**MIE1622H  
Computational Finance and Risk Management**

**Assignment 2**

**Risk-Based and Robust Portfolio Selection Strategies**

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Date: March 3rd, 2020

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# 1.Problem Description:

In this assignment, the same initial conditions as assignment 1 are provided. A portfolio with initial value of around 1 million USD is given along with its initial positions. The portfolio contains 20 stocks, the prices of the 20 stocks in from 2015 to 2016 is provided. In the part two question, the price of stock will be obtained from 2008-2009. The portfolio will rebalance every 2 months, with 12 periods in 2-years. There are seven portfolio strategies to test: buy and hold, equally weighted, minimum variance and maximum Sharpe ratio, equal risk contributor, leveraged equal risk contributions and robust mean-variance optimization.

# 2.Methods

## 2.1 Maximum Sharpe Ratio Strategy

There is little modification compared to last version. When the Sharpe ratio to solve the equation by using data from 2008-2009, the Cplex solver will return error due to the return of portfolio minus the free risk rate turns to be negative. Therefore, we can set the portfolio without any change when meeting this situation.

## 2.2 Equal Risk Contributor Strategy

This strategy help people to select the portfolio with equal risk contributions. The idea of the ERC strategy is to find a risk-balanced portfolio such that the risk contribution is the same for all assets of the portfolio: σi (x) = σj (x). We also checked the asset risk contribution output by using RC\_ERC = (w\_erc \* np.dot(Q, w\_erc)) / std\_ERC. The result shows the risk contribution is all around 0.409; therefore, the results validate this strategy is correct and also the gradient calculation is correct.

## 2.2 Leveraged Equal Risk Contributor Strategy

This strategy is an updated version of equal risk contributor strategy. The only difference is to borrow the same initial value from bank as the risk free rate at beginning of each period expect period 1, therefore we call it 200% leverage. The strategy will pay the interest at each period, and we only show the total cash of our own asset at each period. Usually, if the strategy is beneficial, more return will be obtained, and vice versa.

## 2.3 Robust Mean Variance Optimization Strategy

This strategy tries to minimize the variance of portfolio return, maximize the portfolio return and minimize the portfolio return estimation error at the same time. We should set the target return of portfolio to be the return of min-variance portfolio, and the target risk of the portfolio is the risk from min-variance portfolio. But, in this question, the risk free return can be assumed as the min-variance return. Because compared to the min-variance return calculated by using strategy min-variance, as investor, I hope the return could be stable and relatively high at the same time.

# 

# 3.2015 – 2016 Analysis

## 3.1 Results

|  |
| --- |
| Initial portfolio value = $ 1000002.12  Period 1: start date 1/2/2015, end date 2/27/2015  Strategy "Buy and Hold", value begin = $ 1000002.12, value end = $ 1043785.08  Strategy "Equally Weighted Portfolio", value begin = $ 992880.88, value end = $ 1020038.79  Strategy "Mininum Variance Portfolio", value begin = $ 991454.43, value end = $ 1016159.03  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 990052.34, value end = $ 1007863.43  Strategy "Equal Risk Contributions Portfolio", value begin = $ 992749.72, value end = $ 1018447.55  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 989687.14, value end = $ 1041196.71  Strategy "Robust Optimization Portfolio", value begin = $ 992226.89, value end = $ 1002762.09  Period 2: start date 3/2/2015, end date 4/30/2015  Strategy "Buy and Hold", value begin = $ 1045234.09, value end = $ 1069877.19  Strategy "Equally Weighted Portfolio", value begin = $ 1030724.21, value end = $ 1011178.46  Strategy "Mininum Variance Portfolio", value begin = $ 1023391.23, value end = $ 1014243.70  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1017318.17, value end = $ 1056079.92  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1028334.72, value end = $ 1012417.90  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1060974.35, value end = $ 1029699.15  Strategy "Robust Optimization Portfolio", value begin = $ 1009471.70, value end = $ 1005004.99  Period 3: start date 5/1/2015, end date 6/30/2015  Strategy "Buy and Hold", value begin = $ 1085647.24, value end = $ 1027659.63  Strategy "Equally Weighted Portfolio", value begin = $ 1021173.57, value end = $ 987397.06  Strategy "Mininum Variance Portfolio", value begin = $ 1009285.31, value end = $ 970176.58  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1057391.72, value end = $ 1015502.13  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1018969.21, value end = $ 985543.43  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1042779.53, value end = $ 975785.19  Strategy "Robust Optimization Portfolio", value begin = $ 1003119.50, value end = $ 968097.13  Period 4: start date 7/1/2015, end date 8/31/2015  Strategy "Buy and Hold", value begin = $ 1035245.91, value end = $ 947793.98  Strategy "Equally Weighted Portfolio", value begin = $ 991273.32, value end = $ 934221.34  Strategy "Mininum Variance Portfolio", value begin = $ 972750.92, value end = $ 932853.80  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1011242.32, value end = $ 925455.92  Strategy "Equal Risk Contributions Portfolio", value begin = $ 989200.21, value end = $ 935858.24  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 983103.90, value end = $ 876828.75  Strategy "Robust Optimization Portfolio", value begin = $ 974164.38, value end = $ 934778.54  Period 5: start date 9/1/2015, end date 10/30/2015  Strategy "Buy and Hold", value begin = $ 912055.56, value end = $ 1027307.87  Strategy "Equally Weighted Portfolio", value begin = $ 904423.24, value end = $ 1022625.20  Strategy "Mininum Variance Portfolio", value begin = $ 900915.56, value end = $ 941172.59  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 880468.67, value end = $ 1099329.15  Strategy "Equal Risk Contributions Portfolio", value begin = $ 905888.68, value end = $ 1014648.22  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 816830.24, value end = $ 1034556.45  Strategy "Robust Optimization Portfolio", value begin = $ 905129.34, value end = $ 994263.33  Period 6: start date 11/2/2015, end date 12/31/2015  Strategy "Buy and Hold", value begin = $ 1039856.20, value end = $ 1003328.46  Strategy "Equally Weighted Portfolio", value begin = $ 1039583.58, value end = $ 1035026.26  Strategy "Mininum Variance Portfolio", value begin = $ 945675.27, value end = $ 960203.02  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1102394.20, value end = $ 1216833.73  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1031170.18, value end = $ 1025565.35  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1067562.16, value end = $ 1055911.54  Strategy "Robust Optimization Portfolio", value begin = $ 997900.76, value end = $ 1000809.77  Period 7: start date 1/4/2016, end date 2/29/2016  Strategy "Buy and Hold", value begin = $ 994608.85, value end = $ 970570.87  Strategy "Equally Weighted Portfolio", value begin = $ 1014670.87, value end = $ 954289.07  Strategy "Mininum Variance Portfolio", value begin = $ 949370.41, value end = $ 944913.93  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1175755.97, value end = $ 1007792.91  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1006279.39, value end = $ 954712.78  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1017301.97, value end = $ 914191.99  Strategy "Robust Optimization Portfolio", value begin = $ 987697.88, value end = $ 982936.56  Period 8: start date 3/1/2016, end date 4/29/2016  Strategy "Buy and Hold", value begin = $ 999683.25, value end = $ 975547.52  Strategy "Equally Weighted Portfolio", value begin = $ 982277.17, value end = $ 1052404.73  Strategy "Mininum Variance Portfolio", value begin = $ 956495.37, value end = $ 989239.47  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1031199.45, value end = $ 1003031.96  Strategy "Equal Risk Contributions Portfolio", value begin = $ 981171.67, value end = $ 1031490.45  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 967232.19, value end = $ 1067336.14  Strategy "Robust Optimization Portfolio", value begin = $ 1000983.76, value end = $ 1030082.74  Period 9: start date 5/2/2016, end date 6/30/2016  Strategy "Buy and Hold", value begin = $ 982170.01, value end = $ 1000838.49  Strategy "Equally Weighted Portfolio", value begin = $ 1065731.48, value end = $ 1107472.49  Strategy "Mininum Variance Portfolio", value begin = $ 993717.23, value end = $ 1063046.75  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1006883.97, value end = $ 1094813.58  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1041117.44, value end = $ 1082086.13  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1086550.36, value end = $ 1168419.80  Strategy "Robust Optimization Portfolio", value begin = $ 1034775.81, value end = $ 1106825.31  Period 10: start date 7/1/2016, end date 8/31/2016  Strategy "Buy and Hold", value begin = $ 1003605.67, value end = $ 1067751.34  Strategy "Equally Weighted Portfolio", value begin = $ 1118569.25, value end = $ 1224442.50  Strategy "Mininum Variance Portfolio", value begin = $ 1063341.49, value end = $ 1049350.83  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1094233.78, value end = $ 1115730.66  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1089853.61, value end = $ 1151764.98  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1183998.11, value end = $ 1307655.44  Strategy "Robust Optimization Portfolio", value begin = $ 1107216.31, value end = $ 1092399.06  Period 11: start date 9/1/2016, end date 10/31/2016  Strategy "Buy and Hold", value begin = $ 1073361.15, value end = $ 1090939.15  Strategy "Equally Weighted Portfolio", value begin = $ 1226278.26, value end = $ 1224856.53  Strategy "Mininum Variance Portfolio", value begin = $ 1045773.05, value end = $ 1020324.47  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1114511.56, value end = $ 1177537.74  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1153502.12, value end = $ 1144687.52  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1311148.10, value end = $ 1293649.76  Strategy "Robust Optimization Portfolio", value begin = $ 1089234.28, value end = $ 1062629.86  Period 12: start date 11/1/2016, end date 12/30/2016  Strategy "Buy and Hold", value begin = $ 1077523.53, value end = $ 1173675.24  Strategy "Equally Weighted Portfolio", value begin = $ 1211179.55, value end = $ 1349048.35  Strategy "Mininum Variance Portfolio", value begin = $ 1006897.18, value end = $ 1120976.00  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 1157455.31, value end = $ 1535893.12  Strategy "Equal Risk Contributions Portfolio", value begin = $ 1132945.06, value end = $ 1242963.62  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 1270150.84, value end = $ 1489999.53  Strategy "Robust Optimization Portfolio", value begin = $ 1048512.13, value end = $ 1134668.85 |

The following figure shows the daily portfolio value of seven strategies:

A screenshot of a cell phone

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Figure 1: Daily Portfolio Value of Seven Strategies 2015-2016

The following figure shows the dynamic change in portfolio allocations under strategy 7.

A close up of a map

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Figure 2: Dynamic Change in Portfolio Allocations under Strategy 7, 2015-2016

The following figures shows the dynamic portfolio allocation of strategy 3 and 4, these two plots are collected from report of assignment 1.

A close up of a map

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Figure 3: Dynamic Change in Portfolio Allocations under Strategy 3, 2015-2016

A close up of a map

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Figure 4: : Dynamic Change in Portfolio Allocations under Strategy 4, 2015-2016

## 3.2 Discussion

Compared the three plots of dynamic change in portfolio allocation of strategy 3, 4, 7, we can get a conclusion that robust portfolio selection strategy reduces trading comparing to strategy 3 and 4. We can see these two stocks MSFT and AMZN. In strategy 4, these two stocks change frequently, and they are not hold more than two period. In strategy 3, these two stocks also have more greater fluctuation than strategy 7. Overall, the robust portfolio selection strategy reduce trading as compared with strategies 3 and 4.

In my opinion, maximum Sharpe ratio strategy is the best strategy within these seven strategy. The essential reason is the maximum portfolio value growth rate within 24 periods. Although it shows some weakness from 300-500. In recession periods, the maximum Sharpe ratio strategy is more stable with less fluctuation compared to some other strategies. On the other hand, when assets are appreciating, max Sharpe ratio outperforms leveraging equal risk contributor strategy. Therefore, max Sharpe strategy remains my first choice.

# 4. 2008 – 2009 Analysis

## 4.1 Results

|  |
| --- |
| Initial portfolio value = $ 548247.97  Period 1: start date 1/2/2008, end date 2/29/2008  Strategy "Buy and Hold", value begin = $ 548247.97, value end = $ 465217.72  Strategy "Equally Weighted Portfolio", value begin = $ 544330.39, value end = $ 470120.05  Strategy "Mininum Variance Portfolio", value begin = $ 543920.12, value end = $ 461622.35  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 542793.11, value end = $ 473586.09  Strategy "Equal Risk Contributions Portfolio", value begin = $ 544298.16, value end = $ 471812.43  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 542914.17, value end = $ 397951.87  Strategy "Robust Optimization Portfolio", value begin = $ 544726.59, value end = $ 457822.73  Period 2: start date 3/3/2008, end date 4/30/2008  Strategy "Buy and Hold", value begin = $ 462553.95, value end = $ 511257.48  Strategy "Equally Weighted Portfolio", value begin = $ 463836.30, value end = $ 510330.06  Strategy "Mininum Variance Portfolio", value begin = $ 454202.87, value end = $ 524228.35  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 463810.43, value end = $ 485977.25  Strategy "Equal Risk Contributions Portfolio", value begin = $ 465292.65, value end = $ 520178.34  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 384953.86, value end = $ 494377.79  Strategy "Robust Optimization Portfolio", value begin = $ 455460.08, value end = $ 489664.22  Period 3: start date 5/1/2008, end date 6/30/2008  Strategy "Buy and Hold", value begin = $ 526490.95, value end = $ 486095.76  Strategy "Equally Weighted Portfolio", value begin = $ 527299.02, value end = $ 446634.55  Strategy "Mininum Variance Portfolio", value begin = $ 538846.16, value end = $ 495529.53  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 490094.17, value end = $ 424110.89  Strategy "Equal Risk Contributions Portfolio", value begin = $ 537169.88, value end = $ 461433.49  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 528242.42, value end = $ 377144.25  Strategy "Robust Optimization Portfolio", value begin = $ 502726.83, value end = $ 452981.52  Period 4: start date 7/1/2008, end date 8/29/2008  Strategy "Buy and Hold", value begin = $ 487307.50, value end = $ 485687.69  Strategy "Equally Weighted Portfolio", value begin = $ 446462.76, value end = $ 452570.09  Strategy "Mininum Variance Portfolio", value begin = $ 494803.47, value end = $ 497777.06  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 439029.46, value end = $ 437468.02  Strategy "Equal Risk Contributions Portfolio", value begin = $ 459984.93, value end = $ 463488.36  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 374294.76, value end = $ 381057.76  Strategy "Robust Optimization Portfolio", value begin = $ 451784.88, value end = $ 453608.76  Period 5: start date 9/2/2008, end date 10/31/2008  Strategy "Buy and Hold", value begin = $ 478985.24, value end = $ 369998.60  Strategy "Equally Weighted Portfolio", value begin = $ 451541.75, value end = $ 316590.64  Strategy "Mininum Variance Portfolio", value begin = $ 486574.96, value end = $ 373962.80  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 424808.26, value end = $ 298525.71  Strategy "Equal Risk Contributions Portfolio", value begin = $ 461124.97, value end = $ 334014.32  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 376356.51, value end = $ 122589.51  Strategy "Robust Optimization Portfolio", value begin = $ 447026.39, value end = $ 348088.33  Period 6: start date 11/3/2008, end date 12/31/2008  Strategy "Buy and Hold", value begin = $ 372792.12, value end = $ 338021.03  Strategy "Equally Weighted Portfolio", value begin = $ 315250.71, value end = $ 276890.09  Strategy "Mininum Variance Portfolio", value begin = $ 374251.60, value end = $ 336034.20  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 300526.57, value end = $ 259260.07  Strategy "Equal Risk Contributions Portfolio", value begin = $ 333191.67, value end = $ 294788.43  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 120927.84, value end = $ 44390.88  Strategy "Robust Optimization Portfolio", value begin = $ 350719.14, value end = $ 335812.47  Period 7: start date 1/2/2009, end date 2/27/2009  Strategy "Buy and Hold", value begin = $ 351630.52, value end = $ 325694.94  Strategy "Equally Weighted Portfolio", value begin = $ 288364.02, value end = $ 254341.48  Strategy "Mininum Variance Portfolio", value begin = $ 345876.31, value end = $ 325827.12  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 258401.86, value end = $ 212483.95  Strategy "Equal Risk Contributions Portfolio", value begin = $ 306556.22, value end = $ 271369.10  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 67895.45, value end = $ -2654.51  Strategy "Robust Optimization Portfolio", value begin = $ 342597.82, value end = $ 305223.86  Period 8: start date 3/2/2009, end date 4/30/2009  Strategy "Buy and Hold", value begin = $ 316048.57, value end = $ 392525.73  Strategy "Equally Weighted Portfolio", value begin = $ 243321.89, value end = $ 375356.97  Strategy "Mininum Variance Portfolio", value begin = $ 313011.53, value end = $ 423161.19  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 202283.86, value end = $ 283644.52  Strategy "Equal Risk Contributions Portfolio", value begin = $ 260603.33, value end = $ 381677.99  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ -24218.30, value end = $ 216568.32  Strategy "Robust Optimization Portfolio", value begin = $ 294718.37, value end = $ 383864.14  Period 9: start date 5/1/2009, end date 6/30/2009  Strategy "Buy and Hold", value begin = $ 394998.62, value end = $ 426991.87  Strategy "Equally Weighted Portfolio", value begin = $ 374616.19, value end = $ 413195.37  Strategy "Mininum Variance Portfolio", value begin = $ 419882.64, value end = $ 425476.60  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 274884.28, value end = $ 298679.85  Strategy "Equal Risk Contributions Portfolio", value begin = $ 380642.20, value end = $ 409480.04  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 214597.44, value end = $ 271938.33  Strategy "Robust Optimization Portfolio", value begin = $ 381799.17, value end = $ 389429.75  Period 10: start date 7/1/2009, end date 8/31/2009  Strategy "Buy and Hold", value begin = $ 429930.17, value end = $ 467013.68  Strategy "Equally Weighted Portfolio", value begin = $ 414148.02, value end = $ 463485.62  Strategy "Mininum Variance Portfolio", value begin = $ 424088.34, value end = $ 448900.80  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 294089.23, value end = $ 291308.39  Strategy "Equal Risk Contributions Portfolio", value begin = $ 410190.39, value end = $ 449445.78  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 273328.15, value end = $ 351640.91  Strategy "Robust Optimization Portfolio", value begin = $ 388606.56, value end = $ 412672.39  Period 11: start date 9/1/2009, end date 10/30/2009  Strategy "Buy and Hold", value begin = $ 457407.27, value end = $ 489396.95  Strategy "Equally Weighted Portfolio", value begin = $ 448453.93, value end = $ 480693.09  Strategy "Mininum Variance Portfolio", value begin = $ 437772.36, value end = $ 461060.46  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 275621.82, value end = $ 278967.25  Strategy "Equal Risk Contributions Portfolio", value begin = $ 436565.34, value end = $ 467282.09  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 325949.81, value end = $ 387498.09  Strategy "Robust Optimization Portfolio", value begin = $ 403000.84, value end = $ 423042.99  Period 12: start date 11/2/2009, end date 12/31/2009  Strategy "Buy and Hold", value begin = $ 490582.55, value end = $ 542246.05  Strategy "Equally Weighted Portfolio", value begin = $ 482384.60, value end = $ 552158.27  Strategy "Mininum Variance Portfolio", value begin = $ 457369.26, value end = $ 512308.39  Strategy "Maximum Sharpe Ratio Portfolio", value begin = $ 277740.04, value end = $ 314252.82  Strategy "Equal Risk Contributions Portfolio", value begin = $ 467768.70, value end = $ 523167.12  Strategy "Leveraged Equal Risk Contributions Portfolio", value begin = $ 388457.72, value end = $ 499007.44  Strategy "Robust Optimization Portfolio", value begin = $ 420897.88, value end = $ 468438.34 |

The figure below is the daily portfolio value of seven strategies in 2008-2009A close up of a map

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Figure 5. Daily Portfolio Value of Seven Strategies in 2008 -2009

Below 3 figures are dynamic changes in portfolio allocations under strategy 3, 4 and 7 respectively in 2008 -2009：

A close up of a map

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Figure 6: Dynamic Change in Portfolio Allocations under Strategy 3, 2008-2009

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Figure 7: Dynamic Change in Portfolio Allocations under Strategy 4, 2008-2009

A close up of a map

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Figure 8: Dynamic Change in Portfolio Allocations under Strategy 7, 2008-2009

## 4.2 Discussion

Compared the three plots of dynamic change in portfolio allocation of strategy 3, 4, 7, it is obvious to tell robust mean variance strategy can reduces trading comparing to strategy 3 and 4. The strategy 7 can hold stocks for more periods than strategy 3 and 4. We can see these stocks AMD, AMZN, IBM and T in figure 6,7,8. In strategy 3 and 4, these three stocks change frequently. Overall, robust mean variance strategy can reduces trading.

We know from 2008-2009, the world experienced an economic recession. The stocks prices went down during that period. Compared to 2015-2016, the maximize Sharpe ratio strategy and leveraged equal risk contribution strategy perform worse from 2008 to 2009. And the other five strategies give us a better performance during 2008-2009. Therefore, we can get the conclusion, we can use maximize Sharpe ratio strategy and leveraged equal risk contribution strategy during the economic growth, and choose more conservative strategies during the economic recession.

From 2008 to 2009, the min variance strategy seems to be a better strategies because it keep the highest return in most time. However, it is hard to tell which strategy is the best, because they have similar performance. In recession periods, conservative strategies could keep more value of the portfolio because we may lose much money due to the high transaction fees. We can find the buy and hold strategy and equally weighted are also a considerable strategy for us to keep more value of our portfolio, because low trading save us more transaction fee.