MIE1622 Assignment 2

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*Note: in this report, strategies 1, 2, 3, 4, 5, 6, 7 correspond to Buy and Hold, Equal Weights, Min Variance, Max Sharpe Ratio, ERC, LERC, Robust Optimization Portfolio, respectively.

1. Brief Description of Implementation Part

1.1 Rounding Procedure

The weights of the stocks in the portfolio are firstly computed with CPLEX. The new position (in terms of number of shares) is computed with this set of weights by adopting simple integer type cast as rounding without considering transaction cost. Then the transaction cost is estimated by treating this new position as the actual position and comparing it with the position of last period. This transaction cost is indeed an upper bound of the actual transaction cost. The actual transaction cost can be potentially lower but would be close, since the actual position would not differ much (transaction cost 0.5% is small). The estimated transaction cost is deducted from the portfolio value and the position is recomputed with the same set of weights but new portfolio value, with simple integer type cast again. This rounding process makes sure the transaction cost can be covered and the budget is enough with the rounding process.

1.2 Validation Process

As mentioned previously the rounding procedure would ensure the transaction cost can be covered and the rebalancing is feasible. In addition, a verifying section of code is executed for each strategy at each period checking if the cash account remains nonnegative and the rebalancing is feasible. A message would be thrown if the issue occurs. In fact, such feasibility issue never occurs in my code.

2. Analysis of Results

2.1 Output of strategies for 12 periods

See *Figure 1.1* and *Figure 1.2* in Appendix for the output.

2.2 Daily Portfolio Value Chart

See *Figure 2* in Appendix for the chart.

2.3 Maximum Drawdown Chart

See *Figure 3* in Appendix for the chart.

2.4 Dynamic Change in Portfolio Allocation for Strategy 7 Charts

See *Figure 4.1* and *Figure 4.2* in Appendix for the charts.

Since there is some ambiguity about whether to include weights of position or weights of value for dynamic allocation, I plotted both cases. The dynamic allocation plot does illustrate that robust portfolio selection has reduced trading, as compared to portfolio 3, 4. Portfolios 3, 4 usually have a set of only a few or even one asset with non-zero weights,

and their set are changing. Portfolio 7 has more diversified set of assets with non-zero weight. In addition, the boundary lines in the dynamic changes appear flatter and smoother, meaning the change in portfolio is less sharp, thus less trading.

2.5 Strategy Comparison and Discussion

In this assignment, variation of portfolio values of strategies 2 and 5 can, in some degree, indicate the general trend of the market. From this point of view, from portfolio value of strategy in *Figure 2*, it can be found that the market has an uptrend from January 2019 to around February 2020, following by a downtrend until end of March 2020, then following by an uptrend until end of 2020.

Firstly, compared with ERC (Equal risk contribution) portfolio, LERC (leveraged equal risk contribution) portfolio grows faster in value when the market is in uptrend, and decays faster in value when the market is in downtrend, which can be reflected from the drawdown chart, where the drawdown of LERC is about twice of ERC. The higher sensitivity of LERC's portfolio value to market is because it borrowed money to increase its portfolio value with same weights as ERC. However, regardless of market trend, interest of the money borrowed needs to be paid. While the 12 periods include some with uptrend and some with downtrend, LERC ends up with portfolio value (overall two-year change) close to ERC.

Strategy 1 has the poorest performance among all, because it does not adjust itself and is not optimized for investing objectives. Among strategies 2, 3, 5, and 7, strategy 3 is less capable of growing, because the asset with small variance and correlation with other assets is usually one that is stable in price. Strategies 2, 5, and 7 have similar performance. The constraint parameter set for return of strategy 7 is set to be 120% (greater can result in no feasible solution) of expected return of strategy 3, which indeed results in an overall slightly higher growth. Strategy 4 has similar performance in downtrend market as strategies 2, 3, 5, and 7, but much higher growth in uptrend market. This is because strategy 4 is the only strategy that has return (relative to risk-free rate, while considering risk) as the main objective (robust optimization strategy only has return as a constraint).

Therefore, I would select strategy 4 (Max Sharpe Ratio) because of its capability of growing when the market is in uptrend.

3. Strategy Testing for Year 2008 and 2009

3.1 Output of strategies for 12 periods

See *Figure 5.1* and *Figure 5.2* in Appendix for the output.

3.2 Daily Portfolio Value Chart

See *Figure 6* in Appendix for the chart.

3.3 Maximum Drawdown Chart

See *Figure 7* in Appendix for the chart.

3.4 Dynamic Change in Portfolio Allocation for Strategy 3, 4, 7 Charts

See *Figure 8.1.1*, *Figure 8.1.2*, *Figure 8.2.1*, *Figure 8.2.2*, *Figure 8.3.1*, *Figure 8.3.2* in Appendix for the charts.

Since there is some ambiguity about whether to include weights of position or weights of value for dynamic allocation, I plotted both cases. The dynamic allocation plot does illustrate that robust portfolio selection has reduced trading, as compared to portfolio 3, 4. Portfolios 3, 4 usually have a set of only a few or even one asset with non-zero weights, and their set are changing. Portfolio 7 has more diversified set of assets with non-zero weight. In addition, the boundary lines in the dynamic changes appear flatter and smoother, meaning the change in portfolio is less sharp, thus less trading.

3.5 Strategy Comparison and Discussion

As mentioned in part 2, due to leverage, portfolio value of LERC has higher sensitivity to market trend. When there is a economic crisis, it not only loses more portfolio value because of its larger size, but also has to pay interest for the money borrowed that are lost. Therefore, LERC has the poorest performance during the economic crisis in 2008.

Portfolio has the best performance during 2019, 2020. However, this is not the case from 2008 to 2009. As mentioned in part 2, strategy 4 has similar performance with strategies 2, 3, 5, and 7, which remains. In addition, when the market has decayed enough such that it enters a stable period where there is a gradual growth, strategy 4 does not exhibit a outstanding fast growth. Moreover, there are periods with all expected return negative, and the maximum Sharpe optimization has no feasible solution, which needs to be adjusted by holding same portfolio. Therefore, strategy 4 is not a good option during crisis time, because it is looking for return, which is not apparent during 2008 and 2009. Strategy 1 has a similar performance as strategies 2, 3, 5, and 7, but does not give a gradual growth after April 2009. Strategies 2, 3, 4, and 7 have similar performance during the 2 years. Strategy 2 has slightly better performance during crisis and exhibits a gradual growth as the market does during 2009, resulting in a slightly better overall performance. Therefore, I would select strategy 2 during 2008-2009, when an economic crisis took place. (Appendix starts on next page)

4. Appendix

```
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 = $ 991110.53, value end = $ 1097139.05
  Strategy "Mininum Variance Portfolio", value begin = $ 991694.14, value end = $ 1057727.91
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 990119.39, value end = $ 1016524.41
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 991363.66, value end = $ 1086662.26
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 986432.10, value end = $ 1172542.03
  Strategy "Robust Optimization Portfolio", value begin = $ 992096.73, value end = $ 1069956.01

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 = $ 1103425.44, value end = $ 1188889.41
  Strategy "Mininum Variance Portfolio", value begin = $ 1055676.99, value end = $ 1108275.36
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1007117.74, value end = $ 1076765.61
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1090573.12, value end = $ 1157348.13
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1146569.83, value end = $ 1282835.68
  Strategy "Robust Optimization Portfolio", value begin = $ 1069421.99, value end = $ 1117731.87

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 = $ 1181393.74, value end = $ 1169301.49
  Strategy "Mininum Variance Portfolio", value begin = $ 1092186.69, value end = $ 1099667.41
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1060451.78, value end = $ 1073388.89
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1147858.50, value end = $ 1136875.88
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1225744.12, value end = $ 1196964.23
  Strategy "Robust Optimization Portfolio", value begin = $ 1102421.91, value end = $ 1103148.46

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 = $ 1179796.34, value end = $ 1150032.09
  Strategy "Mininum Variance Portfolio", value begin = $ 1097489.35, value end = $ 1129717.70
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1071209.32, value end = $ 1140264.81
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1142683.75, value end = $ 1126422.74
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1169183.99, value end = $ 1130798.53
  Strategy "Robust Optimization Portfolio", value begin = $ 1103313.54, value end = $ 1104300.72

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 = $ 1138328.41, value end = $ 1252905.01
  Strategy "Mininum Variance Portfolio", value begin = $ 1115970.40, value end = $ 1182721.76
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1139080.87, value end = $ 1246475.50
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1116253.58, value end = $ 1217369.30
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1070364.94, value end = $ 1260261.80
  Strategy "Robust Optimization Portfolio", value begin = $ 1094559.34, value end = $ 1178930.58
```

Figure 1.1: Part 2 Output of Strategies

```
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 = $ 1270616.92, value end = $ 1373610.07
  Strategy "Mininum Variance Portfolio", value begin = $ 1184766.42, value end = $ 1256239.28
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1248551.92, value end = $ 1369849.65
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1231867.09, value end = $ 1323873.67
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1251645.59, value end = $ 1434039.66
  Strategy "Robust Optimization Portfolio", value begin = $ 1186706.80, value end = $ 1255602.63

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 = $ 1396421.26, value end = $ 1258473.94
  Strategy "Mininum Variance Portfolio", value begin = $ 1256601.66, value end = $ 1159796.35
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1379227.69, value end = $ 1284635.75
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1342080.17, value end = $ 1215702.96
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1428159.67, value end = $ 1152446.88
  Strategy "Robust Optimization Portfolio", value begin = $ 1263627.03, value end = $ 1164983.22

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 = $ 1312359.86, value end = $ 1215382.27
  Strategy "Mininum Variance Portfolio", value begin = $ 1210165.17, value end = $ 1077038.70
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1340311.96, value end = $ 1417151.32
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1268900.44, value end = $ 1154499.92
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1220385.44, value end = $ 994780.72
  Strategy "Robust Optimization Portfolio", value begin = $ 1219355.47, value end = $ 1100453.46

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 = $ 1171231.67, value end = $ 1316235.02
  Strategy "Mininum Variance Portfolio", value begin = $ 1046251.05, value end = $ 1081224.98
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1357463.54, value end = $ 1637822.10
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1113522.50, value end = $ 1242592.81
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 875705.65, value end = $ 1075215.58
  Strategy "Robust Optimization Portfolio", value begin = $ 1063274.56, value end = $ 1176847.93

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 = $ 1307180.39, value end = $ 1494126.76
  Strategy "Mininum Variance Portfolio", value begin = $ 1084360.85, value end = $ 1242832.79
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1698911.14, value end = $ 2238261.54
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1237695.85, value end = $ 1426930.01
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1037155.01, value end = $ 1351077.49
  Strategy "Robust Optimization Portfolio", value begin = $ 1185940.10, value end = $ 1361598.84


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 = $ 1504821.99, value end = $ 1407551.72
  Strategy "Mininum Variance Portfolio", value begin = $ 1245046.56, value end = $ 1193651.51
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2285546.99, value end = $ 2164732.78
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1437617.35, value end = $ 1348407.67
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1335860.81, value end = $ 1164319.69
  Strategy "Robust Optimization Portfolio", value begin = $ 1368737.75, value end = $ 1310082.43

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 = $ 1419986.79, value end = $ 1682327.39

  Strategy "Mininum Variance Portfolio", value begin = $ 1204298.45, value end = $ 1273645.25
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 2162771.27, value end = $ 2493427.99
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1359541.70, value end = $ 1597328.37
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1141774.75, value end = $ 1537575.79
  Strategy "Robust Optimization Portfolio", value begin = $ 1319913.09, value end = $ 1445625.82
```

Figure 1.2: Part 2 Output of Strategies (Continue)

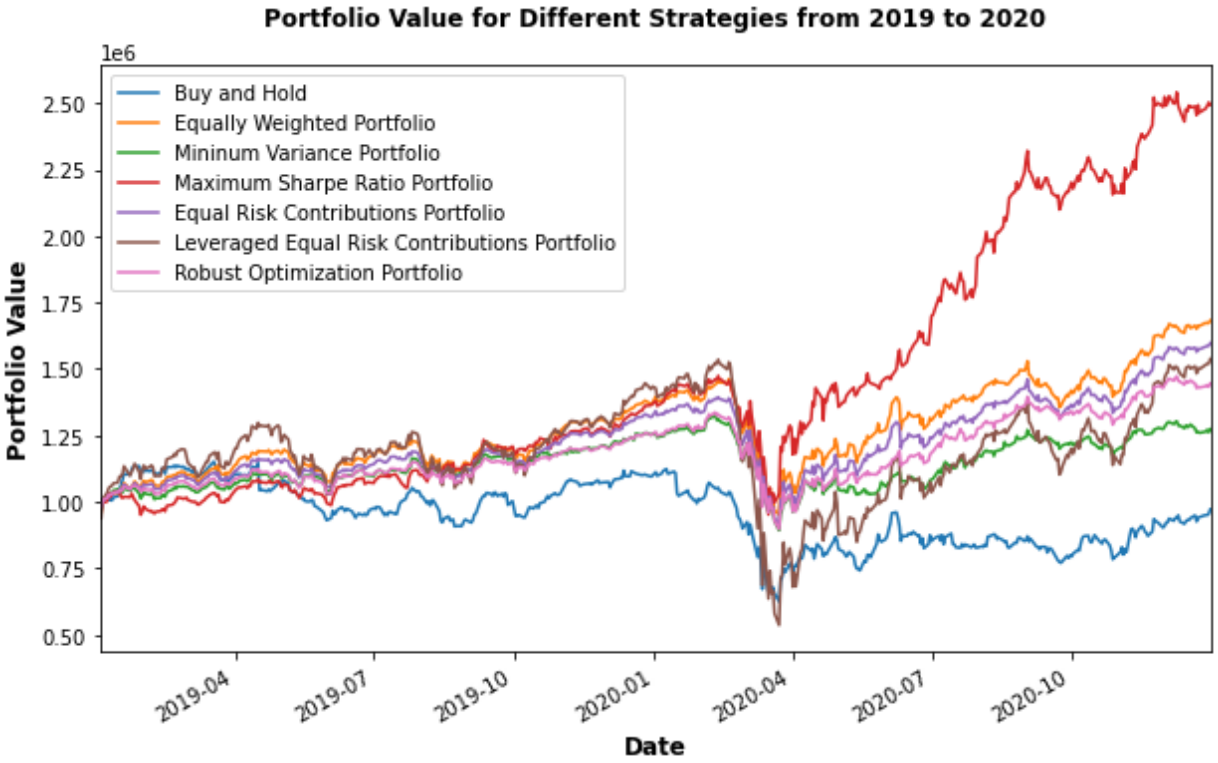

Figure 2: Part 2 Daily Portfolio Value Chart

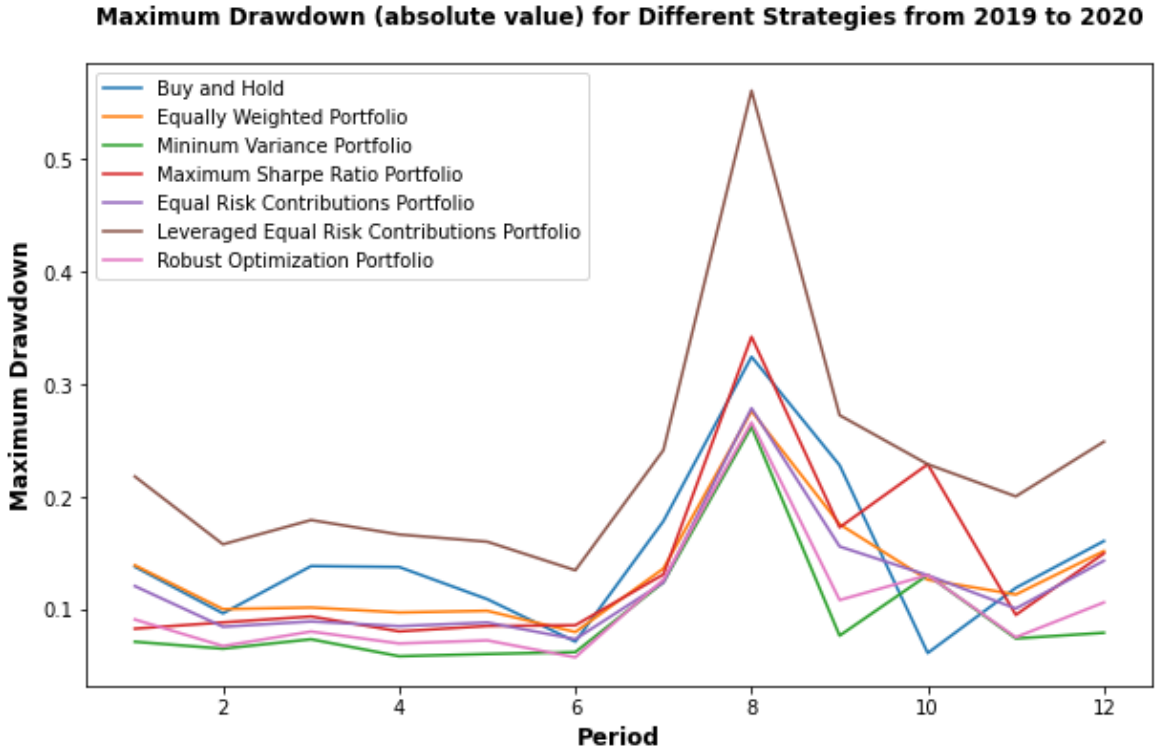

Figure 3: Part 2 Maximum Drawdown Chart

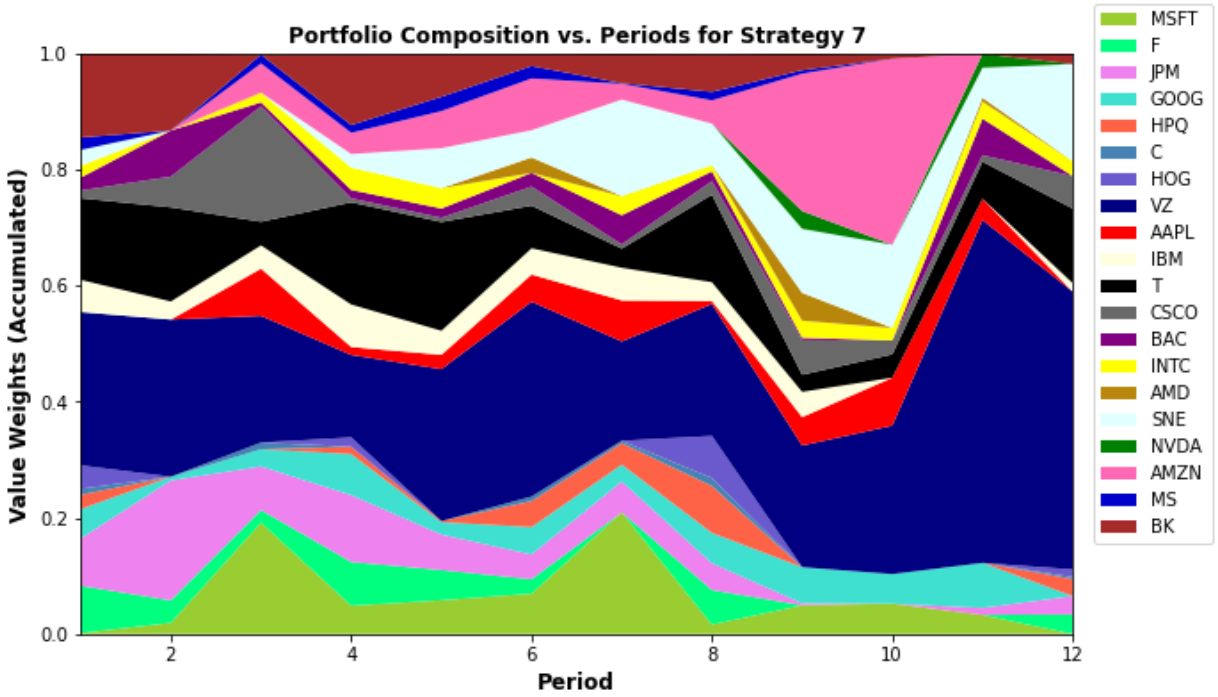

Figure 4.1: Portfolio Dynamic Change (Value Weight) for Strategy 7

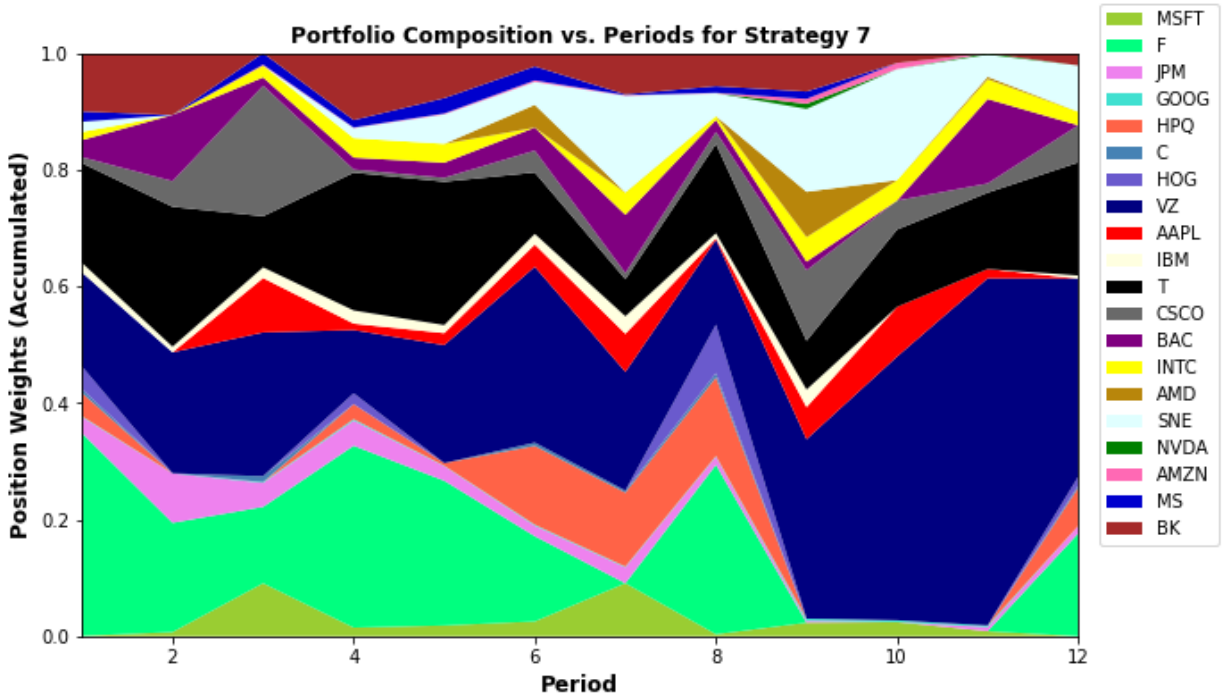

Figure 4.2: Portfolio Dynamic Change (Position Weight) for Strategy 7

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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 = $ 782158.10, value end = $ 669692.42
  Strategy "Mininum Variance Portfolio", value begin = $ 781379.10, value end = $ 666812.77
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 781378.15, value end = $ 681744.86
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 782131.52, value end = $ 674093.13
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 778240.00, value end = $ 556759.17
  Strategy "Robust Optimization Portfolio", value begin = $ 782106.92, value end = $ 679233.31

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 = $ 659705.67, value end = $ 726740.28
  Strategy "Mininum Variance Portfolio", value begin = $ 657738.78, value end = $ 745514.59
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 667671.09, value end = $ 705483.22
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 664182.68, value end = $ 739800.16
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 496065.95, value end = $ 605558.19
  Strategy "Robust Optimization Portfolio", value begin = $ 670983.53, value end = $ 740764.75

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 = $ 750503.35, value end = $ 632811.20
  Strategy "Mininum Variance Portfolio", value begin = $ 760615.09, value end = $ 716520.36
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 715301.68, value end = $ 640487.94
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 761912.32, value end = $ 660649.84
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 611979.17, value end = $ 444330.50
  Strategy "Robust Optimization Portfolio", value begin = $ 758126.54, value end = $ 693571.05

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 = $ 633743.28, value end = $ 647028.72
  Strategy "Mininum Variance Portfolio", value begin = $ 717218.38, value end = $ 726222.41
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 665688.61, value end = $ 645164.69
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 659931.17, value end = $ 668410.86
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 410773.61, value end = $ 418227.45
  Strategy "Robust Optimization Portfolio", value begin = $ 691849.31, value end = $ 691725.66

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 = $ 648620.41, value end = $ 473991.77
  Strategy "Mininum Variance Portfolio", value begin = $ 710110.40, value end = $ 548393.43
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 627266.73, value end = $ 469279.02
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 667936.64, value end = $ 495555.75
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 395707.30, value end = $ 187961.39
  Strategy "Robust Optimization Portfolio", value begin = $ 682557.62, value end = $ 527107.46
```

Figure 5.1: Part 3 Output of Strategies

```
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 = $ 471109.77, value end = $ 407313.79
  Strategy "Mininum Variance Portfolio", value begin = $ 549157.21, value end = $ 505915.93
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 463708.15, value end = $ 358976.86
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 493810.81, value end = $ 434389.95
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 165515.08, value end = $ 124382.50
  Strategy "Robust Optimization Portfolio", value begin = $ 528756.05, value end = $ 489528.57

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 = $ 424689.19, value end = $ 348040.32
  Strategy "Mininum Variance Portfolio", value begin = $ 522331.14, value end = $ 497683.38
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 357686.93, value end = $ 297792.19
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 452573.19, value end = $ 386413.02
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 127639.65, value end = $ 89298.76
  Strategy "Robust Optimization Portfolio", value begin = $ 506138.45, value end = $ 460963.95

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 = $ 331194.19, value end = $ 532512.08
  Strategy "Mininum Variance Portfolio", value begin = $ 478060.28, value end = $ 652538.65
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 283422.17, value end = $ 369418.85
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 370250.70, value end = $ 555324.84
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 73454.90, value end = $ 146468.06
  Strategy "Robust Optimization Portfolio", value begin = $ 444503.00, value end = $ 606729.87

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 = $ 531624.81, value end = $ 559595.05
  Strategy "Mininum Variance Portfolio", value begin = $ 647326.81, value end = $ 654299.48
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 367172.80, value end = $ 379050.65
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 554330.48, value end = $ 575869.06
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 141821.98, value end = $ 151797.74
  Strategy "Robust Optimization Portfolio", value begin = $ 602024.98, value end = $ 611442.58

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 = $ 558952.73, value end = $ 658857.94
  Strategy "Mininum Variance Portfolio", value begin = $ 653690.17, value end = $ 697189.90
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 369816.98, value end = $ 399957.95
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 575867.04, value end = $ 655185.72
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 143978.63, value end = $ 182643.51
  Strategy "Robust Optimization Portfolio", value begin = $ 610400.01, value end = $ 652268.04


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 = $ 635158.26, value end = $ 672317.26
  Strategy "Mininum Variance Portfolio", value begin = $ 680514.47, value end = $ 714844.50
  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 382683.76, value end = $ 382317.91
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 635260.72, value end = $ 673861.20
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 164668.41, value end = $ 183453.09
  Strategy "Robust Optimization Portfolio", value begin = $ 636657.28, value end = $ 665922.66

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 = $ 675085.43, value end = $ 769449.07
  Strategy "Mininum Variance Portfolio", value begin = $ 709542.60, value end = $ 796756.59

  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 380385.07, value end = $ 430688.58
  Strategy "Equal Risk Contributions Portfolio", value begin = $ 675189.90, value end = $ 755652.69
  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 175213.71, value end = $ 215723.68
  Strategy "Robust Optimization Portfolio", value begin = $ 662485.68, value end = $ 741819.93
```

Figure 5.2: Part 3 Output of Strategies

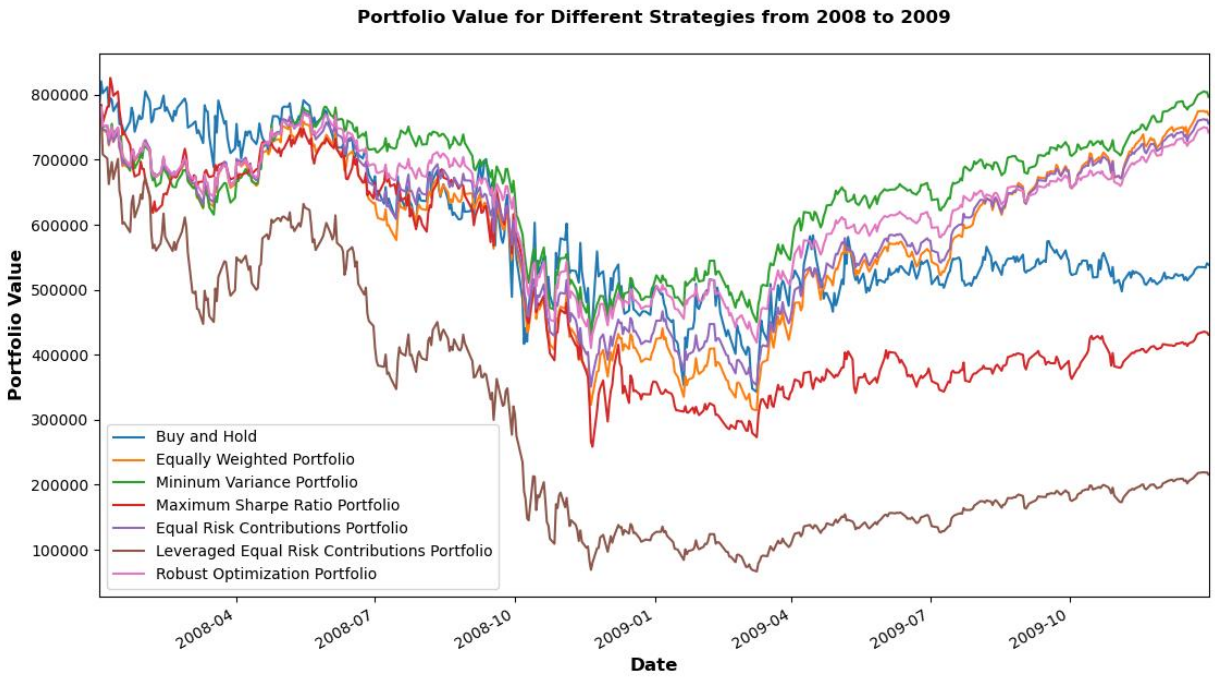

Figure 6: Part 3 Daily Portfolio Value Chart

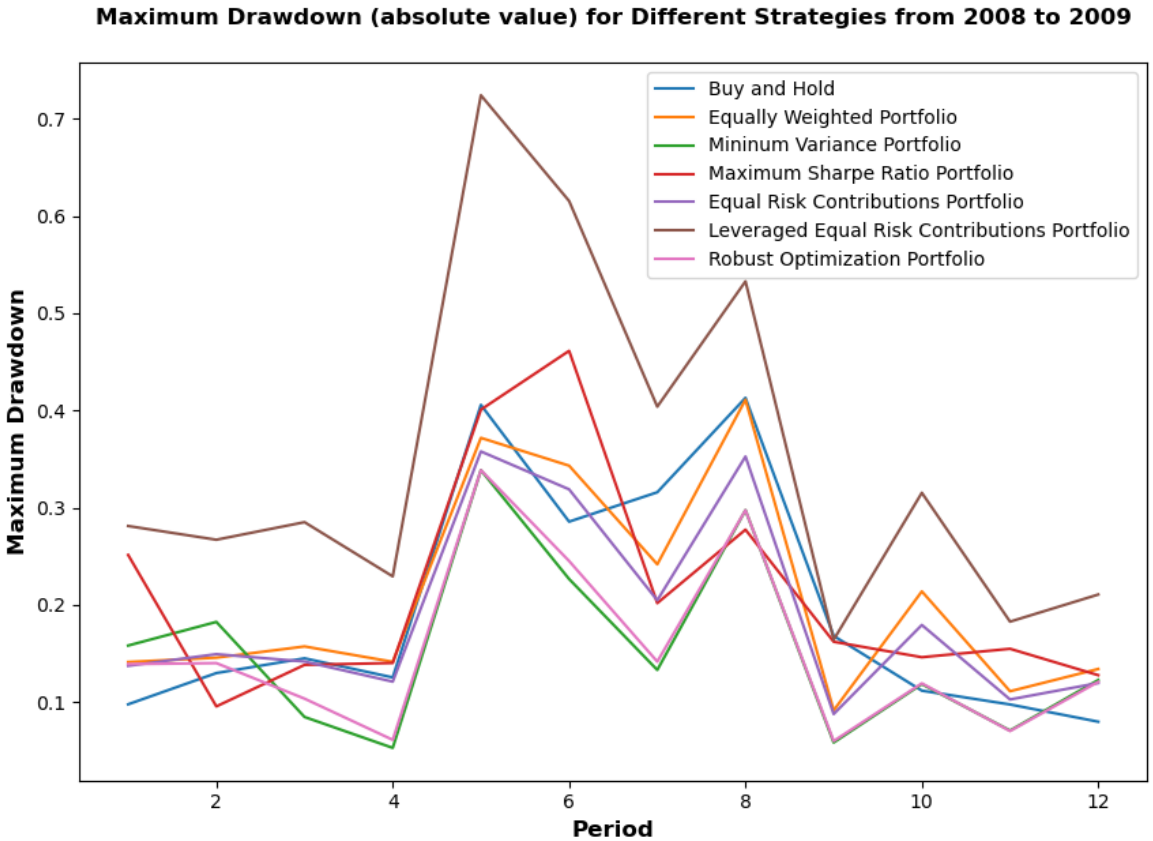

Figure 7: Part 3 Maximum Drawdown Chart

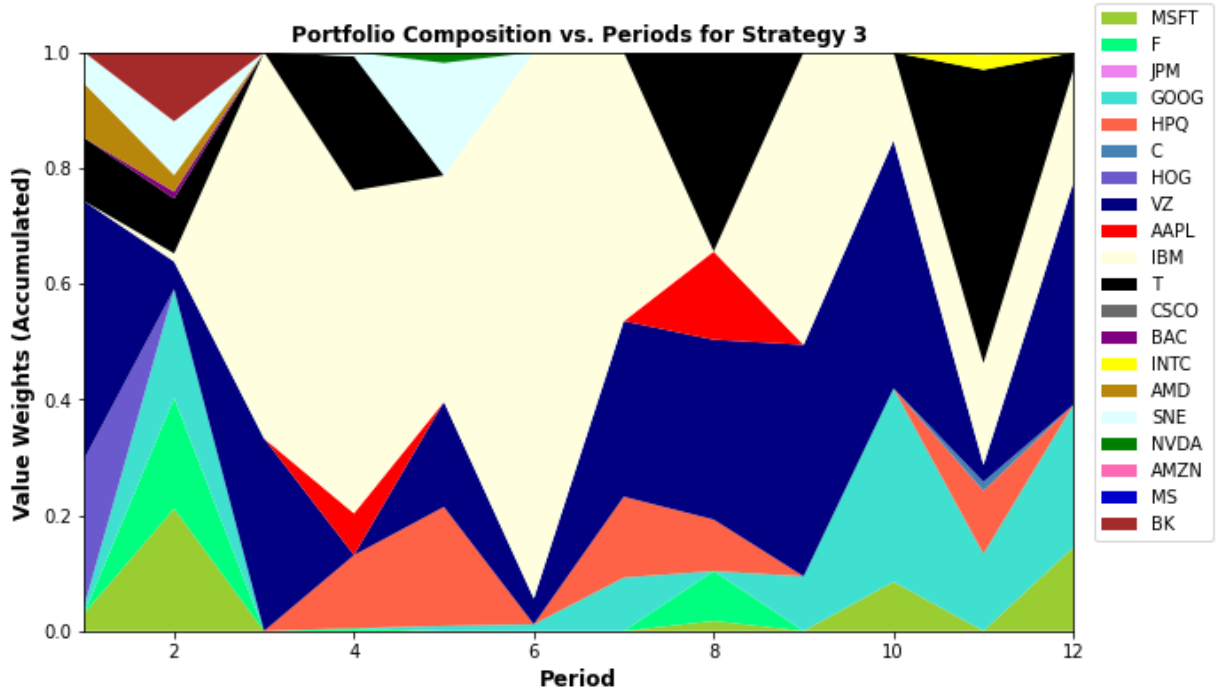

Figure 8.1.1: Portfolio Dynamic Change (Value Weight) for Strategy 3

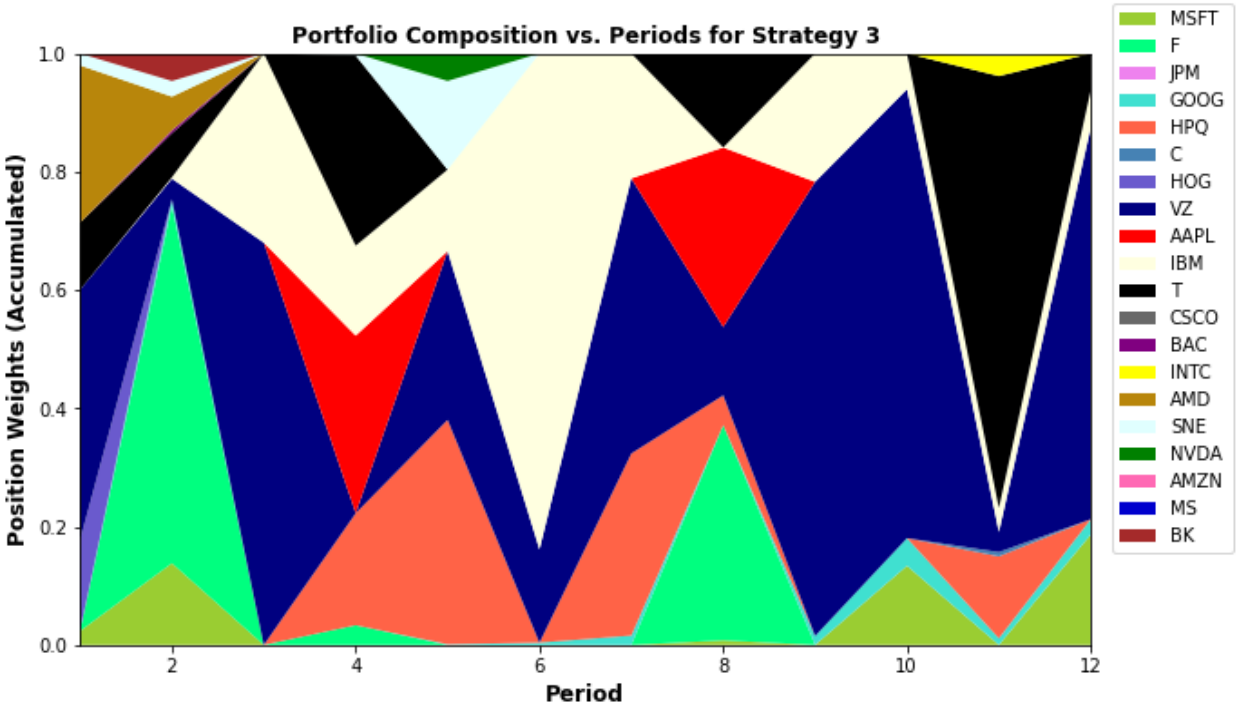

Figure 8.1.2: Portfolio Dynamic Change (Position Weight) for Strategy 3

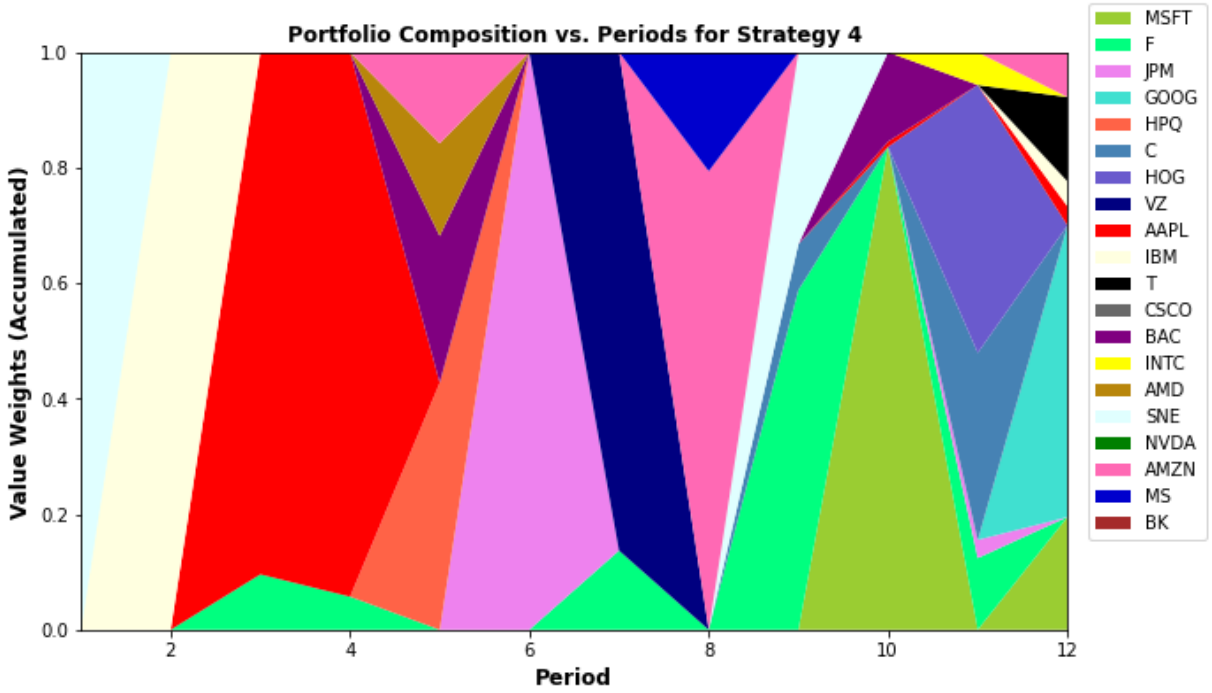

Figure 8.2.1: Portfolio Dynamic Change (Value Weight) for Strategy 4

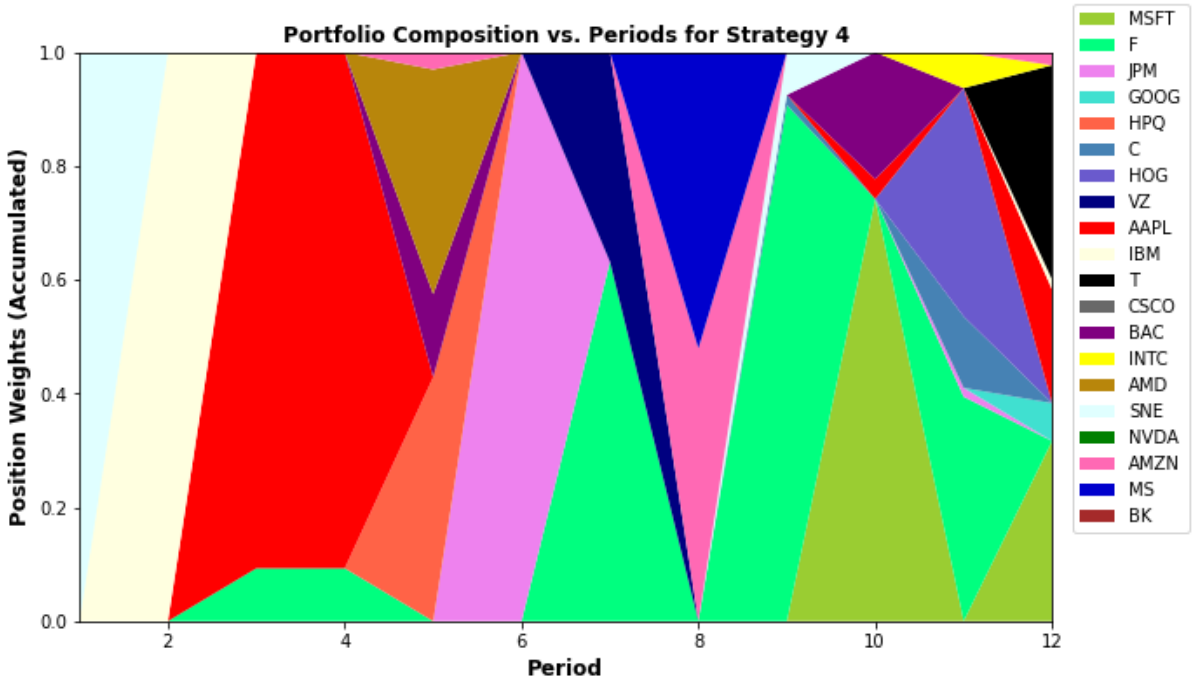

Figure 8.2.2: Portfolio Dynamic Change (Position Weight) for Strategy 4

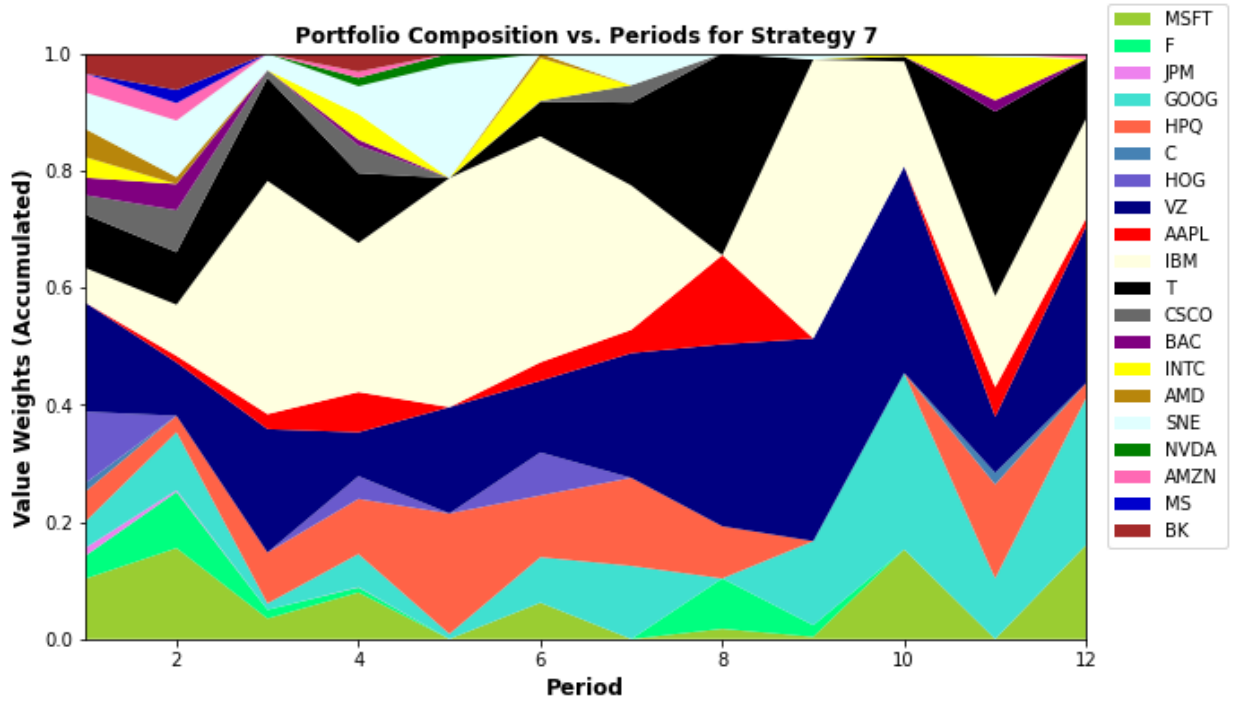

Figure 8.3.1: Portfolio Dynamic Change (Value Weight) for Strategy 7

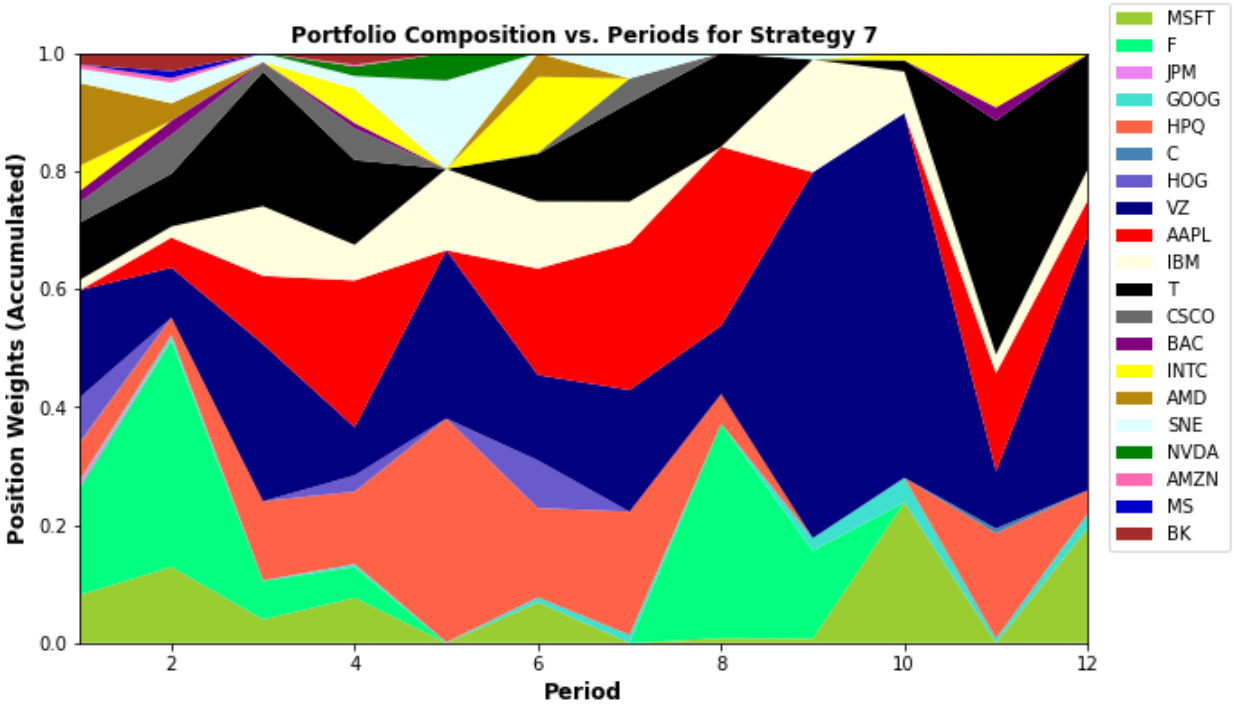

Figure 8.3.2: Portfolio Dynamic Change (Position Weight) for Strategy 7