
14.2 14.4
14.8 15.0
15.4 15.6
16.0 16.2
16.6 16.8
Volatility Short (Bars)

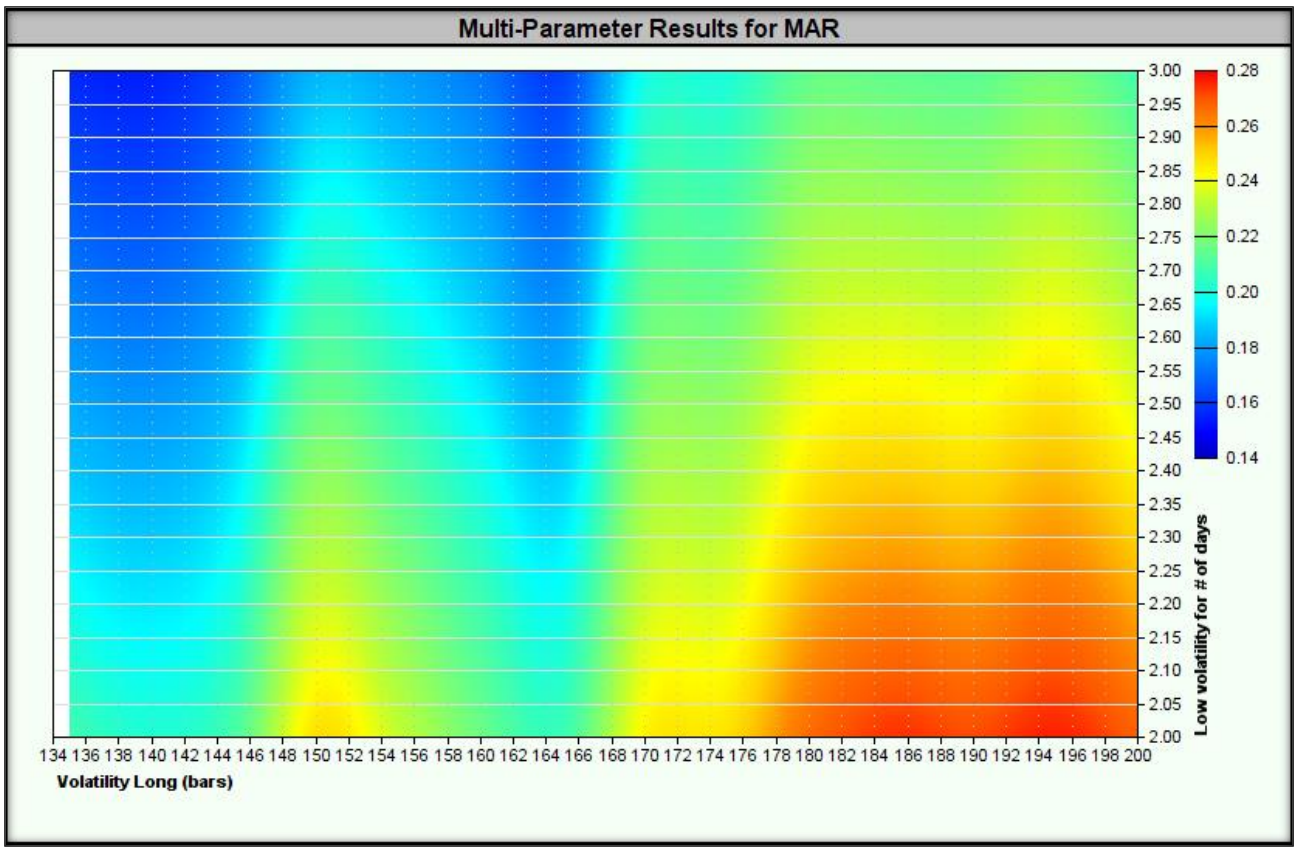

Multi-Parameter Results for MAR
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
11
12
13
14
15
16
17
Volatility Short (Bars)
70
75
80
85
90
Volatility Threshold (Vol Short/V

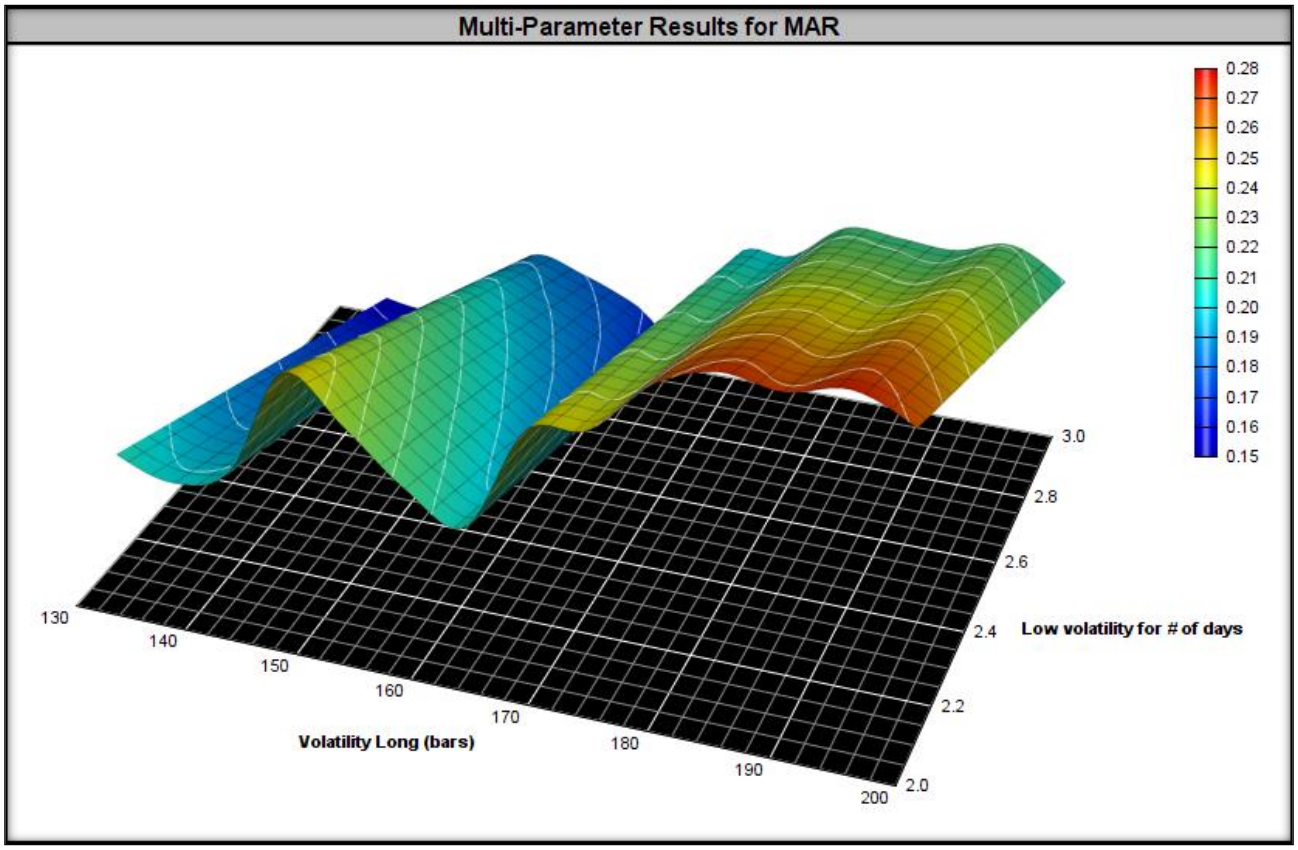

Multi-Parameter Results for MAR
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
11.0
11.4
11.8 12.0
12.4 12.6
13.0 13.2
13.6 13.8
14.2 14.4
14.8 15.0
15.4 15.6
16.0 16.2
16.6 16.8
Volatility Short (Bars)

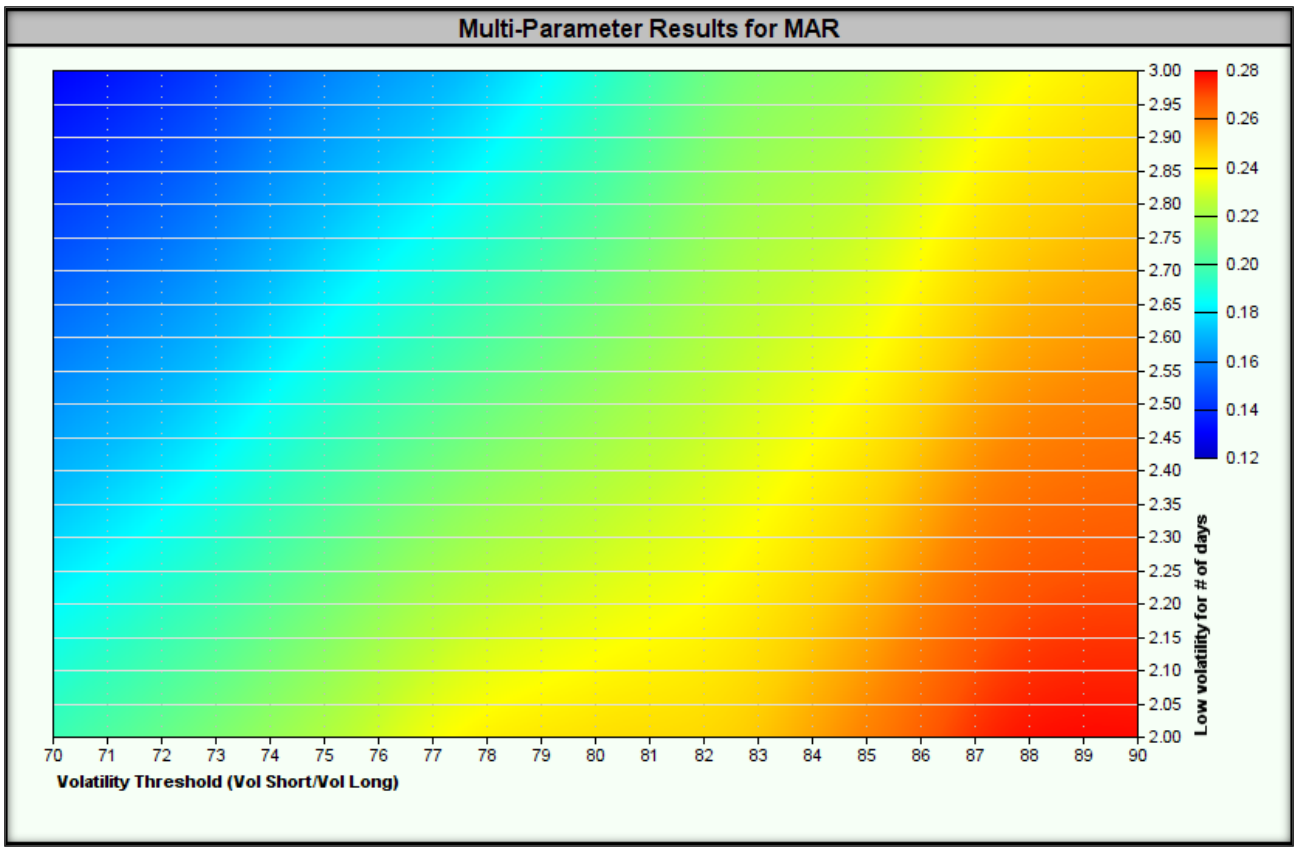

Multi-Parameter Results for MAR
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
11
12
13
14
15
16
17
Volatility Short (Bars)
2.0
2.2
2.4
2.6
2.8
3.0
Low volatility for # of days

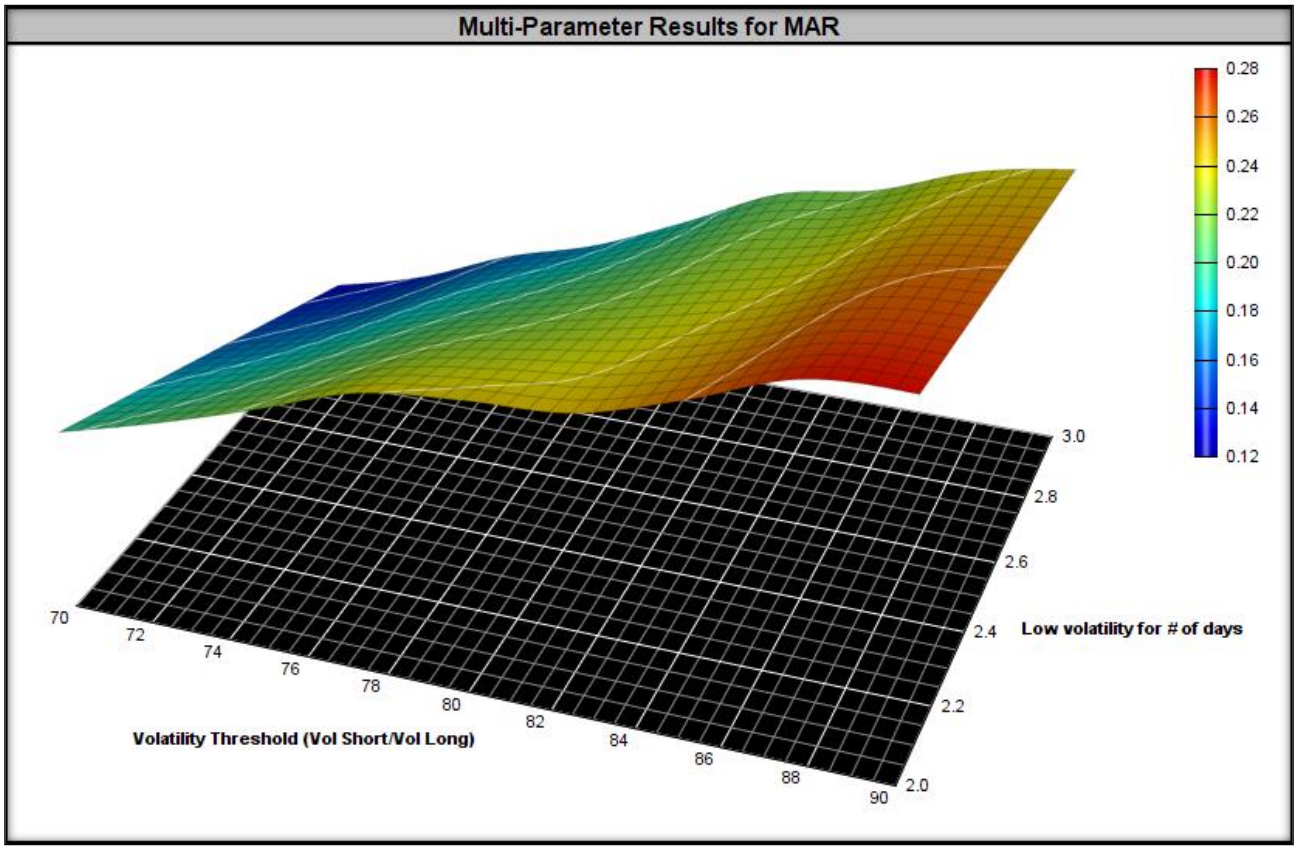

Multi-Parameter Results for MAR
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
Volatility Threshold (Vol Short/Vol Long)
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
134 136 138 140 142 144 146 148 150 152 154 156 158 160 162 164 166 168 170 172 174 176 178 180 182 184 186 188 190 192 194 196 198 200
Volatility Long (bars)

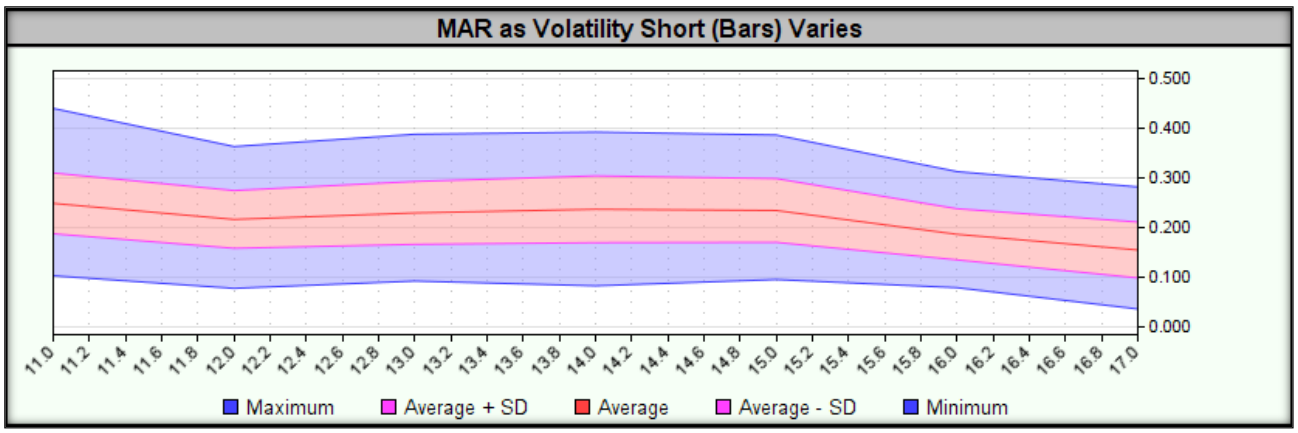

Multi-Parameter Results for MAR
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
130
140
150
160
170
180
190
200
Volatility Long (bars)
70
75
80
85
90
Volatility Threshold (Vol Short/V

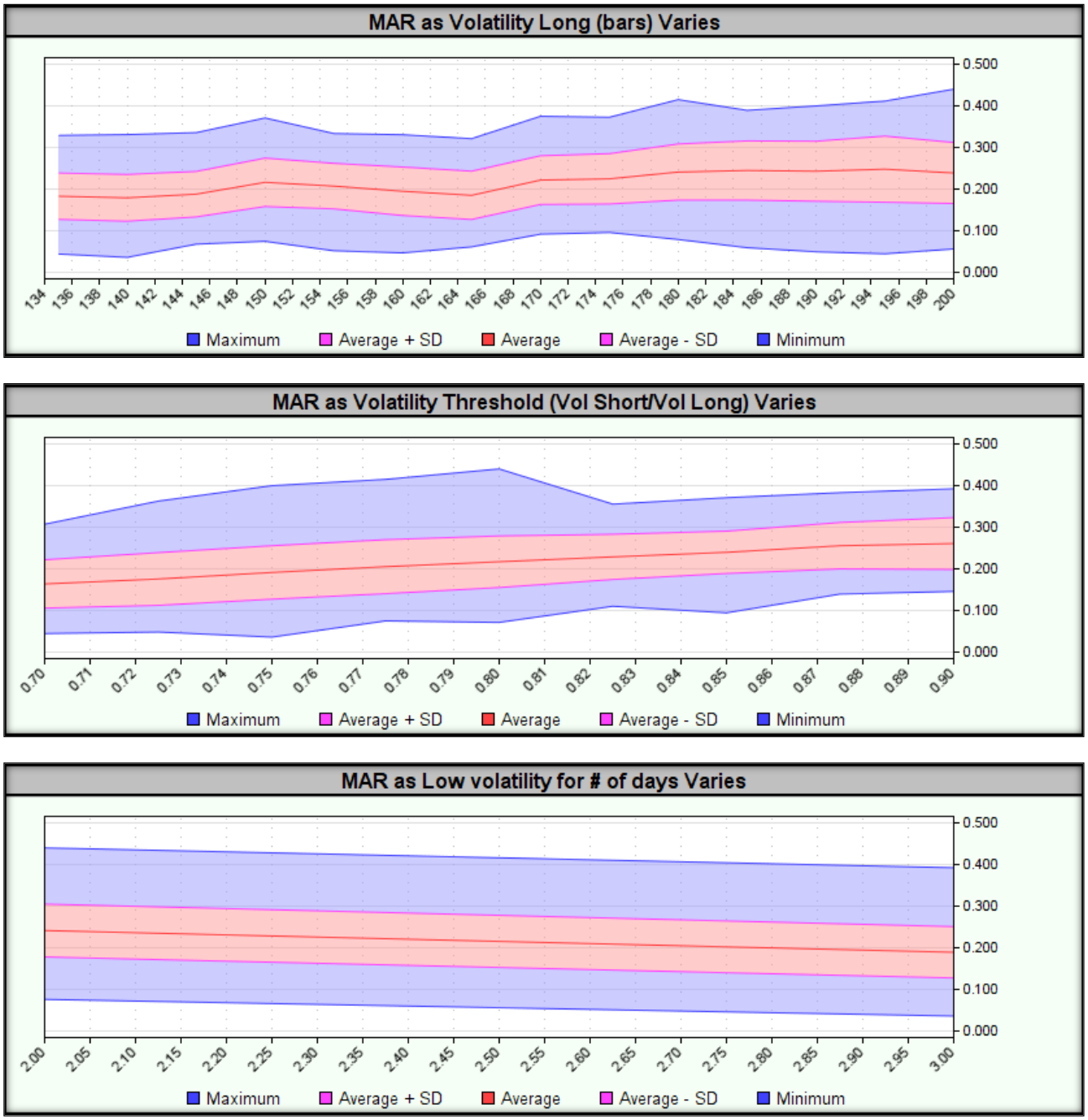

Multi-Parameter Results for MAR
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days
134 136 138 140 142 144 146 148 150 152 154 156 158 160 162 164 166 168 170 172 174 176 178 180 182 184 186 188 190 192 194 196 198 200
Volatility Long (bars)


Multi-Parameter Results for MAR
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
130
140
150
160
170
180
190
200
Volatility Long (bars)
2.0
2.2
2.4
2.6
2.8
3.0
Low volatility for # of days


Multi-Parameter Results for MAR
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
Volatility Threshold (Vol Short/Vol Long)
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days


Multi-Parameter Results for MAR
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
70
72
74
76
78
80
82
84
86
88
90
Volatility Threshold (Vol Short/Vol Long)
3.0
2.8
2.6
2.4
2.2
2.0
Low volatility for # of days


MAR as Volatility Short (Bars) Varies
0.500
0.400
0.300
0.200
0.100
0.000
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4
12.6
12.8
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
14.6
14.8
15.0
15.2
15.4
15.6
15.8
16.0
16.2
16.4
16.6
16.8
17.0
Maximum
Average + SD
Average
Average - SD
Minimum




After passing the stability tests on **in-sample data,** it is time perform the same on **out-of-sample data.** For this purpose, we use **the same range of parameters** as on in-sample data:

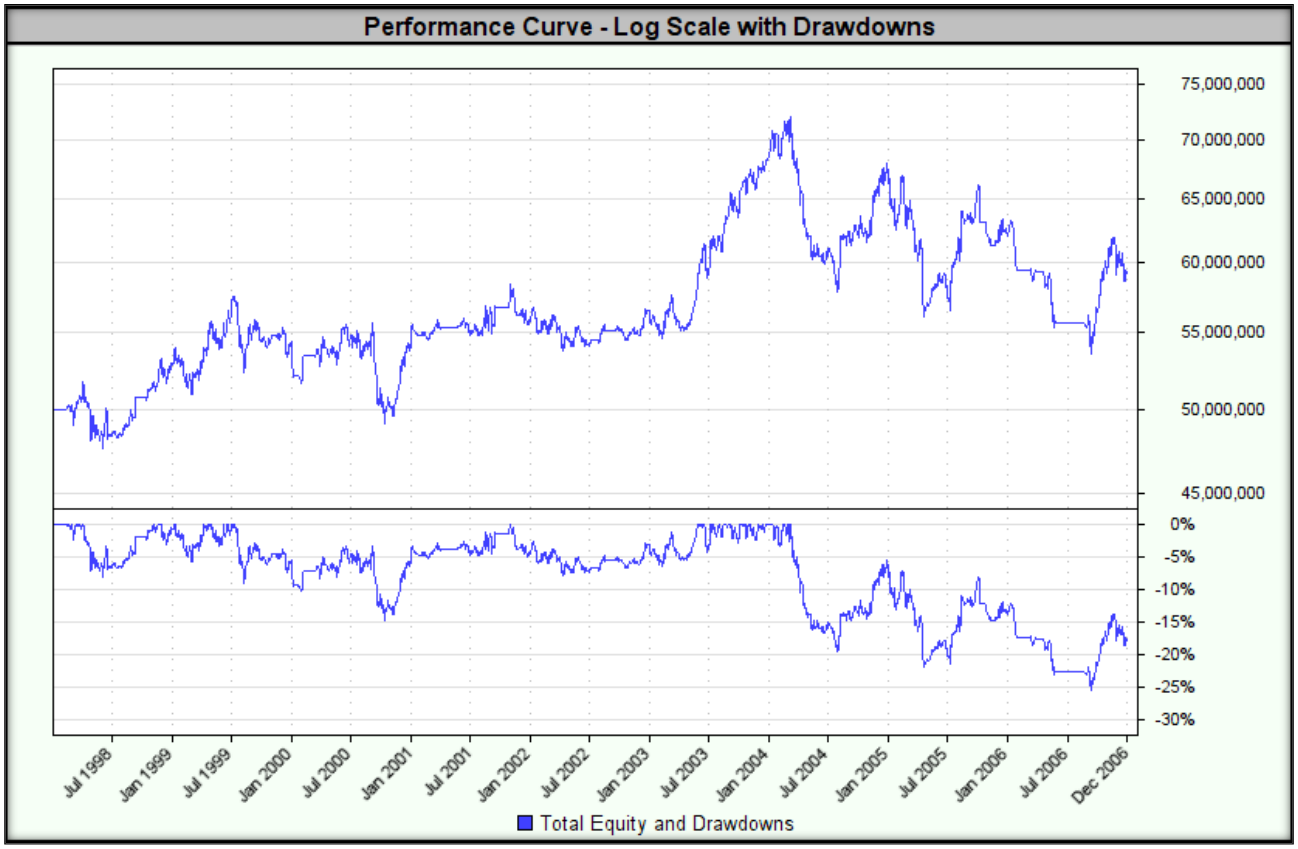
- **VolShort:** range **11-17 days (step: 1);**
- **MALong & VolLong:** range **135-200 days (step: 5);**
- **VolRatio:** range **70%-90% (step: 2.5 pp);**
- **Volatility Contraction & HighestHigh & MaxRange: 2-3 days** range **(step: 1).**

**The lowest MAR value of 0.07** was achieved for the following parameters:

- **VolShort:** 17 days;
- **MALong & VolLong:** 170 days;
- **VolRatio:** 82.5%;
- **Volatility Contraction & HighestHigh & MaxRange:** 3 days.

| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 1650 | 17 | 170 | 82.5% | 3 | $59,230,190.79 | 1.90% | 0.07 | 0.24 | 0.24 | 25.6% |
| 1418 | 16 | 175 | 85.0% | 3 | $60,498,172.05 | 2.14% | 0.08 | 0.27 | 0.25 | 25.7% |
| 1416 | 16 | 175 | 82.5% | 3 | $59,956,703.05 | 2.04% | 0.09 | 0.26 | 0.25 | 24.0% |
| 1400 | 16 | 170 | 85.0% | 3 | $58,956,835.63 | 1.85% | 0.09 | 0.24 | 0.26 | 21.6% |
| 1614 | 17 | 160 | 82.5% | 3 | $61,525,030.27 | 2.33% | 0.09 | 0.29 | 0.27 | 27.0% |
| 1616 | 17 | 160 | 85.0% | 3 | $62,071,082.10 | 2.43% | 0.09 | 0.30 | 0.26 | 28.0% |
| 1414 | 16 | 175 | 80.0% | 3 | $60,079,557.66 | 2.06% | 0.09 | 0.27 | 0.28 | 22.8% |
| 1632 | 17 | 165 | 82.5% | 3 | $61,144,201.03 | 2.26% | 0.09 | 0.28 | 0.28 | 24.9% |
| 1434 | 16 | 180 | 82.5% | 3 | $59,994,065.52 | 2.05% | 0.09 | 0.26 | 0.26 | 22.0% |
| 1436 | 16 | 180 | 85.0% | 3 | $61,027,147.41 | 2.24% | 0.10 | 0.28 | 0.27 | 23.1% |
| 1394 | 16 | 170 | 77.5% | 3 | $60,387,788.92 | 2.12% | 0.10 | 0.28 | 0.32 | 20.7% |
| 1452 | 16 | 185 | 82.5% | 3 | $62,426,452.49 | 2.50% | 0.10 | 0.31 | 0.29 | 24.2% |
| 1432 | 16 | 180 | 80.0% | 3 | $61,114,402.54 | 2.26% | 0.11 | 0.28 | 0.29 | 21.3% |

Below is a graph of the equity curve for **the strategy with the lowest MAR.**



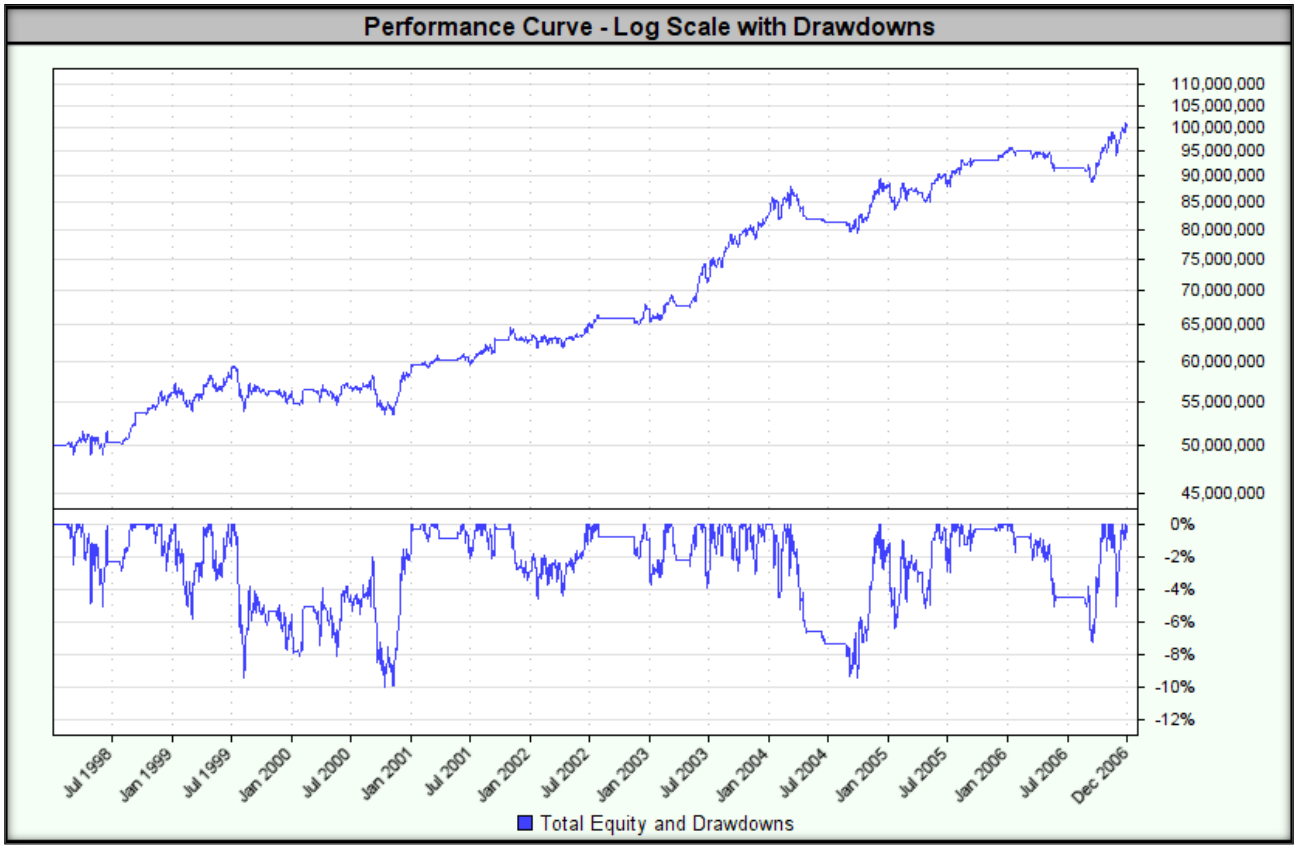

**The highest MAR value of 0.81** was achieved for the following parameters:

- **VolShort:** 12 days;
- **MALong & VolLong:** 150 days;
- **VolRatio:** 72.5%;
- **Volatility Contraction & HighestHigh & MaxRange:** 3 days.

**The highest MAR value** was accompanied by **a drawdown of 10.0%.**

| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 310 | 12 | 150 | 72.5% | 3 | $100,476,725.72 | 8.07% | 0.81 | 1.11 | 1.31 | 10.0% |
| 308 | 12 | 150 | 70.0% | 3 | $102,006,765.41 | 8.25% | 0.76 | 1.12 | 1.35 | 10.9% |
| 328 | 12 | 155 | 72.5% | 3 | $97,712,827.29 | 7.74% | 0.68 | 1.05 | 1.17 | 11.4% |
| 793 | 14 | 145 | 70.0% | 2 | $89,557,305.01 | 6.70% | 0.67 | 0.89 | 0.96 | 10.0% |
| 815 | 14 | 150 | 75.0% | 2 | $90,340,766.89 | 6.80% | 0.66 | 0.83 | 0.88 | 10.3% |
| 811 | 14 | 150 | 70.0% | 2 | $88,451,675.13 | 6.55% | 0.65 | 0.86 | 0.96 | 10.0% |
| 797 | 14 | 145 | 75.0% | 2 | $89,014,330.48 | 6.63% | 0.63 | 0.82 | 0.91 | 10.5% |
| 290 | 12 | 145 | 70.0% | 3 | $94,875,779.56 | 7.38% | 0.62 | 1.02 | 1.21 | 11.9% |
| 775 | 14 | 140 | 70.0% | 2 | $85,980,737.24 | 6.21% | 0.62 | 0.83 | 0.91 | 10.0% |
| 326 | 12 | 155 | 70.0% | 3 | $96,899,799.41 | 7.64% | 0.62 | 1.05 | 1.14 | 12.4% |
| 346 | 12 | 160 | 72.5% | 3 | $92,260,908.98 | 7.05% | 0.61 | 0.95 | 0.95 | 11.5% |
| 1573 | 17 | 150 | 77.5% | 2 | $90,548,747.58 | 6.83% | 0.61 | 0.83 | 1.08 | 11.1% |
| 58 | 11 | 150 | 72.5% | 3 | $91,597,152.67 | 6.96% | 0.60 | 0.97 | 1.01 | 11.5% |

Below is a graph of the equity curve for **the strategy with the highest MAR.**



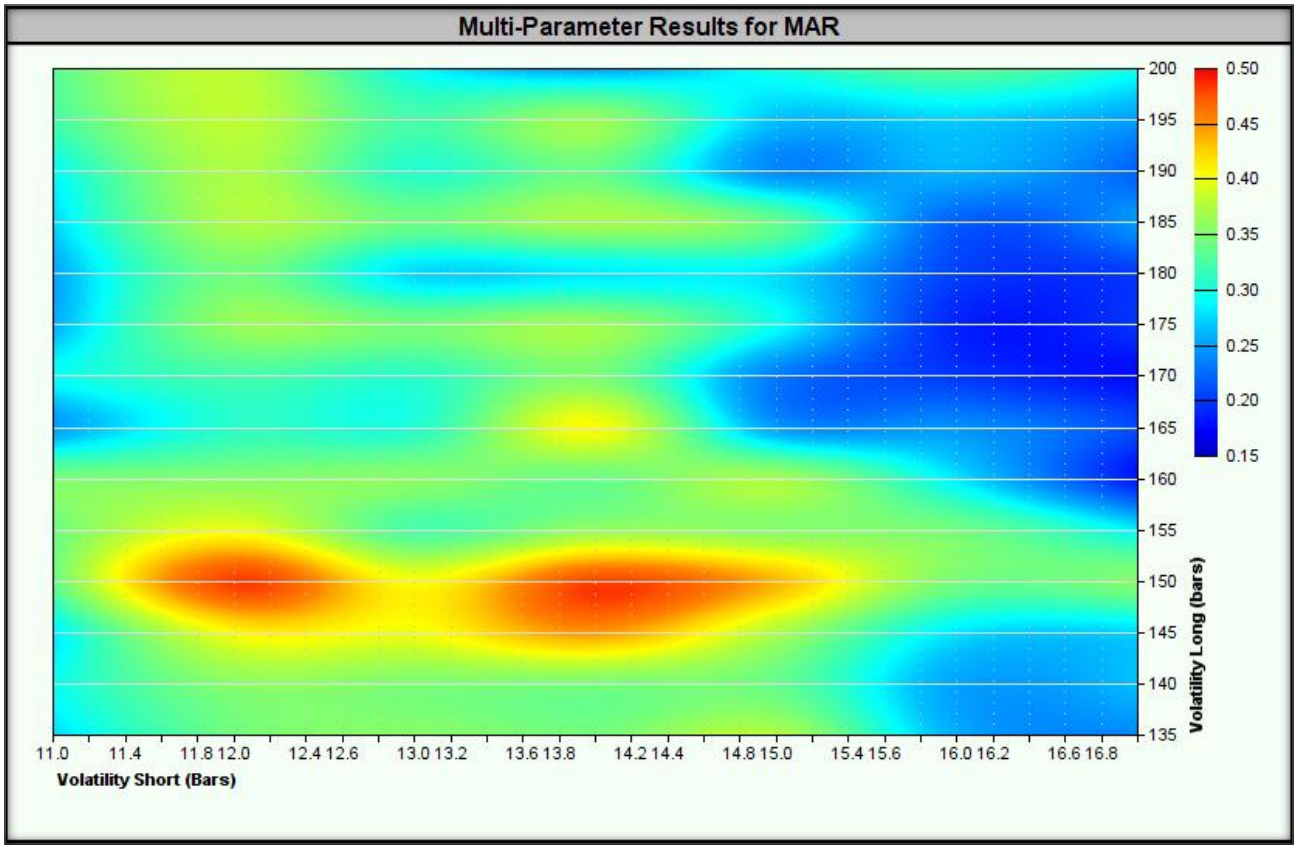

For all combinations of tested parameter ranges, **the highest drawdown was 28.0%.**

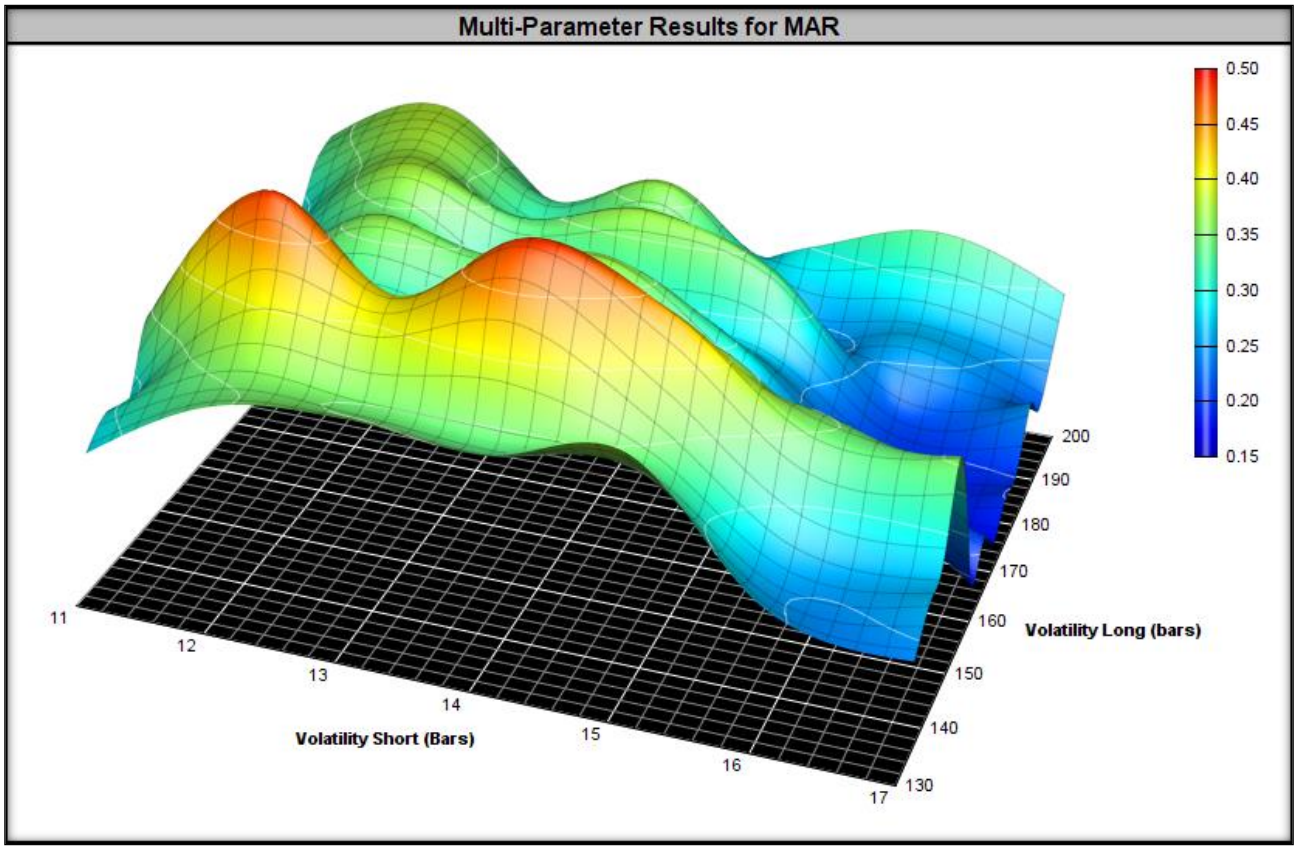
| Test | Volatility Short (Bars) | Volatility Long (bars) | Volatility Threshold (Vol Short/Vol Long) | Low volatility for # of days | End Balance | CAGR% | MAR | Sharpe | Ann. Sharpe | Max TE DD |
|---|---|---|---|---|---|---|---|---|---|---|
| 1616 | 17 | 160 | 85.0% | 3 | $62,071,082.10 | 2.43% | 0.09 | 0.30 | 0.26 | 28.0% |
| 1614 | 17 | 160 | 82.5% | 3 | $61,525,030.27 | 2.33% | 0.09 | 0.29 | 0.27 | 27.0% |
| 1684 | 17 | 180 | 80.0% | 3 | $65,311,552.33 | 3.02% | 0.11 | 0.35 | 0.32 | 26.7% |
| 1686 | 17 | 180 | 82.5% | 3 | $68,980,605.24 | 3.64% | 0.14 | 0.41 | 0.39 | 26.1% |
| 1688 | 17 | 180 | 85.0% | 3 | $69,606,268.87 | 3.75% | 0.15 | 0.42 | 0.40 | 25.8% |
| 1418 | 16 | 175 | 85.0% | 3 | $60,498,172.05 | 2.14% | 0.08 | 0.27 | 0.25 | 25.7% |
| 1650 | 17 | 170 | 82.5% | 3 | $59,230,190.79 | 1.90% | 0.07 | 0.24 | 0.24 | 25.6% |
| 1720 | 17 | 190 | 80.0% | 3 | $69,612,140.21 | 3.75% | 0.15 | 0.42 | 0.36 | 25.1% |
| 1652 | 17 | 170 | 85.0% | 3 | $65,364,163.10 | 3.03% | 0.12 | 0.35 | 0.34 | 25.1% |
| 1241 | 15 | 195 | 90.0% | 2 | $95,908,367.77 | 7.51% | 0.30 | 0.72 | 0.96 | 25.1% |
| 1223 | 15 | 190 | 90.0% | 2 | $88,058,349.75 | 6.50% | 0.26 | 0.65 | 0.73 | 25.0% |
| 1632 | 17 | 165 | 82.5% | 3 | $61,144,201.03 | 2.26% | 0.09 | 0.28 | 0.28 | 24.9% |
| 1668 | 17 | 175 | 82.5% | 3 | $64,640,170.55 | 2.90% | 0.12 | 0.34 | 0.33 | 24.8% |

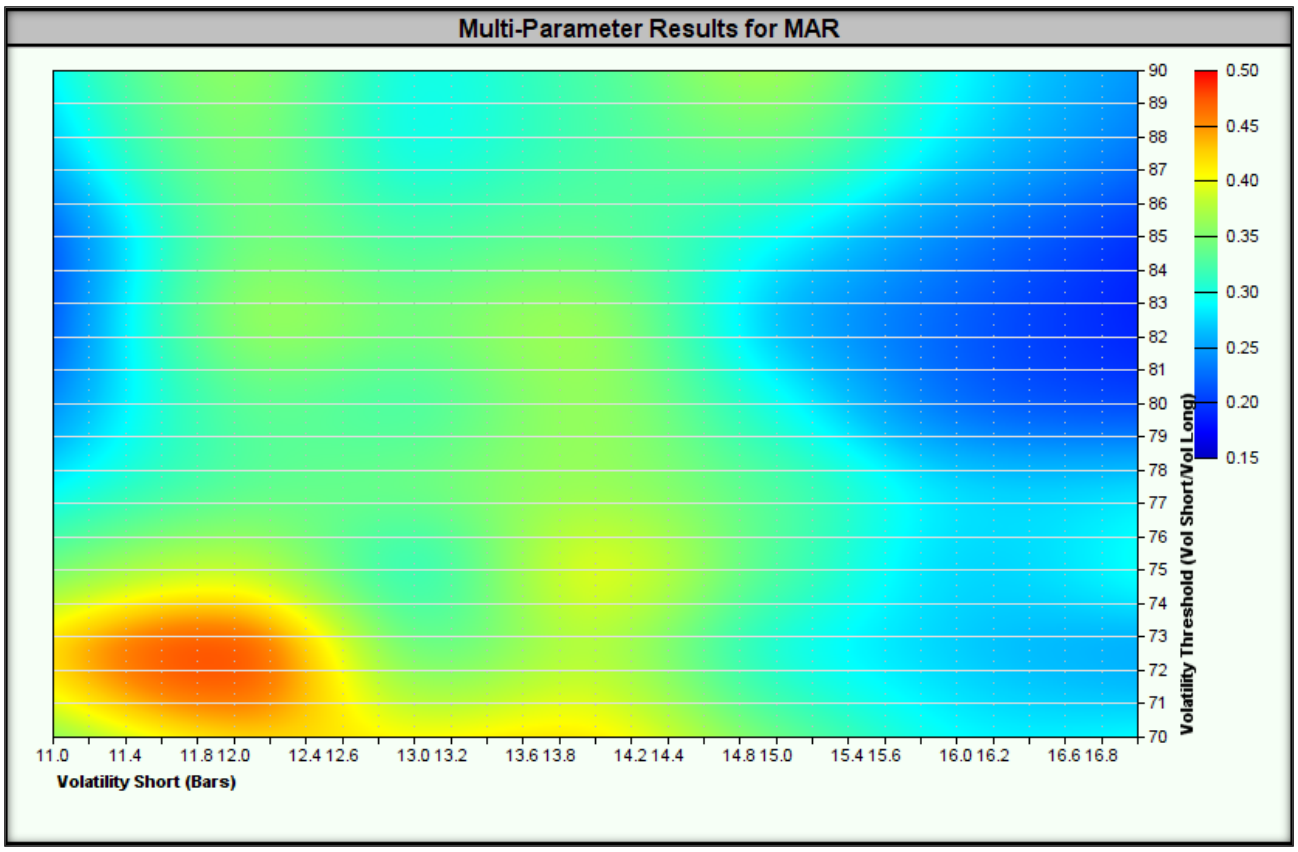
**In summary,** the strategy **passed the stability test** over a wide range of optimized parameters on out-of-sample data because:

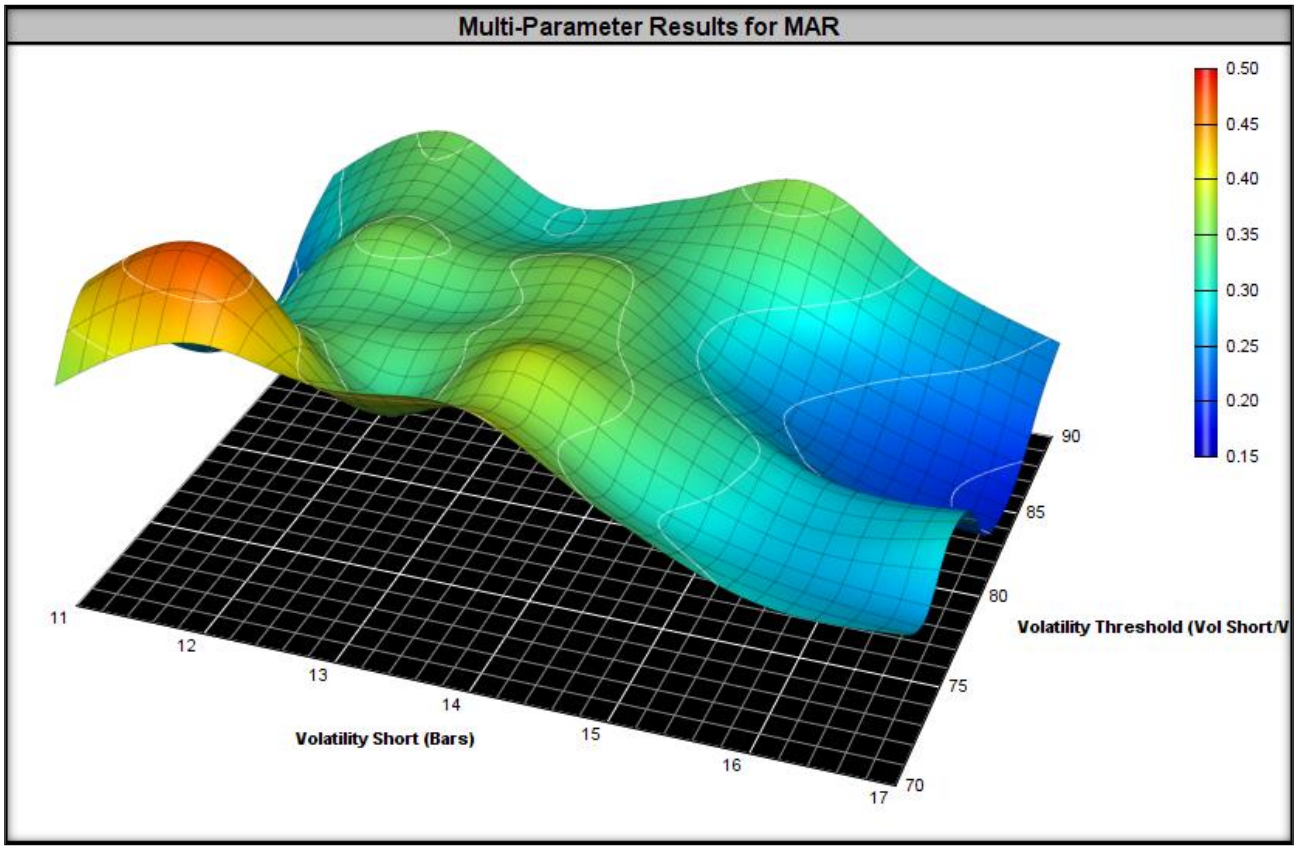
- **All test results showed a positive MAR value** – which indicates the stability of the strategy in various market conditions.
- **The maximum drawdown on out-of-sample data did not exceed 150% of the maximum drawdown value on in-sample data (28.0% vs. 33.9%)** – which means an acceptable risk of capital drawdown.
- **The decrease in the maximum MAR value on out-of-sample data was less than 50% compared to the in-sample test results (0.81 vs. 0.44) –** indicating that the strategy can achieve good results in a variety of market conditions.

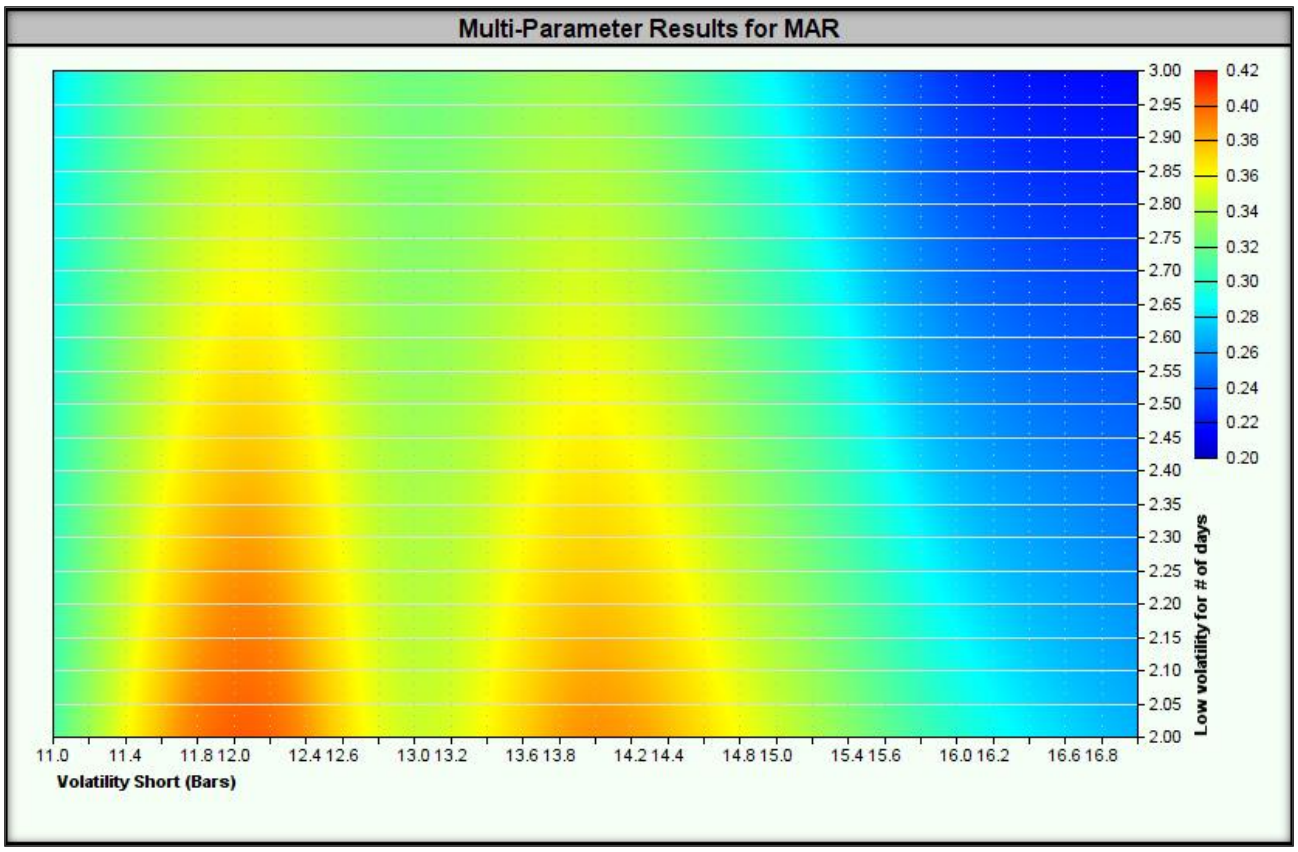
**Heatmaps for the tested ranges** are shown below.

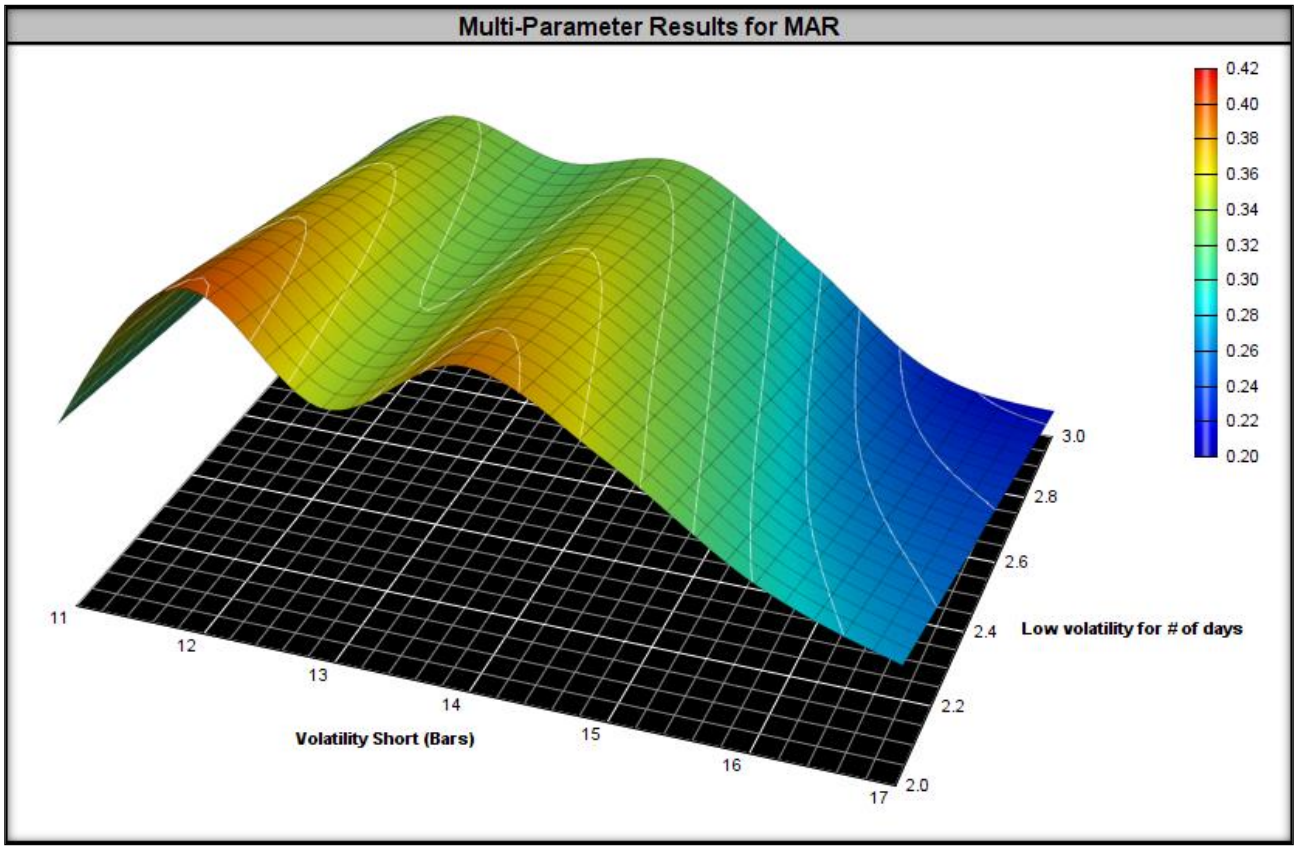


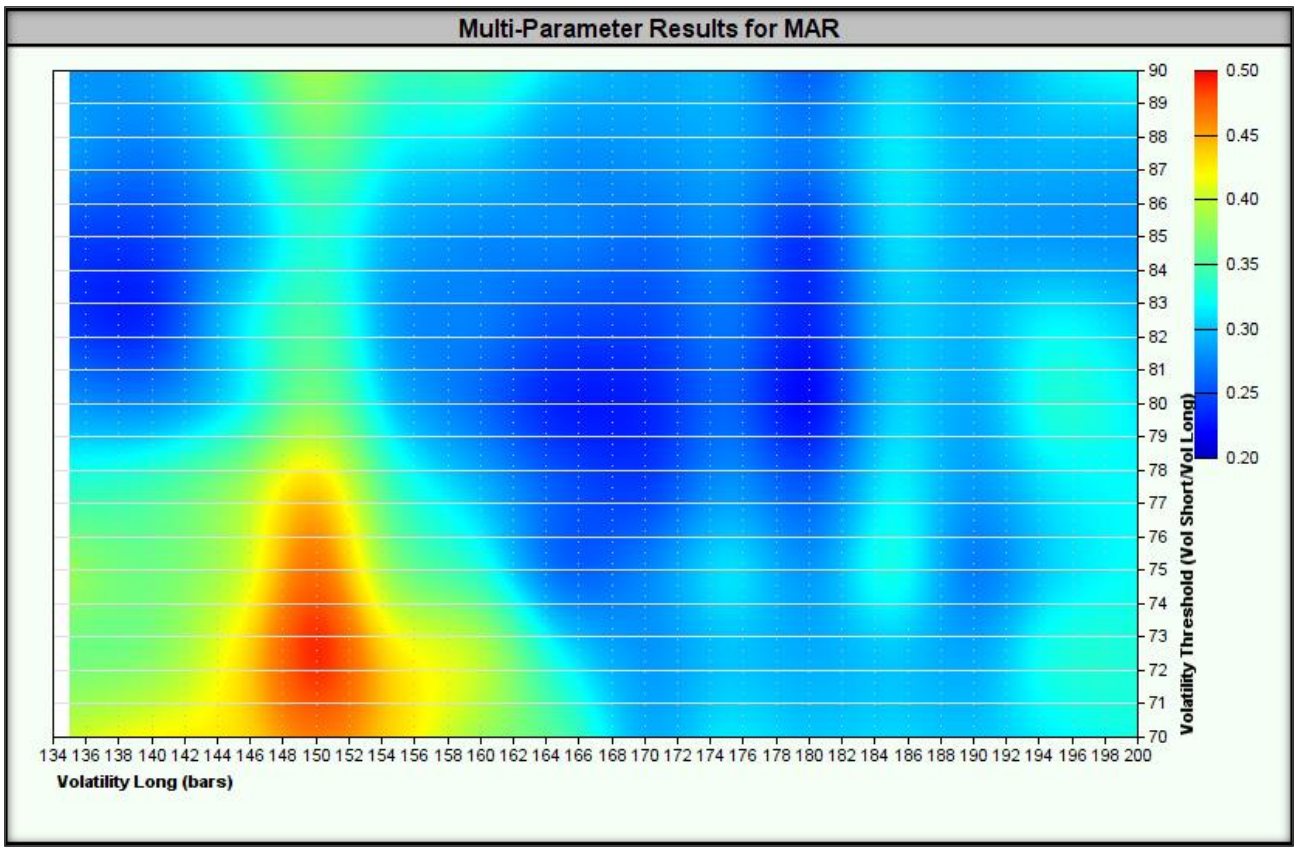

Multi-Parameter Results for MAR
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
200
190
180
170
160
150
140
130
Volatility Long (bars)
11
12
13
14
15
16
17
Volatility Short (Bars)

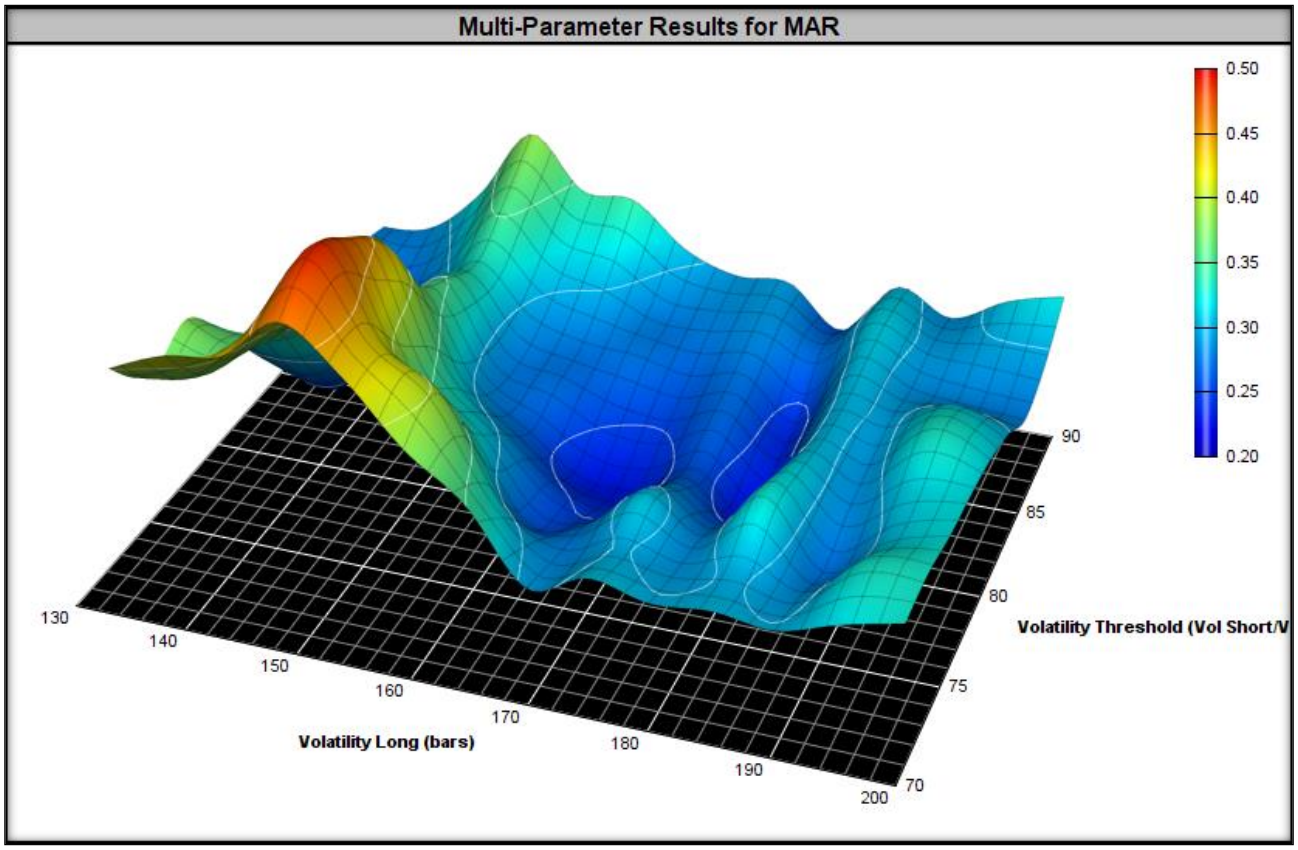

Multi-Parameter Results for MAR
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
Volatility Threshold (Vol Short/Vol Long)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
11.0
11.4
11.8 12.0
12.4 12.6
13.0 13.2
13.6 13.8
14.2 14.4
14.8 15.0
15.4 15.6
16.0 16.2
16.6 16.8
Volatility Short (Bars)

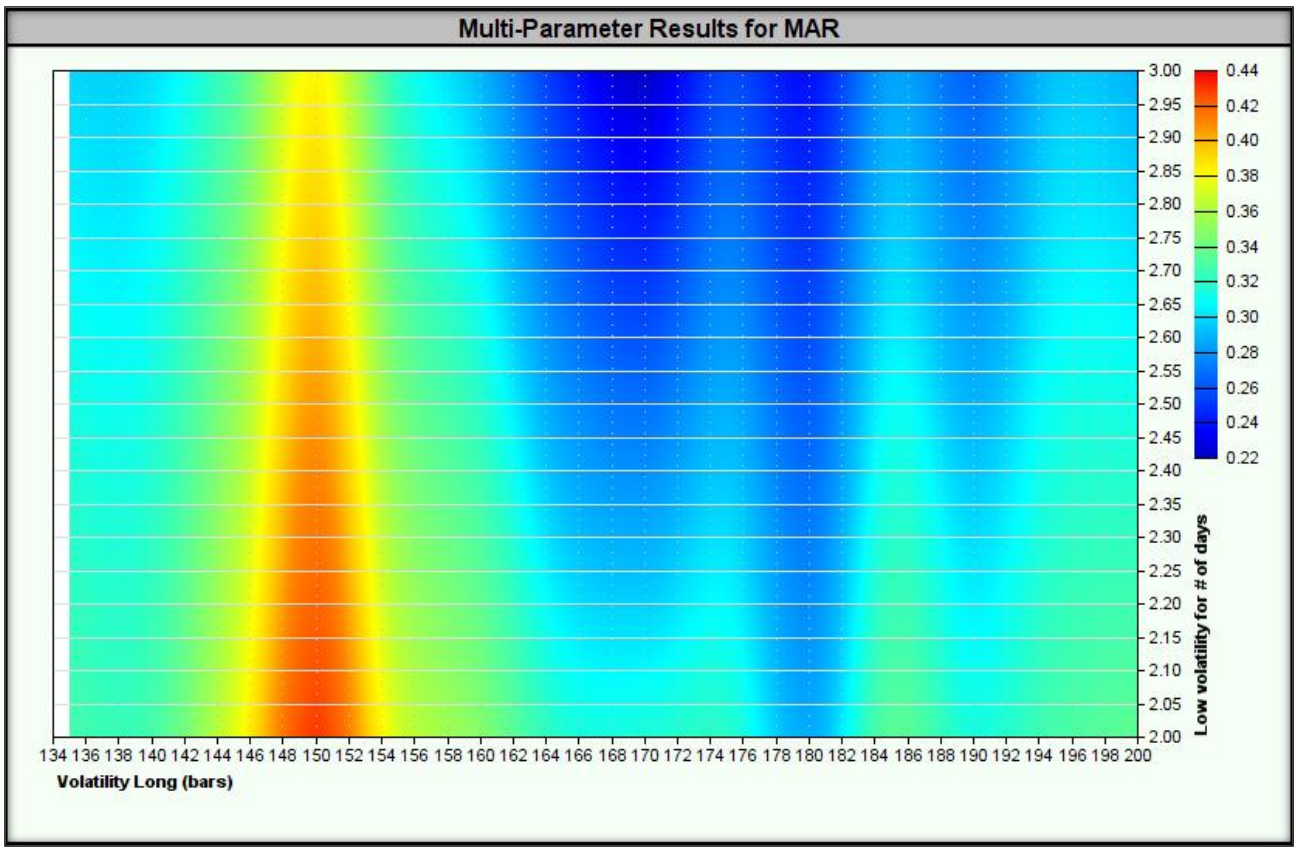

Multi-Parameter Results for MAR
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
11
12
13
14
15
16
17
Volatility Short (Bars)
70
75
80
85
90
Volatility Threshold (Vol Short/V

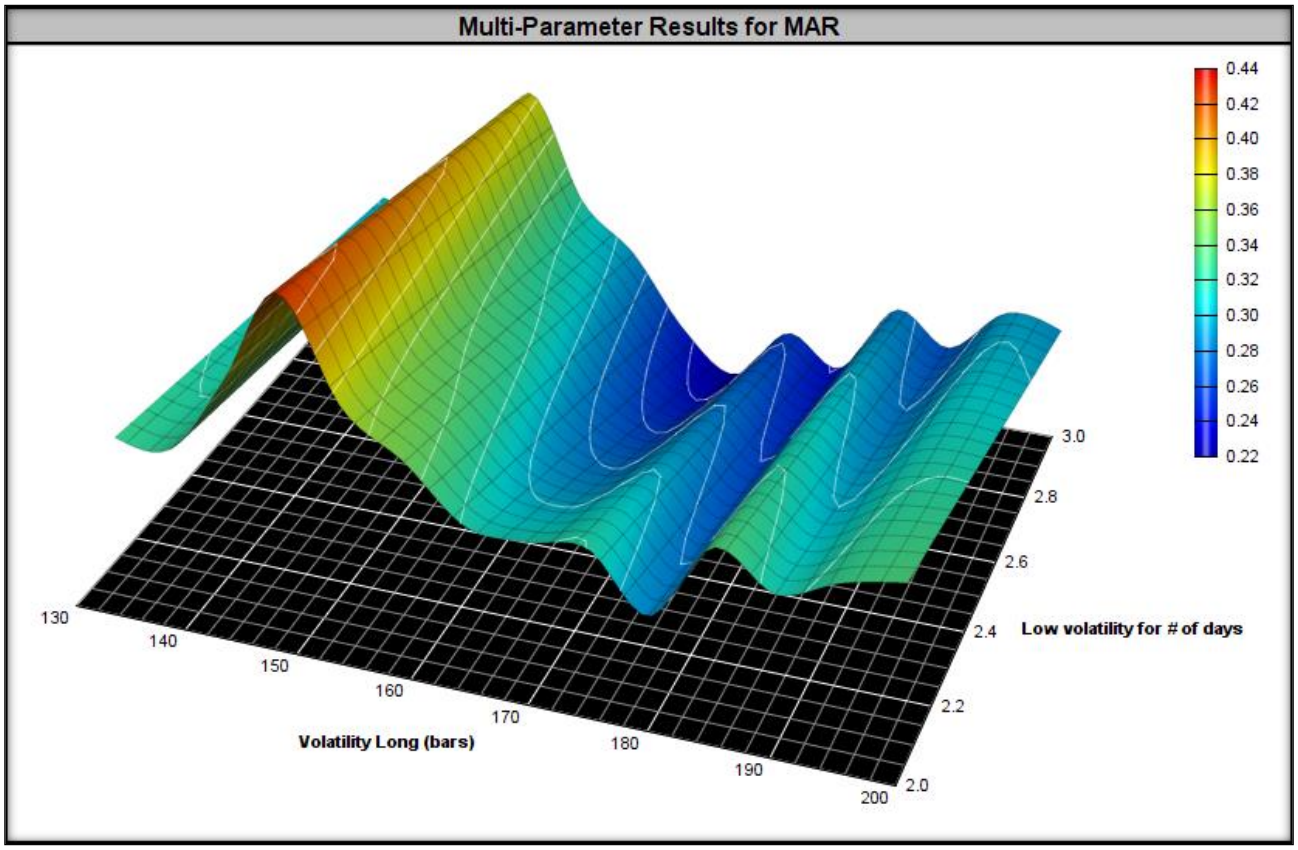

Multi-Parameter Results for MAR
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days
11.0
11.4
11.8 12.0
12.4 12.6
13.0 13.2
13.6 13.8
14.2 14.4
14.8 15.0
15.4 15.6
16.0 16.2
16.6 16.8
Volatility Short (Bars)

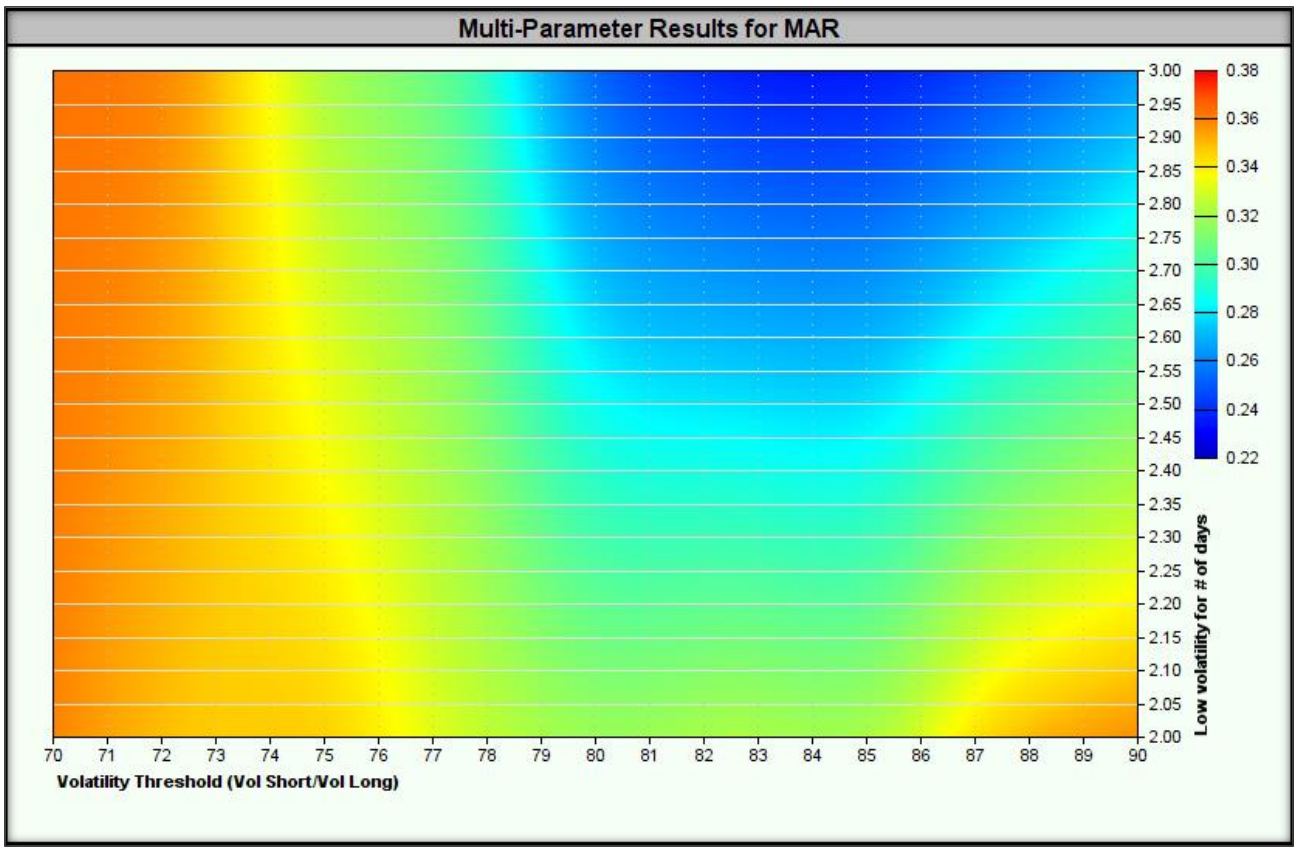

Multi-Parameter Results for MAR
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
11
12
13
14
15
16
17
Volatility Short (Bars)
2.0
2.2
2.4
2.6
2.8
3.0
Low volatility for # of days

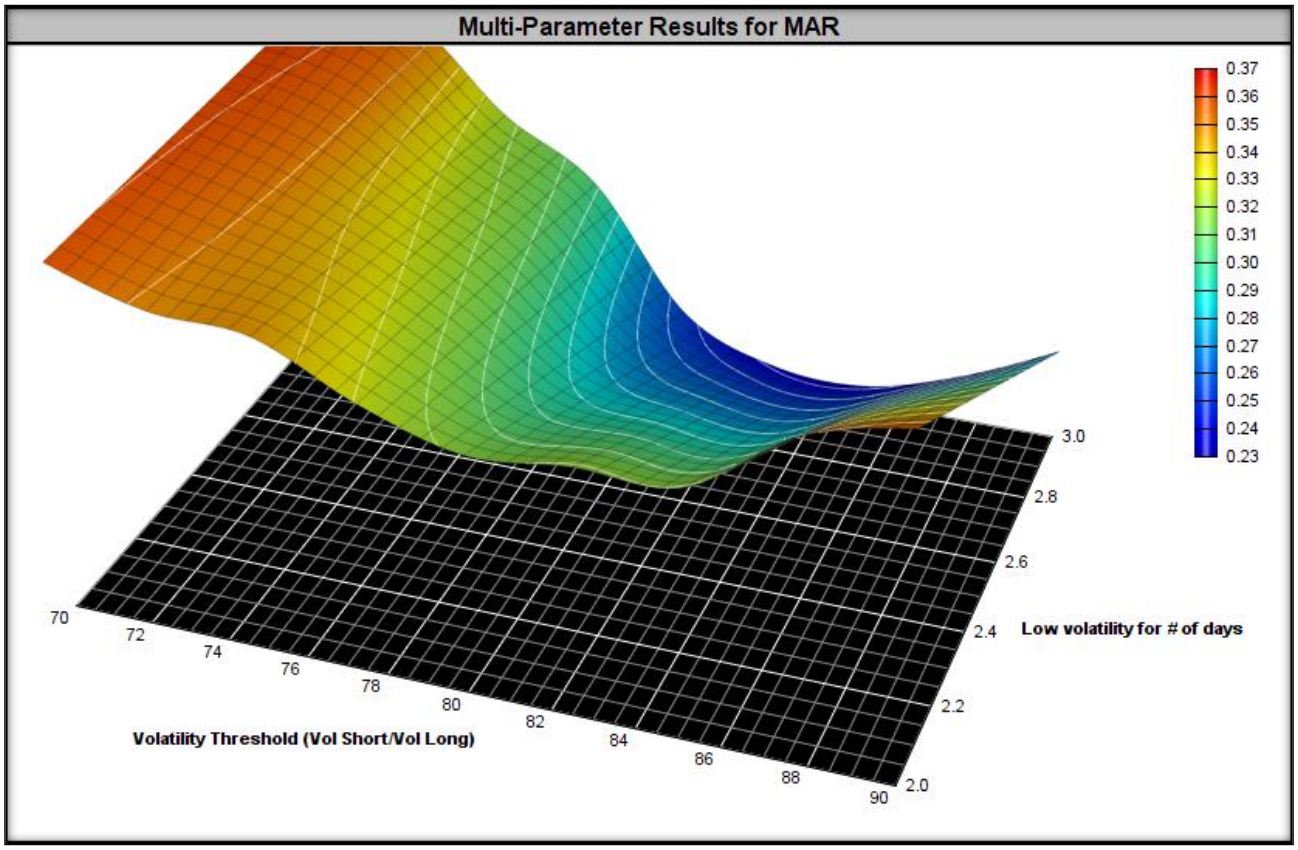

Multi-Parameter Results for MAR
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
Volatility Threshold (Vol Short/Vol Long)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
134 136 138 140 142 144 146 148 150 152 154 156 158 160 162 164 166 168 170 172 174 176 178 180 182 184 186 188 190 192 194 196 198 200
Volatility Long (bars)

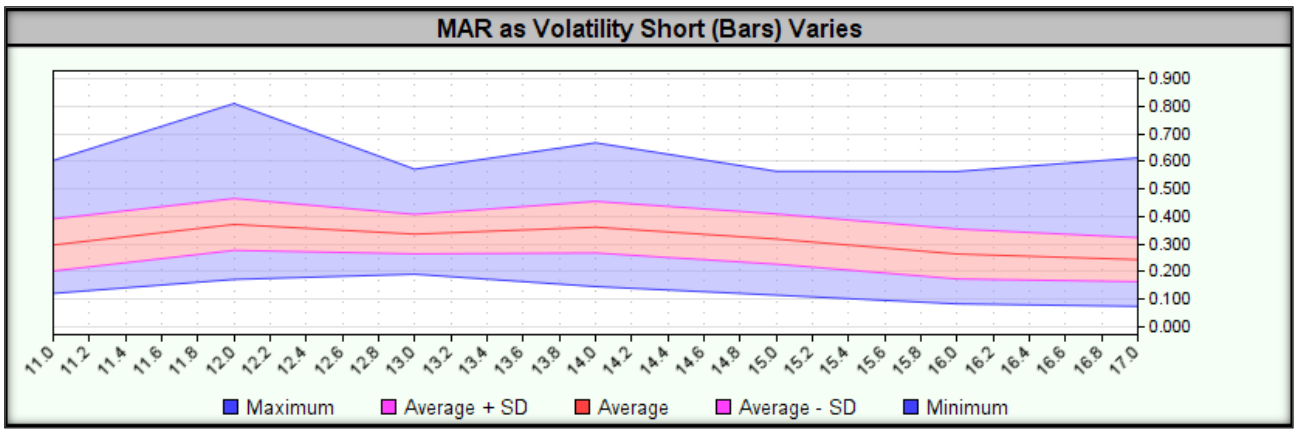

Multi-Parameter Results for MAR
0.50
0.45
0.40
0.35
0.30
0.25
0.20
130
140
150
160
170
180
190
200
Volatility Long (bars)
70
75
80
85
90
Volatility Threshold (Vol Short/V

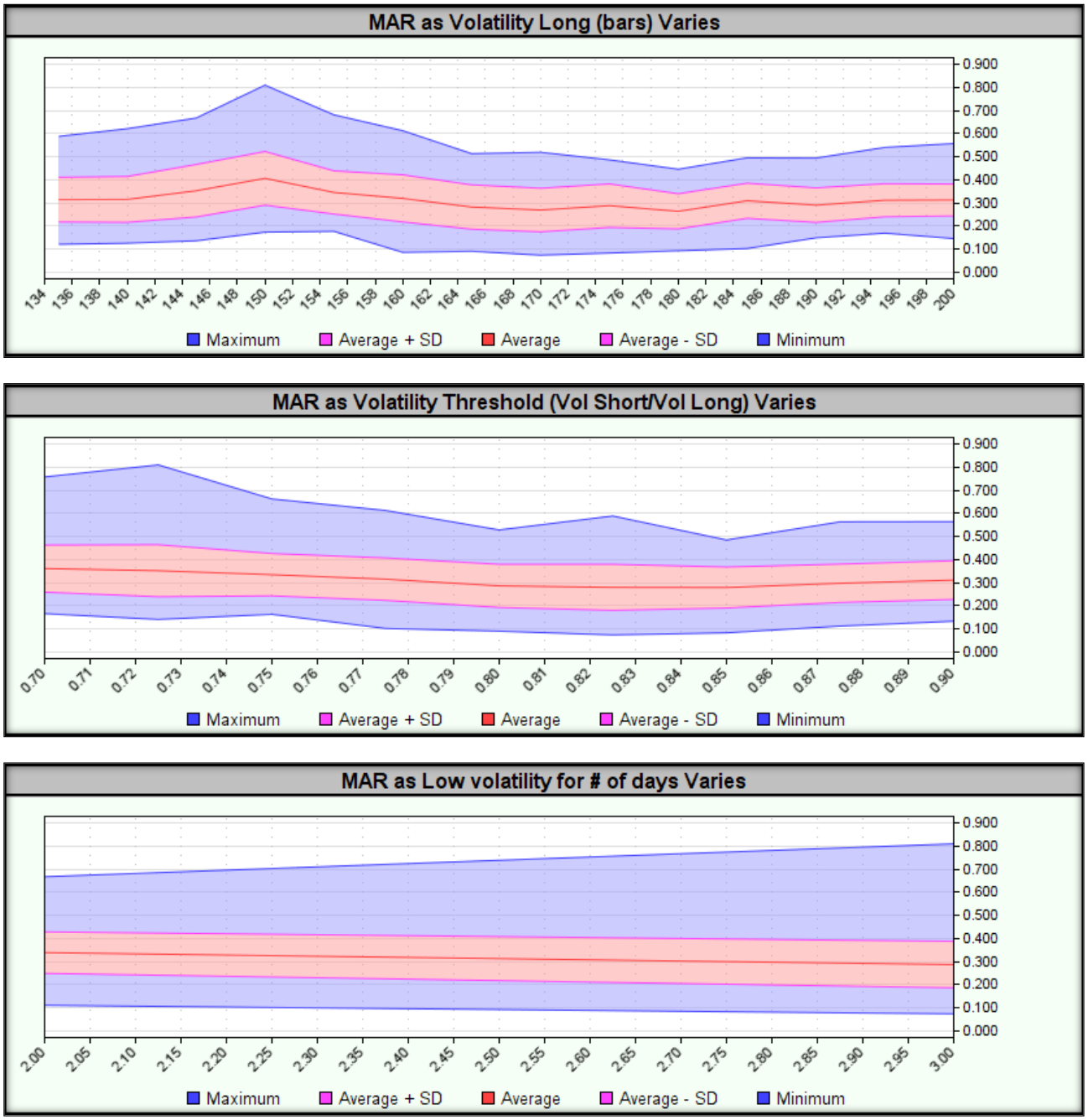

Multi-Parameter Results for MAR
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days
134 136 138 140 142 144 146 148 150 152 154 156 158 160 162 164 166 168 170 172 174 176 178 180 182 184 186 188 190 192 194 196 198 200
Volatility Long (bars)


Multi-Parameter Results for MAR
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
130
140
150
160
170
180
190
200
Volatility Long (bars)
3.0
2.8
2.6
2.4
2.2
2.0
Low volatility for # of days


Multi-Parameter Results for MAR
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
Volatility Threshold (Vol Short/Vol Long)
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Low volatility for # of days


Multi-Parameter Results for MAR
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
0.26
0.25
0.24
0.23
70
72
74
76
78
80
82
84
86
88
90
Volatility Threshold (Vol Short/Vol Long)
2.0
2.2
2.4
2.6
2.8
3.0
Low volatility for # of days


MAR as Volatility Short (Bars) Varies
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4
12.6
12.8
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
14.6
14.8
15.0
15.2
15.4
15.6
15.8
16.0
16.2
16.4
16.6
16.8
17.0
Maximum
Average + SD
Average
Average - SD
Minimum




Once **the stability test has passed across a wide range of optimized parameters,** we can proceed to **stability testing using Monte Carlo simulation.** The conditions for passing this test are similar to those required in the step above.

### 2. Monte Carlo simulation

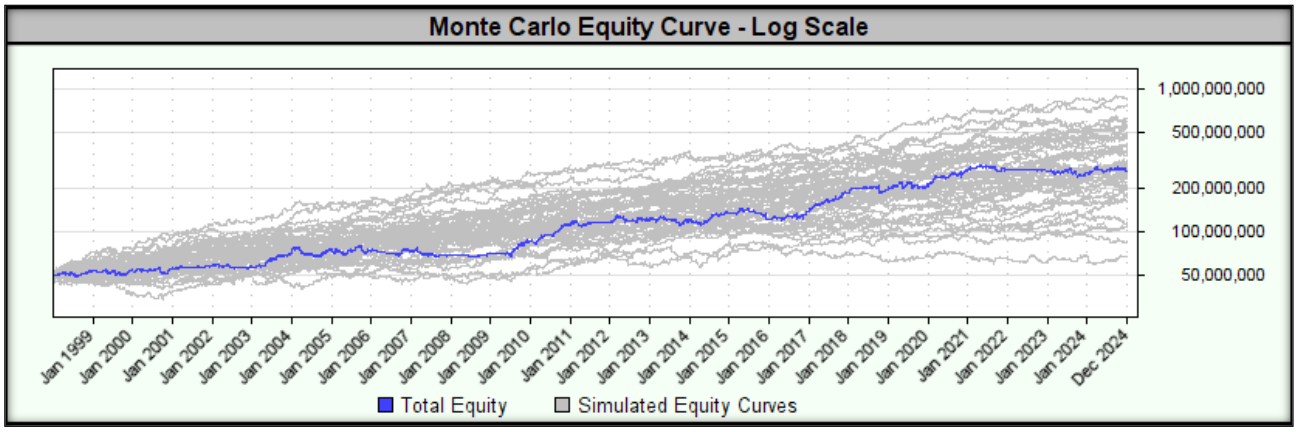
**Monte Carlo simulation** involves running multiple simulations to examine how a strategy might perform under various market scenarios. A key goal of this method is to assess the potential **drawdown** of an optimized strategy. **Monte Carlo simulation** better reflects possible equity curve fluctuations and the depth of potential **drawdown,** allowing for a more realistic risk assessment. It also provides an ideal opportunity to

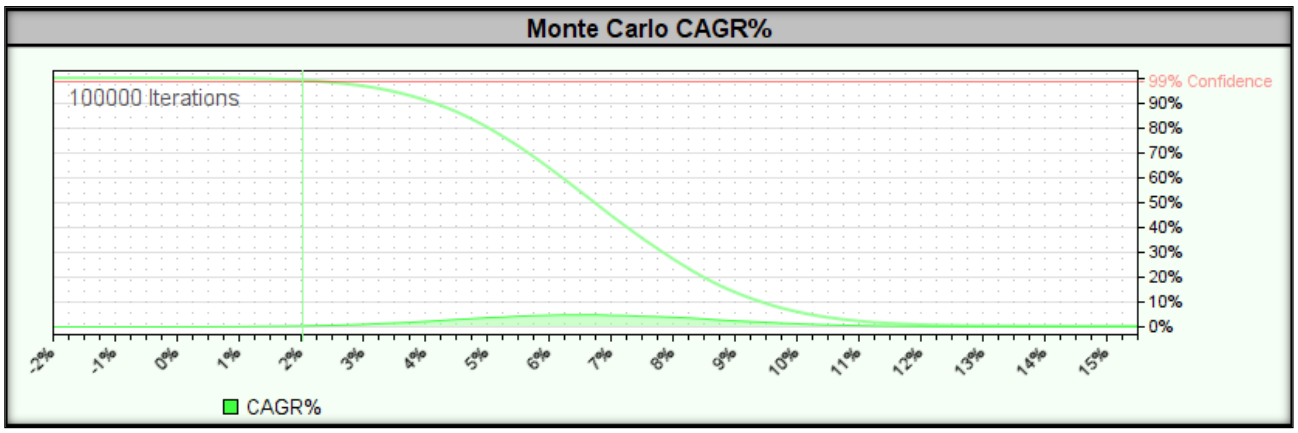
compare **the drawdown** obtained in tests on optimized parameter ranges with the results of **the Monte Carlo simulation,** using **a 99% confidence interval.**

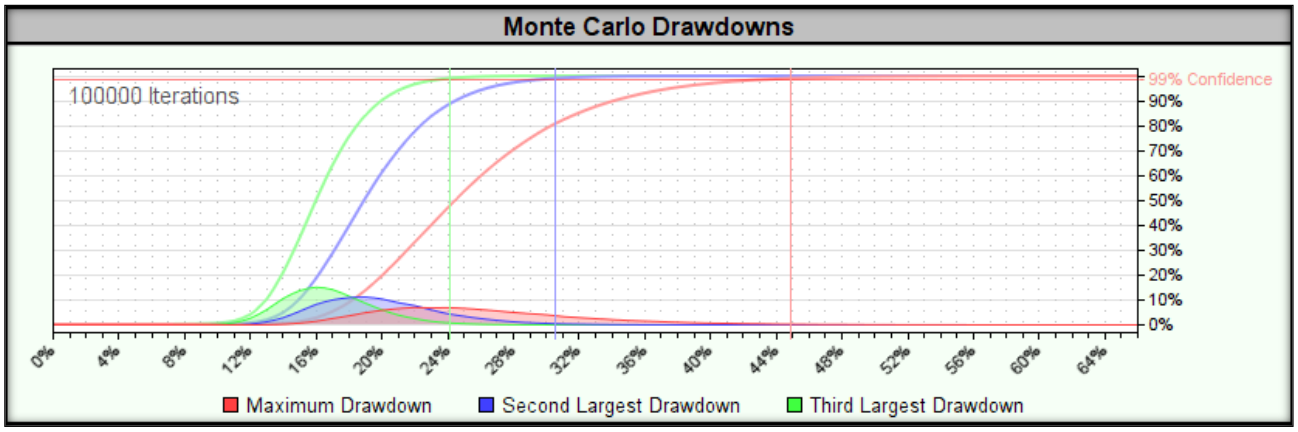
A strategy considered to be **stable (robust)** should achieve **a drawdown in a Monte Carlo simulation** that does not exceed **250% of the drawdown** size **from total tests in-sample and out-of-sample** (for parameters optimized on IS data). Furthermore, the **MAR indicator** should remain positive within the chosen confidence interval.

For data covering the period from **January 1, 1998 to December 31, 2024, a Monte Carlo simulation** was performed using **optimal strategy parameters.** The Monte Carlo simulation was performed **100,000 times,** testing **the variant with replacement (more conservative),** and **the confidence interval was set to 99%.**

**The simulation with sample replacement** are presented below.






- **CAGR%** – In 99% of simulations achieved **a rate of return equal to or higher than 2%.**
- **Drawdown** – 99% of simulations achieved **a drawdown of 45% or less.** For parameters optimized on in-sample data, the drawdown was 17.0%.

The strategy stability criteria **were not met** because **the drawdown In Monte Carlo simulation exceeded 250% values drawdown from tests on optimized parameters.** Therefore, **further testing of the strategy is not justified,** as its use in real transactions **is highly doubtful.**

3. **Stability over a moving time window**

**The step was omitted** due to **failure of previous stability tests.**

4. **Long/short stability**

**The step was omitted** due to **failure of previous stability tests.**

5. **Stability in the portfolio of financial instruments**

**The step was omitted** due to **failure of previous stability tests.**

6. **Money Management (Position Sizing)**

**The step was omitted** due to **failure of previous stability tests.**

7. **Strategy Risk Management**

**The step was omitted** due to **failure of previous stability tests.**

# Step 5: Walk-Forward Analysis

**Walk-Forward Analysis (WFA)** is a key tool for assessing **a strategy's ability to perform in real-world market conditions.** It provides **reliable measures of reward and risk** after the optimization process and allows you to answer several key questions:

1. **What rate of return can you expect from the strategy?**
    - The optimization result often overestimates the expected rate of return, which can lead to unrealistic forecasts.
    - WFA provides more **reliable and realistic measures of return** by minimizing the impact of overfitting to historical data.
2. **What set of parameters should be used in the next period?**
    - Thanks to **WFA,** it is possible **to dynamically adjust the strategy parameters** to **the latest market changes,** increasing its adaptability.

**WFA tests the strategy over multiple time periods, minimizing the risk of overfitting** (overfitting the strategy to historical data). The WFA process consists of **two repeated steps:**

1. **Optimization (In-Sample):**
    - The strategy is optimized over a specific **training period** (**in-sample)**.
    - This step adjusts the parameters to obtain **the best results.**
2. **Testing (Out-of-Sample):**
    - The strategy, using **the parameters optimized in step 1,** is tested on **a test period** (**out-of-sample)**.
    - This stage verifies the effectiveness of the strategy in new market conditions that **were not used** during optimization.

**Walk-Forward Efficiency (WFE)** is a key metric that assesses a strategy's potential to perform under real-world market conditions. WFE compares:

- **The rate of return achieved in the in-sample window** (where parameters were optimized)
- **Rate of return in the out-of-sample window** (where the strategy was running on unknown data)

Similarly, **for the drawdown value,** WFE checks whether the strategy does not lose significant stability outside the optimization period.

A strategy considered **stable (robust) should meet the following conditions:**

- **WFE ≥ 50% for the rate of return** – means that the strategy retains at least half of its effectiveness beyond the optimization period.
- **WFE ≤ 150% for drawdown** – means that the drawdown outside the optimization period is not significantly higher than during the optimization period.

**The step was omitted** due to **failure of previous stability tests.**

# Step 6: Using the strategy in real time

After **extensive testing, implementing a real-time** investment strategy becomes **relatively simple. Buy/sell signals and stop loss orders are automatically generated** by the computer based on pre-established rules and formulas.

The most important element **of strategy execution** is **consistent execution of all signals, without exception. As Larry Williams noted:** *"Trading strategies work. Traders do not."*

Before making **a final decision to implement a strategy,** it's important to verify **whether it actually adds value** to the overall portfolio performance. It doesn't make sense to implement a strategy that **generates similar signals** or **has a similar equity curve.**

**Key criteria for evaluating strategies before implementation:**

1. **Daily return correlation**
   - The **lower the correlation** with other strategies, the better.
   - **Optimal values:** Correlation **close to zero or negative.**
2. **Reducing maximum drawdown**
   - If adding a strategy to a portfolio results in **a lower maximum drawdown,** this is **a strong positive signal.**
3. **Objective Function Improvement (MAR)**
   - If adding a strategy causes **the MAR to increase,** this indicates that **it has added value** to the portfolio.
4. **Better results in Monte Carlo simulation**
   - Monte Carlo simulation determines the potential **maximum drawdown.**
   - If Monte Carlo results **improve** after adding a strategy, this is **a strong positive signal.**

**The above elements are often interrelated** – usually **all** or **none of them are met.**

Once you decide to add a strategy to your portfolio, **the question arises:** *Should you implement the strategy immediately or is it better to wait?*

Some studies suggest **an incubation period** of **3-6 months,** during which:

- The strategy is **monitored** but **does not execute real transactions.**
- **Generated signals, positions and results** are observed to detect **potential anomalies.**

In our case, **the incubation period** lasts from the moment **the strategy is launched in a live environment** until **a drawdown occurs at approximately half the maximum drawdown** observed in historical data. **Only after this threshold is reached does the strategy begin to be used with real funds.**

Thanks to this:

- **We avoid investing real money in an untested environment.**
- **We wait for a drawdown to occur** before launching the strategy, which **reduces the risk of starting at an unfavorable moment.**

The final decision on its full implementation should be based on **thorough testing and analysis of the value added to the portfolio,** so that the strategy actually supports long-term investment goals and does not increase unnecessary risk.