# MIE 1622H S

# Computational Finance and Risk Management

## Assignment 2

## Mean-Variance Portfolio Selection Strategies

Jiacheng Li

1005138405

3.8.2023

# Introduction:

The purpose of this assignment is to compare computational investment strategies based on minimizing portfolio variance and maximizing Sharpe ratio. There are 4 strategies on my analysis:

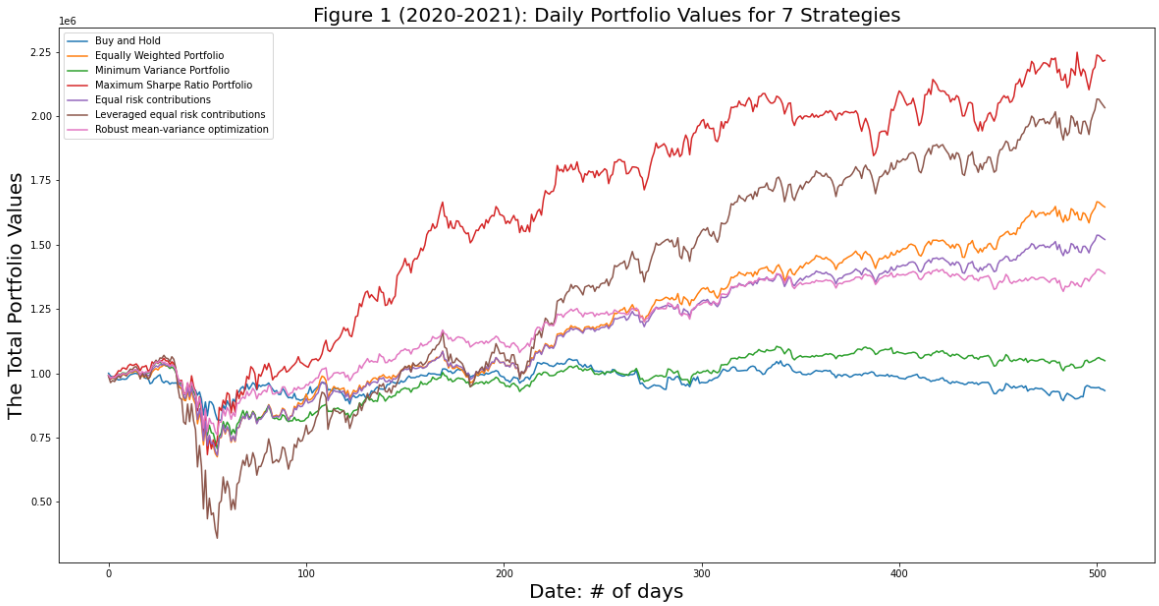
1. "Buy and hold" strategy;
2. "Equally weighted" (also known as "1/n") strategy;
3. "Minimum variance" portfolio strategy;
4. "Maximum Sharpe ratio" portfolio strategy;
5. "Equal risk contributions" portfolio strategy;
6. "Leveraged equal risk contributions" portfolio strategy;
7. "Robust mean-variance optimization" portfolio strategy.

The daily closing prices of 20 stocks from 2020 and 2021are given to test my bi-monthly decisions. All my estimates are computed from the actual data. I also track the value of my portfolio on the first trading day of each 2-month holding period.

# Analyze my results:

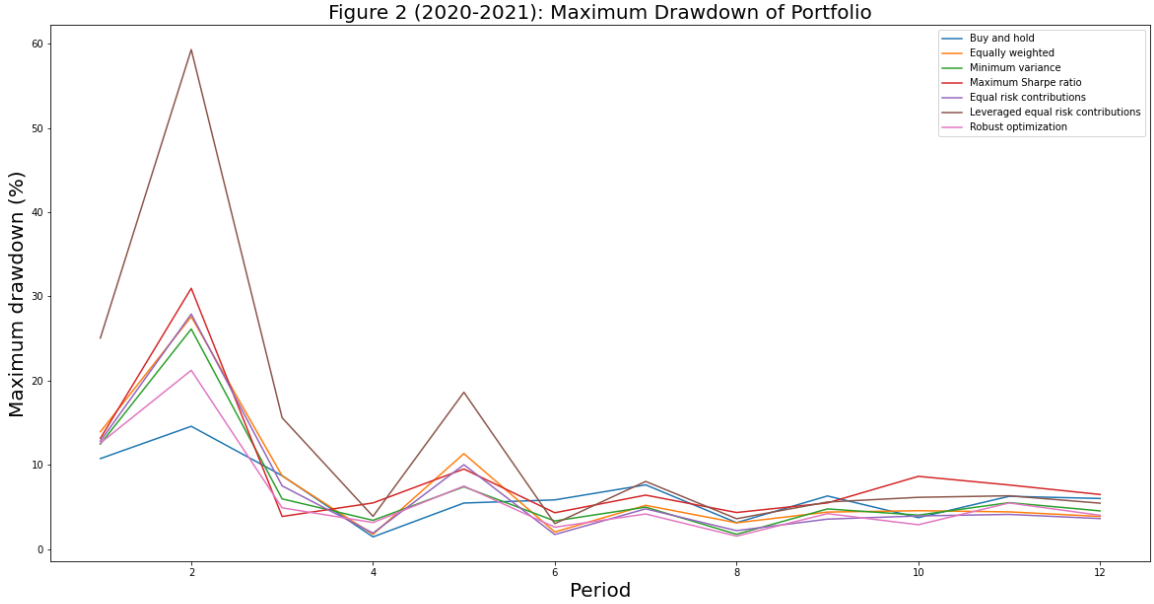
1. **Produce the following output for the 12 periods in years 2020 and 2021 (in appendix A):**

2. **Plot one chart that illustrates the daily value of my portfolio for 7 strategies over the years 2020 and 2021 using daily prices provided.**



3. **Plot one chart that illustrates maximum drawdown of my portfolio (for each of the seven trading strategies) for each of the 12 periods (years 2020 and 2021) using daily prices provided.**

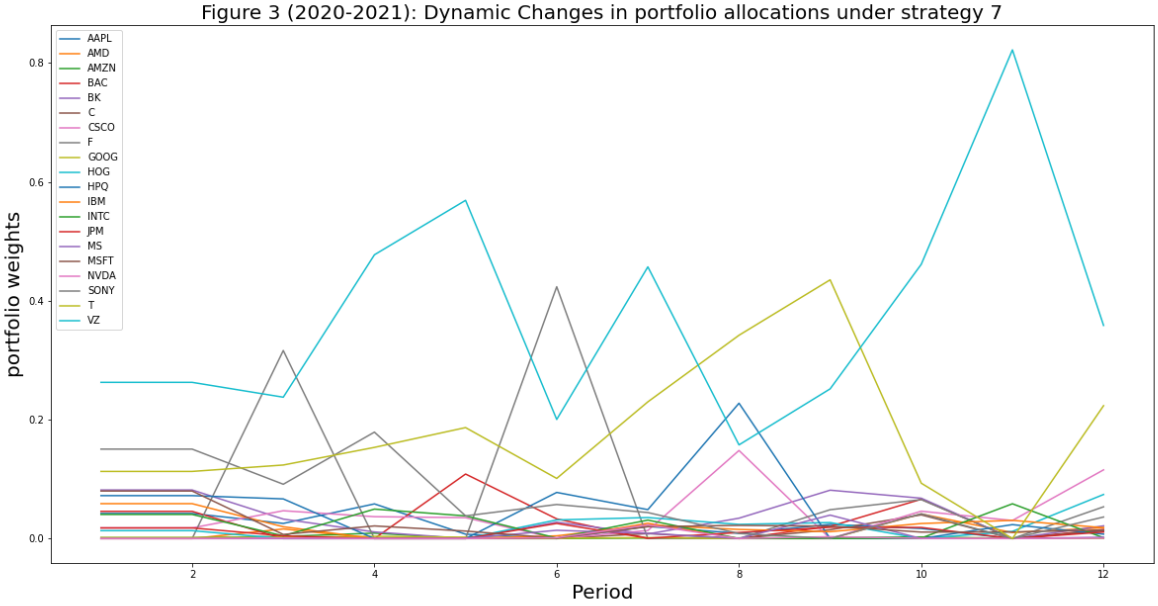
Figure 2 (2020-2021): Maximum Drawdown of Portfolio




We can see that the strategies "Leveraged equal risk contributions" experienced the highest maximum drawdowns in 2021. During the first six periods, the difference in maximum drawdowns of portfolios is big. After that, the seven strategies have similar maximum drawdowns. "Buy and Hold" is the one which has the fewest fluctuations of maximum drawdown line, indicating more stability in its returns.
A large maximum drawdown means that the portfolio has experienced a significant decline from its peak value. This can be an indication of high risk and volatility in the portfolio. It is important for investors to consider the maximum drawdown when evaluating a portfolio's risk and potential returns, as it can have a significant impact on the overall performance and success of the portfolio. A portfolio with a large maximum drawdown may require a longer time to recover to its previous peak value, which can negatively impact the investor's returns and investment goals.

4. **Plot one chart to show dynamic changes in portfolio allocations under strategy 7.**

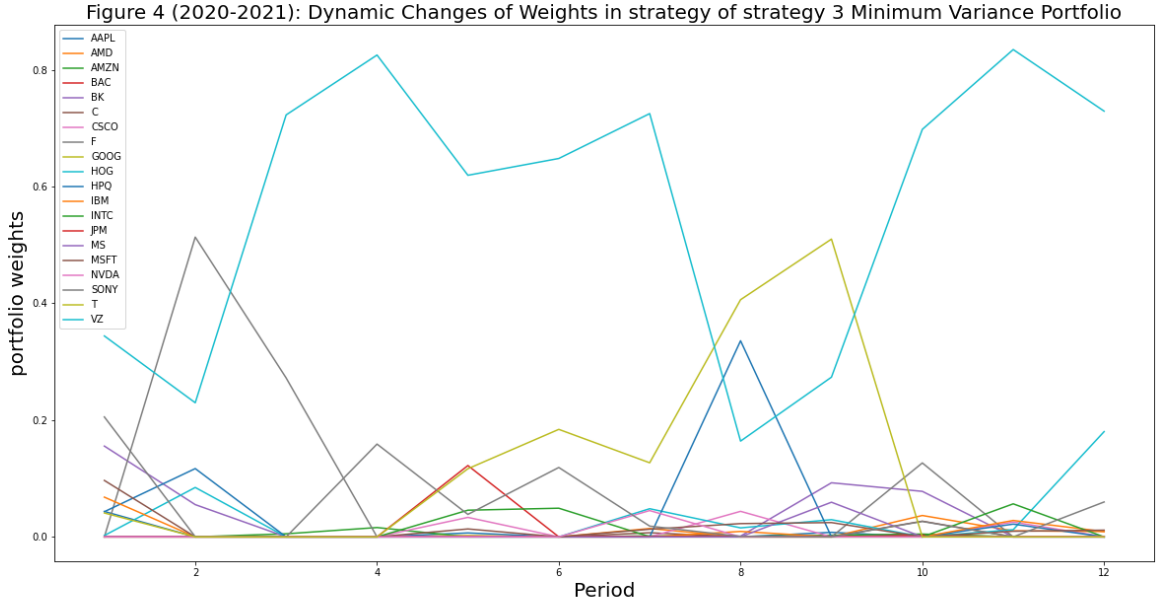
Figure 3 (2020-2021): Dynamic Changes in portfolio allocations under strategy 7




From figure 3 (2020-2021 under strategy 7), we can see the asset called “HOG” has the biggest weighting during the most time, which is around 0.8 at the end. And it is the only one whose weights are larger than 0.5. “T” has the second largest weighting generally, whose proportion dominates in period 9. But its weights are smaller than 0.2 most time. “F”, “SONY”, and “AAPL” are three assets having larger weights compared with others.

**Plot one chart to show dynamic changes in portfolio allocations under strategy 3.**

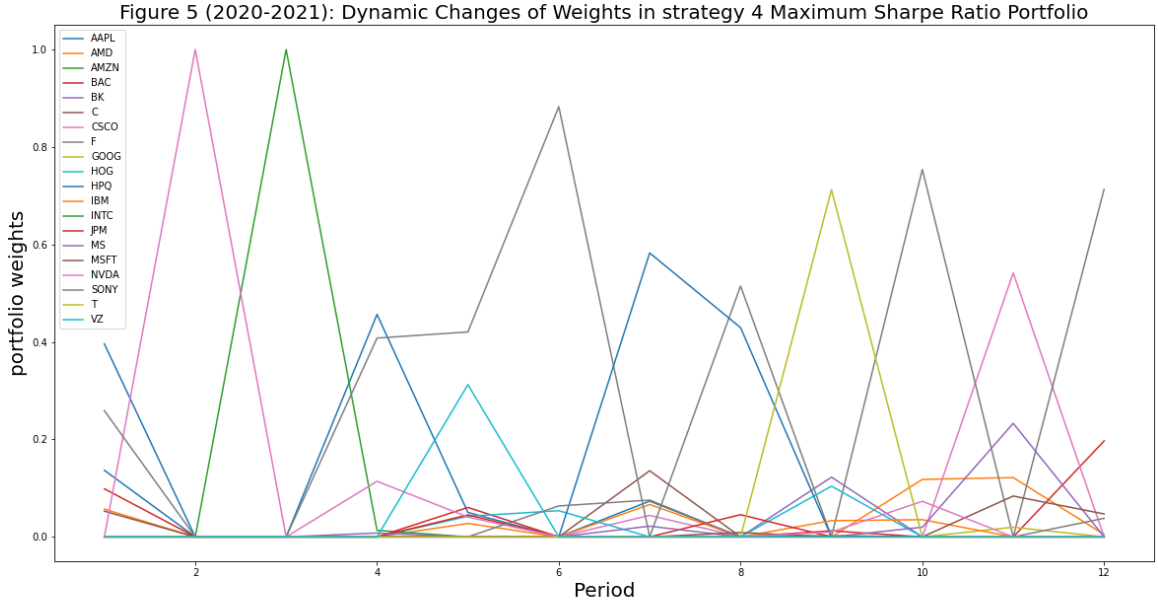
Figure 4 (2020-2021): Dynamic Changes of Weights in strategy of strategy 3 Minimum Variance Portfolio




From figure 4 (2020-2021 under strategy 3), we can see the asset called "HOG" has the biggest weightings during the most time, which are above 0.5 usually. There are two times that the weights of "HOG" are bigger than 0.8. And it is the only one whose weights are larger than 0.5. "T" has the second largest weighting generally, whose proportion dominates in period 9. But its weights are smaller than 0.2 most time. "F", "SONY", and "AAPL" are three assets having larger weights compared with others.

**Plot one chart to show dynamic changes in portfolio allocations under strategy 4.**

Figure 5 (2020-2021): Dynamic Changes of Weights in strategy 4 Maximum Sharpe Ratio Portfolio



From figure 5 (2020-2021 under strategy 4), we can see there are three assets whose weights are larger than 0.8 sometimes, even almost 1.0. And many assets can have weights bigger than 0.5.

**Does robust portfolio selection strategy reduce trading as compared with strategies 3 and 4 that you have implemented in Assignment 1?**

Yes, robust portfolio selection strategy reduced trading. We can see from figure 5 (2020-2021 under strategy 4), there are two assets' weights approaching to 1.0. In figure 3 (2020-2021 under strategy 7), there are two times that assets' weights are bigger than 0.8. However, we found there is only one weight of 20 assets over 12 periods, which is larger than 0.8 one time.

Robust portfolio selection strategies can reduce trading because they typically involve a long-term investment approach that emphasizes diversification and risk management over short-term market timing and frequent trading.

5. **Compare "equal risk contributions", "leveraged equal risk contributions" and "robust mean-variance optimization" trading strategies between each other and to four strategies.**

From figure 1 (2020-2021), we can know "Equal risk contributions" and "Robust mean-variance optimization" perform better than "Leveraged equal risk contributions" do, which have the lowest return during days 0 to 200. After that, the total portfolio value of "Leveraged equal risk contributions" increases a lot. And we found "Equal risk contributions" and "Robust mean-variance optimization" have similar trends of portfolio values. But we cannot say "Leveraged equal risk contributions" is the best among the new three strategies. It has experienced a most significant decline from its peak value based on figure 2 (2020-2021).

It is shown that before the first 40 days overall, the strategy "Buy and Hold" underperformed compared to the other strategies with the lowest returns. After that, we find that the "Leveraged equal risk contributions" strategy struggled in the first half of 2021. But it performs well after the first 6 months. Strategies "Buy and Hold" and "Minimum Variance Portfolio" showed consistent performance throughout the whole period compared to others, while strategy 4 "Maximum Sharpe Ratio Portfolio" showed the highest returns overall, with a significant increase in value in the first half of 2020. Also, it is shown that "Buy and Hold" and "Minimum Variance Portfolio" have similar trends and total values. These two strategies do not perform better than "Equal risk contributions" or "Robust mean-variance optimization".

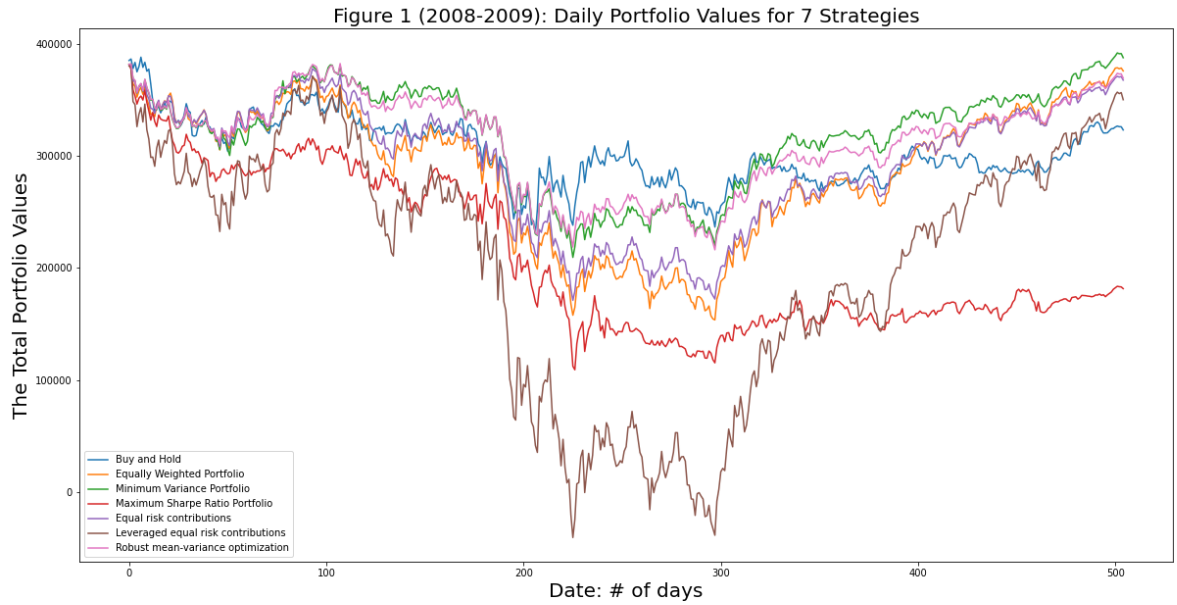
In summary, strategies "Maximum Sharpe Ratio Portfolio" and "Leveraged equal risk contributions" showed the highest returns in the year 2021. "Maximum Sharpe Ratio Portfolio" is the best one with the highest value most time. But they showed mixed results over the period.

I would like to choose "Maximum Sharpe Ratio Portfolio" to manage my portfolio. In the long term, it can maintain the biggest total values and have acceptable maximum drawdowns.

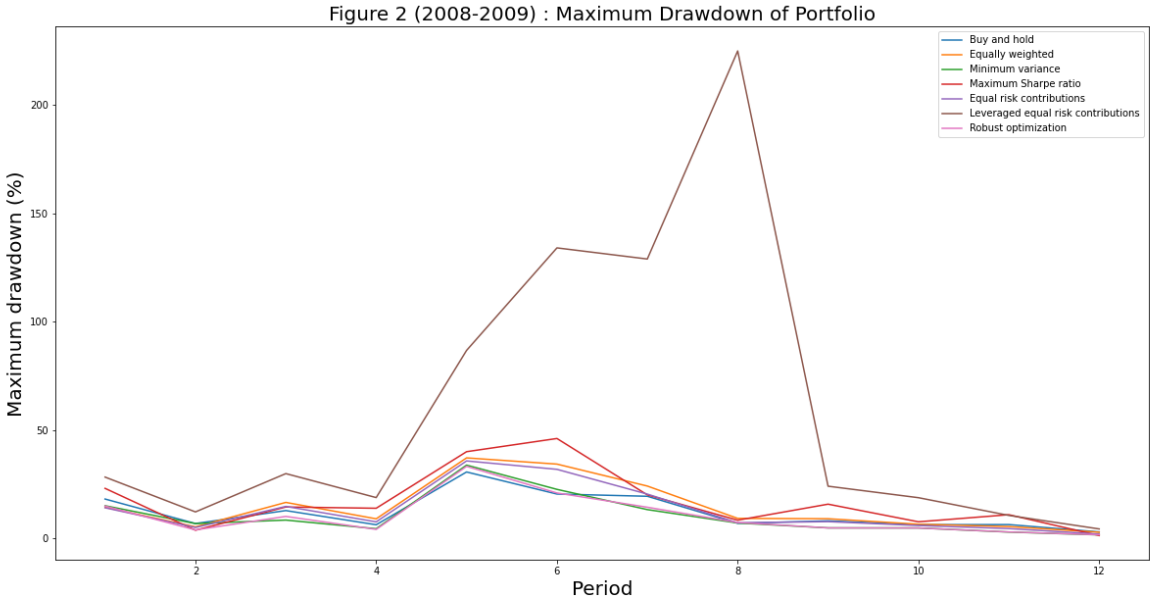
## Test trading strategies for years 2008 and 2009:

1. **Produce output for the 12 periods in years 2008 and 2009 (in appendix B):**

2. **Plot one chart that illustrates the daily value of my portfolio for 7 strategies over the years 2008 and 2009 using daily prices provided.**



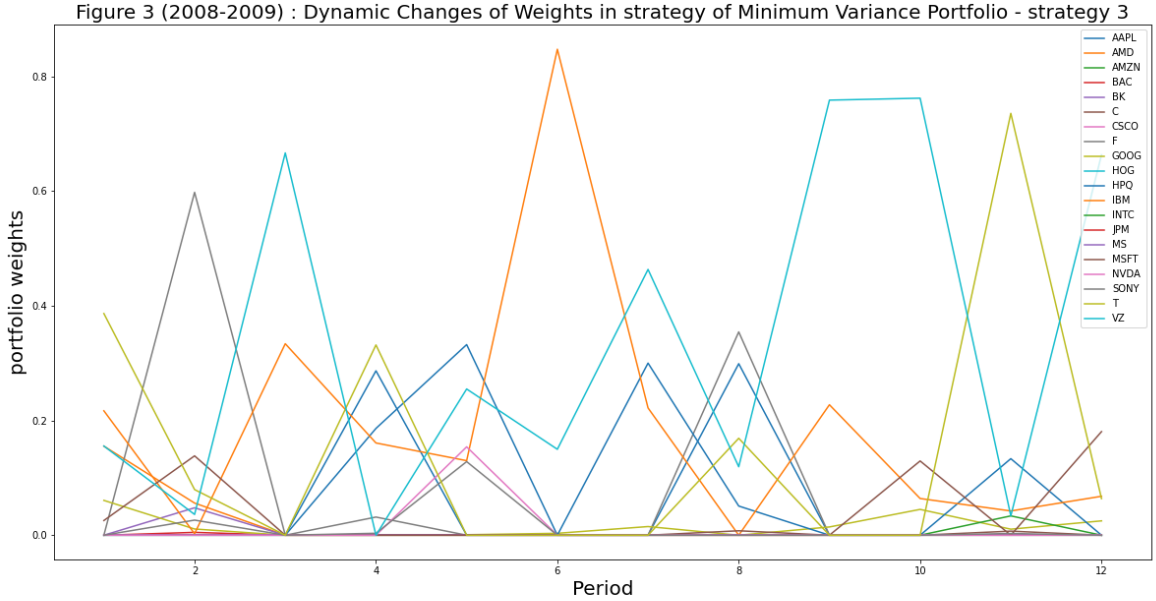

3. **Plot one chart that illustrates maximum drawdown of my portfolio (for each of the seven trading strategies) for each of the 12 periods (years 2008 and 2009) using daily prices provided.**




Based on figure 2 (2008-2009), we can see that "Leveraged equal risk contributions" experienced the highest maximum drawdowns. During periods 4 to 9, its maximum drawdowns of portfolios are much bigger than others, even larger than 200%. The six other strategies have similar trends of maximum drawdowns smaller than 50%. If a strategy shows a large max drawdown, it means that the strategy experienced a significant decline in value from its peak to its trough over a certain period. The maximum drawdown is the largest percentage drop in value that the strategy experienced during that period, and it represents the amount of loss an investor could have suffered if they had invested at the strategy's peak and sold at its trough. Thus, we can tell the strategy "Leveraged equal risk contributions" is riskier than others sometimes.

4. **Plot one chart to show dynamic changes in portfolio allocations under strategy 3.**

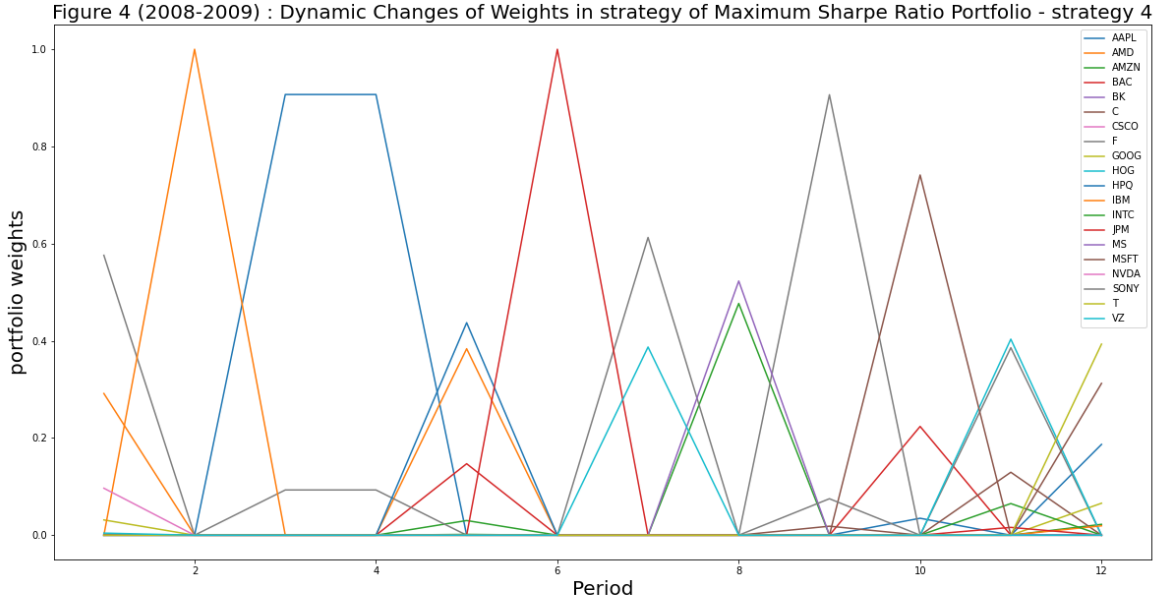
Figure 3 (2008-2009) : Dynamic Changes of Weights in strategy of Minimum Variance Portfolio - strategy 3




Based on figure 3 (2008-2009), We can see that the biggest weight of the asset is bigger than 0.5 belonging to “AMD”. “HOG” has large weights in periods 3 and 9 to 10. And there is one asset called “GOOG” with a weight larger than 0.7 at the end.

**Plot one chart to show dynamic changes in portfolio allocations under strategy 4.**

Figure 4 (2008-2009) : Dynamic Changes of Weights in strategy of Maximum Sharpe Ratio Portfolio - strategy 4

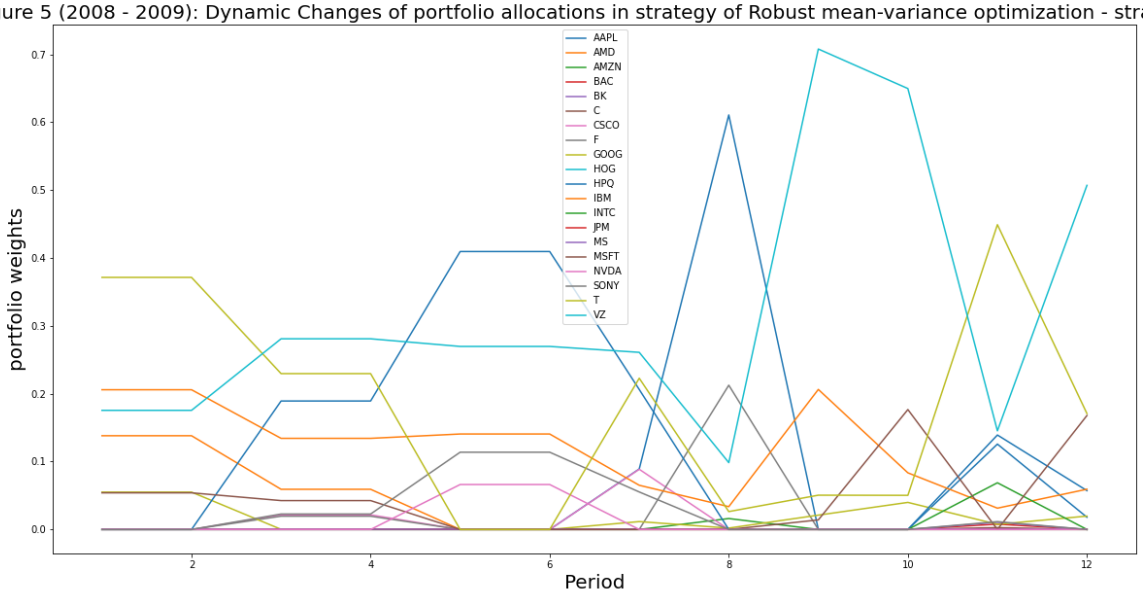



Based on figure (2008-2009), there are two times that weights approach 100%, and two times approaching 0.9. “AMD” dominates the weighting allocation in period 2,

“AAPL” dominates the weighting allocation in periods 3 to 4, and “BAC” dominates the weighting allocation in period 6.

**Plot one chart to show dynamic changes in portfolio allocations under strategy 7.**

Figure 5 (2008 - 2009): Dynamic Changes of portfolio allocations in strategy of Robust mean-variance optimization - strategy 7




Based on figure 5 (2008-2009), the biggest weight of the asset is 0.7 with only one time from “HOG”. And the second largest weight is 0.6 from “HPQ”. Most weights are below 0.5.

**Does robust portfolio selection strategy reduce trading as compared with strategies 3 and 4 that you have implemented in Assignment 1?**

Yes, the robust portfolio selection strategy reduced trading. We can see from figure 3 (2008-2009 under strategy 3), there are three assets’ weights larger than 0.7. In figure 4 (2008-2009 under strategy 4), there are two times that assets’ weights approach 100%. However, we found there is only one weight of 20 assets over 12 periods, which is larger than 0.7 one time.

Robust portfolio selection strategies can reduce trading because they typically involve a long-term investment approach that emphasizes diversification and risk management over short-term market timing and frequent trading.

5. **Compare and discuss relative performance of seven trading strategies during 2020- 2021 and 2008-2009 time periods. Which strategy would be selected for managing my own portfolio during 2008-2009 and why?**

Based on figure 1(2020-2021), we can tell the "Maximum Sharpe Ratio Portfolio" performs best after day 80. The "Leveraged equal risk contributions" strategy

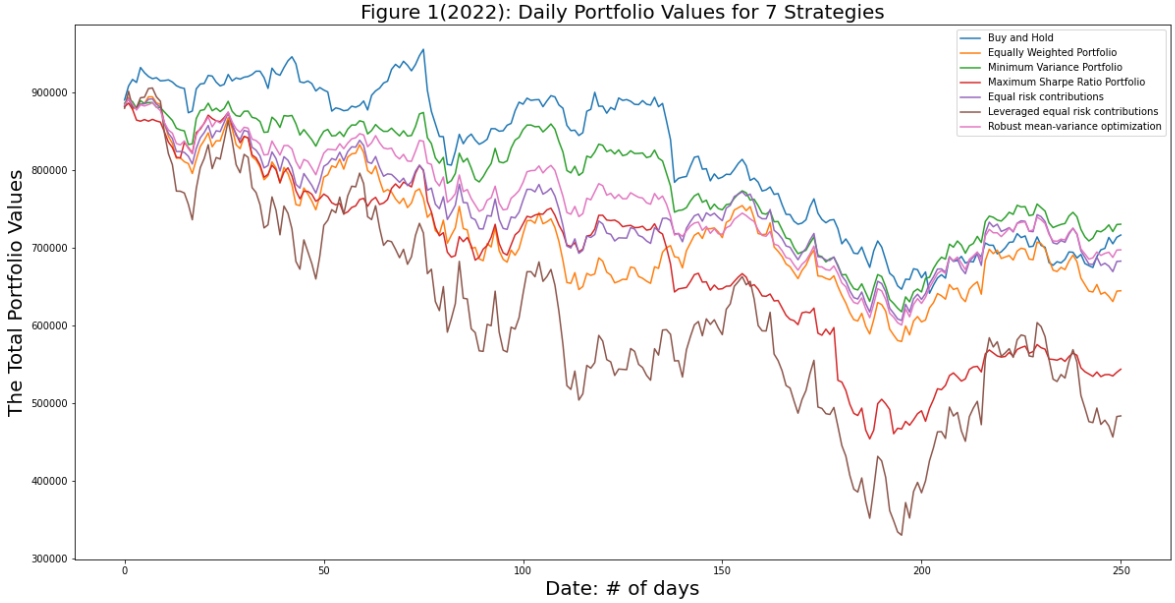
performs the second best after day 230. But it experiences a sharp decline and a pick-up during the first half of 2020. And the 5 other strategies do not that good in the long term.
Compared to figure 1(2020-2021), figure (2008-2009) shows us different trends and different performances. All strategies face declines with some fluctuations generally in 2008 because of the financial crisis. "Maximum Sharpe Ratio Portfolio" and "Leveraged equal risk contributions" have the fewest total portfolio values during the time. Also, it shows that "Buy and Hold" does best from the end of 2008 to the beginning of 2009. However, all strategies show us increasing portfolio values after 2008. "Leveraged equal risk contributions" rises the fastest compared to others. And we can notice “Maximum Sharpe Ratio Portfolio" performs worst in the second half of 2009.
Overall, "Minimum Variance Portfolio" and "Robust mean-variance optimization" show us relatively stable returns and acceptable losses, which have similar trends and similar maximum drawdowns from Figure 2 (2008-2009).
Thus, I would like to choose the strategy "Minimum Variance Portfolio". The "Minimum Variance Portfolio" strategy can be useful during times of high market volatility and uncertainty, such as the 2008-2009 financial crisis. By minimizing the portfolio's overall variance of returns, the strategy aims to reduce the risk of large losses due to market fluctuations and potentially provide better diversification benefits than traditional portfolio construction strategies. Therefore, it could have been a suitable choice for managing a portfolio during the crisis.

## Test trading strategies for years 2008 and 2009:

1. **Produce output for the 12 periods in year 2022 (in appendix C):**

2. **Plot one chart that illustrates the daily value of my portfolio for 7 strategies over the year 2022 using daily prices provided.**

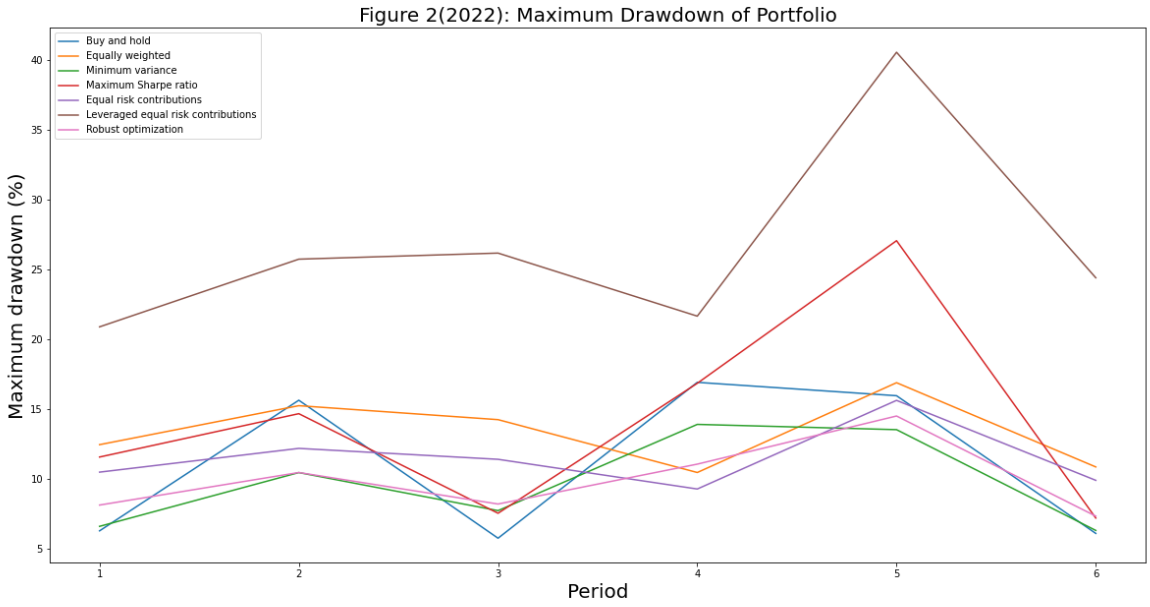
Figure 1(2022): Daily Portfolio Values for 7 Strategies




Based on figure 1 (2022), we can see all strategies experience declines in the total portfolio values generally with some fluctuations. The "Leveraged equal risk contributions" strategy performs the worst. But it is shown that the market is picking up after day 200 in 2022.

**3. Plot one chart that illustrates maximum drawdown of my portfolio (for each of the seven trading strategies) for each of the 6 periods (year 2022) using daily prices provided.**

Figure 2(2022): Maximum Drawdown of Portfolio



From figure 2 (2022), it shows the “Leveraged equal risk contributions” strategy has the biggest maximum drawdowns all the time, which are above 20%. And one strategy called “Maximum Sharpe ratio” approaches 25% maximum drawdown one time in period 5. In addition, the maximum drawdowns of seven strategies in the second half of 2022 are larger than that in the first half.
When maximum drawdowns become larger, it means that an investment or investment strategy has experienced larger losses or higher risk. This can negatively impact investor sentiment, cause portfolio performance to suffer, require a rebalancing of the portfolio, and may necessitate adjustments to the investment strategy to better manage risk.

4. **Compare the maximum draw down for 2022 to the 2008-2009 maximum draw down? How do the two periods called “recessions” compare?**

Both periods in 2022 and 2008-2009 are called “recessions”. From figure 2(2008-2009) and figure 2(2022), the biggest maximum drawdowns are from the strategy “Leveraged equal risk contributions”. The largest maximum drawdown in the line of “Leveraged equal risk contributions” in the plot of 2008-2009 is above 200%, while that in the plot of 2022 is 40% only.
The reasons for the larger maximum drawdowns in the "Leveraged equal risk contributions" strategy during the 2008-2009 recession compared to the 2022 recession may include differences in the underlying causes of the recessions, the speed and extent of market decline, and the overall economic conditions during the two periods.

# Appendix A:

Initial portfolio value = $ 1000013.0

Period 1: start date 01/02/2020, end date 02/28/2020

Strategy "Buy and Hold", value begin = $ 1000013.00, value end = $ 893956.82

Strategy "Equally Weighted Portfolio", value begin = $ 990898.24, value end = $ 893208.59

Strategy "Minimum Variance Portfolio", value begin = $ 992758.41, value end = $ 916240.12

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 990064.08, value end = $ 922087.12

Strategy "Equal risk contributions", value begin = $ 991764.84, value end = $ 904269.40

Strategy "Leveraged equal risk contributions", value begin = $ 987625.96, value end = $ 801842.66

Strategy "Robust mean-variance optimization", value begin = $ 992214.57, value end = $ 917833.69

Period 2: start date 03/02/2020, end date 04/30/2020

Strategy "Buy and Hold", value begin = $ 945076.08, value end = $ 949228.39

Strategy "Equally Weighted Portfolio", value begin = $ 931395.29, value end = $ 862353.83

Strategy "Minimum Variance Portfolio", value begin = $ 955988.34, value end = $ 851552.27

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 962073.71, value end = $ 1017232.42

Strategy "Equal risk contributions", value begin = $ 943554.83, value end = $ 857984.71

Strategy "Leveraged equal risk contributions", value begin = $ 880457.10, value end = $ 711261.14

Strategy "Robust mean-variance optimization", value begin = $ 963167.53, value end = $ 947878.18

Period 3: start date 05/01/2020, end date 06/30/2020

Strategy "Buy and Hold", value begin = $ 937916.75, value end = $ 913415.30

Strategy "Equally Weighted Portfolio", value begin = $ 831101.45, value end = $ 934159.54

Strategy "Minimum Variance Portfolio", value begin = $ 827264.88, value end = $ 854237.62

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 974382.43, value end = $ 1175786.72

Strategy "Equal risk contributions", value begin = $ 827544.07, value end = $ 923533.33

Strategy "Leveraged equal risk contributions", value begin = $ 650801.50, value end = $ 841078.83

Strategy "Robust mean-variance optimization", value begin = $ 919674.19, value end = $ 997796.15

Period 4: start date 07/01/2020, end date 08/31/2020

Strategy "Buy and Hold", value begin = $ 905419.70, value end = $ 994693.42

Strategy "Equally Weighted Portfolio", value begin = $ 927755.25, value end = $ 1060727.96

Strategy "Minimum Variance Portfolio", value begin = $ 856556.48, value end = $ 981500.25

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1219677.78, value end = $ 1606749.62

Strategy "Equal risk contributions", value begin = $ 919911.78, value end = $ 1060207.85

Strategy "Leveraged equal risk contributions", value begin = $ 833606.02, value end = $ 1113205.59

Strategy "Robust mean-variance optimization", value begin = $ 1002082.91, value end = $ 1140319.43

Period 5: start date 09/01/2020, end date 10/30/2020

Strategy "Buy and Hold", value begin = $ 993194.54, value end = $ 971914.18

Strategy "Equally Weighted Portfolio", value begin = $ 1068338.47, value end = $ 999243.10

Strategy "Minimum Variance Portfolio", value begin = $ 983247.54, value end = $ 942756.98

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1640724.87, value end = $ 1553110.75

Strategy "Equal risk contributions", value begin = $ 1068126.51, value end = $ 1002768.01

Strategy "Leveraged equal risk contributions", value begin = $ 1128975.29, value end = $ 998690.52

Strategy "Robust mean-variance optimization", value begin = $ 1145563.91, value end = $ 1097253.48

Period 6: start date 11/02/2020, end date 12/31/2020

Strategy "Buy and Hold", value begin = $ 983801.02, value end = $ 1004435.74

Strategy "Equally Weighted Portfolio", value begin = $ 1008081.57, value end = $ 1194326.17

Strategy "Minimum Variance Portfolio", value begin = $ 951192.00, value end = $ 1005965.27

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1551710.50, value end = $ 1789114.22

Strategy "Equal risk contributions", value begin = $ 1010990.80, value end = $ 1186792.03

Strategy "Leveraged equal risk contributions", value begin = $ 1015129.58, value end = $ 1366280.88

Strategy "Robust mean-variance optimization", value begin = $ 1104553.84, value end = $ 1239463.61

Period 7: start date 01/04/2021, end date 02/26/2021

Strategy "Buy and Hold", value begin = $ 1005601.39, value end = $ 956244.08

Strategy "Equally Weighted Portfolio", value begin = $ 1180783.14, value end = $ 1267218.28

Strategy "Minimum Variance Portfolio", value begin = $ 1003981.40, value end = $ 975148.49

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1737553.76, value end = $ 1851368.10

Strategy "Equal risk contributions", value begin = $ 1173763.69, value end = $ 1226772.08

Strategy "Leveraged equal risk contributions", value begin = $ 1340316.32, value end = $ 1445660.80

Strategy "Robust mean-variance optimization", value begin = $ 1226135.01, value end = $ 1223490.20

Period 8: start date 03/01/2021, end date 04/30/2021

Strategy "Buy and Hold", value begin = $ 957791.35, value end = $ 1019731.32

Strategy "Equally Weighted Portfolio", value begin = $ 1297587.56, value end = $ 1398874.11

Strategy "Minimum Variance Portfolio", value begin = $ 975468.82, value end = $ 1088054.39

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1899745.55, value end = $ 2059574.84

Strategy "Equal risk contributions", value begin = $ 1250751.78, value end = $ 1362050.22

Strategy "Leveraged equal risk contributions", value begin = $ 1493509.44, value end = $ 1716148.95

Strategy "Robust mean-variance optimization", value begin = $ 1233666.22, value end = $ 1365709.00

Period 9: start date 05/03/2021, end date 06/30/2021

Strategy "Buy and Hold", value begin = $ 1022204.61, value end = $ 987842.85

Strategy "Equally Weighted Portfolio", value begin = $ 1397748.67, value end = $ 1459313.30

Strategy "Minimum Variance Portfolio", value begin = $ 1087868.73, value end = $ 1076783.13

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2051037.06, value end = $ 2014883.10

Strategy "Equal risk contributions", value begin = $ 1361002.02, value end = $ 1390889.63

Strategy "Leveraged equal risk contributions", value begin = $ 1714037.08, value end = $ 1773720.66

Strategy "Robust mean-variance optimization", value begin = $ 1364616.64, value end = $ 1362283.14

Period 10: start date 07/01/2021, end date 08/31/2021

Strategy "Buy and Hold", value begin = $ 993283.49, value end = $ 975250.19

Strategy "Equally Weighted Portfolio", value begin = $ 1466719.25, value end = $ 1517805.45

Strategy "Minimum Variance Portfolio", value begin = $ 1076813.56, value end = $ 1086661.37

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2013740.32, value end = $ 2121759.90

Strategy "Equal risk contributions", value begin = $ 1397128.55, value end = $ 1448789.01

Strategy "Leveraged equal risk contributions", value begin = $ 1786179.40, value end = $ 1889556.82

Strategy "Robust mean-variance optimization", value begin = $ 1365053.95, value end = $ 1403921.84

Period 11: start date 09/01/2021, end date 10/29/2021

Strategy "Buy and Hold", value begin = $ 974520.08, value end = $ 949068.41

Strategy "Equally Weighted Portfolio", value begin = $ 1513571.60, value end = $ 1563474.39

Strategy "Minimum Variance Portfolio", value begin = $ 1081129.14, value end = $ 1057285.32

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2102413.32, value end = $ 2144854.73

Strategy "Equal risk contributions", value begin = $ 1442868.67, value end = $ 1457697.42

Strategy "Leveraged equal risk contributions", value begin = $ 1877629.53, value end = $ 1907362.41

Strategy "Robust mean-variance optimization", value begin = $ 1395095.53, value end = $ 1364723.09

Period 12: start date 11/01/2021, end date 12/31/2021

Strategy "Buy and Hold", value begin = $ 951350.41, value end = $ 932471.35

Strategy "Equally Weighted Portfolio", value begin = $ 1584847.25, value end = $ 1646671.96

Strategy "Minimum Variance Portfolio", value begin = $ 1054688.50, value end = $ 1048743.13

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2113773.28, value end = $ 2217106.01

Strategy "Equal risk contributions", value begin = $ 1467876.00, value end = $ 1520269.68

Strategy "Leveraged equal risk contributions", value begin = $ 1927776.42, value end = $ 2032984.44

Strategy "Robust mean-variance optimization", value begin = $ 1358271.60, value end = $ 1388387.41

# Appendix B:

Initial portfolio value = $ 385097.15

Period 1: start date 01/02/2008, end date 02/29/2008

Strategy "Buy and Hold", value begin = $ 385097.15, value end = $ 325918.34

Strategy "Equally Weighted Portfolio", value begin = $ 381649.89, value end = $ 326929.57

Strategy "Minimum Variance Portfolio", value begin = $ 381522.78, value end = $ 326157.48

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 381287.25, value end = $ 295853.59

Strategy "Equal risk contributions", value begin = $ 381717.21, value end = $ 327744.82

Strategy "Leveraged equal risk contributions", value begin = $ 380232.86, value end = $ 272715.40

Strategy "Robust mean-variance optimization", value begin = $ 381567.99, value end = $ 326795.19

Period 2: start date 03/03/2008, end date 04/30/2008

Strategy "Buy and Hold", value begin = $ 325807.08, value end = $ 349997.20

Strategy "Equally Weighted Portfolio", value begin = $ 322097.69, value end = $ 354821.22

Strategy "Minimum Variance Portfolio", value begin = $ 320794.95, value end = $ 363403.92

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 281398.42, value end = $ 297334.99

Strategy "Equal risk contributions", value begin = $ 323833.73, value end = $ 360635.85

Strategy "Leveraged equal risk contributions", value begin = $ 263692.10, value end = $ 336970.67

Strategy "Robust mean-variance optimization", value begin = $ 323600.33, value end = $ 365280.95

Period 3: start date 05/01/2008, end date 06/30/2008

Strategy "Buy and Hold", value begin = $ 357929.49, value end = $ 322881.56

Strategy "Equally Weighted Portfolio", value begin = $ 366424.15, value end = $ 308970.75

Strategy "Minimum Variance Portfolio", value begin = $ 370760.63, value end = $ 349339.00

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 301473.17, value end = $ 269936.96

Strategy "Equal risk contributions", value begin = $ 371400.14, value end = $ 322064.71

Strategy "Leveraged equal risk contributions", value begin = $ 358450.04, value end = $ 260212.48

Strategy "Robust mean-variance optimization", value begin = $ 374410.75, value end = $ 344645.25

Period 4: start date 07/01/2008, end date 08/29/2008

Strategy "Buy and Hold", value begin = $ 324349.75, value end = $ 326489.53

Strategy "Equally Weighted Portfolio", value begin = $ 309425.79, value end = $ 315897.27

Strategy "Minimum Variance Portfolio", value begin = $ 349687.98, value end = $ 354103.90

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 280557.23, value end = $ 271907.21

Strategy "Equal risk contributions", value begin = $ 321711.58, value end = $ 325800.01

Strategy "Leveraged equal risk contributions", value begin = $ 259505.00, value end = $ 267862.20

Strategy "Robust mean-variance optimization", value begin = $ 344368.22, value end = $ 348474.92

Period 5: start date 09/02/2008, end date 10/31/2008

Strategy "Buy and Hold", value begin = $ 333252.73, value end = $ 274022.75

Strategy "Equally Weighted Portfolio", value begin = $ 316675.00, value end = $ 231420.37

Strategy "Minimum Variance Portfolio", value begin = $ 346244.57, value end = $ 267434.72

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 264364.36, value end = $ 197946.32

Strategy "Equal risk contributions", value begin = $ 325560.18, value end = $ 241565.12

Strategy "Leveraged equal risk contributions", value begin = $ 267387.25, value end = $ 100009.49

Strategy "Robust mean-variance optimization", value begin = $ 344229.86, value end = $ 268436.50

Period 6: start date 11/03/2008, end date 12/31/2008

Strategy "Buy and Hold", value begin = $ 282342.11, value end = $ 305967.56

Strategy "Equally Weighted Portfolio", value begin = $ 230011.81, value end = $ 198885.85

Strategy "Minimum Variance Portfolio", value begin = $ 267816.01, value end = $ 246719.52

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 195577.71, value end = $ 151408.38

Strategy "Equal risk contributions", value begin = $ 240721.95, value end = $ 211765.48

Strategy "Leveraged equal risk contributions", value begin = $ 98340.20, value end = $ 40454.16

Strategy "Robust mean-variance optimization", value begin = $ 270550.92, value end = $ 260499.20

Period 7: start date 01/02/2009, end date 02/27/2009

Strategy "Buy and Hold", value begin = $ 313366.90, value end = $ 258275.19

Strategy "Equally Weighted Portfolio", value begin = $ 207366.91, value end = $ 169935.27

Strategy "Minimum Variance Portfolio", value begin = $ 254720.60, value end = $ 242762.29

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 150864.29, value end = $ 125621.51

Strategy "Equal risk contributions", value begin = $ 220634.14, value end = $ 188390.99

Strategy "Leveraged equal risk contributions", value begin = $ 58086.27, value end = $ -6328.97

Strategy "Robust mean-variance optimization", value begin = $ 265765.78, value end = $ 236906.43

Period 8: start date 03/02/2009, end date 04/30/2009

Strategy "Buy and Hold", value begin = $ 248688.22, value end = $ 286368.72

Strategy "Equally Weighted Portfolio", value begin = $ 161713.12, value end = $ 260066.85

Strategy "Minimum Variance Portfolio", value begin = $ 233193.44, value end = $ 317405.62

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 119575.60, value end = $ 155850.57

Strategy "Equal risk contributions", value begin = $ 180516.88, value end = $ 270295.80

Strategy "Leveraged equal risk contributions", value begin = $ -22013.71, value end = $ 156553.93

Strategy "Robust mean-variance optimization", value begin = $ 228706.90, value end = $ 301375.91

Period 9: start date 05/01/2009, end date 06/30/2009

Strategy "Buy and Hold", value begin = $ 287805.37, value end = $ 285824.08

Strategy "Equally Weighted Portfolio", value begin = $ 259634.59, value end = $ 273277.43

Strategy "Minimum Variance Portfolio", value begin = $ 314942.26, value end = $ 318335.08

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 154845.27, value end = $ 159814.69

Strategy "Equal risk contributions", value begin = $ 269843.12, value end = $ 280336.17

Strategy "Leveraged equal risk contributions", value begin = $ 155687.45, value end = $ 176559.36

Strategy "Robust mean-variance optimization", value begin = $ 299933.30, value end = $ 304131.25

Period 10: start date 07/01/2009, end date 08/31/2009

Strategy "Buy and Hold", value begin = $ 286766.63, value end = $ 298338.27

Strategy "Equally Weighted Portfolio", value begin = $ 272967.79, value end = $ 321758.02

Strategy "Minimum Variance Portfolio", value begin = $ 318032.67, value end = $ 339213.08

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 155936.28, value end = $ 168601.60

Strategy "Equal risk contributions", value begin = $ 280332.30, value end = $ 318889.60

Strategy "Leveraged equal risk contributions", value begin = $ 176558.06, value end = $ 253337.85

Strategy "Robust mean-variance optimization", value begin = $ 304031.92, value end = $ 325222.48

Period 11: start date 09/01/2009, end date 10/30/2009

Strategy "Buy and Hold", value begin = $ 291703.36, value end = $ 290193.57

Strategy "Equally Weighted Portfolio", value begin = $ 310182.86, value end = $ 328338.22

Strategy "Minimum Variance Portfolio", value begin = $ 331106.64, value end = $ 347756.91

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 161326.99, value end = $ 161163.51

Strategy "Equal risk contributions", value begin = $ 309196.97, value end = $ 327932.34

Strategy "Leveraged equal risk contributions", value begin = $ 234017.69, value end = $ 271459.93

Strategy "Robust mean-variance optimization", value begin = $ 317690.41, value end = $ 332219.11

Period 12: start date 11/02/2009, end date 12/31/2009

Strategy "Buy and Hold", value begin = $ 288596.05, value end = $ 323101.02

Strategy "Equally Weighted Portfolio", value begin = $ 329690.48, value end = $ 375806.51

Strategy "Minimum Variance Portfolio", value begin = $ 345186.33, value end = $ 387612.76

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 160312.34, value end = $ 181507.78

Strategy "Equal risk contributions", value begin = $ 328575.46, value end = $ 367587.50

Strategy "Leveraged equal risk contributions", value begin = $ 272723.41, value end = $ 350114.99

Strategy "Robust mean-variance optimization", value begin = $ 330358.54, value end = $ 369347.80

# Appendix C:

Initial portfolio value = $ 890077.15

Period 1: start date 01/03/2022, end date 02/28/2022

Strategy "Buy and Hold", value begin = $ 890077.15, value end = $ 924072.93

Strategy "Equally Weighted Portfolio", value begin = $ 881997.57, value end = $ 802549.65

Strategy "Minimum Variance Portfolio", value begin = $ 885873.66, value end = $ 863328.94

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 881222.23, value end = $ 800298.98

Strategy "Equal risk contributions", value begin = $ 882687.51, value end = $ 814758.90

Strategy "Leveraged equal risk contributions", value begin = $ 879463.26, value end = $ 748311.02

Strategy "Robust mean-variance optimization", value begin = $ 883675.91, value end = $ 828053.68

Period 2: start date 03/01/2022, end date 04/29/2022

Strategy "Buy and Hold", value begin = $ 921940.14, value end = $ 807230.89

Strategy "Equally Weighted Portfolio", value begin = $ 783067.12, value end = $ 705796.90

Strategy "Minimum Variance Portfolio", value begin = $ 854828.72, value end = $ 782907.97

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 783840.52, value end = $ 694319.06

Strategy "Equal risk contributions", value begin = $ 798693.30, value end = $ 736335.68

Strategy "Leveraged equal risk contributions", value begin = $ 716567.31, value end = $ 591272.22

Strategy "Robust mean-variance optimization", value begin = $ 819303.00, value end = $ 758423.10

Period 3: start date 05/02/2022, end date 06/30/2022

Strategy "Buy and Hold", value begin = $ 806237.92, value end = $ 877550.83

Strategy "Equally Weighted Portfolio", value begin = $ 716066.23, value end = $ 654767.51

Strategy "Minimum Variance Portfolio", value begin = $ 786244.72, value end = $ 820699.01

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 687940.85, value end = $ 735538.70

Strategy "Equal risk contributions", value begin = $ 744995.69, value end = $ 708635.63

Strategy "Leveraged equal risk contributions", value begin = $ 608654.22, value end = $ 535624.43

Strategy "Robust mean-variance optimization", value begin = $ 762682.75, value end = $ 763333.31

Period 4: start date 07/01/2022, end date 08/31/2022

Strategy "Buy and Hold", value begin = $ 892738.72, value end = $ 742946.10

Strategy "Equally Weighted Portfolio", value begin = $ 656646.38, value end = $ 679030.46

Strategy "Minimum Variance Portfolio", value begin = $ 825927.32, value end = $ 712502.66

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 732580.60, value end = $ 613023.91

Strategy "Equal risk contributions", value begin = $ 712733.20, value end = $ 702240.81

Strategy "Leveraged equal risk contributions", value begin = $ 543830.53, value end = $ 522659.57

Strategy "Robust mean-variance optimization", value begin = $ 768423.48, value end = $ 687380.71

Period 5: start date 09/01/2022, end date 10/31/2022

Strategy "Buy and Hold", value begin = $ 742641.68, value end = $ 682506.51

Strategy "Equally Weighted Portfolio", value begin = $ 675547.95, value end = $ 646239.65

Strategy "Minimum Variance Portfolio", value begin = $ 711049.16, value end = $ 700702.88

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 607825.58, value end = $ 538830.35

Strategy "Equal risk contributions", value begin = $ 700596.47, value end = $ 682681.45

Strategy "Leveraged equal risk contributions", value begin = $ 519371.31, value end = $ 483341.27

Strategy "Robust mean-variance optimization", value begin = $ 685726.30, value end = $ 683426.02

Period 6: start date 11/01/2022, end date 12/30/2022

Strategy "Buy and Hold", value begin = $ 683477.34, value end = $ 716351.42

Strategy "Equally Weighted Portfolio", value begin = $ 648031.33, value end = $ 644576.31

Strategy "Minimum Variance Portfolio", value begin = $ 708668.50, value end = $ 730238.06

Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 533866.53, value end = $ 543620.40

Strategy "Equal risk contributions", value begin = $ 685037.58, value end = $ 682735.06

Strategy "Leveraged equal risk contributions", value begin = $ 488062.31, value end = $ 483534.46

Strategy "Robust mean-variance optimization", value begin = $ 687911.03, value end = $ 697257.84