Dual Moving Average Crossover v.1

Investment Strategy Testing Summary

Moving Strategy Average Crossover is a trend-following trading technique that uses moving averages to identify opening and closing points. Its goal is to capture long-term market movements, both up and down, on daily charts.

However, while stability tests in a wide range of optimized parameters and Monte Carlo simulations were passed, **the strategy failed the moving window test** – for the annual period, only 18 out of 27 periods ended with a positive rate of return (**66.7% against the minimum required 70%)**. This is one of the tests conducted as part of the stability assessment, and failure to pass any of these tests means that **the strategy is not recommended for use in real transactions.**

I cannot emphasize enough that for **a strategy to work** in real conditions, it must also work on **suboptimal parameters** and in **suboptimal conditions.** In a word – **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly reflect 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 the future market conditions, but if we know that our strategy **has historically generated acceptable results** in different market conditions and on different parameter ranges, then we are **a step ahead of other market participants. Dual Moving** Strategy **Average However, the crossover is not included in this group.**

Contents

Step 1: Formulate an investment strategy

Dual Moving Strategy **Average Crossover** is based on the use of two moving averages: **a faster** (around 50 days) and **a slower** (around 200 days). It is a **trend-following strategy,** aimed at capturing long-term market movements – both up and down – on daily charts.

Basic principles of the strategy:

- **Buy signal (long):** generated when **a faster moving average crosses a slower moving average** from below.
- **Sell signal (short):** generated when **a faster moving average crosses a slower moving average** from above.

In the basic version, the strategy is **symmetrical,** which means that **a buy signal** simultaneously **closes a short position,** and **a sell signal** closes **a long position.** In the next steps, you can modify these elements.

Characteristics of the strategy and its strengths and weaknesses:

- **Filtering Market Noise:** Using two **long-term moving averages** effectively filters out market noise that is more visible with shorter moving averages. This allows the strategy to focus on significant, long-term moves while minimizing the impact of false signals.
- **Trend Following:** The strategy uses the mechanism of moving average crossings to **catch the beginning and end of a trend.** This gives you the opportunity to enter the market in the early phase of the trend, when the movement still has the potential to develop further.
- **Positive Expected Value (Edge): Long-term trend-following** strategies such as this one **have historically exhibited positive expected value,** especially in the futures markets. This is because trends tend to persist for an extended period of time, allowing for profits to be larger than potential losses.
- **Signal Lag:** One of the main problems with moving average strategies is **the signal lag.** Moving averages are **lagging indicators,** meaning that buy or sell signals only appear after a trend change. This can lead to entering a trade too late, when a significant part of the move has already taken place.
- **False Signals in Consolidations:** During periods **without a clear trend,** the strategy may generate **false signals** as the moving averages repeatedly cross, leading to a series of losing trades.
- **Requires patience:** Due to **the long-term nature** of the strategy, investors must be prepared **to wait long periods** for entry and exit signals. This requires **discipline** not to abandon the strategy when the market moves against forecasts.
- **Giving back a lot of profits:** Moving averages react **to trend changes with a delay,** which causes **exit signals** to appear too late, when the market is already starting to reverse. This causes the strategy to often **give back a lot of previously earned profits.**

Dual Moving Strategy **Average Crossover** is **a simple but effective method** of following long-term market trends. Its advantage is **the ability to identify large market movements,** making it an effective tool for investors who prefer **a long-term approach.**

However, **its effectiveness depends on market conditions** – it performs well in trends, but may generate **false signals during consolidation periods.** Moreover, due to the delay in generating signals, **profits are often given away** in the final phases of a trend.

Step 2: Define investment principles

Below is **the pseudocode** for the **Dual Moving strategy Average Crossover** on daily data:

1. **Calculating Indicators:**
   - **Faster (XX-day) Moving Average:** For each day, calculate the average of **the last XX closes.**
   - **Slower (YY-day) Moving Average:** For each day, calculate the average of **the last YY closes.**
2. **Generating Long Position Signals:**
   - **Entry requirement:**
     i. Yesterday (**D-1) the 20-day moving average** was **below YY day moving average.**
     ii. Today (**D) the XX-day moving average** is **above YY day moving average.**
   - **Entry: Buy at the open of the** next day.
   - **Maintain Position:** Remain in a long position until a sell signal occurs.
3. **(Long) Signals:**
   - **Entry requirement:**
     i. Yesterday (**D-1) the 20-day moving average** was **above YY day moving average.**
     ii. Today (**D) the XX-day moving average** is **below YY day moving average.**
   - **Entry: Sell at** next day's open.
   - **Maintain Position:** Remain in a short position until a buy signal occurs.
4. **Closing a Position:** Before opening a new position, **close the previous** opposite position.
5. **Every day:**
   - **Calculate XX- and YY-day moving averages.**
   - **Check entry/exit conditions.**
   - **Take or close a position** according to the rules above.
6. **Risk and Position Sizing Management:**
   - **Stop Loss:** The strategy **does not assume a stop loss order** when opening a position.
   - **Position Sizing:**
     i. **Hypothetical stop loss level:** 3 x ATR (40-day).
     ii. **Maximum risk:** 1% of capital value.
     iii. **ATR (Average True Range):** calculated on a **40-day basis.**

The above rules have been 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.

Since the strategy does not assume having a stop loss order at the time of opening the position, **the position size is estimated based on a hypothetical defensive stop loss order distant from the position opening point by 3 x ATR and a risk of 1% of capital.** ATR is calculated on a 40-day basis.

Step 3: Conduct a preliminary test of the investment strategy

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

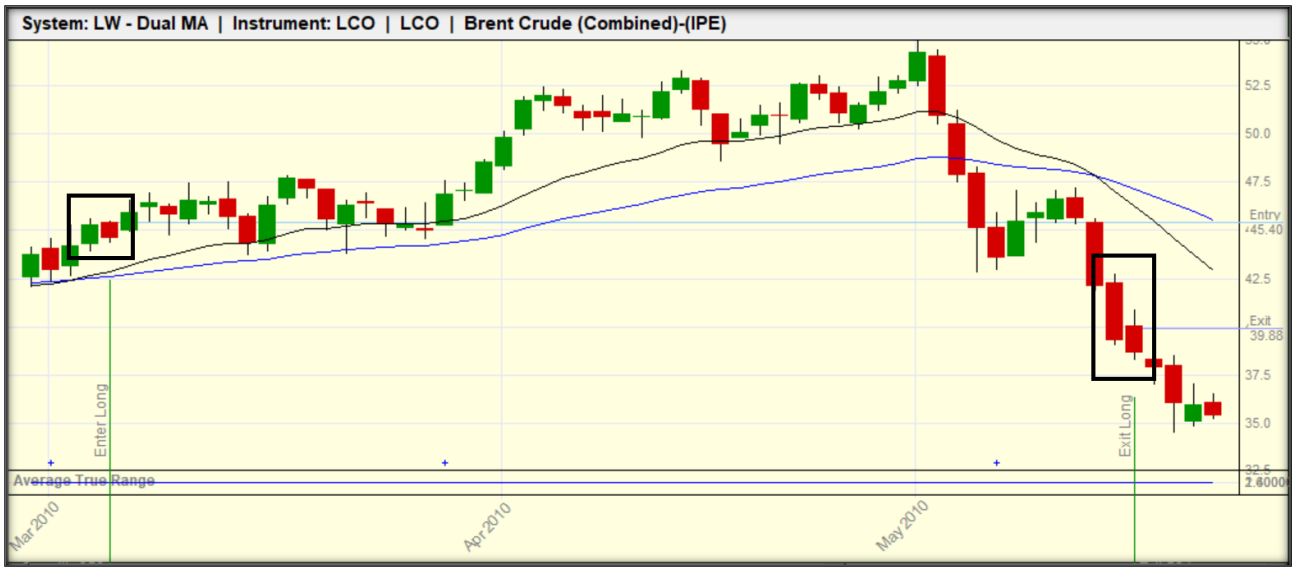
- **Correctness of generated signals;**
- **Direction of opening position;**
- **Moment of opening a position;**
- **Position opening price;**
- **Moment of closing the position;**
- **Closing price of the position;**
- **Compliance of the transaction with the theoretical assumptions of the investment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

At this stage **it does not matter** whether the transactions are **profitable,** what **instrument was used** or whether they took place **recently** or **in the distant past.** The key is **to check whether the transactions are generated correctly** and in accordance with the assumptions described in the previous step.

The first transaction was made on **a Brent futures contract Crude.** In early March 2010, **a buy signal was generated – the fast moving average** crossed **the slow moving average from below.** Two candles are marked **in the rectangle on the left side of the chart:**

- **First candle:** generates **a moving average crossover signal.**
- **Second candle:** this is the day **the position is opened** (we take a position at the opening of the next day).

The system worked properly.



In mid-May 2010, a signal to close a long position was generated **– the fast moving average** crossed **the slow moving average from above.**

Two candles are marked **in the rectangle on the right side of the chart:**

- **First candle:** generates **a moving average crossover signal.**
- **Second candle:** this is the day **of closing the position** (we close the position at the opening of the next day).

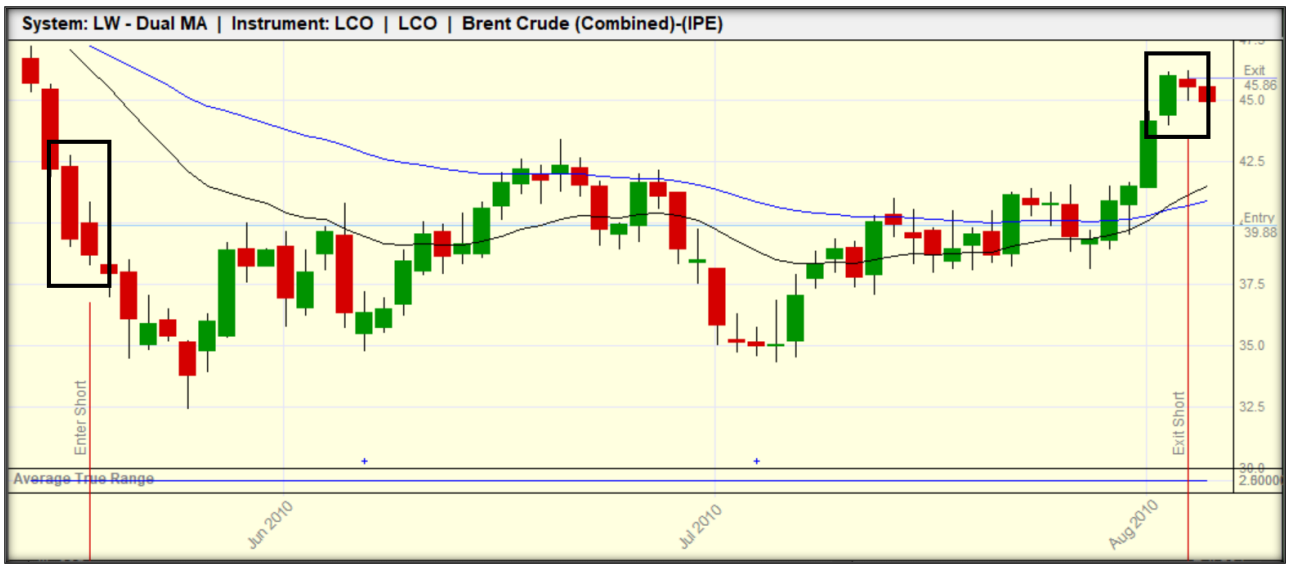
The system worked properly.

Since **our strategy is symmetrical,** which means that **the signal to close a long position** is also **a signal to open a short position,** when the above long position is closed, the system should automatically **open a short position.**

And indeed, this is what happens (see chart below). **The rectangle on the left side of the chart** shows two candles:

- **First candle:** generates **a signal of the crossing of the moving averages.**
- **Second candle:** this is the day **of opening the position** (we take a position at the opening of the next day).

Notice that **these are the same candles** that were marked in the previous example in **the rectangle on the right side of the chart. The system worked correctly.**



At the beginning of August 2010, a signal to close a short position was generated **- the fast moving average** crossed **the slow moving average from below.**

Two candles are marked **in the rectangle on the right side of the chart:**

- **First candle:** generates **a moving average crossover signal.**
- **Second candle:** this is the day **of closing the position** (we close the position at the opening of the next day).

The system worked properly.

And another **test signal,** this time from **November 1998** on **e-mini S&P 500 futures.** The **rectangle on the left side** of the chart shows two candles:

- **First candle:** generates **a signal of the crossing of the moving averages.**
- **Second candle:** this is the day **of opening the position** (we take a position at the opening of the next day).

The system worked properly.

At the beginning of June 1999, a signal to close a long position was generated **- the fast moving average** crossed **the slow moving average from above.**

Two candles are marked **in the rectangle on the right side of the chart:**

- **First candle:** generates **a moving average crossover signal.**
- **Second candle:** this is the day **of closing the position** (we close the position at the opening of the next day).

The system worked properly.

Since **our strategy is symmetrical,** which means that **the signal to close a long position** is also **a signal to open a short position,** when the above long position is closed, the system should automatically **open a short position.**

And indeed, this is what happens (see chart below). **The rectangle on the left side of the chart** shows two candles:

- **First candle:** generates **a signal of the crossing of the moving averages.**
- **Second candle:** this is the day **of opening the position** (we take a position at the opening of the next day).

Notice that **these are the same candles** that were marked in the previous example in **the rectangle on the right side of the chart.**

The system worked properly.

A few days later **the short position was closed** (the rectangle on the right side of the chart) *and* **the system reopened the long position.**

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 performed on **the basic parameters,** which – according to my assessment – should correspond to the assumed goals of the strategy.

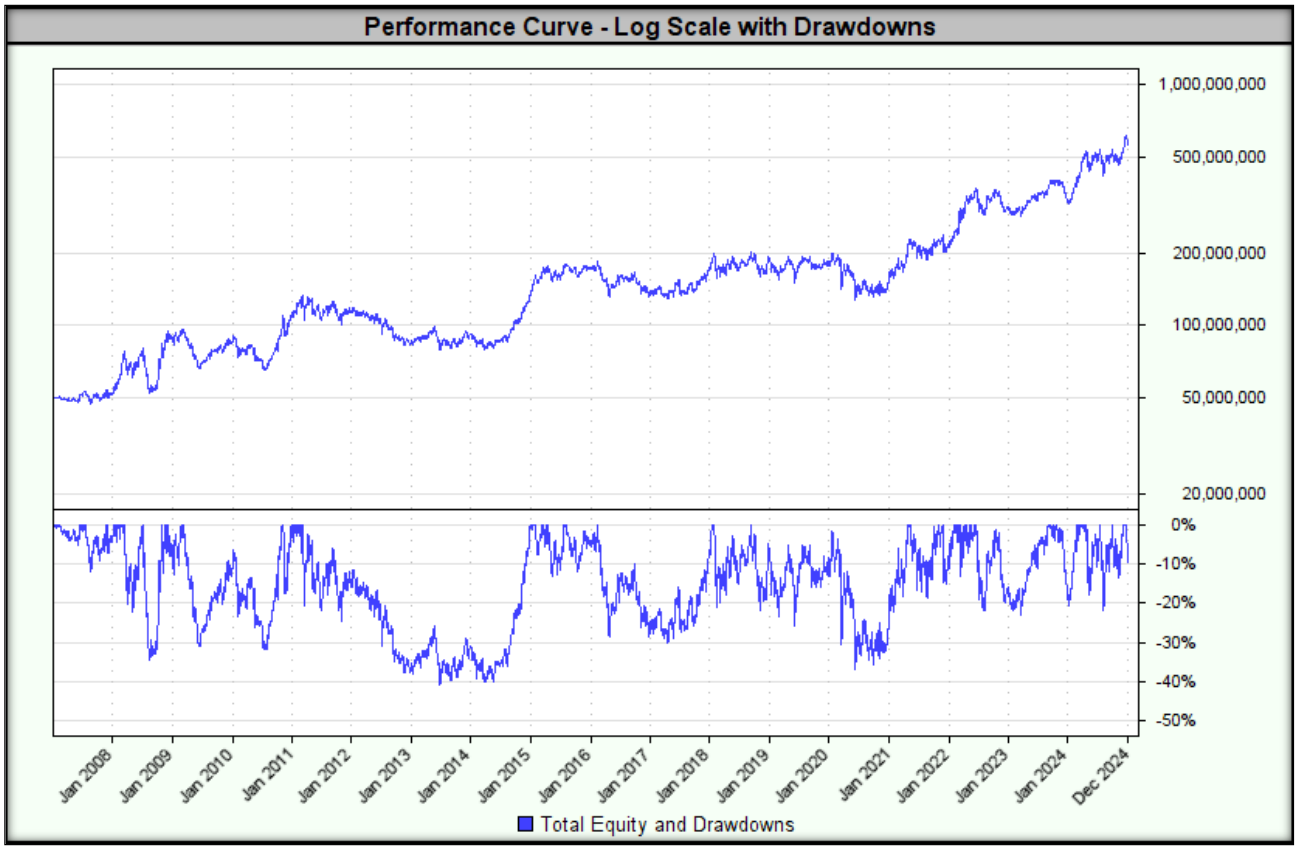
First of all, **we reject strategies that linearly lose capital.** If a strategy exhibits such a pattern, it is a clear signal that any parameter optimization does not make sense.

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

Tested base parameters:

- **Fast moving average:** 50 days (short term trend indicator).
- **Slow Moving Average:** 200 days (long-term trend indicator).
- **How to open a position:** At the opening price of the day following the day generating the signal (in accordance with the principle of taking a position after the signal).
- **Item size:**
  - Estimated based on **a hypothetical defensive order (stop loss).**
  - Stop loss located **3 x ATR (Average True Range)** away from the opening position.
  - **Risk:** 1% of capital per position.
  - **ATR calculated on a 40-day basis** (ATR(40)).

The test result is shown below.



Indicators/Measures	Dual Moving Average Crossover
CAGR%	14.6%
MAR Ratio	0.35
RAR%	10.6%
R-Cubed	0.14
Robust Sharpe Ratio	0.39
Max Drawdown	41.1%
Wins	28.5%
Losses	71.5%
Average Win%	5.37%
Average Loss %	1.32%
Win/ Loss Ratio	4.06
Average Trade Duration (days)	255
Percent Profit Factor	1.62
SQN	-
Number of transactions	617

In summary, the system works properly and generates signals as expected. Additionally, tests on basic parameters have yielded satisfactory results. We can now move on to the most interesting stage of creating an investment strategy – **optimization and stability.**

Step 4: Optimization and assessment of investment strategy stability

This stage of strategy creation and testing is **crucial,** as it determines how **effective** the strategy will be in **real conditions. I cannot** emphasize enough that for **a strategy to work** in real conditions, it must also work on **suboptimal parameters** and in **suboptimal conditions.** In a word – **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly reflect 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 subject of considerations in **Step 5 of the "Walk Forward Analysis",** but before we get to that, **we need to know whether our strategy is stable** at all.

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

Moving Strategy Average Crossover v.1 in this version it assumes **optimization of parameters using The Grid** method **Search.** It consists of **full optimization of all indicated parameters by creating a wide range of possible combinations.** Our goal is to find such **parameter ranges** that **the strategy remains stable (robust),** which will allow us to assess its usefulness in real market conditions.

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

In the first step, we test the stability of the parameters on **the in-sample data.** For this purpose, we determine the ranges of parameter **values** so that **the quotient of the highest and lowest values of the range was at least 150%.**

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

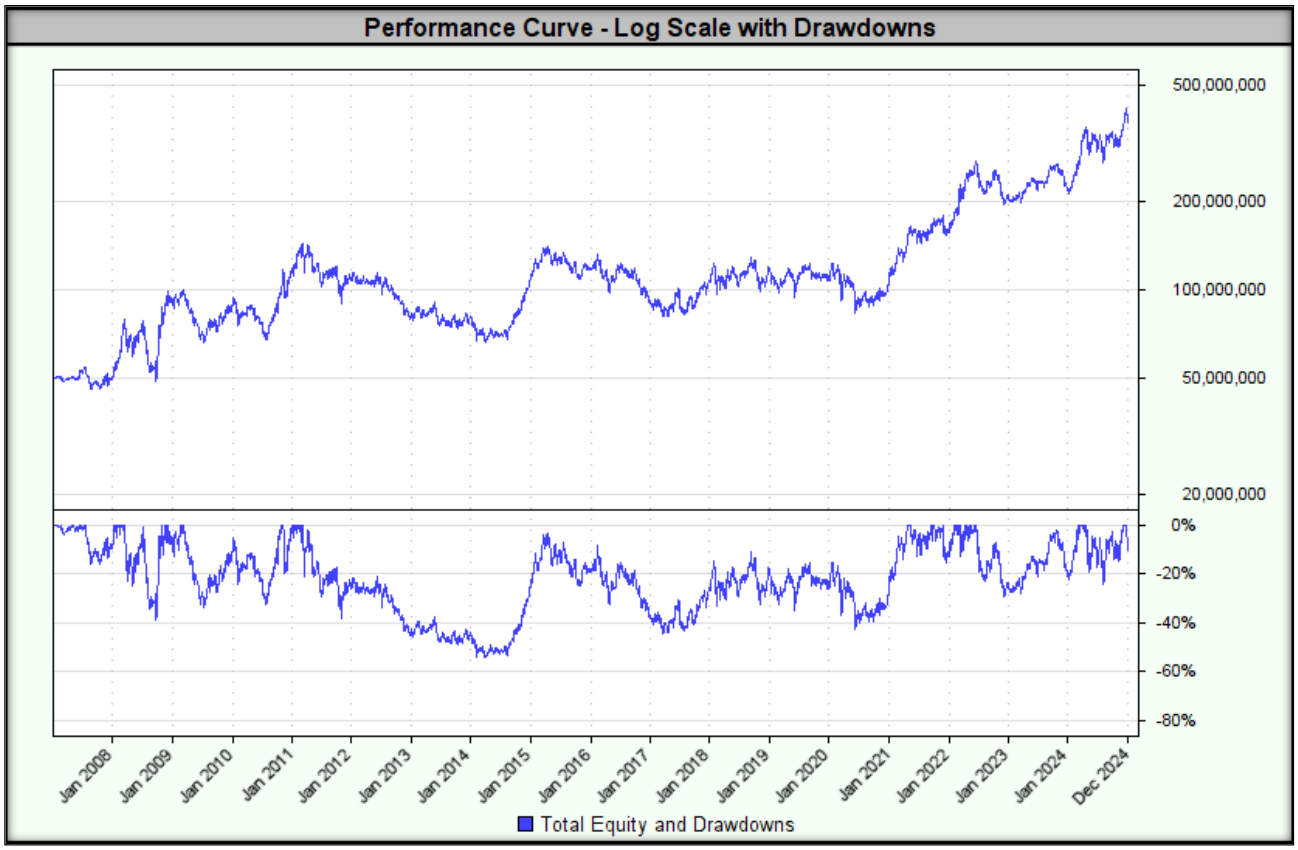
- **Fast moving average:** range **50-80 days (step: 1);**
- **Slow Moving Average:** Range **130-200 days (step: 2).**

The lowest MAR value of 0.22 was achieved for the following parameters:

- **Fast moving average:** 50;
- **Slow moving average:** 134.

Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
3	50	134	$386,434,406.00	12.03%	0.22	0.53	0.41	54.2%	121.6	835	0.08
39	51	134	$357,203,874.77	11.54%	0.22	0.52	0.40	51.6%	72.4	829	0.06
38	51	132	$391,316,545.80	12.11%	0.22	0.54	0.42	53.8%	121.6	837	0.08
4	50	136	$370,792,227.77	11.78%	0.23	0.53	0.41	51.9%	72.3	827	0.06
74	52	132	$381,157,774.60	11.95%	0.23	0.53	0.41	52.2%	72.3	819	0.06
110	53	132	$386,877,576.77	12.04%	0.23	0.54	0.41	52.0%	72.3	809	0.06
289	58	130	$404,077,526.87	12.31%	0.23	0.54	0.41	53.0%	72.0	773	0.07
219	56	134	$416,480,251.61	12.50%	0.23	0.55	0.42	53.5%	70.4	777	0.08
181	55	130	$391,776,464.64	12.12%	0.23	0.54	0.40	51.7%	72.3	807	0.07
325	59	130	$423,382,739.78	12.60%	0.23	0.55	0.41	53.7%	72.0	769	0.08
254	57	132	$409,480,946.01	12.39%	0.24	0.54	0.41	52.7%	72.1	773	0.07

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



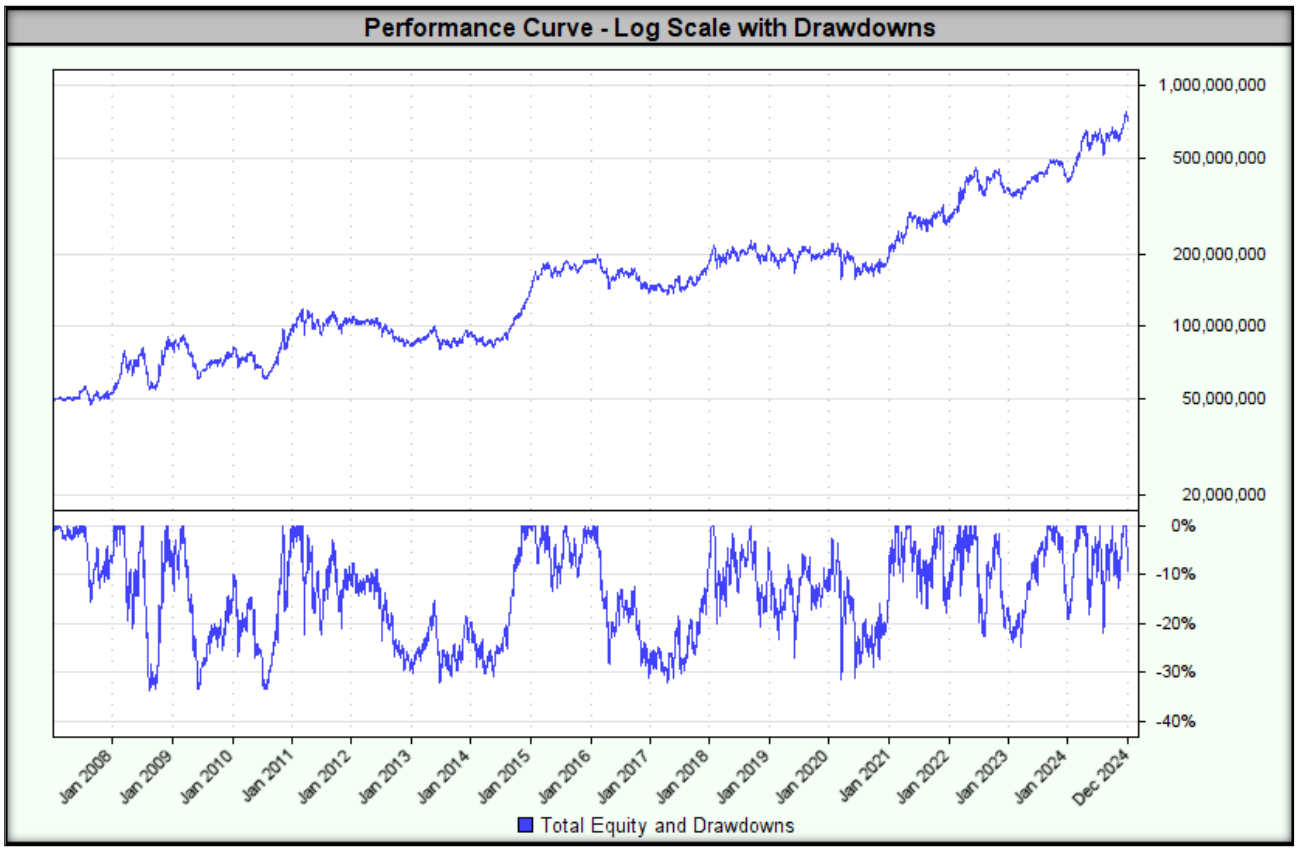
The highest MAR value of 0.48 was achieved for the following parameters:

- **Fast moving average:** 66;
- **Slow moving average:** 174.

The highest MAR value was accompanied by **a drawdown of 33.7%.**

Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
599	66	174	$727,908,260.16	16.04%	0.48	0.70	0.61	33.7%	44.1	576	0.18
600	66	176	$725,879,944.25	16.03%	0.47	0.69	0.60	34.4%	44.8	564	0.20
566	65	180	$720,826,384.64	15.98%	0.47	0.69	0.59	34.3%	44.4	564	0.18
564	65	176	$714,002,629.53	15.92%	0.46	0.69	0.60	34.2%	44.1	576	0.20
598	66	172	$699,830,347.69	15.79%	0.46	0.69	0.59	34.1%	44.3	594	0.18
563	65	174	$696,150,678.41	15.76%	0.46	0.69	0.59	34.1%	44.1	588	0.18
529	64	178	$691,699,384.05	15.72%	0.46	0.68	0.58	34.1%	44.3	576	0.20
528	64	176	$700,504,074.77	15.80%	0.46	0.69	0.60	34.3%	44.1	586	0.20
531	64	182	$705,279,095.62	15.84%	0.46	0.69	0.59	34.5%	44.4	564	0.18
494	63	180	$685,003,854.32	15.65%	0.46	0.68	0.59	34.1%	44.3	578	0.19
635	67	174	$696,202,966.34	15.76%	0.46	0.69	0.59	34.3%	44.8	572	0.17

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 54.2%.**

Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
3	50	134	$386,434,406.00	12.03%	0.22	0.53	0.41	54.2%	121.6	835	0.08
38	51	132	$391,316,545.80	12.11%	0.22	0.54	0.42	53.8%	121.6	837	0.08
325	59	130	$423,382,739.78	12.60%	0.23	0.55	0.41	53.7%	72.0	769	0.08
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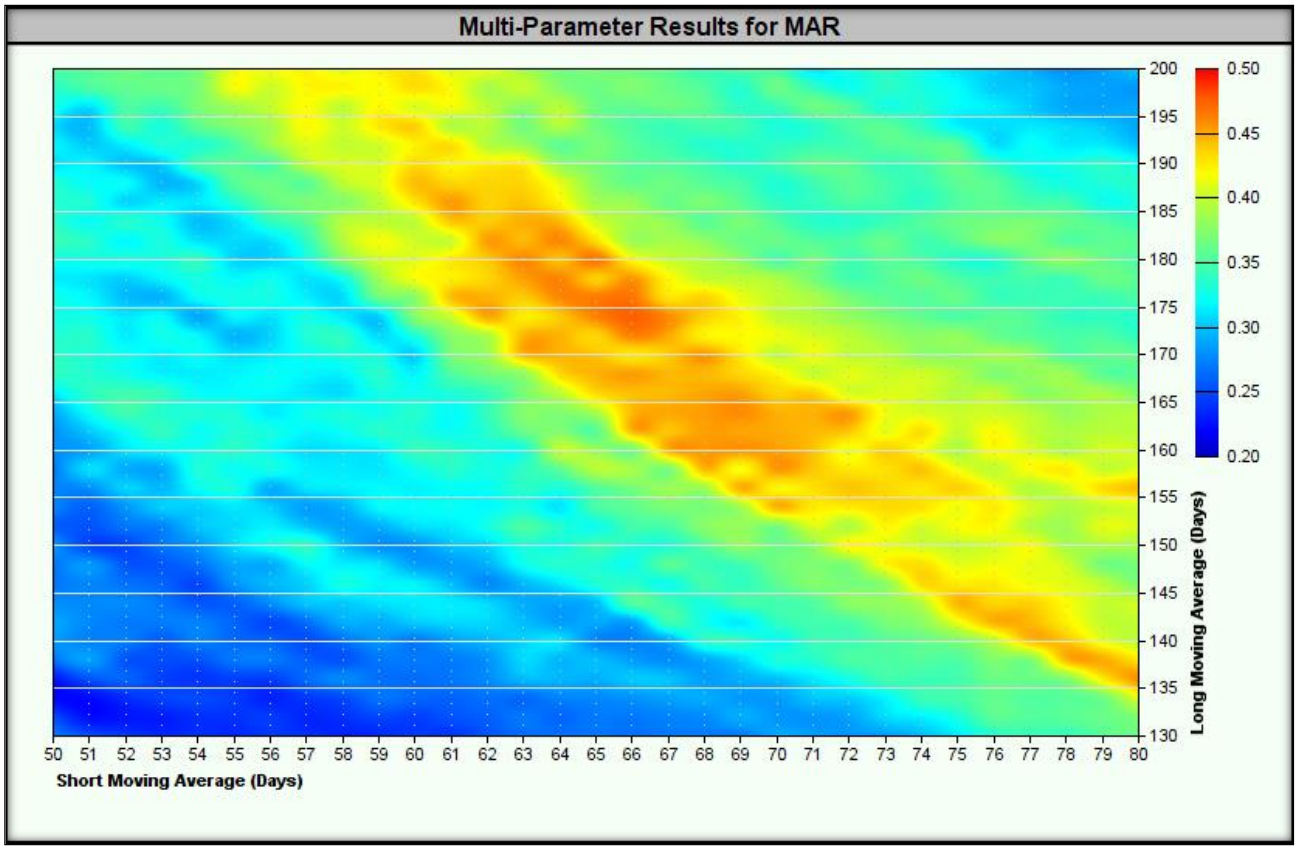
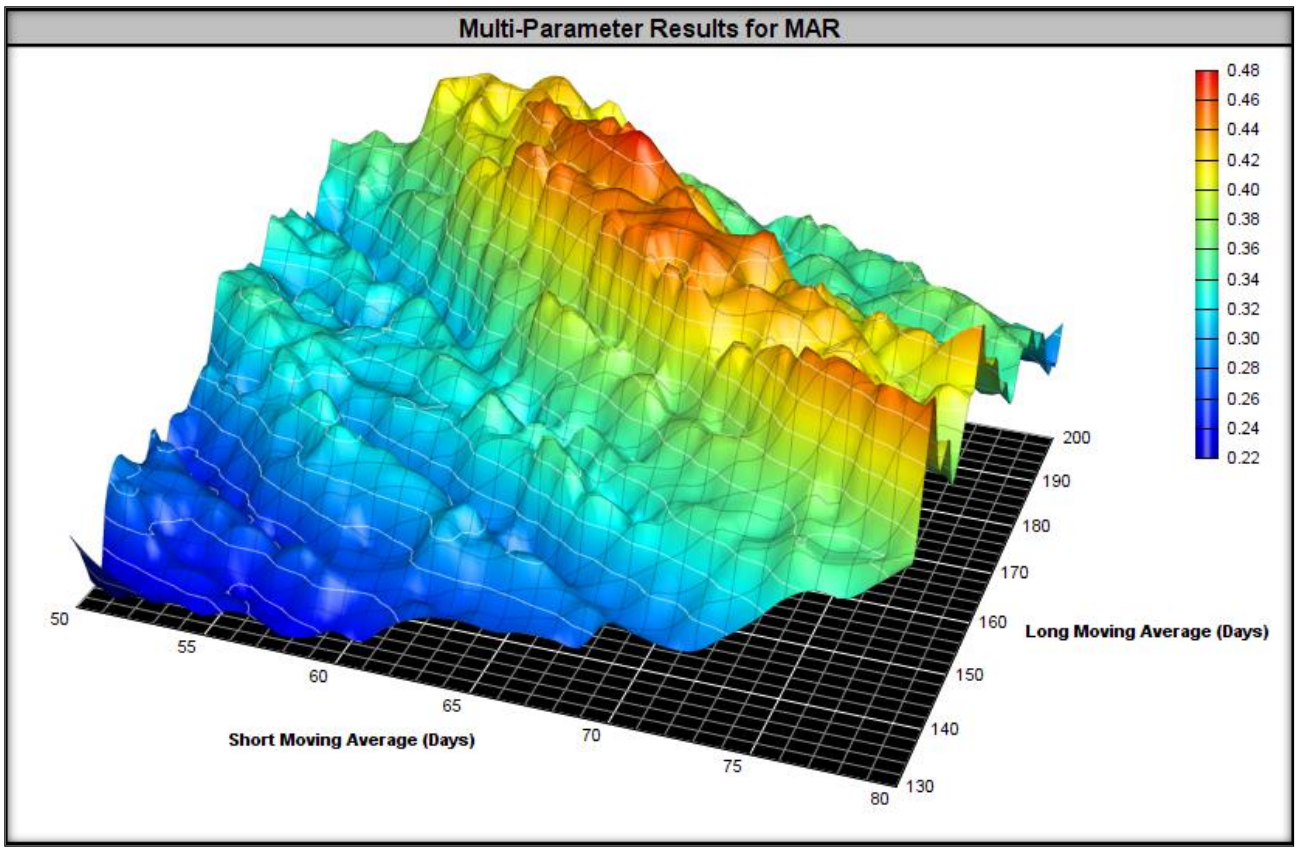
289	58	130	$404,077,526.87	12.31%	0.23	0.54	0.41	53.0%	72.0	773	0.07
362	60	132	$454,420,720.87	13.05%	0.25	0.56	0.42	52.9%	60.4	748	0.10
254	57	132	$409,480,946.01	12.39%	0.24	0.54	0.41	52.7%	72.1	773	0.07
361	60	130	$438,036,255.84	12.82%	0.24	0.56	0.43	52.6%	60.4	766	0.09
397	61	130	$422,903,163.18	12.59%	0.24	0.55	0.41	52.6%	62.0	756	0.08
290	58	132	$425,914,902.78	12.64%	0.24	0.55	0.41	52.6%	72.0	769	0.08
326	59	132	$455,798,374.29	13.06%	0.25	0.57	0.42	52.5%	70.4	763	0.09

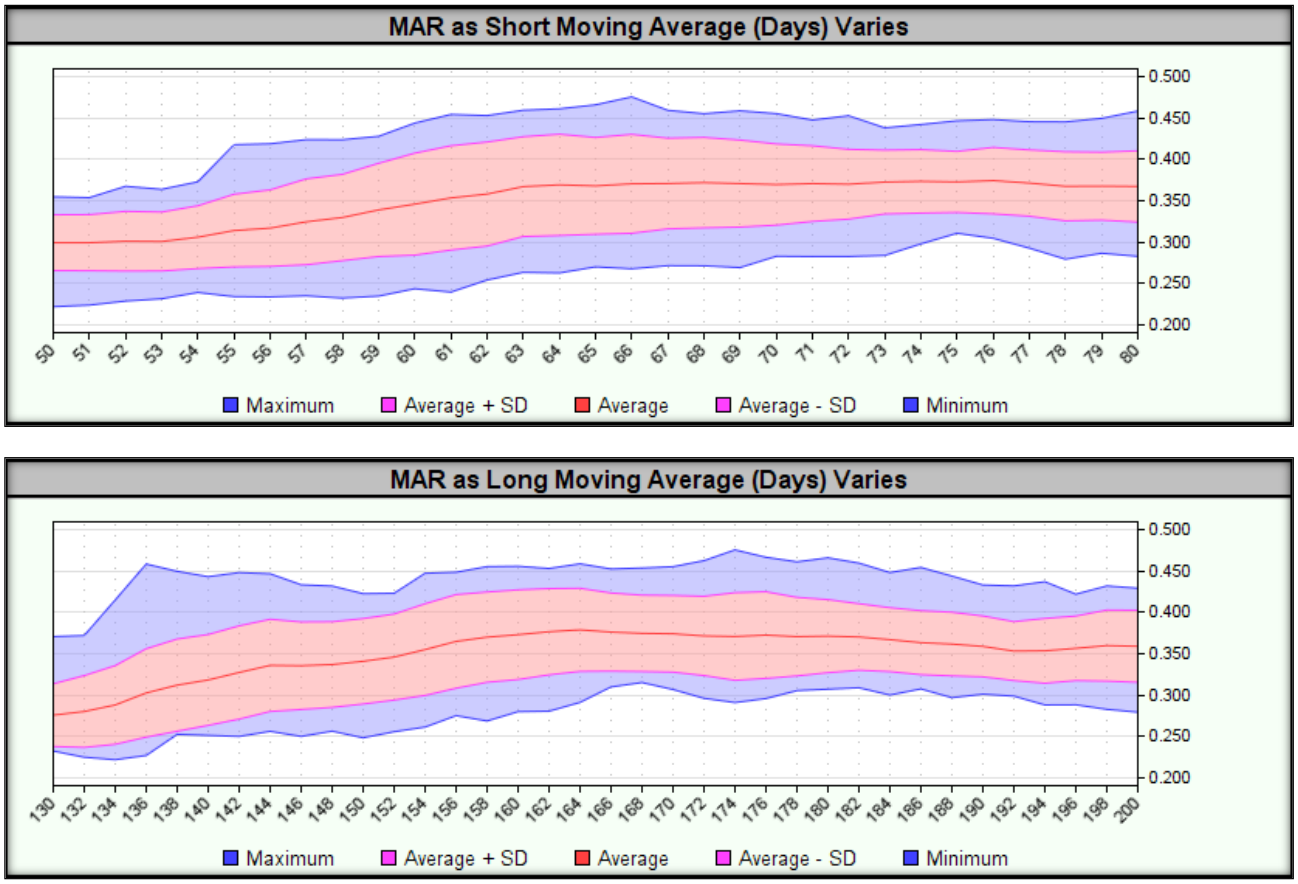
In summary, the strategy **passed the stability test** in a wide range of optimized parameters on in-sample data because:

- **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 (**54.2% vs. 33.7%)** – which means an acceptable risk of deep capital drawdowns.

Heatmaps for the tested ranges are presented below.


Multi-Parameter Results for MAR
Short Moving Average (Days)
Long Moving Average (Days)


Multi-Parameter Results for MAR
Short Moving Average (Days)
Long Moving Average (Days)



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

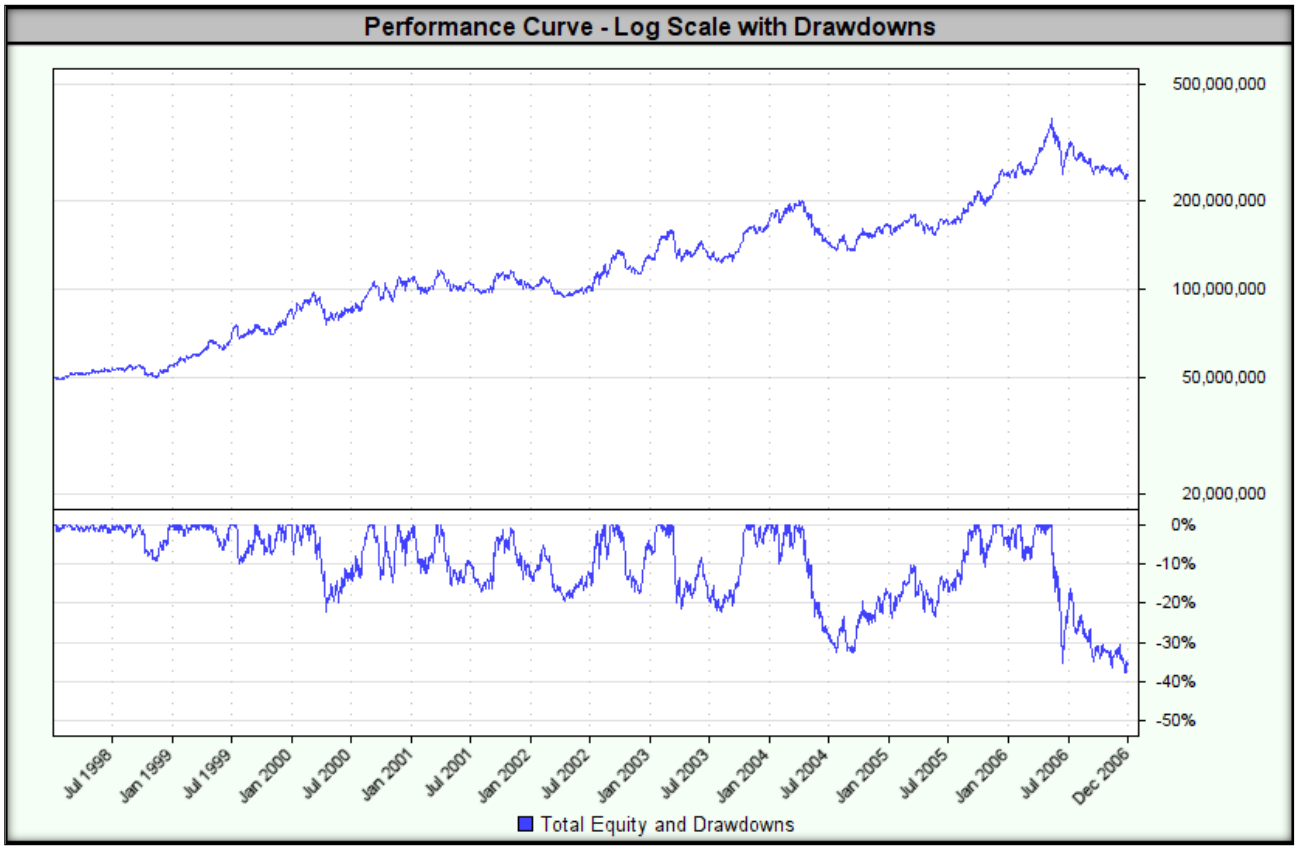
- **Fast moving average:** range **50-80 days (step: 1);**
- **Slow Moving Average:** Range **130-200 days (step: 2).**

The lowest MAR value of 0.51 was achieved for the following parameters:

- **Fast Moving Average:** 54;
- **Slow moving average:** 134.

Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
147	54	134	$244,232,262.96	19.29%	0.51	0.83	0.90	37.5%	17.5	320	0.86
112	53	136	$243,228,211.79	19.24%	0.52	0.82	0.89	37.2%	17.5	320	0.85
3	50	134	$240,932,230.46	19.11%	0.52	0.81	0.88	36.8%	17.9	341	0.72
38	51	132	$246,937,832.34	19.44%	0.53	0.83	0.91	36.9%	18.5	340	0.77
114	53	140	$257,705,558.28	20.01%	0.53	0.86	0.88	37.9%	17.5	320	0.90
148	54	136	$250,738,644.45	19.64%	0.53	0.84	0.91	37.2%	17.5	319	0.89
77	52	138	$246,074,619.36	19.39%	0.53	0.83	0.91	36.6%	17.9	323	0.84
183	55	134	$251,275,531.82	19.67%	0.53	0.84	0.89	37.1%	17.5	320	0.89
182	55	132	$247,471,798.08	19.47%	0.53	0.83	0.90	36.7%	17.5	322	0.87
219	56	134	$256,793,868.44	19.96%	0.53	0.85	0.92	37.4%	17.5	315	0.92
7	50	142	$246,960,936.05	19.44%	0.53	0.84	0.93	36.4%	17.5	326	0.86
41	51	138	$250,178,173.48	19.61%	0.54	0.84	0.94	36.6%	17.5	324	0.88

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



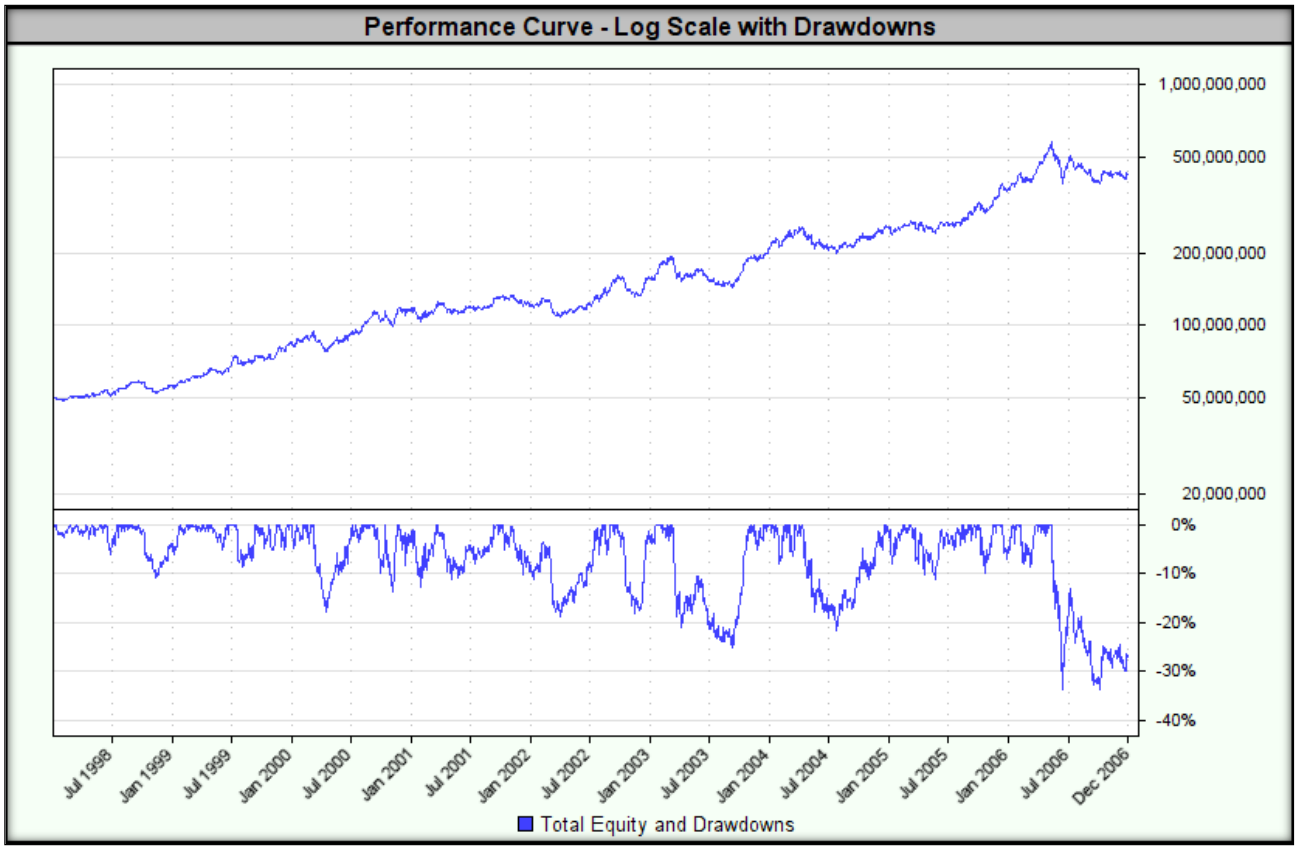
The highest MAR value of 0.80 was achieved for the following parameters:

- **Fast Moving Average:** 74;
- **Slow moving average:** 200.

The highest MAR value was accompanied by **a drawdown of 33.6%.**

Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
900	74	200	$422,828,057.16	26.80%	0.80	1.14	1.82	33.6%	9.8	193	2.02
935	75	198	$419,598,592.67	26.69%	0.79	1.14	1.82	33.6%	10.0	194	1.98
468	62	200	$410,395,276.84	26.38%	0.79	1.13	2.07	33.3%	9.9	214	2.26
971	76	198	$420,472,595.19	26.72%	0.79	1.14	1.80	33.7%	9.1	193	2.24
936	75	200	$419,067,580.55	26.68%	0.79	1.14	1.81	33.7%	10.0	194	2.20
1080	79	200	$415,508,283.15	26.56%	0.79	1.15	1.83	33.5%	10.3	187	2.40
1116	80	200	$409,575,591.36	26.35%	0.79	1.14	1.80	33.4%	10.3	185	2.11
1110	80	188	$428,138,275.31	26.98%	0.79	1.15	1.75	34.2%	10.0	196	2.19
1115	80	198	$408,746,234.51	26.32%	0.79	1.14	1.84	33.4%	10.3	187	2.16
970	76	196	$409,756,343.95	26.36%	0.78	1.13	1.78	33.7%	10.0	196	1.94
683	68	198	$409,557,375.68	26.35%	0.78	1.13	1.86	33.7%	9.9	210	2.00
1008	77	200	$400,279,117.18	26.03%	0.78	1.12	1.75	33.3%	10.2	185	2.05

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



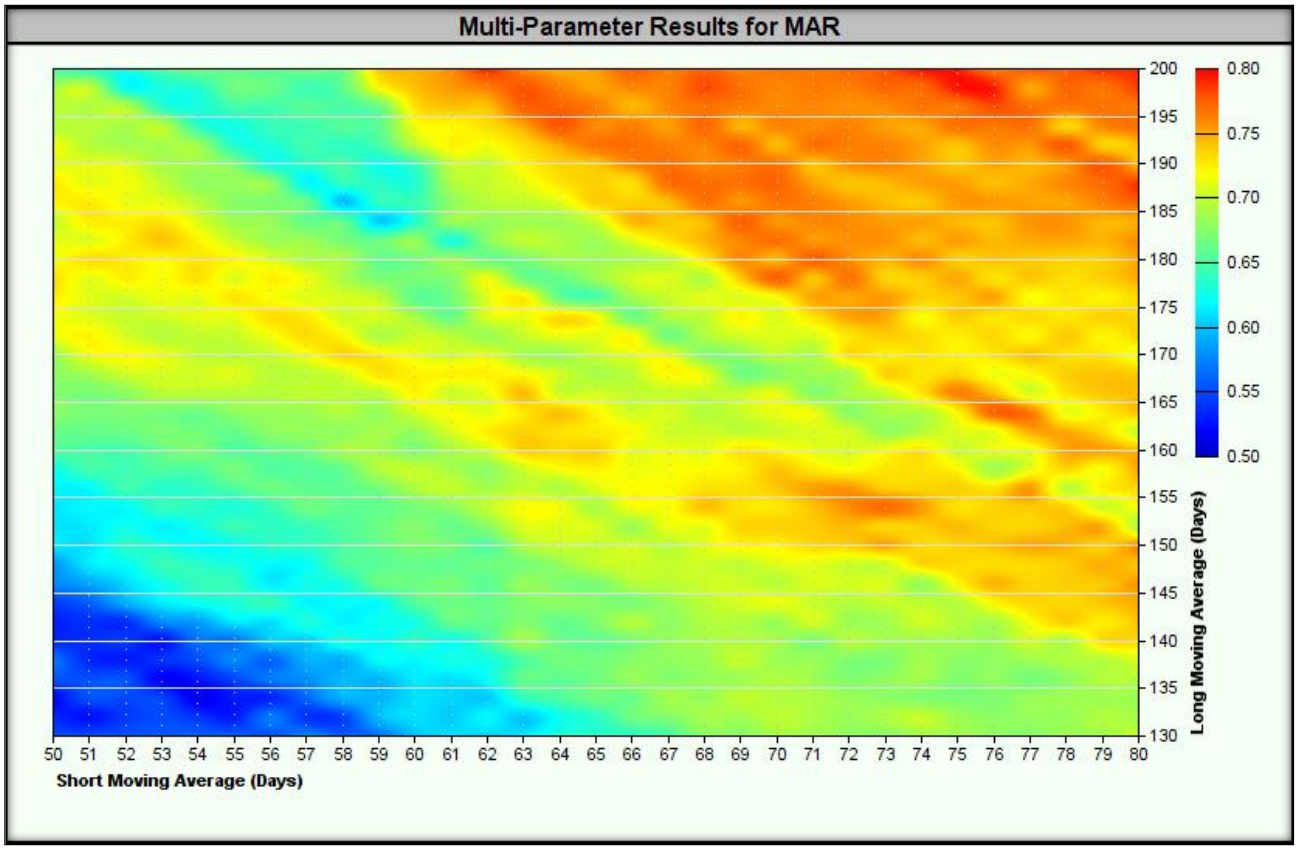
For all combinations of tested parameter ranges, **the highest drawdown was 37.9%.**

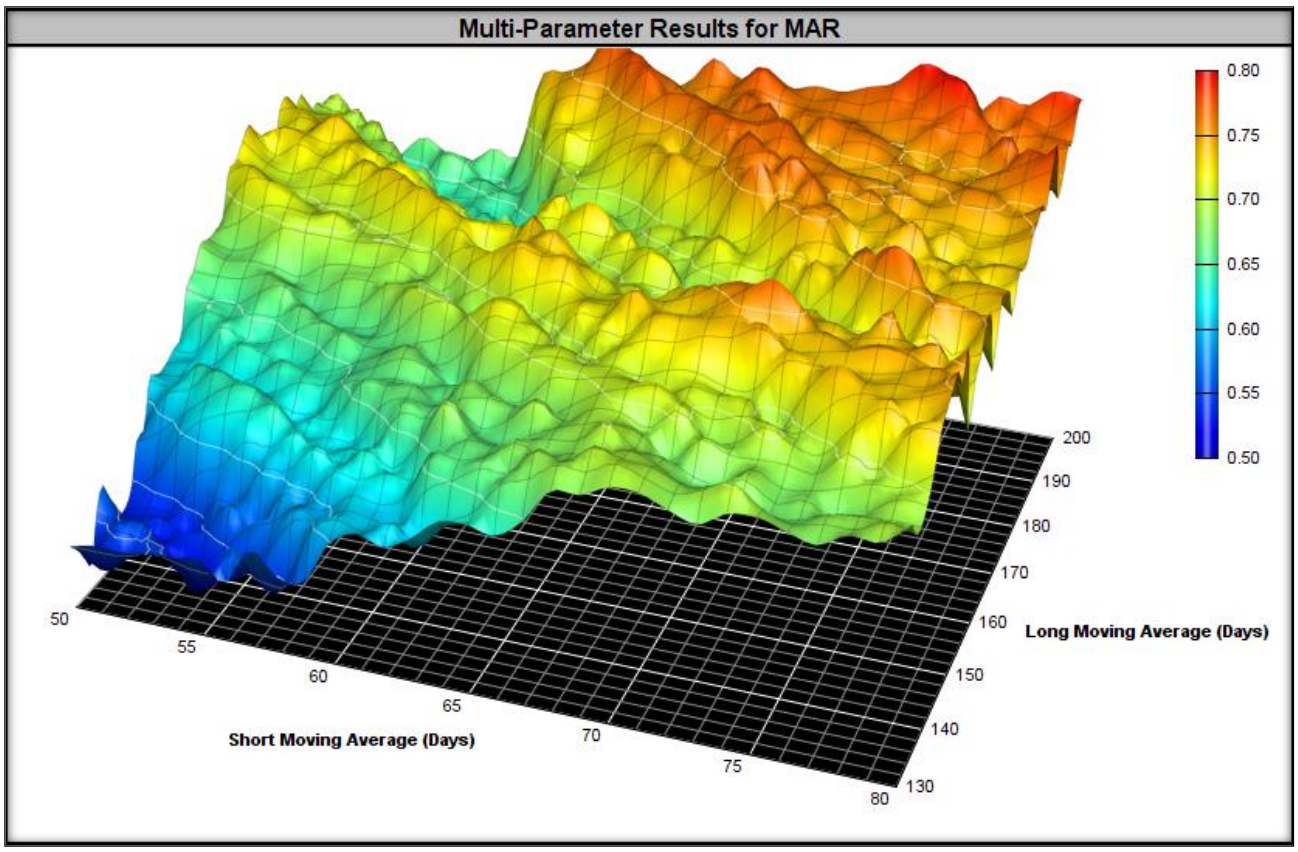
Test	Short Moving Average (Days)	Long Moving Average (Days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3
114	53	140	$257,705,558.28	20.01%	0.53	0.86	0.88	37.9%	17.5	320	0.90
147	54	134	$244,232,262.96	19.29%	0.51	0.83	0.90	37.5%	17.5	320	0.86
290	58	132	$268,141,156.78	20.54%	0.55	0.88	0.92	37.5%	17.5	320	0.97
219	56	134	$256,793,868.44	19.96%	0.53	0.85	0.92	37.4%	17.5	315	0.92
148	54	136	$250,738,644.45	19.64%	0.53	0.84	0.91	37.2%	17.5	319	0.89
112	53	136	$243,228,211.79	19.24%	0.52	0.82	0.89	37.2%	17.5	320	0.85
255	57	134	$275,471,778.08	20.90%	0.56	0.89	0.94	37.1%	17.5	315	1.01
183	55	134	$251,275,531.82	19.67%	0.53	0.84	0.89	37.1%	17.5	320	0.89
506	64	132	$324,021,212.58	23.10%	0.62	0.98	1.11	37.0%	17.5	300	1.40
122	53	156	$333,407,567.36	23.49%	0.64	1.01	1.24	37.0%	17.0	275	1.44
435	62	134	$306,601,979.56	22.35%	0.60	0.95	1.10	37.0%	17.0	297	1.37
254	57	132	$257,569,605.68	20.00%	0.54	0.86	0.90	37.0%	17.5	317	0.92

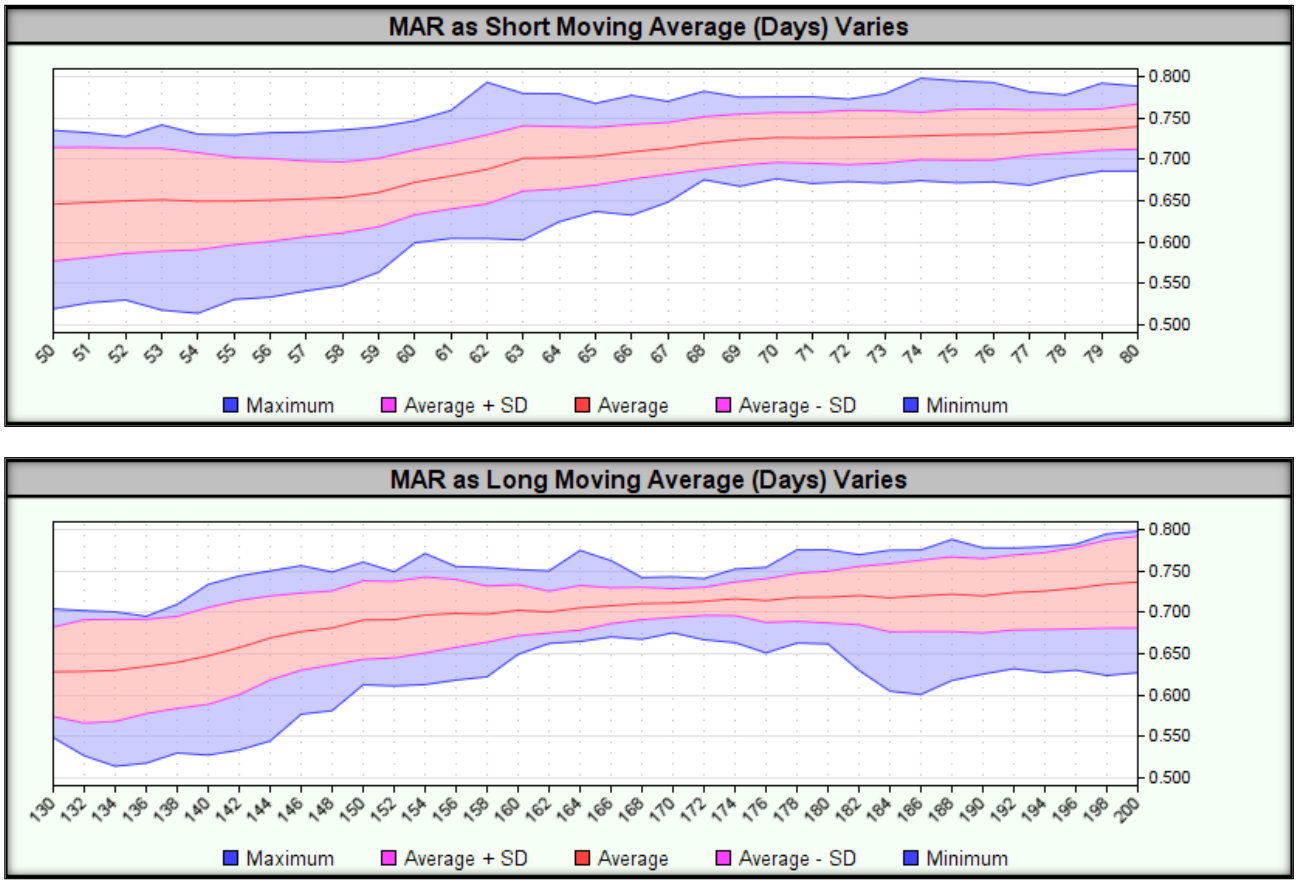
In summary, the strategy **passed the stability test** over a wide range of optimized parameters on out-of-sample data because:

- **MAR value** – which indicates the stability of the strategy in various market conditions.
- **Maximum drawdown on out-of-sample data did not exceed 150% of the maximum drawdown value on in-sample data (37.9 % vs. 54.2 %)** – which means an acceptable risk of capital drawdown.
- **The decrease in the maximum MAR value on the out-of-sample data was less than 50% relative to the in-sample test results (0.80 vs. 0.48)** – indicating that the strategy can perform well in a variety of market conditions.

Heatmaps for the tested ranges are presented below.


Multi-Parameter Results for MAR
Short Moving Average (Days)
Long Moving Average (Days)


Multi-Parameter Results for MAR
Short Moving Average (Days)
Long Moving Average (Days)



After passing **the stability test in 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 above step.

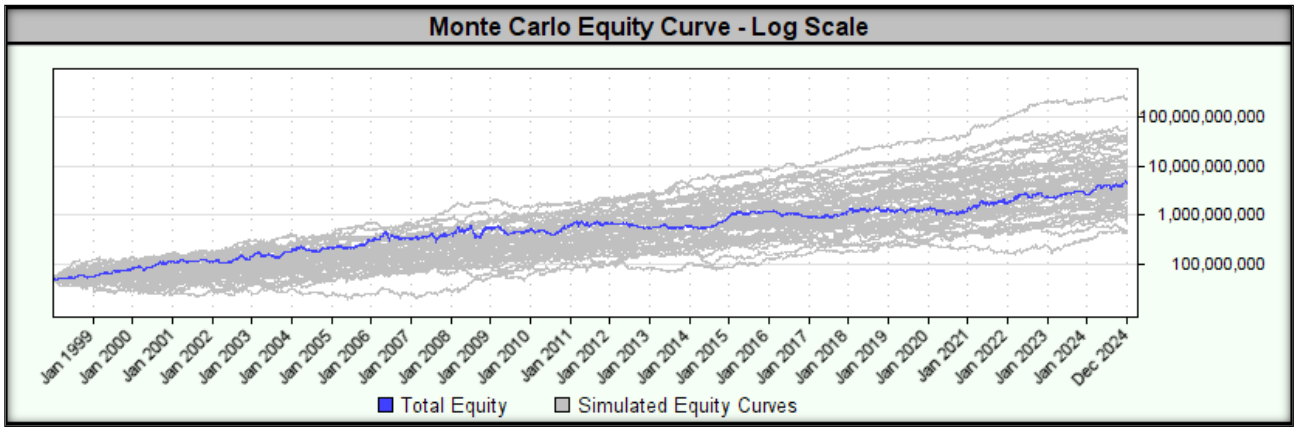
2. Monte Carlo simulation

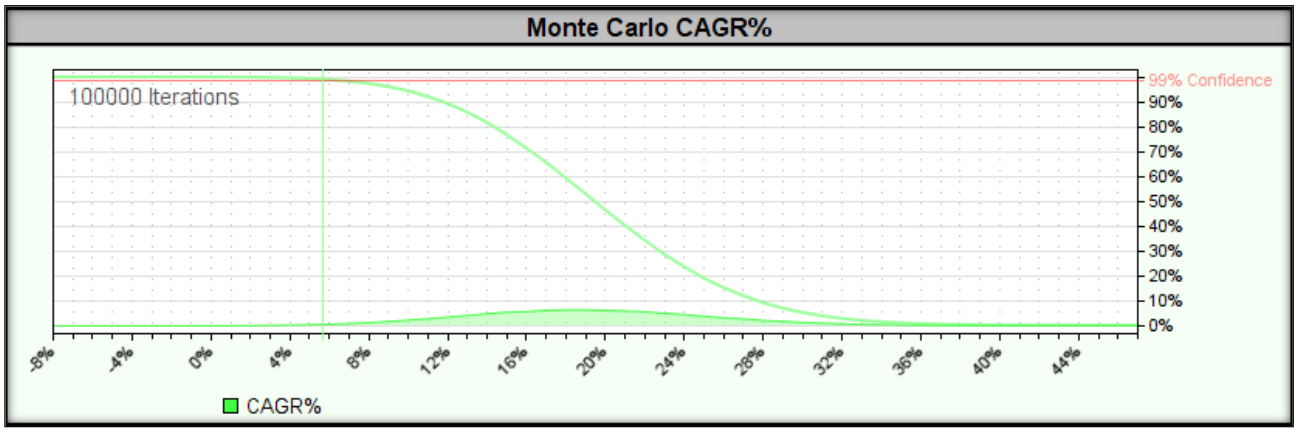
Monte Carlo simulation involves running multiple simulations to examine how a strategy might perform in different market scenarios. The key objective of this method is to assess the potential **drawdown** of an optimized strategy. **Monte Carlo simulation** better reflects the possible swings of the equity curve and the depth of the potential **drawdown,** allowing for a more realistic risk assessment. It is also 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.**

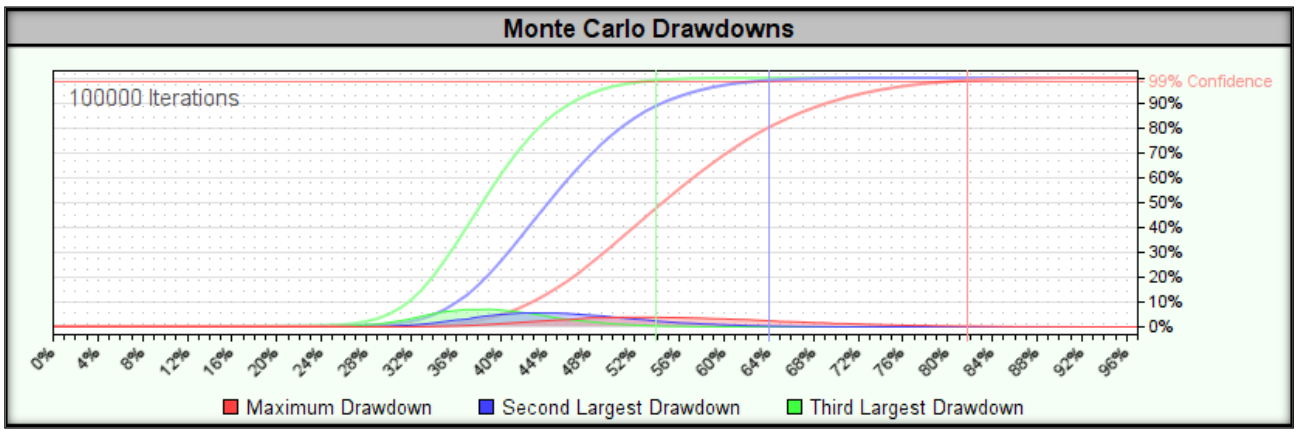
A strategy considered to be **stable (robust)** should achieve **a drawdown in a Monte Carlo simulation** that does not exceed **250% of the drawdown** size **from total tests in-sample and out-of-sample** (for parameters optimized on IS data). Furthermore, the **MAR indicator** should remain positive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

For data covering the period from **01.01.1998 to 31.12.2024** was carried out **Monte Carlo simulation** on **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.







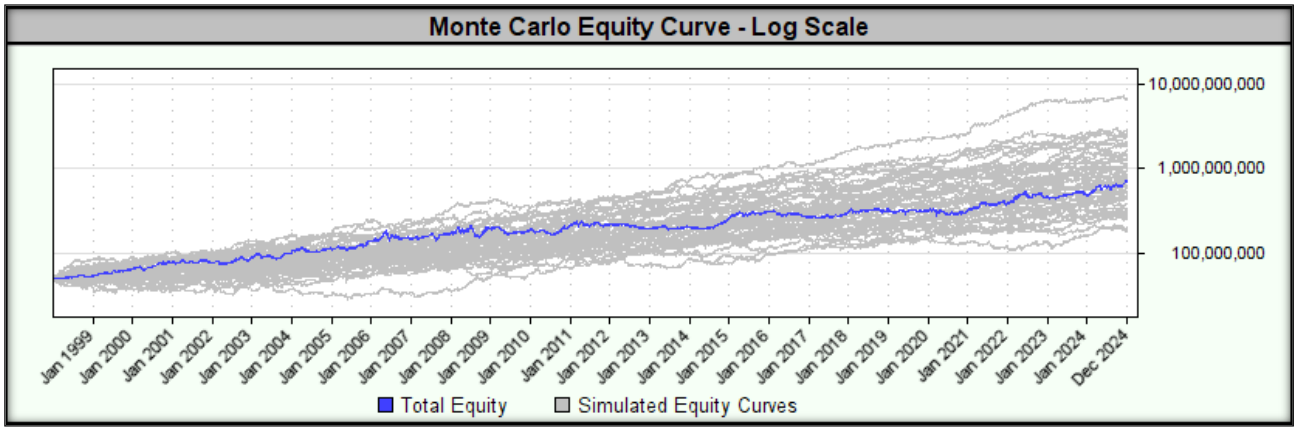
- **CAGR%** – In 99% of simulations achieved **a rate of return equal to or higher than 6.0%.**
- **Drawdown** – in 99% of simulations, **drawdown equal to or lower than 82% was achieved.** For parameters optimized on in-sample data, drawdown was 43.0%.

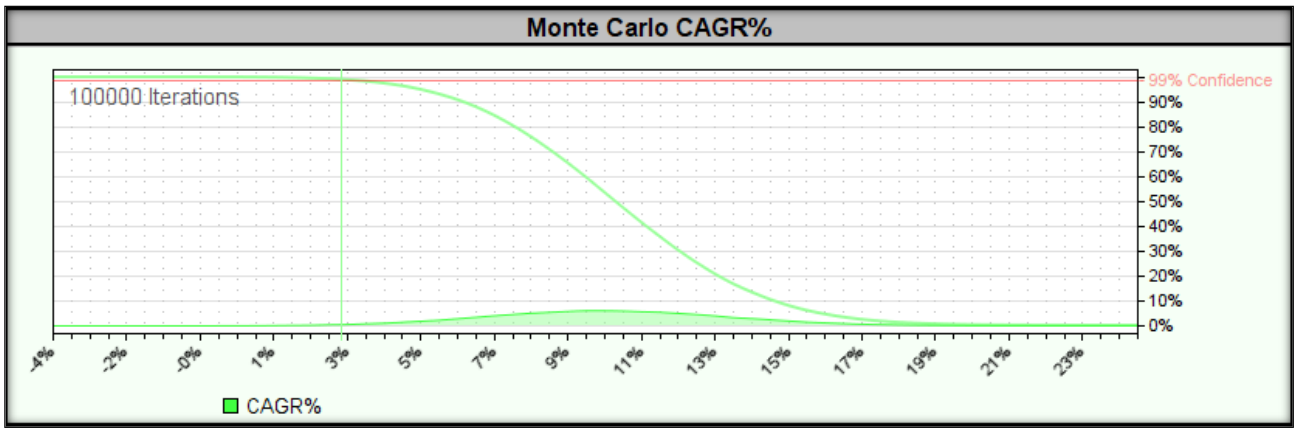
The strategy stability criteria were met because **the drawdown** in **the Monte Carlo simulation** did not exceed **250% of the drawdown** value from tests on **optimized parameters.** In addition, the **MAR indicator** remained positive in **99%** of tests, which was also a condition for the strategy stability.

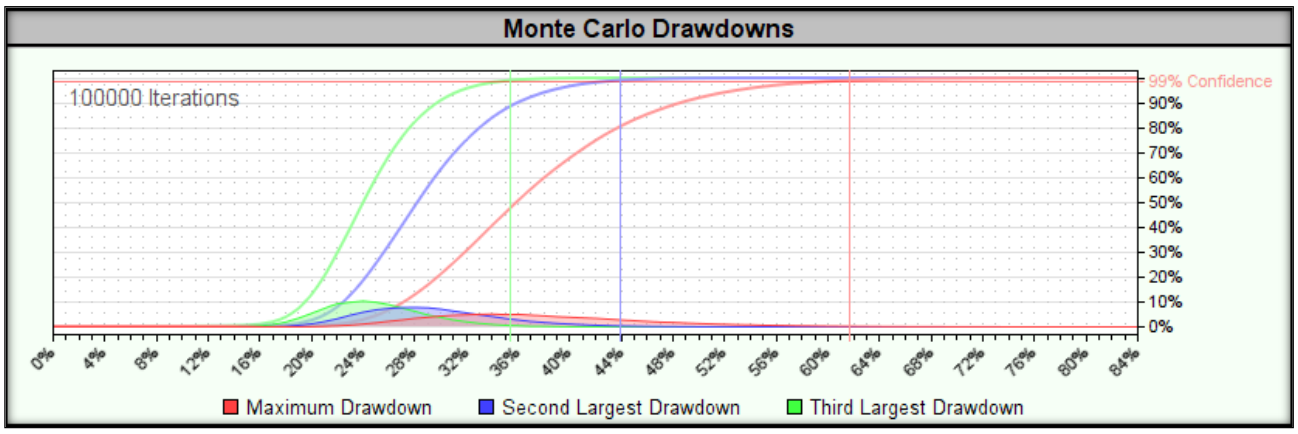
The problem with these tests, however, is the fact that **the drawdown on the optimized parameters is 43.0%,** which means that **even with a 100% loss of capital in the Monte Carlo tests we will not exceed the stability criterion (250% drawdown).** Therefore, **it is necessary to reduce the position size so that the simulation results make sense.**

For the purpose of **the repeated Monte Carlo test we are reducing the position size to 0.5% of capital per position** (from 1%).

The results of repeated tests for the simulation with sample replacement are presented below.







- **CAGR%** – In 99% of simulations achieved **a rate of return equal to or higher than 3.0%.**
- **Drawdown** – in 99% of simulations, **drawdown equal to or lower than 62% was achieved.** For parameters optimized on in-sample data, drawdown was 27.3%.

The strategy stability criteria were met, as **the drawdown** in **the Monte Carlo simulation** did not exceed **250% of the drawdown** value from tests on **optimized parameters.** In addition, the **MAR indicator** remained positive in **99%** of tests, which was also a condition for the strategy stability.

Now that we know the strategy is **stable** across **wide data ranges** and **a changing environment,** it's time to test its **stability** over **different time periods.**

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

Rolling window stability testing involves **estimating one- and three-year returns in time windows that move by one year** (for both in-sample and out-of-sample data). This process involves applying **strategy parameters optimized on the in-sample data,** setting a one- or three-year trading window, and moving it by one year.

We then analyze what portion of these one- and three-year periods showed positive returns. **A strategy considered stable (robust) should achieve profitable results in at least 70% of the one- and three-year periods.**

For data covering the period from **01.01.1998 to 31.12.2024** was carried out **testing optimized parameters** on **a moving data window.**

Two variants of test windows were tested:

- **Annual testing window (365 days),** tested **every 365 days** – this means that **we measure the annual rate of return every year.**
- **Three-year testing window (1095 days),** tested **every 365 days** – this means **we measure a three-year rate of return every year.**

A one-year (365/365) testing window are shown below.

	Test Start Date	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]	%PF	Expectancy
1	19980101	$58,056,645.98	16.13%	1.64	1.28	2.00	9.8%	3.5	16	63.78	15.32	2.61	0.00
2	19990101	$61,433,312.75	22.95%	3.02	1.97	NA	7.6%	2.7	20	41.34	13.23	3.11	0.00
3	20000101	$66,058,300.63	32.55%	3.30	1.73	NA	9.9%	3.5	26	45.35	18.06	3.00	0.00
4	20010101	$49,282,650.40	-1.44%	-0.16	-0.09	-2.06	9.1%	4.1	28	-8.54	-4.10	0.94	0.00
5	20020101	$60,147,447.16	20.31%	1.47	1.23	2.00	13.8%	3.3	27	14.84	9.77	2.31	0.00
6	20030101	$59,314,772.67	18.64%	2.22	0.92	2.00	8.4%	6.4	23	18.60	7.26	2.07	0.00
7	20040101	$51,710,388.90	3.42%	0.35	0.42	NA	9.8%	8.7	33	-15.77	-8.53	1.14	0.00
8	20050101	$56,960,041.59	14.10%	1.03	0.88	NA	13.7%	8.0	25	-10.46	-6.05	1.79	0.00
9	20060101	$42,507,956.96	-15.03%	-0.72	-1.43	-2.01	20.8%	7.7	34	-24.80	-22.27	0.53	0.00
10	20070101	$52,990,335.20	5.98%	0.38	0.46	1.99	15.6%	5.9	31	-0.49	-0.26	1.26	0.00
11	20080101	$65,262,142.08	30.55%	1.25	0.93	NA	24.5%	7.2	34	0.51	0.45	2.67	0.00
12	20090101	$56,178,882.25	12.37%	1.32	0.92	2.00	9.3%	5.4	37	5.08	3.06	1.62	0.00
13	20100101	$51,661,907.58	3.34%	0.18	0.25	NA	18.2%	11.5	32	-17.59	-14.22	1.20	0.00
14	20110101	$59,592,948.89	19.43%	1.10	0.93	NA	17.6%	4.9	30	39.03	18.01	2.17	0.00
15	20120101	$42,337,088.41	-15.37%	-0.76	-1.99	NA	20.1%	9.0	30	-22.42	-18.00	0.48	0.00
16	20130101	$47,963,737.94	-4.08%	-0.30	-0.42	-2.01	13.5%	8.3	34	-8.05	-5.23	0.83	0.00
17	20140101	$80,157,689.79	60.37%	8.06	2.82	2.00	7.5%	4.2	37	60.80	33.66	3.64	0.00
18	20150101	$47,666,758.36	-4.67%	-0.65	-0.91	-2.01	7.2%	4.7	11	-13.44	-2.52	0.16	0.00
19	20160101	$46,754,421.44	-6.51%	-0.46	-0.37	NA	14.3%	4.6	40	-4.75	-4.39	0.79	0.00
20	20170101	$51,314,075.92	2.64%	0.16	0.24	1.98	16.3%	6.3	31	-9.55	-8.46	1.13	0.00
21	20180101	$50,693,035.16	1.39%	0.08	0.17	1.97	16.6%	10.1	38	-23.83	-15.13	1.12	0.00
22	20190101	$47,043,147.31	-5.92%	-0.29	-0.23	-2.01	20.4%	8.7	33	-27.36	-17.37	0.80	0.00
23	20200101	$51,120,809.46	2.24%	0.08	0.21	NA	28.8%	9.0	42	-13.19	-19.28	1.12	0.00
24	20210101	$45,953,592.33	-8.12%	-0.40	-0.37	NA	20.1%	4.6	27	-7.53	-7.44	0.70	0.00
25	20220101	$54,780,420.98	9.68%	0.97	0.72	NA	9.9%	2.6	29	27.16	16.60	1.55	0.00
26	20230101	$52,268,026.92	4.55%	0.47	0.52	2.00	9.6%	3.6	30	13.41	9.18	1.21	0.00
27	20240101	$42,486,654.68	-15.04%	-0.84	-1.25	NA	17.9%	8.0	30	-26.12	-17.25	0.46	0.00

A three-year testing window (1095/365) are shown below.

	Test Start Date	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]	%PF	Expectancy
1	19980101	$116,157,835.10	32.54%	1.90	1.67	2.64	17.1%	4.2	62	20.66	31.63	3.33	0.00
2	19990101	$84,244,072.15	19.01%	1.08	0.96	1.06	17.6%	6.5	74	7.53	26.52	1.96	0.00
3	20000101	$81,662,674.43	17.81%	0.93	0.81	1.13	19.2%	9.8	81	2.53	11.79	1.90	0.00
4	20010101	$77,106,670.34	15.54%	0.75	0.73	0.98	20.9%	9.4	78	1.30	8.49	1.77	0.00
5	20020101	$97,914,923.39	25.13%	1.21	1.10	2.21	20.8%	9.0	83	6.19	26.94	2.25	0.00
6	20030101	$81,728,210.76	17.83%	0.79	0.92	1.58	22.5%	17.9	81	1.66	7.55	1.81	0.00
7	20040101	$55,539,283.40	3.57%	0.10	0.28	0.48	36.2%	9.2	92	0.64	5.20	1.20	0.00
8	20050101	$60,857,302.57	6.79%	0.17	0.40	0.75	40.3%	19.7	90	0.51	3.27	1.33	0.00
9	20060101	$68,884,008.60	11.29%	0.28	0.47	0.46	40.1%	14.0	99	0.84	6.82	1.48	0.00
10	20070101	$77,473,859.82	15.73%	0.47	0.60	0.60	33.7%	9.8	102	2.24	17.22	1.66	0.00
11	20080101	$83,478,887.19	18.65%	0.66	0.71	1.35	28.3%	22.7	103	1.15	6.67	1.91	0.00
12	20090101	$74,678,335.58	14.35%	0.49	0.66	1.83	29.4%	9.9	99	3.00	18.30	1.54	0.00
13	20100101	$46,277,338.52	-2.55%	-0.10	-0.02	-0.22	26.6%	15.9	92	0.52	3.58	0.91	0.00
14	20110101	$55,969,149.42	3.84%	0.16	0.30	0.26	24.4%	26.9	94	-0.25	-1.29	1.15	0.00
15	20120101	$70,384,691.29	12.09%	0.60	0.77	0.43	20.1%	29.5	101	-0.26	-0.82	1.51	0.00
16	20130101	$88,528,725.24	20.99%	1.10	0.98	1.05	19.1%	17.3	82	7.19	24.20	2.47	0.00
17	20140101	$79,095,597.63	16.55%	0.54	0.74	0.49	30.8%	10.6	88	6.69	27.70	2.08	0.00
18	20150101	$53,289,348.72	2.15%	0.09	0.21	0.10	24.9%	26.9	82	-2.72	-8.58	1.12	0.00
19	20160101	$69,829,061.10	11.79%	0.58	0.70	0.74	20.3%	8.9	109	1.14	6.85	1.43	0.00
20	20170101	$62,418,296.21	7.69%	0.33	0.45	0.56	23.6%	15.7	102	0.81	5.90	1.25	0.00
21	20180101	$53,319,144.90	2.17%	0.07	0.21	0.38	29.9%	12.7	113	-0.43	-2.77	1.06	0.00
22	20190101	$63,065,947.64	8.05%	0.24	0.45	0.42	33.3%	22.2	102	0.81	5.38	1.34	0.00
23	20200101	$100,784,481.98	26.37%	0.92	0.96	1.46	28.8%	10.5	98	6.92	38.12	2.25	0.00
24	20210101	$80,581,781.48	17.26%	0.76	0.78	0.60	22.7%	9.4	86	5.85	27.85	1.87	0.00
25	20220101	$113,530,555.04	31.53%	1.50	1.48	0.98	21.0%	5.3	89	9.21	27.30	2.64	0.00

In both cases, **success** is completing at least **70% of the periods** (both **365-day** and **1095-day) with positive returns.**

- **For the one-year test window (365/365): 18 out of 27 periods** ended with a positive rate of return (**66.7%**).
- **For the three-year test window (1095/365): 24 out of 25 periods** ended with a positive rate of return (**96.0%**).

Thus, **the test of the strategy's stability on a moving data window <u>was failed and we are terminating further testing of the strategy.</u>**

4. **Stability long / short**

This step was skipped due to **failure of previous stability tests.**

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

This step was skipped due to **failure of previous stability tests.**

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

This step was skipped due to **failure of previous stability tests.**

7. **Strategy Risk Management**

This step was skipped 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 under real market conditions.** It provides **reliable measures of profit and risk** after the optimization process and allows for answering 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 a more **reliable and realistic measure 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, which helps **minimize 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)**.
    - In this step, parameters are adjusted 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 measure that assesses whether a strategy has the potential to perform under real market conditions. WFE compares:

- **The rate of return achieved in the in-sample window** (where parameters were optimized)
- **The rate of return in the out-of-sample window** (where the strategy was operating 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 outside the optimization period.
- **WFE ≤ 150% for drawdown** – means that the drawdown outside the optimization period is not significantly higher than during the optimization period.

This step was skipped due to **failure of previous stability tests.**

Step 6: Using the strategy in real time

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

The most important element of **strategy implementation** is **consistent enforcement of all signals, without exceptions. How Larry Williams noted:** *"Trading strategies work. Traders do not."*

Before making **a final decision to implement a strategy,** it is necessary to check **whether it really adds value** to the results of the entire portfolio. It does not make sense to implement a strategy that **generates similar signals** or **is characterized by a similar course of the equity curve.**

Key criteria for evaluating the strategy 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 of them are met** or **none of them are met.**

Once you decide to add a strategy to your portfolio, **the question arises:** *Should you implement your strategy right away 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 identify **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 a level of about half of the maximum drawdown** observed in historical data. **Only after reaching this threshold 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 to fully implement it 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.