MIE1622 Assignment 2 Report

Di Tong Liu

Implementation of Investment Strategies in Python

```
Initial portfolio value = $ 1000070.06


Period 1: start date 01/02/2019, end date 02/28/2019
   Strategy "Buy and Hold", value begin = $ 1000070.06, value end = $ 1121179.83
   Strategy "Equally Weighted Portfolio", value begin = $ 991124.38, value end = $ 1097031.81
   Strategy "Mininum Variance Portfolio", value begin = $ 991702.28, value end = $ 1057440.44
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 990119.39, value end = $ 1016524.41
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 991358.16, value end = $ 1086323.72
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 987624.94, value end = $ 1177757.97
   Strategy "Robust Optimization Portfolio", value begin = $ 992817.25, value end = $ 1092802.62


Period 2: start date 03/01/2019, end date 04/30/2019
   Strategy "Buy and Hold", value begin = $ 1126131.27, value end = $ 1075001.89
   Strategy "Equally Weighted Portfolio", value begin = $ 1103260.47, value end = $ 1188731.33
   Strategy "Mininum Variance Portfolio", value begin = $ 1055378.90, value end = $ 1107930.67
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1007118.10, value end = $ 1076636.20
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 1090145.43, value end = $ 1157540.37
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1185515.12, value end = $ 1319934.06
   Strategy "Robust Optimization Portfolio", value begin = $ 1092872.92, value end = $ 1142154.36


Period 3: start date 05/01/2019, end date 06/28/2019
   Strategy "Buy and Hold", value begin = $ 1070867.54, value end = $ 969057.81
   Strategy "Equally Weighted Portfolio", value begin = $ 1181234.03, value end = $ 1169139.09
   Strategy "Mininum Variance Portfolio", value begin = $ 1091907.85, value end = $ 1099494.27
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1060338.50, value end = $ 1073404.96
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 1147998.02, value end = $ 1137253.31
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1300882.31, value end = $ 1279429.04
   Strategy "Robust Optimization Portfolio", value begin = $ 1126947.23, value end = $ 1127907.31


Period 4: start date 07/01/2019, end date 08/30/2019
   Strategy "Buy and Hold", value begin = $ 976973.31, value end = $ 933721.61
   Strategy "Equally Weighted Portfolio", value begin = $ 1179634.22, value end = $ 1149869.96
   Strategy "Mininum Variance Portfolio", value begin = $ 1097336.69, value end = $ 1129311.06
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1071286.10, value end = $ 1140344.20
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 1143052.13, value end = $ 1126483.44
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1290999.16, value end = $ 1258201.91
   Strategy "Robust Optimization Portfolio", value begin = $ 1128341.55, value end = $ 1130500.02


Period 5: start date 09/03/2019, end date 10/31/2019
   Strategy "Buy and Hold", value begin = $ 922211.42, value end = $ 1028337.74
   Strategy "Equally Weighted Portfolio", value begin = $ 1138167.02, value end = $ 1252745.95
   Strategy "Mininum Variance Portfolio", value begin = $ 1115582.54, value end = $ 1182495.62
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1139157.61, value end = $ 1246555.84
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 1116314.26, value end = $ 1217210.21
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1237824.91, value end = $ 1439921.85
   Strategy "Robust Optimization Portfolio", value begin = $ 1121050.31, value end = $ 1201988.98


Period 6: start date 11/01/2019, end date 12/31/2019
   Strategy "Buy and Hold", value begin = $ 1037933.42, value end = $ 1099403.03
   Strategy "Equally Weighted Portfolio", value begin = $ 1270461.87, value end = $ 1373479.86
   Strategy "Mininum Variance Portfolio", value begin = $ 1184511.14, value end = $ 1255872.45
   Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1248630.54, value end = $ 1370124.66
   Strategy "Equal Risk Contributions Portfolio", value begin = $ 1231663.67, value end = $ 1323790.16
   Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1468843.65, value end = $ 1653102.03
   Strategy "Robust Optimization Portfolio", value begin = $ 1209980.30, value end = $ 1280153.24
```

Period 7: start date 01/02/2020, end date 02/28/2020
  Strategy "Buy and Hold", value begin = $ 1112112.69, value end = $ 900207.54
  Strategy "Equally Weighted Portfolio", value begin = $ 1396296.22, value end = $ 1258330.19
  Strategy "Mininum Variance Portfolio", value begin = $ 1256164.22, value end = $ 1159346.53
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1379534.38, value end = $ 1284831.08
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1342081.92, value end = $ 1217401.08
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1689705.53, value end = $ 1440509.75
  Strategy "Robust Optimization Portfolio", value begin = $ 1288829.46, value end = $ 1192108.81

Period 8: start date 03/02/2020, end date 04/30/2020
  Strategy "Buy and Hold", value begin = $ 924774.25, value end = $ 856285.51
  Strategy "Equally Weighted Portfolio", value begin = $ 1312225.31, value end = $ 1215208.23
  Strategy "Mininum Variance Portfolio", value begin = $ 1209653.03, value end = $ 1077520.12
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1340554.90, value end = $ 1417410.10
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1271009.52, value end = $ 1156179.74
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1547674.13, value end = $ 1317817.08
  Strategy "Robust Optimization Portfolio", value begin = $ 1245392.45, value end = $ 1205642.91

Period 9: start date 05/01/2020, end date 06/30/2020
  Strategy "Buy and Hold", value begin = $ 822532.65, value end = $ 875128.45
  Strategy "Equally Weighted Portfolio", value begin = $ 1171040.04, value end = $ 1316082.51
  Strategy "Mininum Variance Portfolio", value begin = $ 1046783.13, value end = $ 1081097.46
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1357711.42, value end = $ 1638069.98
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1115080.88, value end = $ 1244442.75
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1235798.87, value end = $ 1493908.94
  Strategy "Robust Optimization Portfolio", value begin = $ 1157589.08, value end = $ 1256061.41

Period 10: start date 07/01/2020, end date 08/31/2020
  Strategy "Buy and Hold", value begin = $ 852159.31, value end = $ 852474.32
  Strategy "Equally Weighted Portfolio", value begin = $ 1307022.80, value end = $ 1493983.95
  Strategy "Mininum Variance Portfolio", value begin = $ 1084116.26, value end = $ 1242140.70
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1699166.66, value end = $ 2238757.92
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1239477.88, value end = $ 1427406.30
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1483880.73, value end = $ 1859905.56
  Strategy "Robust Optimization Portfolio", value begin = $ 1261581.77, value end = $ 1435974.62

Period 11: start date 09/01/2020, end date 10/30/2020
  Strategy "Buy and Hold", value begin = $ 857122.42, value end = $ 795062.75
  Strategy "Equally Weighted Portfolio", value begin = $ 1504676.72, value end = $ 1407362.52
  Strategy "Mininum Variance Portfolio", value begin = $ 1244341.51, value end = $ 1193122.73
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2286127.06, value end = $ 2163972.69
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1437975.10, value end = $ 1349367.68
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1881076.63, value end = $ 1703793.07
  Strategy "Robust Optimization Portfolio", value begin = $ 1442582.93, value end = $ 1381722.12

Period 12: start date 11/02/2020, end date 12/31/2020
  Strategy "Buy and Hold", value begin = $ 811070.20, value end = $ 972162.37
  Strategy "Equally Weighted Portfolio", value begin = $ 1419803.51, value end = $ 1682239.09

  Strategy "Mininum Variance Portfolio", value begin = $ 1203779.19, value end = $ 1273097.92
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2162013.24, value end = $ 2492775.63
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1360500.81, value end = $ 1598049.38
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1726028.40, value end = $ 2200905.43
  Strategy "Robust Optimization Portfolio", value begin = $ 1390906.94, value end = $ 1560888.16

Rounding procedure:

For rounding of stock shares, I used the math.floor() function in all of my strategies to round all shares computed down to the nearest integer. I chose to round stock shares down in order to prevent the cash account from becoming negative.

Validation procedure:

I wrote the following code as a validation procedure:

```python
while cash[strategy, period-1] < 0:

    if cash[5,0] < 0: # if using leveraged equal risk contributions strategy
        V_init = (np.dot(cur_prices, curr_positions) + curr_cash) * 2
    else:
        V_init = np.dot(cur_prices, curr_positions) + curr_cash

    x_normalized = x[strategy][period-1]/np.sum(x[strategy][period-1])
    cash_extra = abs(cash[strategy][period-1])*x_normalized
    x_extra = np.ceil(cash_extra/cur_prices)
    x[strategy][period-1] = x[strategy][period-1] - x_extra
    txn_cost = 0.005*np.dot(cur_prices, abs(x[strategy][period-1]-curr_positions))
    cash[strategy][period-1] = V_init - np.sum(cur_prices*x[strategy][period-1]) - txn_cost
```
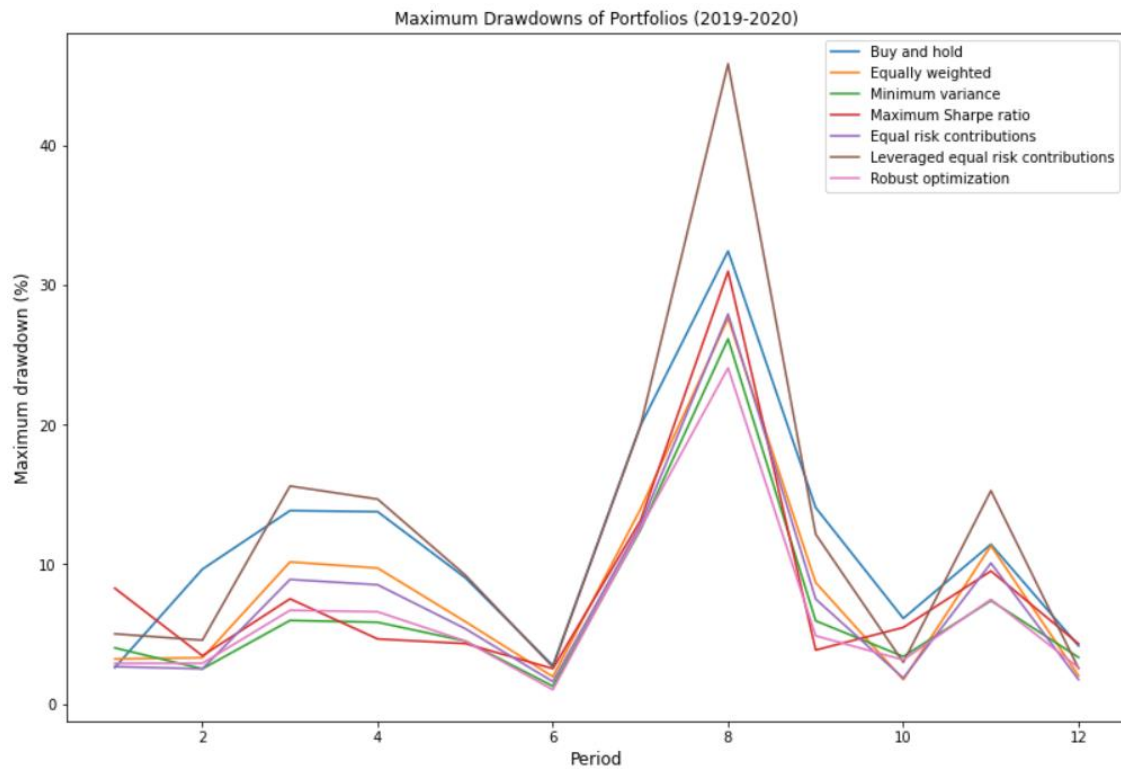
In the case where there is not enough budget to re-balance the portfolio for a specific period thus resulting in the cash account to be negative, the above algorithm will subtract an equal amount of shares from each stock until the cash account becomes non-negative again for that specific period.
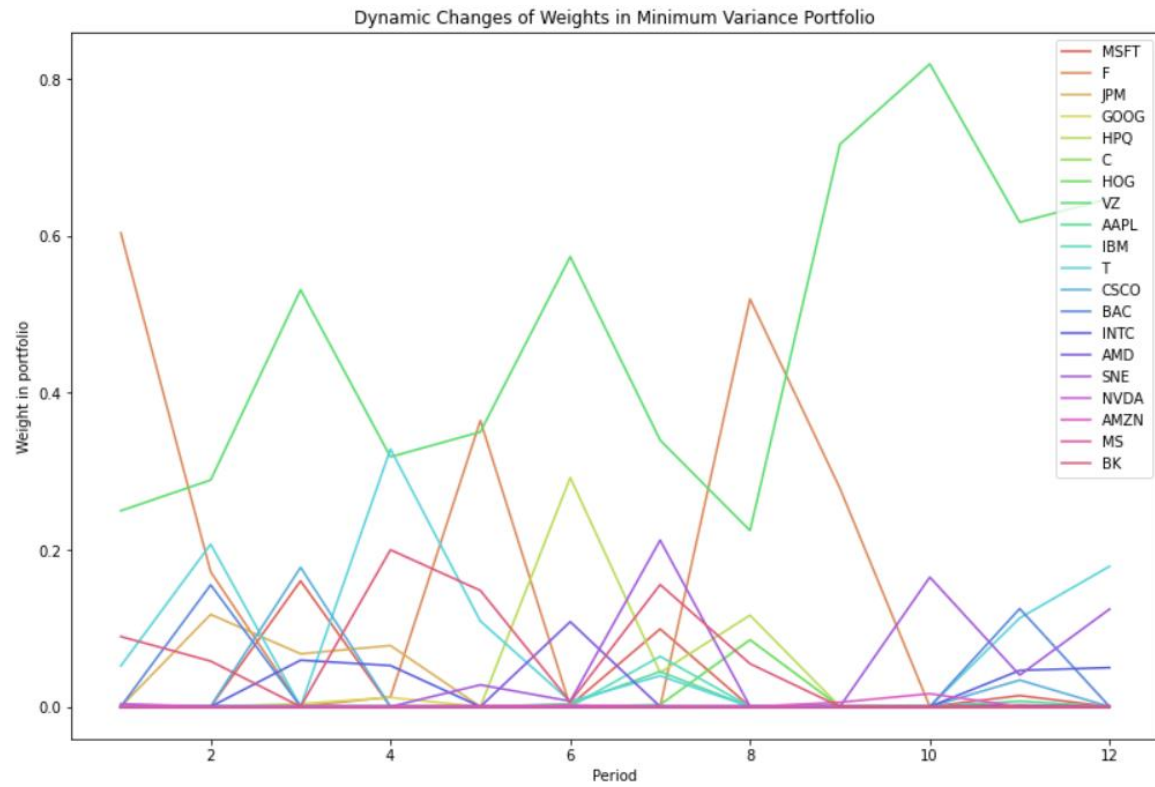
Analysis of results
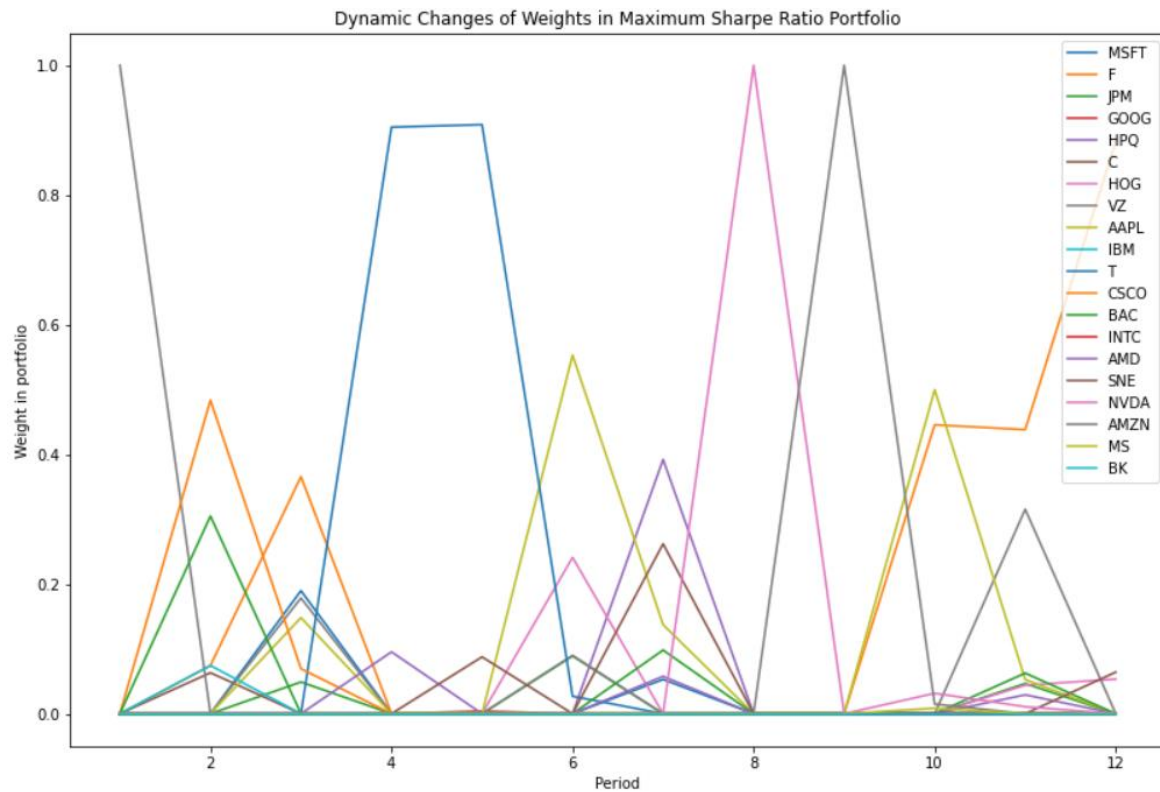
Daily values of portfolios plot:
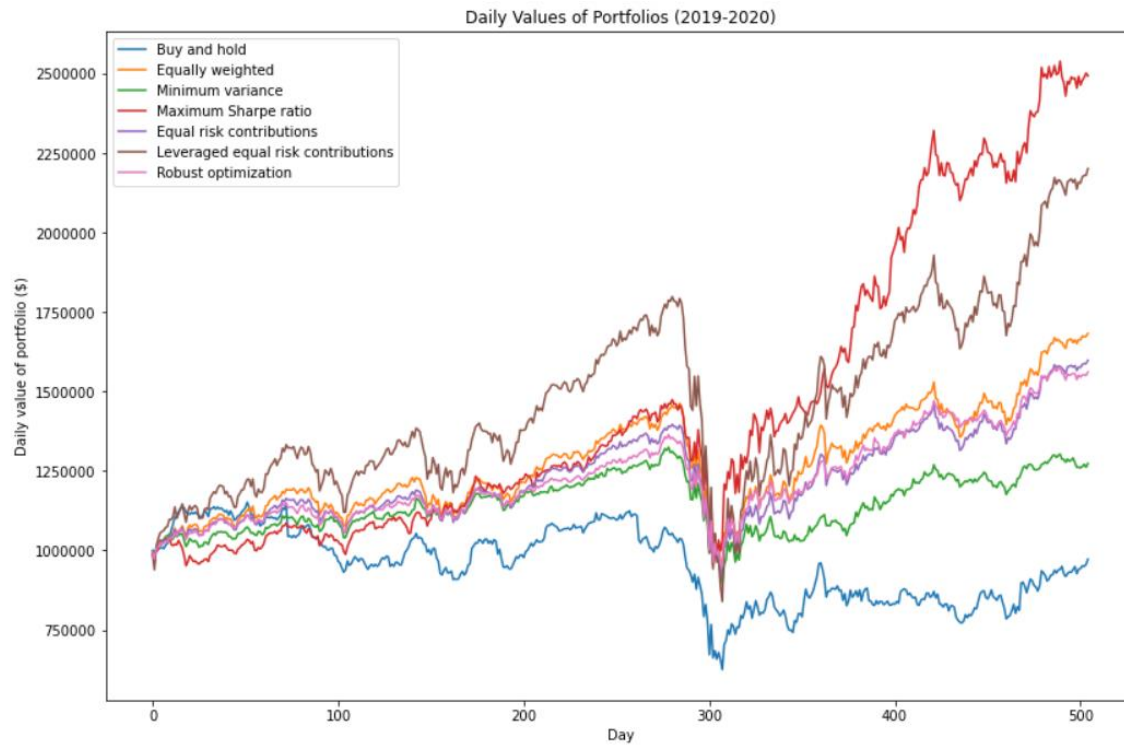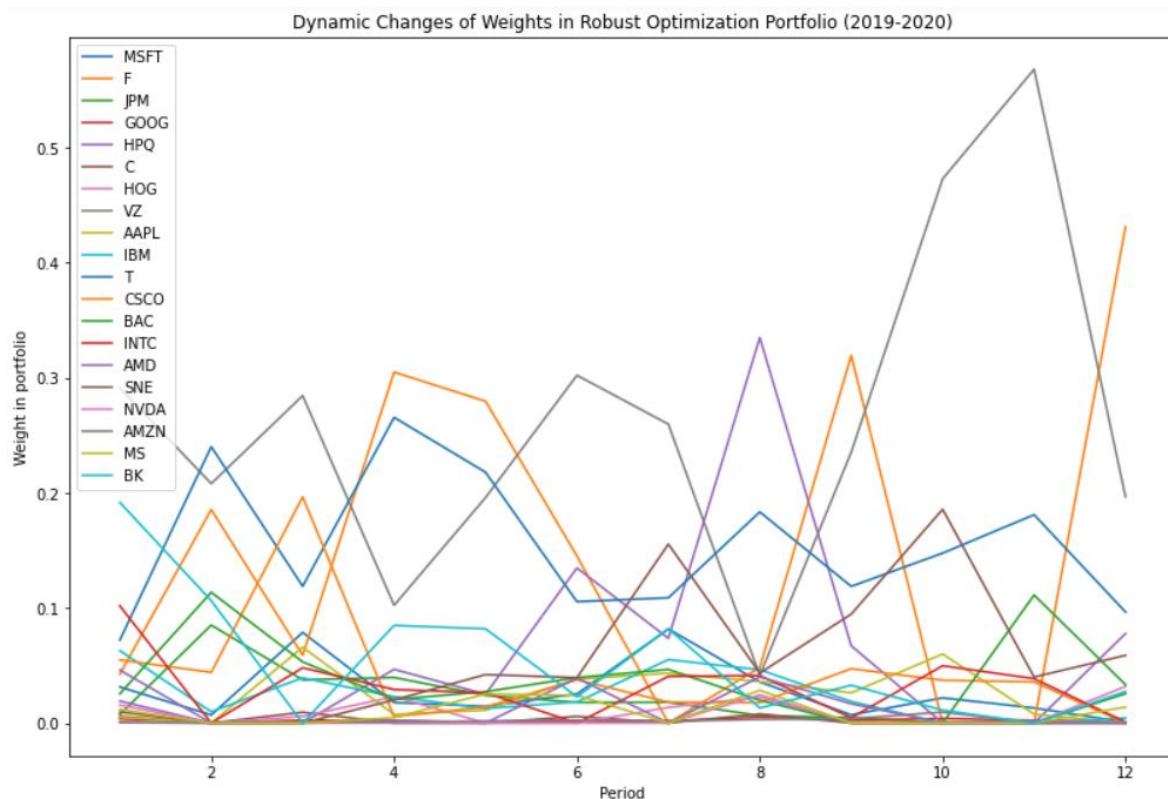

Maximum drawdowns of portfolios plot:

Dynamic changes of weights in minimum variance portfolio (strategy 3):

Dynamic changes of weights in maximum Sharpe ratio portfolio (strategy 4):

Dynamic changes of weights in robust optimization portfolio (strategy 7):

Dynamic Changes of Weights in Robust Optimization Portfolio (2019-2020)

Compared to the minimum variance portfolio and the maximum Sharpe ratio portfolio, the robust optimization portfolio reduces the trading of stocks by a substantial amount.

Comparison of trading strategies:

```
Period 12: start date 11/02/2020, end date 12/31/2020
  Strategy "Buy and Hold", value begin = $ 811070.20, value end = $ 972162.37
  Strategy "Equally Weighted Portfolio", value begin = $ 1419803.51, value end = $ 1682239.09

  Strategy "Mininum Variance Portfolio", value begin = $ 1203779.19, value end = $ 1273097.92
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2162013.24, value end = $ 2492775.63
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1360500.81, value end = $ 1598049.38
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1726028.40, value end = $ 2200905.43
  Strategy "Robust Optimization Portfolio", value begin = $ 1390906.94, value end = $ 1560888.16
```

Out of the three new strategies implemented in this assignment, the leveraged equal risk contributions strategy (strategy 5) had the best performance in terms of portfolio value at the end of the 12 periods. The equal risk contributions strategy (strategy 6) had the second highest portfolio value, while the robust optimization strategy (strategy 7) had the lowest portfolio value of the three at the end of the 12 periods. However, the maximum Sharpe ratio strategy was still able to outperform all three new strategies in terms of end portfolio value. Therefore, I would still choose the maximum Sharpe ratio strategy if I was going to manage my own portfolio, since it is able to outperform all of the other six strategies.

Testing of trading strategies using 2008-2009 data

```
Initial portfolio value = $ 789230.94


Period 1: start date 01/02/2008, end date 02/29/2008
  Strategy "Buy and Hold", value begin = $ 789230.94, value end = $ 749509.71
  Strategy "Equally Weighted Portfolio", value begin = $ 782163.77, value end = $ 669696.11
  Strategy "Mininum Variance Portfolio", value begin = $ 781380.14, value end = $ 666675.23
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 781378.15, value end = $ 681744.86
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 782136.77, value end = $ 674041.67
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 778890.79, value end = $ 562728.04
  Strategy "Robust Optimization Portfolio", value begin = $ 782385.39, value end = $ 664753.18

Period 2: start date 03/03/2008, end date 04/30/2008
  Strategy "Buy and Hold", value begin = $ 754361.26, value end = $ 752687.89
  Strategy "Equally Weighted Portfolio", value begin = $ 659796.35, value end = $ 726864.96
  Strategy "Mininum Variance Portfolio", value begin = $ 657693.85, value end = $ 745034.45
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 667671.09, value end = $ 705483.22
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 664220.25, value end = $ 739764.48
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 543133.09, value end = $ 693655.87
  Strategy "Robust Optimization Portfolio", value begin = $ 661517.72, value end = $ 711612.42

Period 3: start date 05/01/2008, end date 06/30/2008
  Strategy "Buy and Hold", value begin = $ 779329.50, value end = $ 663602.44
  Strategy "Equally Weighted Portfolio", value begin = $ 750646.94, value end = $ 632893.40
  Strategy "Mininum Variance Portfolio", value begin = $ 760131.74, value end = $ 716216.51
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 715301.67, value end = $ 640479.53
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 761861.88, value end = $ 660755.86
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 737799.84, value end = $ 535913.68
  Strategy "Robust Optimization Portfolio", value begin = $ 729096.74, value end = $ 671114.59

Period 4: start date 07/01/2008, end date 08/29/2008
  Strategy "Buy and Hold", value begin = $ 674748.24, value end = $ 619979.82
  Strategy "Equally Weighted Portfolio", value begin = $ 633824.42, value end = $ 647087.17
  Strategy "Mininum Variance Portfolio", value begin = $ 716933.13, value end = $ 725985.60
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 665679.04, value end = $ 645155.08
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 660025.89, value end = $ 668513.76
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 534478.01, value end = $ 551487.60
  Strategy "Robust Optimization Portfolio", value begin = $ 670585.23, value end = $ 678541.19

Period 5: start date 09/02/2008, end date 10/31/2008
  Strategy "Buy and Hold", value begin = $ 621151.79, value end = $ 579282.75
  Strategy "Equally Weighted Portfolio", value begin = $ 648678.95, value end = $ 474129.85
  Strategy "Mininum Variance Portfolio", value begin = $ 709865.31, value end = $ 548181.02
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 627257.85, value end = $ 469536.74
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 668068.14, value end = $ 496080.22
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 550599.70, value end = $ 207274.04
  Strategy "Robust Optimization Portfolio", value begin = $ 670257.65, value end = $ 522647.30

Period 6: start date 11/03/2008, end date 12/31/2008
  Strategy "Buy and Hold", value begin = $ 576738.59, value end = $ 500698.25
  Strategy "Equally Weighted Portfolio", value begin = $ 471245.36, value end = $ 407527.29
  Strategy "Mininum Variance Portfolio", value begin = $ 548940.54, value end = $ 505665.94
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 463913.54, value end = $ 359134.59
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 494361.31, value end = $ 434908.30
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 203836.57, value end = $ 84879.90
  Strategy "Robust Optimization Portfolio", value begin = $ 526760.46, value end = $ 507181.79
```

Period 7: start date 01/02/2009, end date 02/27/2009
  Strategy "Buy and Hold", value begin = $ 505855.81, value end = $ 414408.26
  Strategy "Equally Weighted Portfolio", value begin = $ 424896.34, value end = $ 348178.16
  Strategy "Mininum Variance Portfolio", value begin = $ 522074.98, value end = $ 497631.15
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 357844.09, value end = $ 297962.79
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 453099.77, value end = $ 386896.22
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 121131.18, value end = $ -11137.01
  Strategy "Robust Optimization Portfolio", value begin = $ 517438.48, value end = $ 461311.19

Period 8: start date 03/02/2009, end date 04/30/2009
  Strategy "Buy and Hold", value begin = $ 400004.61, value end = $ 475987.18
  Strategy "Equally Weighted Portfolio", value begin = $ 331313.10, value end = $ 532702.15
  Strategy "Mininum Variance Portfolio", value begin = $ 478008.71, value end = $ 650587.53
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 283619.95, value end = $ 369651.26
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 370727.72, value end = $ 555919.64
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ -43401.63, value end = $ 322913.59
  Strategy "Robust Optimization Portfolio", value begin = $ 445337.03, value end = $ 586875.97

Period 9: start date 05/01/2009, end date 06/30/2009
  Strategy "Buy and Hold", value begin = $ 483627.06, value end = $ 538125.39
  Strategy "Equally Weighted Portfolio", value begin = $ 531813.99, value end = $ 559778.43
  Strategy "Mininum Variance Portfolio", value begin = $ 645541.69, value end = $ 652502.40
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 367271.55, value end = $ 379056.96
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 554930.04, value end = $ 576517.01
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 321190.04, value end = $ 364071.33
  Strategy "Robust Optimization Portfolio", value begin = $ 584065.00, value end = $ 592258.75

Period 10: start date 07/01/2009, end date 08/31/2009
  Strategy "Buy and Hold", value begin = $ 528549.59, value end = $ 554215.70
  Strategy "Equally Weighted Portfolio", value begin = $ 559139.95, value end = $ 659133.18
  Strategy "Mininum Variance Portfolio", value begin = $ 651881.68, value end = $ 695330.69
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 369857.91, value end = $ 399906.49
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 576515.73, value end = $ 655794.66
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 364066.57, value end = $ 521795.40
  Strategy "Robust Optimization Portfolio", value begin = $ 592064.34, value end = $ 633342.19

Period 11: start date 09/01/2009, end date 10/30/2009
  Strategy "Buy and Hold", value begin = $ 529171.54, value end = $ 510275.57
  Strategy "Equally Weighted Portfolio", value begin = $ 635416.56, value end = $ 672535.95
  Strategy "Mininum Variance Portfolio", value begin = $ 678712.50, value end = $ 712890.22
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 382645.57, value end = $ 382257.61
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 635856.86, value end = $ 674371.53
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 482108.63, value end = $ 559027.26
  Strategy "Robust Optimization Portfolio", value begin = $ 618671.72, value end = $ 647019.22
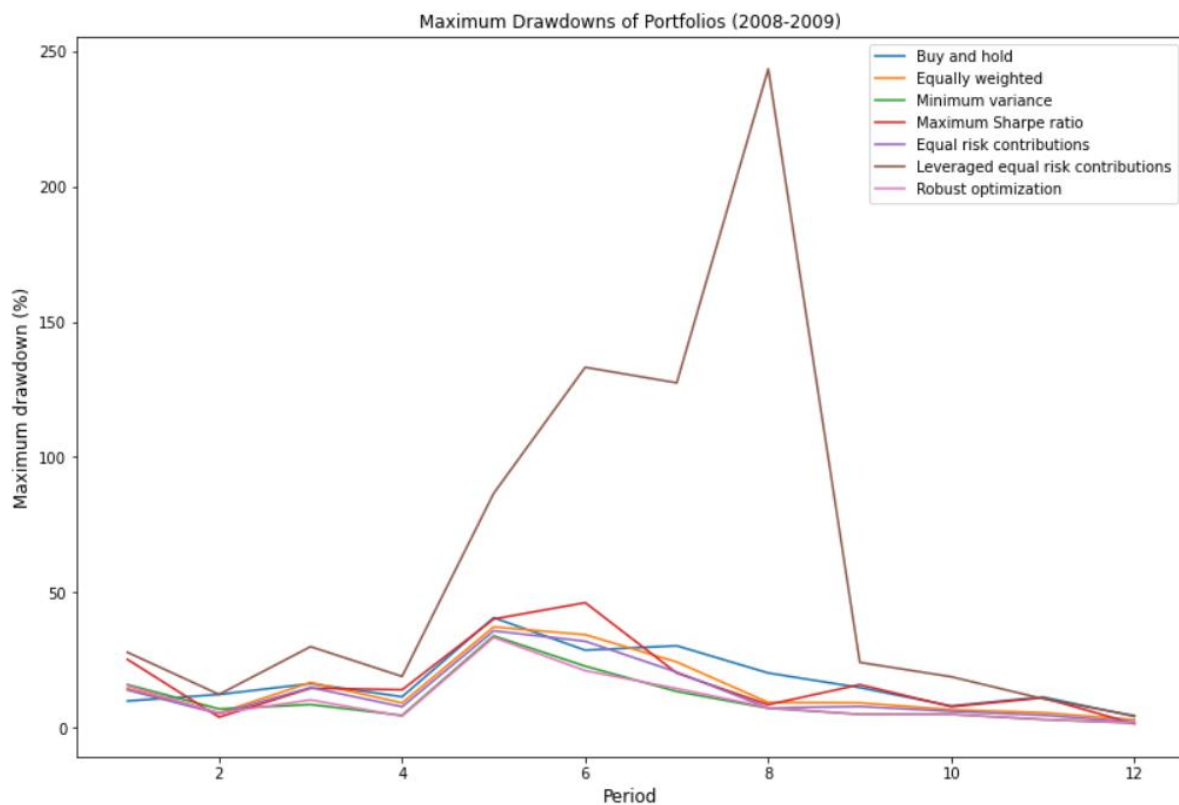
Period 12: start date 11/02/2009, end date 12/31/2009
  Strategy "Buy and Hold", value begin = $ 515205.91, value end = $ 538768.59
  Strategy "Equally Weighted Portfolio", value begin = $ 675305.57, value end = $ 769734.96
  Strategy "Mininum Variance Portfolio", value begin = $ 707617.72, value end = $ 794634.11

  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 380229.45, value end = $ 430613.38
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 675703.86, value end = $ 755301.66
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 561630.85, value end = $ 719647.85
  Strategy "Robust Optimization Portfolio", value begin = $ 643394.06, value end = $ 719380.72
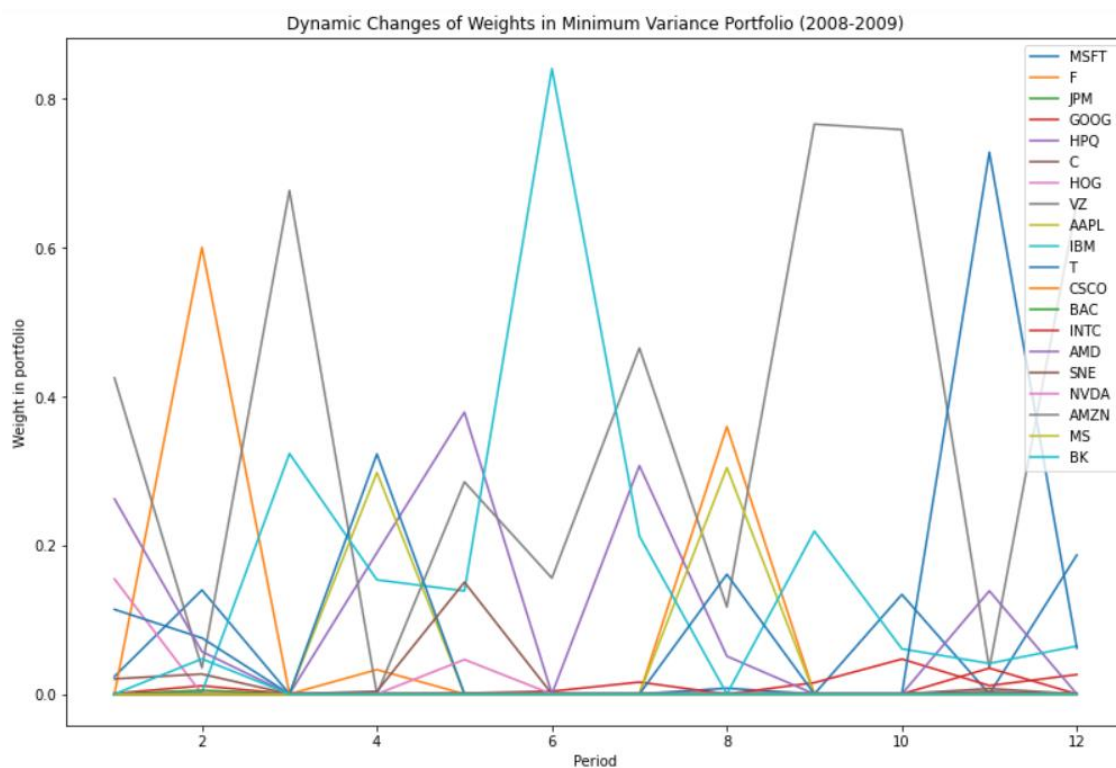
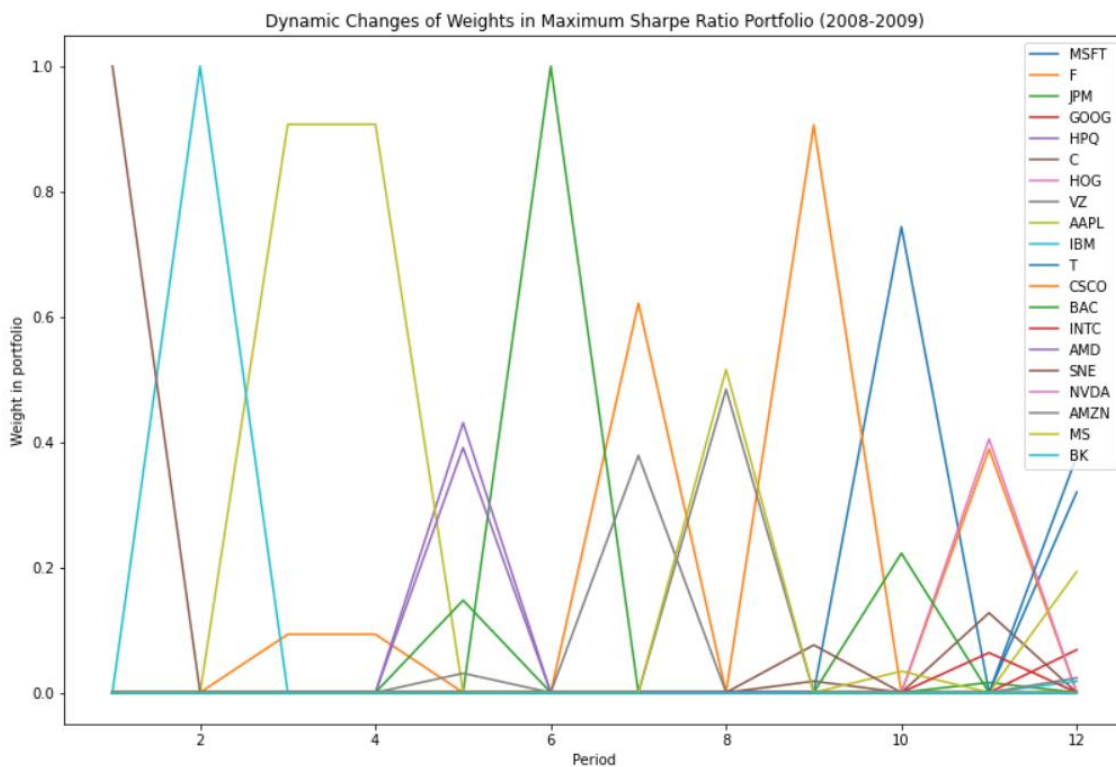Daily values of portfolios plot:
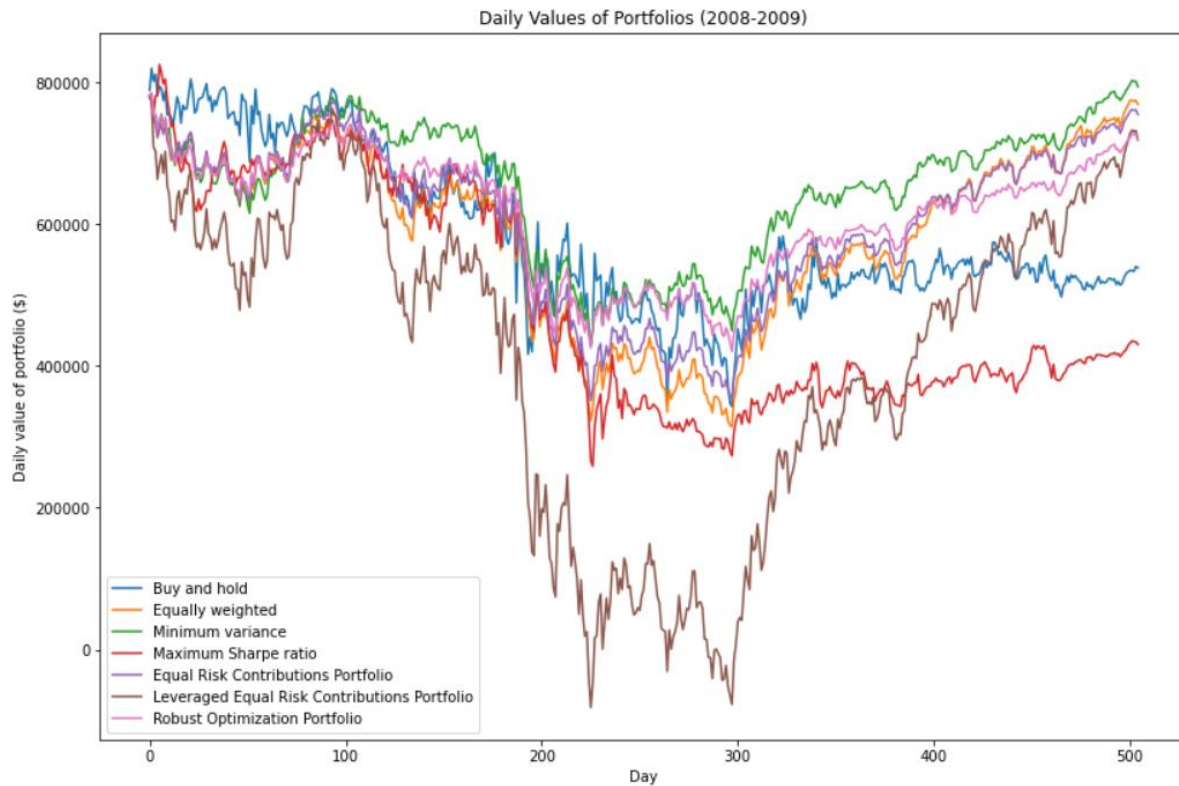
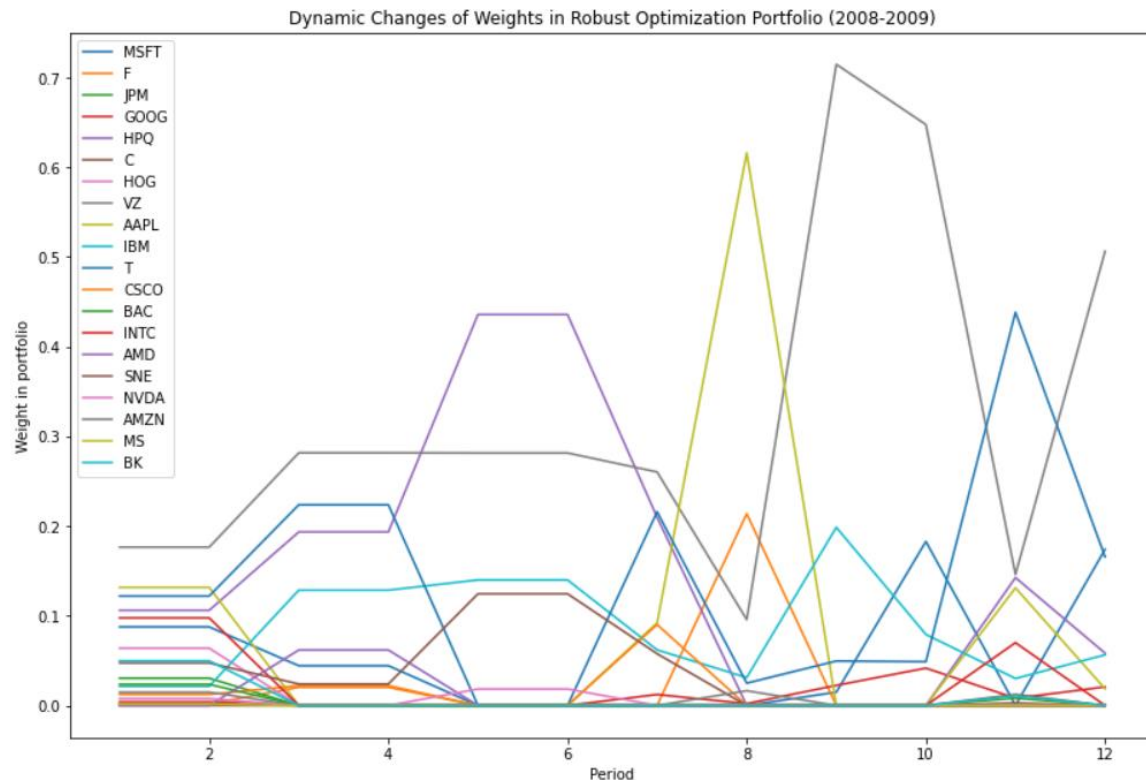Maximum drawdowns of portfolios plot:

Dynamic changes of weights in minimum variance portfolio (strategy 3):

Dynamic changes of weights in maximum Sharpe ratio portfolio (strategy 4):

Dynamic changes of weights in robust optimization portfolio (strategy 7):

Dynamic Changes of Weights in Robust Optimization Portfolio (2008-2009)

Compared to the minimum variance portfolio and the maximum Sharpe ratio portfolio, the robust optimization portfolio reduces the trading of stocks by a substantial amount for the 2008-2009 data.

Comparison between 2008-2009 and 2019-2020 data:

```
Period 12: start date 11/02/2020, end date 12/31/2020
  Strategy "Buy and Hold", value begin = $ 811070.20, value end = $ 972162.37
  Strategy "Equally Weighted Portfolio", value begin = $ 1419803.51, value end = $ 1682239.09

  Strategy "Mininum Variance Portfolio", value begin = $ 1203779.19, value end = $ 1273097.92
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2162013.24, value end = $ 2492775.63
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1360500.81, value end = $ 1598049.38
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1726028.40, value end = $ 2200905.43
  Strategy "Robust Optimization Portfolio", value begin = $ 1390906.94, value end = $ 1560888.16


Period 12: start date 11/02/2009, end date 12/31/2009
  Strategy "Buy and Hold", value begin = $ 515205.91, value end = $ 538768.59
  Strategy "Equally Weighted Portfolio", value begin = $ 675305.57, value end = $ 769734.96
  Strategy "Mininum Variance Portfolio", value begin = $ 707617.72, value end = $ 794634.11

  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 380229.45, value end = $ 430613.38
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 675703.86, value end = $ 755301.66
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 561630.85, value end = $ 719647.85
  Strategy "Robust Optimization Portfolio", value begin = $ 643394.06, value end = $ 719380.72
```

As previously stated, for the 2019-2020 time period the maximum Sharpe ratio strategy (strategy 4) had the best performance in terms of end portfolio value. However, this is no longer the case for the 2008-2009 time period. When using 2008-2009 data, it is actually the minimum variance portfolio that has the highest end portfolio value, followed by the equally weighted portfolio and the equal risk contributions portfolio. Therefore, I would choose the minimum variance strategy if I was going to manage my own portfolio during the 2008-2009 time period, since the minimum variance portfolio gives the highest end portfolio value out of all seven strategies for this time period.