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Table of Contents

Introduction	1
Parameter Estimation:.....	2
Part A	2
Mean Variance Optimization (MVO):.....	5
How Lambda was calculated	5
Robust Mean Variance Optimization (RMVO):	6
Risk Parity Optimization	8
Market capitalization.....	9
Part 1 b)	10
Part 2 b) – January 2011 to June 2011	11
Part 2 b) – January 2011 to July 2011	13
Part 2 b) – January 2011 to August 2011	15
Part 2 b) – January 2011 to September 2011	17
Part 2 b) – January 2011 to October 2011	19
Further discussion of the Risk Parity and Market Capitalization based	21
Risk Parity optimization with no short selling.....	21
Market Capitalization	22
Part C).....	22
Conclusion.....	27
References	29
Appendix:	30
Appendix Part 2 b) – January 2011 to June 2011	30
Appendix Part 2 b) – January 2011 to July 2011	35
Appendix Part 2 b) – January 2011 to August 2011.....	41
Appendix Part 2 b) – January 2011 to September 2011	47
Appendix Part 2 b) – January 2011 to October 2011.....	53

Introduction

The purpose of this project is to implement and compare several different financial optimization models. Portfolios will be generated using these models and these portfolios will be tested out-of-sample. The optimization models that were implemented in this report are the following.

- (1) Mean-variance optimization (MVO)
- (2) Robust mean-variance optimization
- (3) Risk Parity optimization with no short selling.

The investment universe consists of 20 stocks (n=20) all of which are constituents of the S&P 500. The stock symbols are the following:

Table 1: The stocks that are considered in all the portfolios

# of Stocks	Stock Symbols
1	F (Ford Motor Co.)
2	CAT (Caterpillar Inc.)
3	DIS
4	MCD
5	KO
6	PEP
7	WMT
8	C
9	WFC
10	JPM
11	AAPL
12	IBM
13	PFE
14	JNJ
15	XOM
16	MRO
17	ED
18	T
19	V Z
20	NEM

Parameter Estimation:

Part A

In part A, for the last trading day of each month, the adjusted closing prices for each stock from Table 1 above were used from Dec-2007 to June-2011 to compute the sample mean, sample variance, and sample covariances. The following portfolios generated are MVO, robust MVO, and risk parity. A fourth portfolio was considered which is a portfolio of the 20 stocks where the weights are based on market capitalizations where the 20 stocks were assumed to be the market.

Table 2 below shows the sample mean for each stock for data from Dec-2007 to June-2011.

Table 2: Sample Mean for each stock for data from Dec 2007 to June 2011

Stocks	Sample Mean
Ford Motor Co. (F)	0.0447
Caterpillar Inc. (CAT)	0.0199
Walt Disney Co. (DIS)	0.0084
McDonald's Corp. (MCD)	0.0124
Coca-Cola Co. (KO)	0.0062
PepsiCo Inc. (PEP)	0.0020
Walmart Inc. (WMT)	0.0055
Citigroup Inc. (C)	-0.0174
Wells Fargo & Co. (WFC)	0.0109
JPMorgan Chase & Co. (JPM)	0.0058
Apple Inc. (AAPL)	0.0195
IBM Corp. (IBM)	0.0144
Pfizer Inc. (PFE)	0.0042
Johnson & Johnson (JNJ)	0.0038
Exxon Mobil Corp. (XOM)	-0.0003
Marathon Oil Corp. (MRO)	0.0035
Consolidated Edison Inc. (ED)	0.0076
AT&T Inc. (T)	0.0015
Verizon Communications Inc. (VZ)	0.0040
Newmont Corp. (NEM)	0.0099

Table 3 below shows the sample Variance for each stock for data from Dec-2007 to June-2011.

Table 3: Sample Variance for each stock for data from Dec 2007 to June 2011

Stocks	Sample Variance
Ford Motor Co. (F)	0.0695
Caterpillar Inc. (CAT)	0.0176
Walt Disney Co. (DIS)	0.0069
McDonald's Corp. (MCD)	0.0021
Coca-Cola Co. (KO)	0.0032
PepsiCo Inc. (PEP)	0.0028
Walmart Inc. (WMT)	0.0025
Citigroup Inc. (C)	0.0516
Wells Fargo & Co. (WFC)	0.0215
JPMorgan Chase & Co. (JPM)	0.0126
Apple Inc. (AAPL)	0.0130
IBM Corp. (IBM)	0.0037
Pfizer Inc. (PFE)	0.0045
Johnson & Johnson (JNJ)	0.0024
Exxon Mobil Corp. (XOM)	0.0030
Marathon Oil Corp. (MRO)	0.0099
Consolidated Edison Inc. (ED)	0.0021
AT&T Inc. (T)	0.0037
Verizon Communications Inc. (VZ)	0.0036
Newmont Corp. (NEM)	0.0140

Table 4 below shows the sample covariance for each stock for data ranging from Dec-2007 to June-2011.

Table 4: Sample Covariance for each stock for data from Dec 2007 to June 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.067728	0.020316	0.011126	0.001586	0.004715	0.003739	0.003908	0.022277	0.018991	0.015465	0.010225	0.00617	0.002094	0.003157	0.003091	0.00838	0.000449	0.004897	0.005556	0.000953
'CAT.csv'	0.020316	0.017101	0.007383	0.002115	0.004193	0.003712	0.002719	0.015026	0.009239	0.007119	0.007254	0.004047	0.004017	0.003376	0.003222	0.007183	0.000703	0.005002	0.004795	0.004513
'DIS.csv'	0.011126	0.007383	0.00663	0.001869	0.002155	0.001918	0.000716	0.010959	0.006816	0.004837	0.00521	0.002776	0.002714	0.002378	0.002013	0.005469	0.001303	0.001976	0.001977	0.001056
'MCD.csv'	0.001586	0.002115	0.001869	0.002085	0.001462	0.001341	0.000739	0.004833	0.002544	0.001219	0.001553	0.000457	0.001643	0.001396	0.001166	0.001258	0.000828	0.001054	0.001013	0.001635
'KO.csv'	0.004715	0.004193	0.002155	0.001462	0.003151	0.002163	0.000959	0.005061	0.002952	0.002117	0.001719	0.001166	0.001793	0.001482	0.001247	0.002035	0.000778	0.001807	0.00173	0.002619
'PEP.csv'	0.003739	0.003712	0.001918	0.001341	0.002163	0.002753	0.001061	0.005176	0.002527	0.00211	0.001693	0.00141	0.001467	0.00168	0.000813	0.002271	0.000954	0.001187	0.001332	0.001226
'WMT.csv'	0.003908	0.002719	0.000716	0.000739	0.000959	0.001061	0.002394	0.004436	0.002491	0.002564	0.000621	0.00079	0.001386	0.000909	0.000686	0.000231	0.000213	0.001094	0.001147	0.000902
'C.csv'	0.022277	0.015026	0.010959	0.004833	0.005061	0.005176	0.004436	0.05038	0.024588	0.018417	0.008519	0.004291	0.008767	0.005471	0.003165	0.008478	0.004097	0.003534	0.003154	0.000674
'WFC.csv'	0.018991	0.009239	0.006816	0.002544	0.002952	0.002527	0.002491	0.024588	0.020999	0.013434	0.001985	0.001816	0.005679	0.002828	0.001303	0.003635	0.000809	0.001417	0.0015	-0.0014
'JPM.csv'	0.015465	0.007119	0.004837	0.001219	0.002117	0.00211	0.002564	0.018417	0.013434	0.01222	0.002857	0.002964	0.003702	0.002248	0.00067	0.002502	0.001189	0.001491	0.001521	-0.00164
'AAPL.csv'	0.010225	0.007254	0.00521	0.001553	0.001719	0.001693	0.000621	0.008519	0.001985	0.002857	0.012699	0.003304	0.000906	0.002423	0.001996	0.005545	0.001934	0.003837	0.003212	-0.00032
'IBM.csv'	0.00617	0.004047	0.002776	0.000457	0.001166	0.00141	0.00079	0.004291	0.001816	0.002964	0.003304	0.003648	0.000989	0.001523	0.000632	0.003993	0.000644	0.000668	0.000901	0.000999
'PFE.csv'	0.002094	0.004017	0.002714	0.001643	0.001793	0.001467	0.001386	0.008767	0.005679	0.003702	0.000906	0.000989	0.00438	0.001806	0.00114	0.002288	0.000971	0.001635	0.001602	0.001332
'JNJ.csv'	0.003157	0.003376	0.002378	0.001396	0.001482	0.00168	0.000909	0.005471	0.002828	0.002248	0.002423	0.001523	0.001806	0.002386	0.000963	0.001895	0.001107	0.001249	0.001275	0.001362
'XOM.csv'	0.003091	0.003222	0.002013	0.001166	0.001247	0.000813	0.000686	0.003165	0.001303	0.00067	0.001996	0.000632	0.00114	0.000963	0.002891	0.002562	0.000673	0.001044	0.001637	0.001448
'MRO.csv'	0.00838	0.007183	0.005469	0.001258	0.002035	0.002271	0.000231	0.008478	0.003635	0.002502	0.005545	0.003993	0.002288	0.001895	0.002562	0.009671	0.00111	0.001235	0.002285	0.002323
'ED.csv'	0.000449	0.000703	0.001303	0.000828	0.000778	0.000954	0.000213	0.004097	0.000809	0.001189	0.001934	0.000644	0.000971	0.001107	0.000673	0.00111	0.002013	0.001038	0.001185	-0.00096
'T.csv'	0.004897	0.005002	0.001976	0.001054	0.001807	0.001187	0.001094	0.003534	0.001417	0.001491	0.003837	0.000668	0.001635	0.001249	0.001044	0.001235	0.001038	0.003655	0.002866	0.000995
'VZ.csv'	0.005556	0.004795	0.001977	0.001013	0.00173	0.001332	0.001147	0.003154	0.0015	0.001521	0.003212	0.000901	0.001602	0.001275	0.001637	0.002285	0.001185	0.002866	0.003541	0.001153
'NEM.csv'	0.000953	0.004513	0.001056	0.001635	0.002619	0.001226	0.000902	0.000674	-0.0014	-0.00164	-0.00032	0.000999	0.001332	0.001362	0.001448	0.002323	-0.00096	0.000995	0.001153	0.01367

Mean Variance Optimization (MVO):

The following version of MVO was used:

$$\max \mu^T x - \lambda x^T Q x$$

$$\text{Subject to } e^T x = 1$$

where, $\mu \in R^n$ is the vector of expected returns, $Q \in R^{n \times n}$ is the covariance matrix,

and $e \in R^n$ is a vector of n ones. Short selling is allowed.

The risk aversion parameter which $\lambda > 0$.

How Lambda was calculated

The risk aversion parameter (λ) is calculated using the Black-Litterman approach.

$$\lambda = \frac{E_{r_{mkt}} - r_f}{\sigma_{mkt}^2}$$

where, $E_{r_{mkt}}$ is the expected return of the market, r_f is the risk free rate,

and the σ_{mkt}^2 is the variance of the market returns.

The expected return of the market is calculated using the market capitalization weights for each asset in that the weighted sum followed by the mean was taken. The market capitalization for each asset was found online and since the data ranged from Dec-2007 to June-2011, the yearly market capitalization for each asset was taken from 2008 to 2011 and averaged out. Although this method is not accurate since the data stops at June-2011, the monthly market capitalization data was not freely available. If so, the monthly market capitalization for each stock would be taken from 2008 to Jun-2011 and averaged out. [1]

The next step is to calculate the risk-free rate in that the US bonds (6-month treasury bill rates) were used from the period between 2008 to 2011 and the mean was taken. The rate was divided by 12 to get the per month rate and then divided by 100 to convert the rate into number form. [2]

The variance of the market was calculated by using the following formula below

$$Var = \sigma_{mkt}^2 = x' * Q * x$$

where, x is the weights and Q is the covariance matrix.

Table 5 below displays the weights obtained by the MVO model for the data from Dec-2007 to June-2011.

Table 5: Mean-variance optimization (MVO) for data from Dec 2007 to June 2011

Stocks	Weights
Ford Motor Co. (F)	0.107539
Caterpillar Inc. (CAT)	2.514694
Walt Disney Co. (DIS)	-1.30267
McDonald's Corp. (MCD)	3.691278
Coca-Cola Co. (KO)	1.308079
PepsiCo Inc. (PEP)	-2.87764
Walmart Inc. (WMT)	1.099649
Citigroup Inc. (C)	-0.99628
Wells Fargo & Co. (WFC)	0.618274
JPMorgan Chase & Co. (JPM)	-0.43102
Apple Inc. (AAPL)	1.240879
IBM Corp. (IBM)	0.547591
Pfizer Inc. (PFE)	0.964781
Johnson & Johnson (JNJ)	-2.57134
Exxon Mobil Corp. (XOM)	-2.28035
Marathon Oil Corp. (MRO)	-0.55043
Consolidated Edison Inc. (ED)	4.697159
AT&T Inc. (T)	-4.43134
Verizon Communications Inc. (VZ)	-0.42215
Newmont Corp. (NEM)	0.073294

Robust Mean Variance Optimization (RMVO):

The version of MVO used above was manipulated to be a robust MVO using the box uncertainty set. The robust MVO is shown below.

$$\max \mu^T x - \delta^T |x| - \lambda x^T Q x$$

$$\text{Subject to } e^T x = 1$$

$$y \geq x$$

$$y \leq -x$$

$\mu \in R^n$ is the vector of expected returns, $Q \in R^{n \times n}$ is the covariance matrix, and $e \in R^n$ is a vector of n ones. Short selling is allowed. The risk aversion parameter which $\lambda > 0$. δ is the delta which is the maximum 'distance' between μ_i and μ_i^{true} and $y \in R^n$ is an auxiliary

variable to replace the absolute value of $|x|$

For robust MVO, two versions were considered in that one had a confidence level of 95% and the other had a confidence level of 90%.

Table 6 below displays the weights obtained by the robust MVO model for the data from Dec-2007 to June-2011 with a 95% confidence level.

Table 6: Robust MOV (CL = 95%) for data from Dec 2007 to June 2011

Stocks	Weights
Ford Motor Co. (F)	5.80E-12
Caterpillar Inc. (CAT)	6.67E-12
Walt Disney Co. (DIS)	2.04E-14
McDonald's Corp. (MCD)	0.762589
Coca-Cola Co. (KO)	5.37E-13
PepsiCo Inc. (PEP)	1.19E-12
Walmart Inc. (WMT)	1.33E-13
Citigroup Inc. (C)	9.26E-13
Wells Fargo & Co. (WFC)	4.51E-12
JPMorgan Chase & Co. (JPM)	-6.97E-13
Apple Inc. (AAPL)	5.94E-13
IBM Corp. (IBM)	0.237411
Pfizer Inc. (PFE)	4.65E-13
Johnson & Johnson (JNJ)	4.88E-13
Exxon Mobil Corp. (XOM)	1.69E-12
Marathon Oil Corp. (MRO)	1.28E-12
Consolidated Edison Inc. (ED)	1.52E-08
AT&T Inc. (T)	-2.05E-12
Verizon Communications Inc. (VZ)	-9.40E-13
Newmont Corp. (NEM)	-1.73E-12

Table 7 below displays the weights obtained by the robust MVO model for the data from Dec-2007 to June-2011 with a 90% confidence level.

Table 7: Robust MVO (CL = 90%) for data from Dec 2007 to June 2011

Stocks	Weights
Ford Motor Co. (F)	-1.15E-11
Caterpillar Inc. (CAT)	8.90E-13
Walt Disney Co. (DIS)	1.51E-12
McDonald's Corp. (MCD)	0.73031
Coca-Cola Co. (KO)	2.98E-12
PepsiCo Inc. (PEP)	1.74E-12
Walmart Inc. (WMT)	2.93E-11
Citigroup Inc. (C)	-1.28E-12

Wells Fargo & Co. (WFC)	1.55E-13
JPMorgan Chase & Co. (JPM)	2.68E-12
Apple Inc. (AAPL)	6.74E-12
IBM Corp. (IBM)	0.26969
Pfizer Inc. (PFE)	-1.45E-12
Johnson & Johnson (JNJ)	1.89E-12
Exxon Mobil Corp. (XOM)	-2.29E-12
Marathon Oil Corp. (MRO)	1.89E-12
Consolidated Edison Inc. (ED)	2.44E-08
AT&T Inc. (T)	8.03E-12
Verizon Communications Inc. (VZ)	1.09E-11
Newmont Corp. (NEM)	-7.63E-13

Risk Parity Optimization

Risk parity optimization is an investment strategy that focuses on allocating equal risk across all assets in each portfolio. Sometimes, it is referred to as Equal Risk Contribution (ERC). The alternative formulation of the original risk parity optimization problem was utilized as it is computationally more efficient.

$$\begin{aligned}
 \min \quad & \sum_{i=1}^n (x_i(Qx)_i - \theta)^2 \\
 \text{s.t.} \quad & 1^T x = 1 \\
 & x \geq 0,
 \end{aligned}$$

where $\theta \in \mathbb{R}$ is an auxiliary unconstrained variable. [3]

Table 8 below displays the weights obtained by the Risk Parity model for the data from Dec-2007 to June-2011.

Table 8: Risk Parity optimization with no short selling for data from Dec 2007 to June 2011

Stocks	Weights
Ford Motor Co. (F)	0.05
Caterpillar Inc. (CAT)	0.05
Walt Disney Co. (DIS)	0.05
McDonald's Corp. (MCD)	0.05
Coca-Cola Co. (KO)	0.05
PepsiCo Inc. (PEP)	0.05
Walmart Inc. (WMT)	0.05
Citigroup Inc. (C)	0.0499

Wells Fargo & Co. (WFC)	0.0499
JPMorgan Chase & Co. (JPM)	0.0499
Apple Inc. (AAPL)	0.0499
IBM Corp. (IBM)	0.0499
Pfizer Inc. (PFE)	0.0499
Johnson & Johnson (JNJ)	0.05
Exxon Mobil Corp. (XOM)	0.05
Marathon Oil Corp. (MRO)	0.05
Consolidated Edison Inc. (ED)	0.05
AT&T Inc. (T)	0.05
Verizon Communications Inc. (VZ)	0.05
Newmont Corp. (NEM)	0.05

Market capitalization

Table 9 below displays the weights obtained by the market capitalization for the data of June 2011. [4]

The data for June-2011 was only considered when building this portfolio because the main goal is to evaluate the performance in July 2011 using the latest market capitalization weights. Hence, the weights need to be from the prior month.

Table 9: Market Capitalizations of June 30

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	\$52.37	0.018706
Caterpillar Inc. (CAT)	\$68.60	0.024503
Walt Disney Co. (DIS)	\$73.79	0.026357
McDonald's Corp. (MCD)	\$87.48	0.031247
Coca-Cola Co. (KO)	\$154.04	0.055022
PepsiCo Inc. (PEP)	\$111.32	0.039762
Walmart Inc. (WMT)	\$184.52	0.065909
Citigroup Inc. (C)	\$121.61	0.043438
Wells Fargo & Co. (WFC)	\$148.41	0.053011
JPMorgan Chase & Co. (JPM)	\$162.68	0.058108
Apple Inc. (AAPL)	\$310.40	0.110872
IBM Corp. (IBM)	\$207.78	0.074217
Pfizer Inc. (PFE)	\$162.76	0.058136
Johnson & Johnson (JNJ)	\$182.34	0.06513
Exxon Mobil Corp. (XOM)	\$400.84	0.143176

Marathon Oil Corp. (MRO)	\$37.51	0.013398
Consolidated Edison Inc. (ED)	\$15.57	0.005561
AT&T Inc. (T)	\$186.01	0.066441
Verizon Communications Inc. (VZ)	\$105.32	0.037619
Newmont Corp. (NEM)	\$26.28	0.009387

Part 1 b)

Table 10: Evaluating the portfolio performance in July 2011 using data from December 2007 till June 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	0.7516	0.1907	0.4367	1.7212
Robust mean-variance optimization (CL = 95%)	0.0338	0.0398	0.1995	0.1694
Robust mean-variance optimization (CL = 90%)	0.0349	0.0395	0.1987	0.1757
Risk Parity optimization with no short selling.	-0.0160	0.0003	0.0179	-0.8953
Market Capitalizations	-0.0015	0.0003	0.0176	-0.0833

Based on the provided data from Table 5, MVO provided the highest portfolio return out of all the other optimization models. It also had the largest risk (portfolio variance) out of all the portfolios; however, it had the highest Sharpe ratio out of all the optimization models considered which means that it has the best risk-adjusted return.

The robust MVO has a much smaller portfolio return compared to the MVO model which also resulted in a lower portfolio variance. The Sharpe ratio is also much smaller which indicated a less favorable risk-adjusted return. When comparing the robust MVO at a 95% CL and 90% CL, the robust MVO with a 90% CL performed better in terms of higher return, lower variance and higher Sharpe ratio.

The Risk Parity optimization portfolio resulted in having the lowest portfolio return and along with the lowest portfolio variance. This optimization model also yielded the lowest Sharpe ratio which indicated a poor risk-adjusted return.

The market capitalization optimization model was similar to the risk parity optimization model in that it performed poorly overall. It has slightly better portfolio return than the risk parity model, same portfolio variance and a Sharpe ratio closer to zero indicating a less unfavorable risk-adjusted return when compared to the Risk Parity portfolio.

Part 2 b) – January 2011 to June 2011

Table 11 below displays all 20 assets with the sample mean and sample variance for the months spanning Jan-2011 to Jun-2011. The Weights for the MVO, robust MVO, risk parity and, Market cap was calculated.

Table 11: Asset Parameters and Portfolio weights – January 2011 to June 2011

Assets / Parameter	Sample mean	Sample Variance	Weights MVO	Weights RMVO 95%	Weights RMVO 90%	Risk Parity	Market Cap
Ford Motor Co. (F)	0.0447	0.0695	0.107539	5.80E-12	-1.15E-11	0.05	0.018706
Caterpillar Inc. (CAT)	0.0199	0.0176	2.514694	6.67E-12	8.90E-13	0.05	0.024503
Walt Disney Co. (DIS)	0.0084	0.0069	-1.30267	2.04E-14	1.51E-12	0.05	0.026357
McDonald's Corp. (MCD)	0.0124	0.0021	3.691278	0.762589	0.73031	0.05	0.031247
Coca-Cola Co. (KO)	0.0062	0.0032	1.308079	5.37E-13	2.98E-12	0.05	0.055022
PepsiCo Inc. (PEP)	0.002	0.0028	-2.87764	1.19E-12	1.74E-12	0.05	0.039762
Walmart Inc. (WMT)	0.0055	0.0025	1.099649	1.33E-13	2.93E-11	0.05	0.065909
Citigroup Inc. (C)	-0.0174	0.0516	-0.99628	9.26E-13	-1.28E-12	0.0499	0.043438
Wells Fargo & Co. (WFC)	0.0109	0.0215	0.618274	4.51E-12	1.55E-13	0.0499	0.053011
JPMorgan Chase & Co. (JPM)	0.0058	0.0126	-0.43102	-6.97E-13	2.68E-12	0.0499	0.058108
Apple Inc. (AAPL)	0.0195	0.013	1.240879	5.94E-13	6.74E-12	0.0499	0.110872
IBM Corp. (IBM)	0.0144	0.0037	0.547591	0.237411	0.26969	0.0499	0.074217
Pfizer Inc. (PFE)	0.0042	0.0045	0.964781	4.65E-13	-1.45E-12	0.0499	0.058136
Johnson & Johnson (JNJ)	0.0038	0.0024	-2.57134	4.88E-13	1.89E-12	0.05	0.06513
Exxon Mobil Corp. (XOM)	-0.0003	0.003	-2.28035	1.69E-12	-2.29E-12	0.05	0.143176
Marathon Oil Corp. (MRO)	0.0035	0.0099	-0.55043	1.28E-12	1.89E-12	0.05	0.013398

Consolidated Edison Inc. (ED)	0.0076	0.0021	4.697159	1.52E-08	2.44E-08	0.05	0.005561
AT&T Inc. (T)	0.0015	0.0037	-4.43134	-2.05E-12	8.03E-12	0.05	0.066441
Verizon Communications Inc. (VZ)	0.004	0.0036	-0.42215	-9.40E-13	1.09E-11	0.05	0.037619
Newmont Corp. (NEM)	0.0099	0.014	0.073294	-1.73E-12	-7.63E-13	0.05	0.009387

Table 12: Evaluating the portfolio performance in July 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	7.0778e+05	0.0000 + 0.0440i	0.1483 + 0.1483i	2.3866e+06 - 2.3866e+06i
Robust mean-variance optimization (CL = 95%)	9.2740e+04	0.0193	0.1388	6.6814e+05
Robust mean-variance optimization (CL = 90%)	2.6408e+03	0.0204	0.1430	1.8468e+04
Risk Parity optimization with no short selling.	-0.0160	0.0001	0.0076	-2.0948
Market Capitalizations	-0.0015	0.0001	0.0076	-0.1916

Table 12 above evaluates the portfolio performance in July of 2011 based on the data in Table 11. The data obtained for MVO and robust MVO are not favorable. This is due to the 6-month window used to evaluate the parameters listed in Table 12. The MVO suggests a 7.0778e+05 portfolio return which is extremely high and this aligns with the weights in Table 11 in that the MVO model took an aggressive approach when assigning the weights for each asset whether that was significantly positive weights (buying the asset) or significantly negative weights (shorting the asset). For example, MCD and ED (highlighted in yellow) had the two highest weighted stocks in the MVO model therefore, these assets must have performed extremely well in the month of July-2011. The complex numbers for portfolio variance and Sharpe ratio indicate an error in the data which is mainly due to the 6-month period used to obtain the data.

The robust MVO also yielded in the largest portfolio gain for a confidence level of 95%, a small portfolio variance, and had the largest Sharpe ratio indicating high returns per unit of risk. The robust MVO with 90% confidence level performed poorly against the robust MVO with a confidence level of 95% in terms of lower portfolio return, higher variance (risk) and lower Sharpe ratio.

The risk parity optimization model had a negative portfolio gain indicating poor performance for the month of July-2011. The variance is extremely low, indicating low risk, and the Sharpe ratio is negative which indicates a poor risk-adjusted performance.

The market capitalization optimization model performed similar to the risk parity optimization model in that it performed poorly overall. It has slightly better portfolio return than the risk parity model, same portfolio variance and a Sharpe ratio closer to zero indicating a less unfavorable risk-adjusted return when compared to the Risk Parity portfolio.

The errors in in MVO and robust MVO are due to the short historical period used to obtain data (Jan-2011 to June-2011). The issue lies in the covariance matrix which is crucial for portfolio optimization. The short historical period caused the data set to be nearly invertible. The robust MVO lowers estimation risk by considering uncertainty however, with the small data set from Jan-2011 to June-2011 the robust optimization model has unstable/unpredictable weight allocation to each asset.

Part 2 b) – January 2011 to July 2011

Table 13 below displays all 20 assets with the sample mean and sample variance for the months spanning Jan-2011 to July 2011. The Weights for the MVO, robust MVO, risk parity and Market cap were calculated.

Table 13: Asset Parameters and Portfolio weights – January 2011 to July 2011

Assets / Parameter	Sample mean	Sample Variance	Weights MVO	Weights RMVO 95%	Weights RMVO 90%	Risk Parity	Market Cap
Ford Motor Co. (F)	-0.04234	0.002342	-8.30E+07	-5.02E+05	-9.22E+04	0.0499	0.016723
Caterpillar Inc. (CAT)	0.006408	0.003908	3.40E+07	1.30E-01	3.89E-01	0.0499	0.022958
Walt Disney Co. (DIS)	0.000597	3.51E-03	-2.57E+07	-1.14E-02	-9.00E-02	0.0499	0.026323
McDonald's Corp. (MCD)	0.029833	0.000172	4.56E+07	5.24E+05	9.62E+04	0.0499	0.032356
Coca-Cola Co. (KO)	0.015806	0.000259	2.63E+07	4.45E+05	8.17E+04	0.0499	0.056147
PepsiCo Inc. (PEP)	0.003043	0.002468	1.09E+07	1.64E-02	7.48E-02	0.0499	0.03655
Walmart Inc. (WMT)	-0.00717	0.001643	-2.20E+07	-2.14E-01	-3.59E-01	0.0499	0.066007
Citigroup Inc. (C)	-0.03608	2.44E-03	-3.40E+07	-8.45E+04	-1.55E+04	0.0499	0.04038
Wells Fargo & Co. (WFC)	-0.02282	0.000738	-7.05E+07	-6.84E+05	-1.26E+05	0.0499	0.053291

JPMorgan Chase & Co. (JPM)	-0.015	0.000993	-4.57E+07	-2.62E+04	-4.81E+03	0.0499	0.057965
Apple Inc. (AAPL)	0.025672	0.004308	1.11E+07	-6.19E-02	-1.49E-01	0.0499	0.130554
IBM Corp. (IBM)	#####	0.000562	3.82E+07	4.67E-02	2.78E-01	0.0499	0.078319
Pfizer Inc. (PFE)	0.013804	0.002408	5.33E+06	1.16E-01	2.82E-01	0.05	0.054846
Johnson & Johnson (JNJ)	0.017685	0.002431	3.62E+07	-4.29E-02	-8.51E-02	0.05	0.064045
Exxon Mobil Corp. (XOM)	0.000773	0.001631	2.24E+06	-5.10E-02	-1.29E-01	0.05	0.141748
Marathon Oil Corp. (MRO)	0.024182	0.001935	2.38E+07	8.84E-01	1.23E+00	0.05	0.007952
Consolidated Edison Inc. (ED)	0.012795	0.000201	1.33E+07	6.09E-02	1.02E-01	0.05	0.005547
AT&T Inc. (T)	0.017285	0.001584	2.74E+07	3.28E+05	6.02E+04	0.05	0.062487
Verizon Communications Inc. (VZ)	0.003198	0.000899	2.34E+06	1.71E-01	4.00E-01	0.05	0.036024
Newmont Corp. (NEM)	0.00353	0.001567	4.06E+06	-2.71E-01	-4.35E-01	0.05	0.009777

Table 14 below evaluates the portfolio performance based on the data in Table 13 for the month of August-2011.

Table 14: Evaluating the portfolio performance in August 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	2.1542e+07	0.0692	0.2631	8.1878e+07
Robust mean-variance optimization (CL = 95%)	1.3972e+05	0.0208	0.1441	9.6971e+05
Robust mean-variance optimization (CL = 90%)	2.5660e+04	0.0184	0.1357	1.8913e+05
Risk Parity optimization with no short selling.	-0.0260	0.0001	0.0078	-3.3475
Market Capitalizations	-0.0301	0.0001	0.0077	-3.9056

The data obtained for MVO and robust MVO still have errors due to the short historical data used of 7 months. The MVO suggests a $2.1542e+07$ portfolio return which is extremely high and this aligns with the weights in Table 13 in that the MVO model took an aggressive approach when assigning the weights for each asset whether that was significantly positive weights (buying the asset) or significantly negative weights (shorting the asset). MCD and ED are still the largest weighted stocks in the MVO model therefore, these assets must have performed extremely well in the month of August-2011. No complex numbers were obtained in variance or Sharpe ratio which means the error in the data is becoming smaller as the historical data range increased from 6 months to 7 months.

The robust MVO also has errors due to the large portfolio return. The 90% confidence level yielded a better portfolio return and lower variance (risk) than the 95% confidence level of 95%. It only performed worse for the Sharpe ratio in that the 95% confidence level yielded a higher Sharpe ratio compared to a 90% confidence level.

The risk parity optimization model had a negative portfolio gain indicating poor performance for the month of August-2011. The variance is extremely low, indicating low risk, and the Sharpe ratio is negative which indicates a poor risk-adjusted performance.

The market capitalization optimization model performed similar to the risk parity optimization model in that it performed poorly overall. It has slightly better portfolio return than the risk parity model, same portfolio variance and a Sharpe ratio closer to zero indicating a less unfavorable risk-adjusted return when compared to the Risk Parity portfolio.

The errors in MVO and robust MVO are due to the short historical period used to obtain data (Jan-2011 to July-2011). The issue is the same as stated previously in that the covariance matrix which is crucial for portfolio optimization. The short historical period caused the data set to be nearly invertible. The robust MVO lowers estimation risk by considering uncertainty however, with the small data set from Jan-2011 to July-2011 the robust optimization model has unstable/unpredictable weight allocation to each asset.

Part 2 b) – January 2011 to August 2011

Table 15 below displays all 20 assets with the sample mean and sample variance for the months spanning Jan-2011 to Aug-2011. The Weights for the MVO, robust MVO, risk parity and Market cap were calculated.

Table 15: Asset Parameters and Portfolio weights – January 2011 to August 2011

Assets / Parameter	Sample mean	Sample Variance	Weights MVO	Weights RMVO 95%	Weights RMVO 90%	Risk Parity	Market Cap
Ford Motor Co. (F)	-4.90E-02	0.002277	- 7.44E+07	- 5.86E+00	- 9.28E+04	0.05	0.015833

Caterpillar Inc. (CAT)	-5.77E-03	0.00424	2.95E+07	1.31E-13	-7.70E-03	0.05	0.022031
Walt Disney Co. (DIS)	-1.64E-02	0.004734	- 2.27E+07	-6.72E-14	-3.53E-02	0.05	0.023688
McDonald's Corp. (MCD)	3.31E-02	2.11E-04	4.17E+07	6.73E+00	6.89E+04	0.05	0.034956
Coca-Cola Co. (KO)	1.87E-02	0.000271	1.88E+07	2.23E-11	-1.10E-01	0.05	0.060619
PepsiCo Inc. (PEP)	4.64E-03	0.00213	1.13E+07	-3.48E-13	1.87E-04	0.05	0.038209
Walmart Inc. (WMT)	-3.80E-03	0.001476	- 1.65E+07	-1.16E-13	3.03E-02	0.05	0.069215
Citigroup Inc. (C)	-5.81E-02	0.004998	- 2.12E+07	2.07E-13	- 2.11E+03	0.05	0.033952
Wells Fargo & Co. (WFC)	-2.84E-02	0.000818	- 6.86E+07	- 6.70E+00	- 9.57E+04	0.05	0.05164
JPMorgan Chase & Co. (JPM)	-2.31E-02	0.001241	- 4.59E+07	-8.21E-13	- 4.10E+04	0.05	0.054878
Apple Inc. (AAPL)	1.99E-02	0.00389	1.64E+07	-1.13E-13	9.77E-02	0.05	0.133698
IBM Corp. (IBM)	1.09E-02	0.001111	4.85E+07	1.71E+00	5.39E+04	0.0499	0.076935
Pfizer Inc. (PFE)	1.14E-02	0.002098	3.52E+06	1.45E-13	1.71E-01	0.05	0.055492
Johnson & Johnson (JNJ)	1.87E-02	0.00209	3.45E+07	4.97E-14	-1.37E-01	0.05	0.06757
Exxon Mobil Corp. (XOM)	-8.79E-03	0.001947	8.40E+05	-6.74E-14	-5.12E-01	0.05	0.134867
Marathon Oil Corp. (MRO)	2.75E-03	0.004415	3.83E+07	9.28E-01	3.42E+04	0.05	0.007203
Consolidated Edison Inc. (ED)	2.25E-02	0.000737	2.80E+06	-4.01E-13	-1.83E-01	0.05	0.006168
AT&T Inc. (T)	1.10E-02	0.001595	3.05E+07	4.19E+00	7.47E+04	0.05	0.063246
Verizon Communications Inc. (VZ)	6.30E-03	0.000829	- 1.00E+07	-3.72E-13	-3.05E-01	0.05	0.038359
Newmont Corp. (NEM)	2.10E-02	0.003182	- 1.73E+07	-1.09E-13	- 2.60E+01	0.05	0.011441

Table 16 below evaluates the portfolio performance based on the data in table 15 for the month of August-2011.

Table 16: Evaluating the portfolio performance in September 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	1.4311e+07	0.0967	0.3109	4.6027e+07
Robust mean-variance optimization (CL = 95%)	0.9309	0.1040	0.3225	2.8870
Robust mean-variance optimization (CL = 90%)	2.0122e+04	0.1256	0.3545	5.6768e+04
Risk Parity optimization with no short selling.	-0.0466	0.0002	0.0124	-3.7412
Market Capitalizations	-0.0268	0.0001	0.0121	-2.2156

The robust MVO for confidence level of 95% was able to converge when calculating the weights. This resulted in usable data when evaluating the portfolio performance in September 2011. The data obtained for MVO and robust MVO for a confidence level of 90% still has errors due to the short historical data used of 8 months. For the robust MVO with a confidence level of 90% the data on MATLAB did not converge as the 90% confidence level provided tighter constraints making it more challenging to find a solution. No complex numbers were obtained in variance or Sharpe ratio which means the error in the data is becoming smaller as the historical data range increased from 6 months to 7 months to 8 months.

Part 2 b) – January 2011 to September 2011

Table 17 below displays all 20 assets with the sample mean and sample variance for the months spanning Jan-2011 to Sept-2011. The Weights for the MVO, robust MVO, risk parity and Market cap were calculated.

Table 17: Asset Parameters and Portfolio weights – January 2011 to September 2011

Assets / Parameter	Sample mean	Sample Variance	Weights MVO	Weights RMVO 95%	Weights RMVO 90%	Risk Parity	Market Cap
Ford Motor Co. (F)	-5.92E-02	7.36E-03	- 3.68E+05	2.69E-02	2.69E-02	0.05	0.014428

Caterpillar Inc. (CAT)	-2.86E-02	5.20E-03	1.62E+05	4.74E-02	4.74E-02	0.05	0.018733
Walt Disney Co. (DIS)	-2.86E-02	6.01E-04	- 1.23E+05	4.42E-02	4.42E-02	0.05	0.02198
McDonald's Corp. (MCD)	2.54E-02	5.46E-04	2.26E+05	6.43E-02	6.43E-02	0.0499	0.03558
Coca-Cola Co. (KO)	1.20E-02	2.07E-03	9.86E+04	5.82E-02	5.82E-02	0.0499	0.060918
PepsiCo Inc. (PEP)	-8.53E-04	1.34E-03	5.76E+04	5.31E-02	5.31E-02	0.05	0.03847
Walmart Inc. (WMT)	-6.36E-03	5.87E-03	- 8.08E+04	4.78E-02	4.78E-02	0.05	0.070249
Citigroup Inc. (C)	-7.27E-02	9.62E-04	- 1.00E+05	2.18E-02	2.18E-02	0.05	0.029356
Wells Fargo & Co. (WFC)	-3.43E-02	4.44E-03	- 3.37E+05	3.38E-02	3.38E-02	0.05	0.050008
JPMorgan Chase & Co. (JPM)	-4.49E-02	3.50E-03	- 1.95E+05	3.66E-02	3.66E-02	0.0499	0.046117
Apple Inc. (AAPL)	1.63E-02	9.77E-04	7.75E+04	5.88E-02	5.88E-02	0.05	0.138825
IBM Corp. (IBM)	1.17E-02	2.53E-03	2.19E+05	5.64E-02	5.64E-02	0.0499	0.082015
Pfizer Inc. (PFE)	1.41E-03	2.11E-03	1.58E+04	5.70E-02	5.70E-02	0.05	0.054171
Johnson & Johnson (JNJ)	1.23E-02	1.71E-03	1.78E+05	6.04E-02	6.04E-02	0.0499	0.068541
Exxon Mobil Corp. (XOM)	-1.00E-02	8.29E-03	- 2.48E+04	4.90E-02	4.90E-02	0.05	0.13868
Marathon Oil Corp. (MRO)	-2.24E-02	6.52E-04	2.09E+05	5.09E-02	5.09E-02	0.0499	0.006048
Consolidated Edison Inc. (ED)	2.15E-02	1.41E-03	1.52E+04	6.06E-02	6.06E-02	0.05	0.006554
AT&T Inc. (T)	9.81E-03	7.39E-04	1.23E+05	5.80E-02	5.80E-02	0.0499	0.066369
Verizon Communications Inc. (VZ)	7.69E-03	2.80E-03	- 7.17E+04	5.44E-02	5.44E-02	0.05	0.040905
Newmont Corp. (NEM)	1.97E-02		- 8.13E+04	6.05E-02	6.05E-02	0.0499	0.012052

Table 18 below evaluates the portfolio performance based on the data in Table 17 for the month of October-2011.

Table 18: Evaluating the portfolio performance in October 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	-6.0699e+04	0.0816	0.2857	-2.1243e+05
Robust mean-variance optimization (CL = 95%)	0.0845	0.0257	0.1602	0.5277
Robust mean-variance optimization (CL = 90%)	0.0845	0.0257	0.1602	0.5277
Risk Parity optimization with no short selling.	0.0761	0.0002	0.0130	5.8588
Market Capitalizations	0.0550	0.0002	0.0123	4.4755

The robust MVO for confidence levels of 95% and 90% were able to converge when calculating the weights. This resulted in usable data when evaluating the portfolio performance in October - 2011. The data obtained for MVO still has errors due to the short historical data used of 9 months. For the robust MVO with a confidence level of 90% the data on MATLAB did converge as the extra month of data aided in the optimization model with a 90% confidence level to converge. No complex numbers were obtained in variance or Sharpe ratio which means the error in the data is becoming smaller as the historical data range increased from 6 months to 7 months to 8 months to 9 months.

Part 2 b) – January 2011 to October 2011

Table 19 below displays all 20 assets with the sample mean and sample variance for the months spanning Jan-2011 to Oct-2011. The Weights for the MVO, robust MVO, risk parity and Market cap were calculated.

Table 19: Asset Parameters and Portfolio weights – January 2011 to October 2011

Assets / Parameter	Sample mean	Sample Variance	Weights MVO	Weights RMVO 95%	Weights RMVO 90%	Risk Parity	Market Cap
Ford Motor Co. (F)	-2.95E-02	9.46E-03	- 1.06E+07	-2.68E-08	-3.19E-14	0.05	0.016279
Caterpillar Inc. (CAT)	6.37E-03	1.63E-02	3.33E+07	-1.21E-09	1.69E-14	0.05	0.022383

Walt Disney Co. (DIS)	-8.06E-03	8.00E-03	2.23E+06	-1.66E-09	-1.17E-14	0.0499	0.023743
McDonald's Corp. (MCD)	2.89E-02	6.35E-04	4.99E+07	1.28E+00	1.75E+00	0.05	0.035137
Coca-Cola Co. (KO)	1.19E-02	4.86E-04	- 2.86E+07	1.36E-09	-3.41E-14	0.05	0.056918
PepsiCo Inc. (PEP)	1.13E-03	1.88E-03	- 1.93E+07	-7.61E-10	-2.64E-14	0.05	0.036098
Walmart Inc. (WMT)	4.67E-03	2.16E-03	2.86E+06	-1.14E-09	9.53E-14	0.05	0.071707
Citigroup Inc. (C)	-3.87E-02	1.44E-02	- 6.01E+06	-1.41E-08	8.50E-15	0.05	0.033809
Wells Fargo & Co. (WFC)	-2.23E-02	2.02E-03	- 2.48E+07	-2.78E-01	-7.46E-01	0.05	0.050179
JPMorgan Chase & Co. (JPM)	-2.17E-02	8.26E-03	- 4.24E+07	-1.08E-08	-5.79E-14	0.05	0.049714
Apple Inc. (AAPL)	2.13E-02	3.31E-03	5.68E+06	4.38E-10	6.17E-15	0.05	0.138001
IBM Corp. (IBM)	1.66E-02	1.06E-03	1.82E+07	2.89E-10	9.58E-14	0.05	0.079817
Pfizer Inc. (PFE)	1.12E-02	3.02E-03	7.50E+06	-9.64E-10	1.06E-14	0.0499	0.055117
Johnson & Johnson (JNJ)	1.22E-02	1.88E-03	- 2.63E+06	-6.94E-11	-1.34E-14	0.0499	0.064723
Exxon Mobil Corp. (XOM)	-5.73E-04	2.24E-03	- 6.85E+06	-1.82E-09	1.57E-14	0.0499	0.13927
Marathon Oil Corp. (MRO)	3.01E-03	1.25E-02	1.17E+07	-1.14E-09	8.13E-15	0.0499	0.006815
Consolidated Edison Inc. (ED)	2.08E-02	5.84E-04	1.56E+07	8.11E-09	-2.21E-14	0.0499	0.006214
AT&T Inc. (T)	1.41E-02	1.40E-03	2.65E+06	-5.53E-10	1.81E-14	0.0499	0.063711
Verizon Communications Inc. (VZ)	8.94E-03	6.69E-04	- 9.91E+06	2.83E-10	6.71E-15	0.0499	0.038401
Newmont Corp. (NEM)	2.43E-02	2.66E-03	1.37E+06	2.54E-10	5.98E-14	0.0499	0.011965

Table 20 below evaluates the portfolio performance based on the data in Table 19 for the month of November-2011.

Table 20: Evaluating the portfolio performance in November 2011

	Portfolio Return	Portfolio Variance	Standard Deviation	Sharpe Ratio
Mean-variance optimization (MVO)	1.1680e+07	0.1381	0.3716	3.1433e+07
Robust mean-variance optimization (CL = 95%)	0.0365	0.0285	0.1687	0.2161
Robust mean-variance optimization (CL = 90%)	0.0740	0.0407	0.2018	0.3668
Risk Parity optimization with no short selling.	-0.0385	0.0002	0.0137	-2.8143
Market Capitalizations	-0.0380	0.0002	0.0130	-2.9328

With 10 – months of historical data from Jan-2011 to October-2011 the MVO still could not converge when weights were calculated. This resulted in error with the portfolio return, variance and Sharpe ratio. The robust MVO for confidence levels of 95% and 90% were able to converge when calculating the weights. This resulted in usable data when evaluating the portfolio performance in October - 2011. The data obtained for MVO still has errors due to the short historical data used of 10 months. No complex numbers were obtained in variance or Sharpe ratio which means the error in the data is becoming smaller as the historical data range increased from 6 months to 7 months to 8 months to 9 months to 10 months.

Further discussion of the Risk Parity and Market Capitalization based

Risk Parity optimization with no short selling

The risk parity optimization assigned each stock an equal weight of approximately 0.05. This indicates that the model executed correctly by providing equal weights to all stocks. Calculating the portfolio return, variance, standard deviation, and sharpe ratio has provided an insight into the performance of each portfolio. The highest portfolio return was –0.0160 and appeared twice, once in June 2011 (when computed by using data from December 2007 till June 2011) and again in July 2011 (when computed by using data from

January 2011 till June 2011). The lowest portfolio return was -0.0466 and appeared in September 2011. This shows that despite each asset having equal risk allocation, it did not prevent it from losing 1.60% for the month of July 2011 and even worse 4.66% for September 2011. When comparing the risk parity optimization to other optimization strategies such as the Mean-variance optimization (MVO) and Robust mean-variance optimization, it can be seen that it generally yields lower returns and Sharpe ratios. This indicates that while the risk is equal across all the assets in the portfolio, the returns might not always be high. Also, negative returns mean that the value of the portfolio has decreased over a given period. This could be a major problem during market downturns, especially if many assets are affected by it. Also, while the primary objective of the risk parity model is to ensure that each stock has equal risk, this does not mean that it will minimize loss. Moreover, while the risk parity model aids in maintaining a risk balanced portfolio, high performing assets will not be utilized to their full potential which will lead the portfolio to obtaining lower returns. Furthermore, the variance and standard deviation are all low, which is a byproduct of equalizing risk across all assets but leads to lower portfolio returns and Sharpe ratios.

Market Capitalization

Different market capitalizations for all 20 stocks were utilized. The market capitalization weights for the portfolios that had to be tested on were determined by using data that was as close to the end of the previous testing month to ensure they reflect the most recent information prior to evaluating the performance of said month. When calculating the portfolio performance of July 2011 till November 2011, the highest portfolio return of 5.5% occurred in October 2011 while the lowest portfolio of return -3.8% occurred in November 2011. The performance of this strategy differed across different months. This highlights the volatility of this strategy and how it reacts to the market conditions. During market downturns, the July, August, September, and November 2011 portfolios did not perform well while the October 2011 portfolio fared better during favorable market conditions.

Part C)

Table 21: Summary from all the portfolio performance in Part B from July-2011 to November-2011

Month	Mean-variance optimization (MVO)	Robust mean-variance optimization (CL = 95%)	Robust mean-variance optimization (CL = 90%)	Risk Parity optimization with no short selling.	Market Capitalizations
Jul-11	7.0778E+05	9.2740E+04	2.6408E+03	-0.0160	-0.00150

Aug-11	2.1542E+07	1.3972E+05	2.5660E+04	-0.0260	-0.0301
Sep-11	1.4311E+07	0.9309	2.0122E+04	-0.0466	-0.0268
Oct-11	-6.0699E+04	0.0845	0.0845	0.0761	0.0550
Nov-11	1.168E+07	0.0365	0.074	-0.0385	-0.038

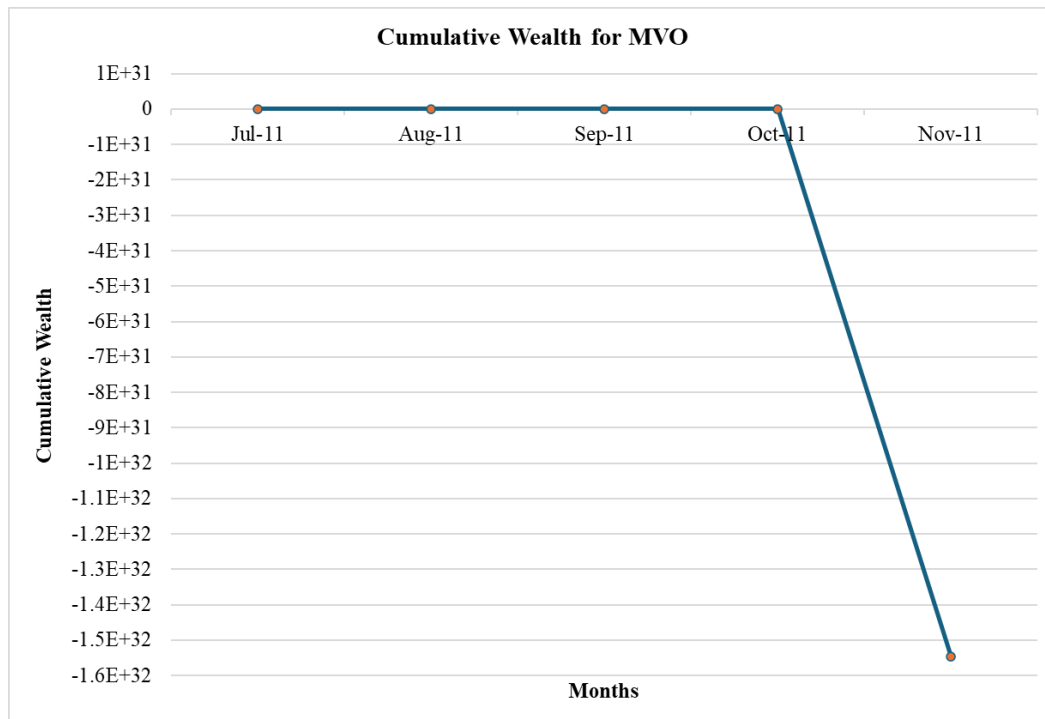


Figure 1: Cumulative Wealth using MVO for portfolios spanning from July 2011 till November 2011

The figure above shows the cumulative wealth using MVO for portfolios spanning from July 2011 till November 2011. The wealth in July starts off at 707781. It then increases in August, and it increases again in September before decreasing in October. It then slightly recovers in November. The MVO portfolio is highly sensitive to the returns of individual months as seen in the figure above. This highlights the pitfalls of using only historical data and underscores the importance of risk management, diversification, and robustness.

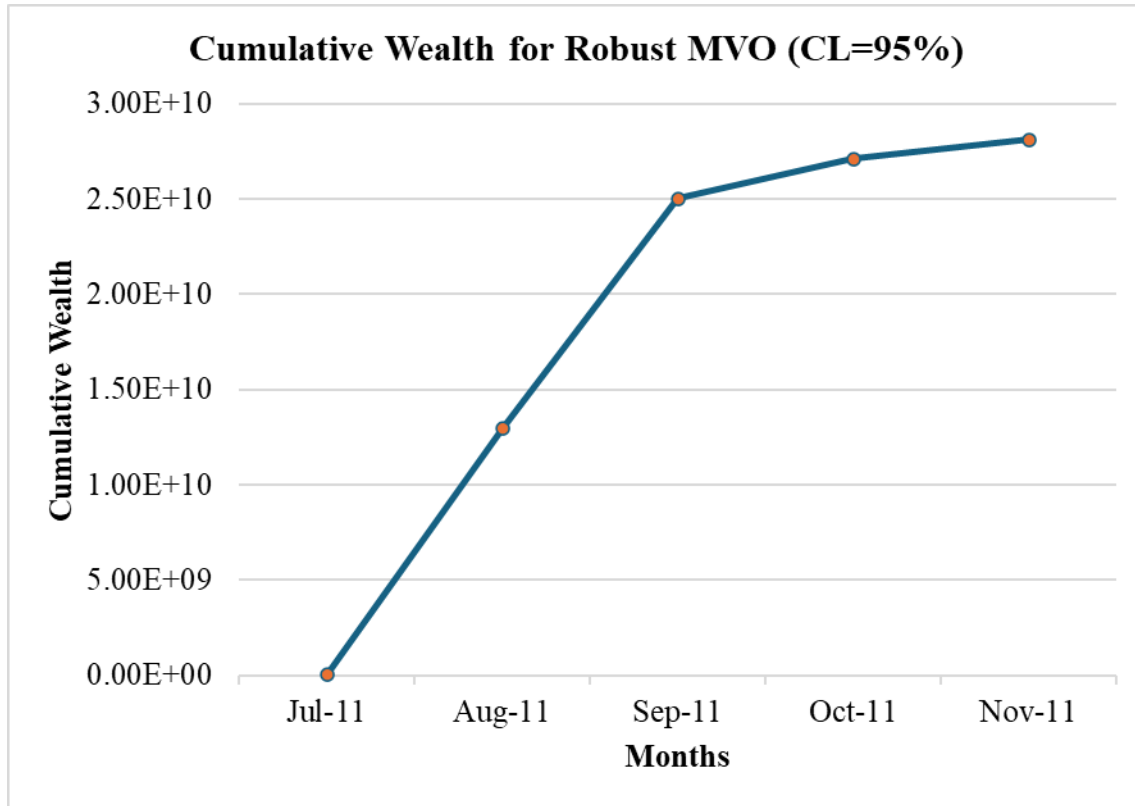


Figure 2: Cumulative Wealth using Robust MVO (CL=95%) for portfolios spanning from July 2011 till November 2011

The figure above shows the cumulative wealth using Robust MVO (CL=95%) for portfolios spanning from July 2011 till November 2011. The model clearly shows steady growth and moderate returns as the months increase. The strategy with this model is to obtain positive returns while reducing risk. Also, this model is less volatile when compared to MVO (Figure 1). Moreover, since this portfolio does not contain any negative returns, it highlights the portfolio's resilience to adverse market conditions.

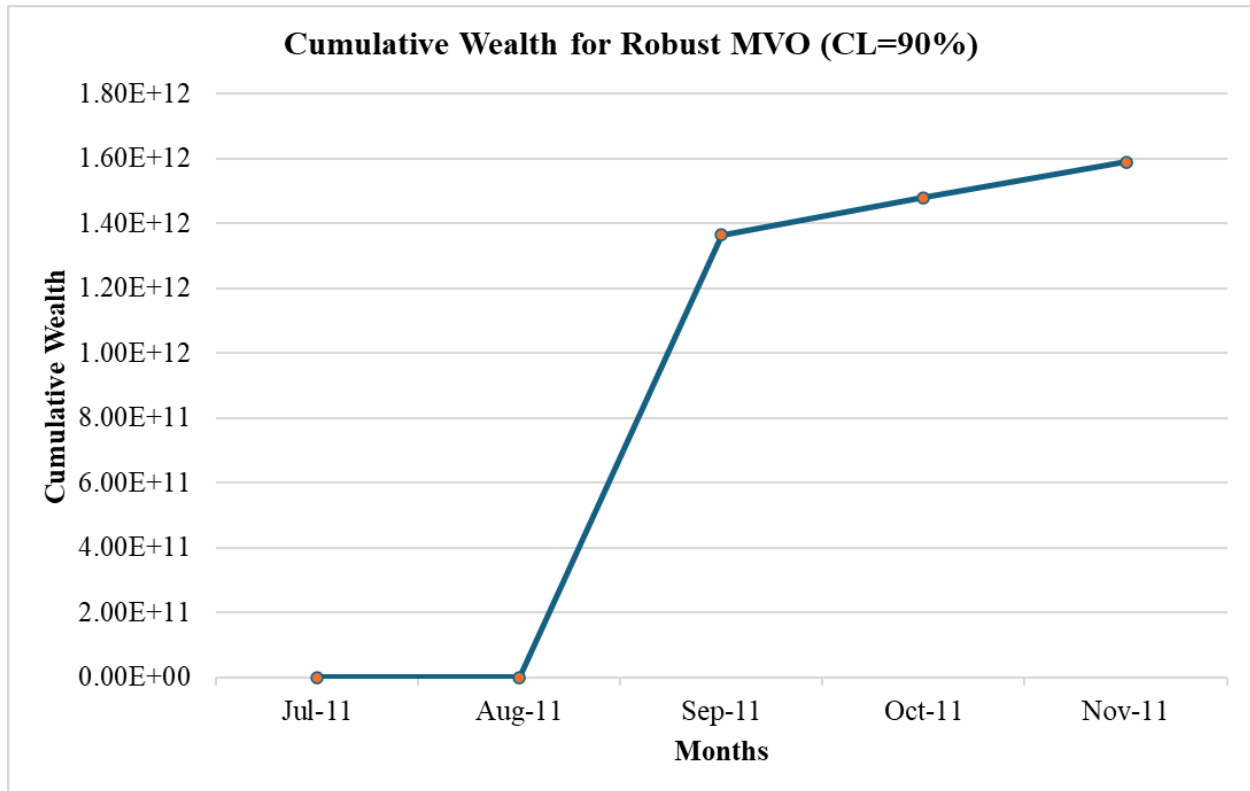


Figure 3: Cumulative Wealth using Robust MVO (CL=90%) for portfolios spanning from July 2011 till November 2011

Figure 3 shows the cumulative wealth using Robust MVO (CL=90%) for portfolios spanning from July 2011 till November 2011. The returns when compared to Robust MVO at 95% (Figure 2) are slightly lower. This points to a more conservative approach while still obtaining lower positive returns. Additionally, this portfolio shows consistent growth and moderate returns similar to Figure 2.

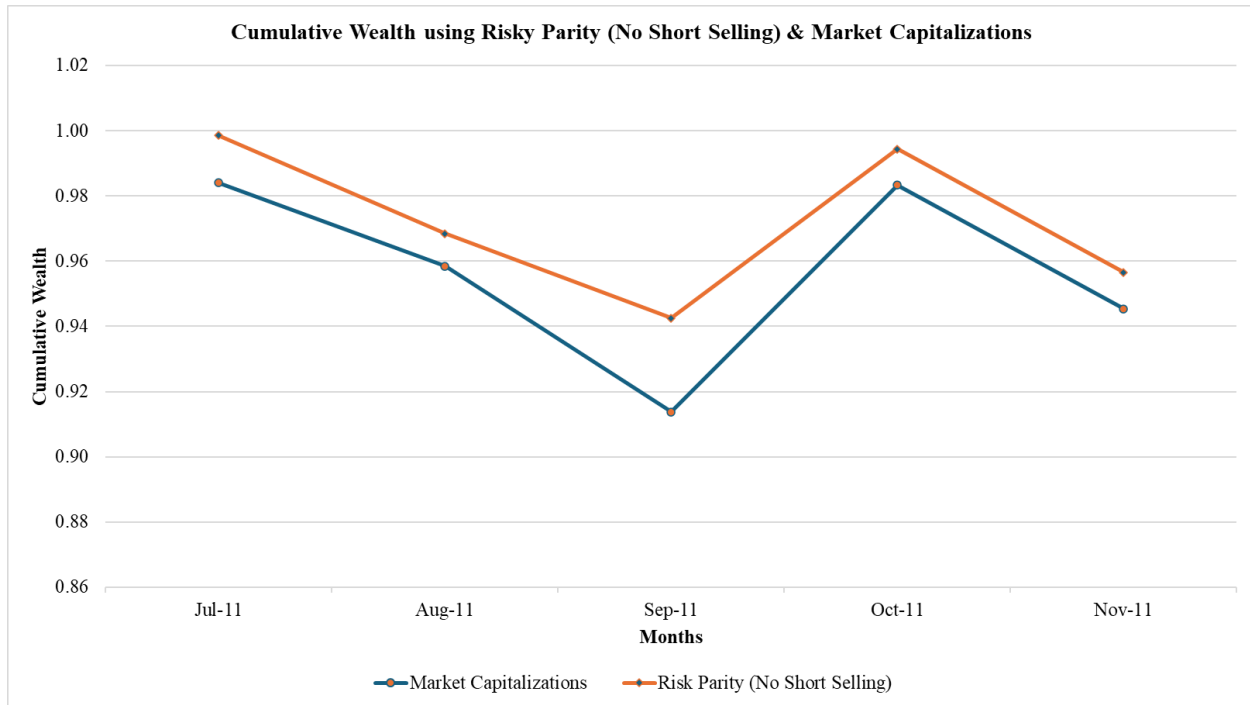


Figure 4: Cumulative Wealth using Risk Parity and Market Capitalizations for portfolios spanning from July 2011 till November 2011

The cumulative wealth using Risk Parity and Market Capitalizations for portfolios spanning from July 2011 till November 2011 are closely similar. They both started negative in July and August. This might indicate a turbulent market. Then both experienced positive growth in October which was short lived as their returns went back negative in November.

Conclusion

To conclude, four portfolios were generated which are the MVO, robust MVO, risk parity, and market capitalization (where the 20 stocks were assumed to be the market) were considered. In Part A, the four portfolios calculated the sample mean, sample variance, and sample covariance were calculated for stocks in Table 1 for the duration of Dec-2007 to June-2011. Using the weights generated from the time frame of Dec-2007 to June-2011 and just the realized return for July-2011, the portfolio return, portfolio variance, standard deviation, and Sharpe ratio were computed. All four portfolios were compared to each other using these parameters (portfolio return, portfolio variance, standard deviation, and Sharpe ratio) and the result was, MVO did better than robust MVO and the Risky parity and market cap portfolios performed poorly.

In Part B, a rolling 6-month horizon test was performed in that the time horizon from Jan-2011 to June-2011 was only considered. Part A was re-done considering on this 6-month horizon and then the portfolio was tested for July-2011. The portfolio return, portfolio variance, standard deviation, and Sharpe ratio were computed. All four portfolios were compared to each other using these parameters. This rolling 6-month horizon test was computed for Aug-2011, Sept-2011, Oct-2011, and Nov-11 with the horizon test increasing by 1 month for each test (6-month, 7-month, 8-month, 9-month, and 10-month). For each rolling horizon test and the portfolio return, portfolio variance, standard deviation, and Sharpe ratio were computed. All four portfolios were compared to each other using these parameters. The key observation from these data points is that the portfolios for the MVO and robust MVO did not converge therefore no optimal solution was found when calculating the weights. This was due to the short time horizon of only 6-months of data. As the rolling horizon test increased from 6-months to 7-months, the portfolios for the MVO and Robust MVO still did not converge. When the rolling horizon increased from 7-months to 8-months, the portfolio for the robust MVO with a 95% confidence level converged optimal weights were found however, for the robust MVO with a 90% confidence did not converge with 8-months of data as a 90% confidence level has tight constraints compared to a 95% confidence level. The portfolio for MVO did not converge. When the rolling horizon increased from 8-months to 9-months, the robust MVO for 90% and 95% confidence level converged therefore, that extra month of data allowed the portfolio to converge and obtain weights (for 90% confidence level). The portfolio for MVO did not converge. Lastly, when the rolling horizon increased from 9-months to 10-months, the robust MVO for 90% and 95% confidence level converged however, the portfolio for MVO still did not converge. Therefore, a longer time horizon is needed for the MVO portfolio to converge. The robust MVO converges with less data points due to the uncertainty within the model which allows it to have more constraints therefore finding an optimal weights with less data points.

From July to November 2011, the portfolio performance across various optimization strategies showed diverse outcomes. Mean-variance optimization (MVO) started with high wealth in July, saw increases in August and September, but declined in October and slightly recovered in November, highlighting its sensitivity to monthly returns and the importance of risk management. Robust MVO with a 95% confidence level demonstrated steady growth with moderate returns and no negative returns, indicating resilience to adverse market conditions. The 90% confidence level version also showed consistent growth, though with slightly lower returns, suggesting a more conservative approach. Risk Parity and Market Capitalization strategies both started with negative returns in July and August, experienced growth in October, but turned negative again in November, reflecting market turbulence during this period. A key observation is that the data used in this report includes the economic downturn that happened in 2007/2008 and the economic recovery that followed. Hence, this report leads to certain outcomes such as favoring one optimization model over another. Having observed the performance of these optimization models during market downturns, it is important to compare the outcomes during favorable market conditions.

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Appendix:

Appendix Part 2 b) – January 2011 to June 2011

Table 22: Sample Mean for each stock for data from Jan 2011 to June 2011

Stocks	Sample Mean
Ford Motor Co. (F)	-0.02789
Caterpillar Inc. (CAT)	0.021315
Walt Disney Co. (DIS)	0.002868
McDonald's Corp. (MCD)	0.030676
Coca-Cola Co. (KO)	0.016827
PepsiCo Inc. (PEP)	0.021798
Walmart Inc. (WMT)	-0.00699
Citigroup Inc. (C)	-0.0275
Wells Fargo & Co. (WFC)	-0.02653
JPMorgan Chase & Co. (JPM)	-0.01682
Apple Inc. (AAPL)	-0.00185
IBM Corp. (IBM)	0.013377
Pfizer Inc. (PFE)	0.029672
Johnson & Johnson (JNJ)	0.026423
Exxon Mobil Corp. (XOM)	0.004835
Marathon Oil Corp. (MRO)	0.031906
Consolidated Edison Inc. (ED)	0.017758
AT&T Inc. (T)	0.031017
Verizon Communications Inc. (VZ)	0.011781
Newmont Corp. (NEM)	-0.00184

Table 23: Sample Variance for each stock for data from Jan 2011 to June 2011

Stocks	Sample Variance
Ford Motor Co. (F)	0.001558
Caterpillar Inc. (CAT)	0.003356
Walt Disney Co. (DIS)	0.004182
McDonald's Corp. (MCD)	0.000203
Coca-Cola Co. (KO)	0.000304
PepsiCo Inc. (PEP)	0.000851
Walmart Inc. (WMT)	0.001971
Citigroup Inc. (C)	0.002487
Wells Fargo & Co. (WFC)	0.000803
JPMorgan Chase & Co. (JPM)	0.001172
Apple Inc. (AAPL)	0.000625
IBM Corp. (IBM)	0.000312

Pfizer Inc. (PFE)	0.001379
Johnson & Johnson (JNJ)	0.002459
Exxon Mobil Corp. (XOM)	0.001859
Marathon Oil Corp. (MRO)	0.001964
Consolidated Edison Inc. (ED)	9.33E-05
AT&T Inc. (T)	0.00077
Verizon Communications Inc. (VZ)	0.000637
Newmont Corp. (NEM)	0.001708

Table 24: Sample Covariance for each stock for data from Jan 2011 to June 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.001558	0.000558	-0.00012	-2.03E-04	1.69E-04	0.001051	0.001528	0.000507	-0.00097	0.000257	0.000122	0.000471	0.000578	0.001144	0.000473	0.000189	0.000262	0.000607	-0.00018	0.001368
'CAT.csv'	0.000558	0.003356	0.001717	-6.65E-04	9.08E-04	-0.00023	-0.00038	0.001371	-4.48E-05	0.001394	0.000425	0.000357	0.000766	-0.00036	0.001537	0.001612	-0.00023	0.001057	0.001239	0.001056
'DIS.csv'	-0.00012	0.001717	0.004182	3.29E-05	1.30E-04	-0.00067	-0.00144	7.42E-05	0.000312	0.00208	0.001551	-0.00013	0.001702	0.000887	0.002308	0.002265	2.57E-06	0.000425	0.000802	0.000892
'MCD.csv'	-0.0002	-0.00067	3.29E-05	0.000203	-0.00024	-3.58E-05	-0.00012	-0.00013	1.01E-05	-0.00012	5.88E-05	-5.64E-05	-0.00013	0.000297	-5.06E-05	-0.00028	4.08E-05	-0.00033	-0.00026	-0.00013
'KO.csv'	0.000169	0.000908	0.00013	-2.43E-04	3.04E-04	-3.64E-05	4.95E-06	0.000223	3.27E-05	0.000232	-2.31E-05	6.31E-05	0.000166	-0.00037	0.000164	0.000405	-7.20E-05	0.000378	0.000367	0.00015
'PEP.csv'	0.001051	-0.00023	-0.00067	-3.58E-05	-3.64E-05	0.000851	0.001266	0.000281	-0.00076	-0.00018	-9.57E-05	0.000333	0.000112	0.000891	-1.18E-05	-0.00035	0.000218	0.000198	-0.0004	0.000808
'WMT.csv'	0.001528	-0.00038	-0.00144	-1.18E-04	4.95E-06	0.001266	0.001971	0.000255	-0.00105	-0.00048	-0.00033	0.000449	5.83E-05	0.00097	-0.00035	-0.0006	0.000301	0.000363	-0.00057	0.000991
'C.csv'	0.000507	0.001371	7.42E-05	-1.30E-04	2.23E-04	0.000281	0.000255	0.002487	-0.00076	0.00037	-5.27E-05	0.000767	-0.00071	0.001042	0.001173	-0.0006	-0.00014	-0.00023	5.39E-05	0.001221
'WFC.csv'	-0.00097	-4.48E-05	0.000312	1.01E-05	3.27E-05	-0.00076	-0.00105	-0.00076	0.000803	-1.55E-05	-9.42E-06	-0.00044	-1.11E-05	-0.00112	-0.00037	0.000366	-0.00017	-7.05E-05	0.000352	-0.00099
'JPM.csv'	0.000257	0.001394	0.00208	-1.24E-04	2.32E-04	-0.00018	-0.00048	0.00037	-1.55E-05	0.001172	0.000758	7.69E-05	0.000928	0.000498	0.001337	0.00126	-4.52E-06	0.000434	0.000528	0.000765
'AAPL.csv'	0.000122	0.000425	0.001551	5.88E-05	-2.31E-05	-9.57E-05	-0.00033	-5.27E-05	-9.42E-06	0.000758	0.000625	-2.72E-05	0.00072	0.000587	0.000868	0.000802	6.76E-05	0.000152	0.00017	0.000462
'IBM.csv'	0.000471	0.000357	-0.00013	-5.64E-05	6.31E-05	0.000333	0.000449	0.000767	-0.00044	7.69E-05	-2.72E-05	0.000312	-0.00013	0.000554	0.000345	-0.00023	2.68E-05	2.15E-05	-8.62E-05	0.000598
'PFE.csv'	0.000578	0.000766	0.001702	-1.30E-04	1.66E-04	0.000112	5.83E-05	-0.00071	-1.11E-05	0.000928	0.00072	-0.00013	0.001379	0.000334	0.000751	0.001464	0.000165	0.000736	0.00037	0.000583
'JNJ.csv'	0.001144	-0.00036	0.000887	2.97E-04	-3.69E-04	0.000891	0.00097	0.001042	-0.00112	0.000498	0.000587	0.000554	0.000334	0.002459	0.001234	-0.00029	0.000314	-0.00026	-0.00067	0.001625
'XOM.csv'	0.000473	0.001537	0.002308	-5.06E-05	1.64E-04	-1.18E-05	-0.00035	0.001173	-0.00037	0.001337	0.000868	0.000345	0.000751	0.001234	0.001859	0.000995	9.03E-06	0.000226	0.00038	0.001295
'MRO.csv'	0.000189	0.001612	0.002265	-2.83E-04	4.05E-04	-0.00035	-0.0006	-0.0006	0.000366	0.00126	0.000802	-0.00023	0.001464	-0.00029	0.000995	0.001964	2.05E-06	0.000901	0.000849	0.000365
'ED.csv'	0.000262	-0.00023	2.57E-06	4.08E-05	-7.20E-05	0.000218	0.000301	-0.00014	-0.00017	-4.52E-06	6.76E-05	2.68E-05	0.000165	0.000314	9.03E-06	2.05E-06	9.33E-05	4.46E-05	-0.00015	0.000188
'T.csv'	0.000607	0.001057	0.000425	-3.28E-04	3.78E-04	0.000198	0.000363	-0.00023	-7.05E-05	0.000434	0.000152	2.15E-05	0.000736	-0.00026	0.000226	0.000901	4.46E-05	0.00077	0.00043	0.0004
'VZ.csv'	-0.00018	0.001239	0.000802	-2.60E-04	3.67E-04	-0.0004	-0.00057	5.39E-05	0.000352	0.000528	0.00017	-8.62E-05	0.00037	-0.00067	0.00038	0.000849	-0.00015	0.00043	0.000637	-5.29E-05
'NEM.csv'	0.001368	0.001056	0.000892	-1.27E-04	1.50E-04	0.000808	0.000991	0.001221	-0.00099	0.000765	0.000462	0.000598	0.000583	0.001625	0.001295	0.000365	0.000188	0.0004	-5.29E-05	0.001708

Table 25: Mean-variance optimization (MVO) for data from Jan 2011 to June 2011

Stocks	Weights
Ford Motor Co. (F)	-7.85E+07
Caterpillar Inc. (CAT)	3.63E+07
Walt Disney Co. (DIS)	-2.07E+07
McDonald's Corp. (MCD)	5.21E+07
Coca-Cola Co. (KO)	2.09E+07
PepsiCo Inc. (PEP)	2.77E+07
Walmart Inc. (WMT)	-3.43E+07
Citigroup Inc. (C)	-2.56E+07
Wells Fargo & Co. (WFC)	-7.05E+07
JPMorgan Chase & Co. (JPM)	-5.20E+07
Apple Inc. (AAPL)	-2.41E+07
IBM Corp. (IBM)	2.47E+07
Pfizer Inc. (PFE)	1.80E+07
Johnson & Johnson (JNJ)	4.87E+07
Exxon Mobil Corp. (XOM)	5.24E+06
Marathon Oil Corp. (MRO)	2.51E+07
Consolidated Edison Inc. (ED)	1.84E+07
AT&T Inc. (T)	3.30E+07
Verizon Communications Inc. (VZ)	8.36E+06
Newmont Corp. (NEM)	-1.27E+07

Table 26: Robust MVO (CL=95%) for data from Jan 2011 to June 2011

Stocks	Weights
Ford Motor Co. (F)	-9.87E+05
Caterpillar Inc. (CAT)	1.82E-01
Walt Disney Co. (DIS)	-7.35E-02
McDonald's Corp. (MCD)	9.61E+05
Coca-Cola Co. (KO)	2.48E+05
PepsiCo Inc. (PEP)	4.73E-02
Walmart Inc. (WMT)	-5.77E-02
Citigroup Inc. (C)	-1.73E-01
Wells Fargo & Co. (WFC)	-1.13E+06
JPMorgan Chase & Co. (JPM)	-1.30E+05
Apple Inc. (AAPL)	-8.70E+00
IBM Corp. (IBM)	1.42E-01
Pfizer Inc. (PFE)	3.22E-02
Johnson & Johnson (JNJ)	-6.64E-02
Exxon Mobil Corp. (XOM)	-6.08E-02
Marathon Oil Corp. (MRO)	9.47E-02

Consolidated Edison Inc. (ED)	9.98E-02
AT&T Inc. (T)	1.04E+06
Verizon Communications Inc. (VZ)	1.51E-01
Newmont Corp. (NEM)	-7.34E-02

Table 27: Robust MVO (CL=90%) for data from Jan 2011 to June 2011

Stocks	Weights
Ford Motor Co. (F)	-2.81E+04
Caterpillar Inc. (CAT)	2.68E-01
Walt Disney Co. (DIS)	-1.79E-01
McDonald's Corp. (MCD)	2.74E+04
Coca-Cola Co. (KO)	7.07E+03
PepsiCo Inc. (PEP)	1.33E-01
Walmart Inc. (WMT)	-8.38E-02
Citigroup Inc. (C)	-1.27E+00
Wells Fargo & Co. (WFC)	-3.21E+04
JPMorgan Chase & Co. (JPM)	-3.69E+03
Apple Inc. (AAPL)	1.28E-01
IBM Corp. (IBM)	4.52E-01
Pfizer Inc. (PFE)	6.52E-02
Johnson & Johnson (JNJ)	-8.33E-02
Exxon Mobil Corp. (XOM)	-1.24E-01
Marathon Oil Corp. (MRO)	1.84E-01
Consolidated Edison Inc. (ED)	1.50E-01
AT&T Inc. (T)	2.95E+04
Verizon Communications Inc. (VZ)	2.89E-01
Newmont Corp. (NEM)	-1.30E-01

Table 28: Risk Parity optimization with no short selling for data from January 2011 to June 2011

Stocks	Weights
Ford Motor Co. (F)	0.05
Caterpillar Inc. (CAT)	0.05
Walt Disney Co. (DIS)	0.05
McDonald's Corp. (MCD)	0.05
Coca-Cola Co. (KO)	0.05
PepsiCo Inc. (PEP)	0.05
Walmart Inc. (WMT)	0.05
Citigroup Inc. (C)	0.05
Wells Fargo & Co. (WFC)	0.05
JPMorgan Chase & Co. (JPM)	0.05

Apple Inc. (AAPL)	0.05
IBM Corp. (IBM)	0.0499
Pfizer Inc. (PFE)	0.05
Johnson & Johnson (JNJ)	0.05
Exxon Mobil Corp. (XOM)	0.05
Marathon Oil Corp. (MRO)	0.05
Consolidated Edison Inc. (ED)	0.05
AT&T Inc. (T)	0.05
Verizon Communications Inc. (VZ)	0.05
Newmont Corp. (NEM)	0.05

Table 29: Market Capitalizations of June 2011 [4]

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	53.37	0.05
Caterpillar Inc. (CAT)	68.6	0.05
Walt Disney Co. (DIS)	73.79	0.05
McDonald's Corp. (MCD)	87.48	0.05
Coca-Cola Co. (KO)	154	0.05
PepsiCo Inc. (PEP)	111.32	0.05
Walmart Inc. (WMT)	184.52	0.05
Citigroup Inc. (C)	121.61	0.05
Wells Fargo & Co. (WFC)	148.41	0.05
JPMorgan Chase & Co. (JPM)	162.68	0.05
Apple Inc. (AAPL)	310.4	0.05
IBM Corp. (IBM)	207.78	0.05
Pfizer Inc. (PFE)	162.73	0.0499
Johnson & Johnson (JNJ)	182.34	0.05
Exxon Mobil Corp. (XOM)	400.88	0.05
Marathon Oil Corp. (MRO)	37.51	0.05
Consolidated Edison Inc. (ED)	15.57	0.05
AT&T Inc. (T)	186	0.05
Verizon Communications Inc. (VZ)	105.32	0.05
Newmont Corp. (NEM)	26.28	0.05

Appendix Part 2 b) – January 2011 to July 2011

Table 30: Sample Mean for each stock for data from Jan 2011 to July 2011

Stocks	Sample Mean
Ford Motor Co. (F)	-0.04234
Caterpillar Inc. (CAT)	0.006408

Walt Disney Co. (DIS)	0.000597
McDonald's Corp. (MCD)	0.029833
Coca-Cola Co. (KO)	0.015806
PepsiCo Inc. (PEP)	0.003043
Walmart Inc. (WMT)	-0.00717
Citigroup Inc. (C)	-0.03608
Wells Fargo & Co. (WFC)	-0.02282
JPMorgan Chase & Co. (JPM)	-0.015
Apple Inc. (AAPL)	0.025672
IBM Corp. (IBM)	#####
Pfizer Inc. (PFE)	0.013804
Johnson & Johnson (JNJ)	0.017685
Exxon Mobil Corp. (XOM)	0.000773
Marathon Oil Corp. (MRO)	0.024182
Consolidated Edison Inc. (ED)	0.012795
AT&T Inc. (T)	0.017285
Verizon Communications Inc. (VZ)	0.003198
Newmont Corp. (NEM)	0.00353

Table 31: Sample Variance for each stock for data from Jan 2011 to June 2011

Stocks	Sample Variance
Ford Motor Co. (F)	0.002342
Caterpillar Inc. (CAT)	0.003908
Walt Disney Co. (DIS)	3.51E-03
McDonald's Corp. (MCD)	0.000172
Coca-Cola Co. (KO)	0.000259
PepsiCo Inc. (PEP)	0.002468
Walmart Inc. (WMT)	0.001643
Citigroup Inc. (C)	2.441E-03
Wells Fargo & Co. (WFC)	0.000738
JPMorgan Chase & Co. (JPM)	0.000993
Apple Inc. (AAPL)	0.004308
IBM Corp. (IBM)	0.000562
Pfizer Inc. (PFE)	0.002408
Johnson & Johnson (JNJ)	0.002431
Exxon Mobil Corp. (XOM)	0.001631
Marathon Oil Corp. (MRO)	0.001935
Consolidated Edison Inc. (ED)	0.000201
AT&T Inc. (T)	0.001584
Verizon Communications Inc. (VZ)	0.000899
Newmont Corp. (NEM)	0.001567

Table 32: Sample Covariance for each stock for data from Jan 2011 to July 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.002342	0.001541	6.44E-05	-0.00011	0.0002144	0.00223	0.001286	0.001043	-0.00108	8.26E-05	-0.00189	-1.689E-04	0.001628	0.001584	0.000688	0.000715	0.000576	0.001498	0.000469	0.000752
'CAT.csv'	0.001541	0.003908	0.0016	-0.00049	0.0008327	0.00121	-0.0003	0.001782	-0.00031	0.001026	-0.0017	-2.824E-04	0.001821	0.00035	0.001584	0.001919	0.000177	0.001904	0.001672	0.000479
'DIS.csv'	6.44E-05	0.0016	0.003511	3.70E-05	0.0001198	-0.00034	-1.19E-03	0.000159	0.000218	0.001713	0.00098	-2.006E-04	0.001598	0.000839	0.001969	0.001975	5.85E-05	0.00051	0.000766	0.000682
'MCD.csv'	-0.00011	-0.00049	3.70E-05	0.000172	-0.000198	4.92E-05	-9.72E-05	-7.25E-05	-7.21E-06	-0.00011	-6.70E-05	-7.976E-05	-4.17E-05	0.000284	-2.50E-05	-0.0002	5.49E-05	-0.00022	-0.00018	-0.00013
'KO.csv'	0.000214	0.000833	0.00012	-0.0002	0.0002588	6.54E-05	5.07E-06	0.00023	8.32E-06	0.000184	-0.00016	1.287E-05	0.000219	-0.00026	0.000158	0.000377	-3.47E-05	0.000385	0.00035	9.78E-05
'PEP.csv'	0.00223	0.00121	-0.00034	4.92E-05	6.54E-05	0.002468	0.001073	0.001039	-0.00098	-0.00032	-0.00266	-4.519E-04	0.001581	0.001562	0.000371	0.000435	0.000647	0.001452	0.000471	0.00017
'WMT.csv'	0.001286	-0.0003	-0.00119	-9.72E-05	5.07E-06	0.001073	0.001643	0.00022	-0.00088	-0.0004	-0.0003	3.670E-04	6.32E-05	0.000816	-0.00029	-0.0005	0.000256	0.000315	-0.00046	0.000821
'C.csv'	0.001043	0.001782	0.000159	-7.25E-05	0.0002296	0.001039	0.00022	0.002441	-0.00079	0.00023	-0.00123	3.053E-04	8.67E-05	0.001244	0.001152	-0.00016	9.42E-05	0.000399	0.000413	0.000787
'WFC.csv'	-0.00108	-0.00031	0.000218	-7.21E-06	8.32E-06	-0.00098	-0.00088	-0.00079	0.000738	2.08E-05	0.000503	-2.189E-04	-0.0003	-0.0011	-0.00038	0.000161	-0.00023	-0.00031	0.000134	-0.00073
'JPM.csv'	8.26E-05	0.001026	0.001713	-0.00011	0.0001836	-0.00032	-0.0004	0.00023	2.08E-05	0.000993	0.000882	1.349E-04	0.000629	0.000335	0.001077	0.00098	-4.89E-05	0.000237	0.000362	0.000686
'AAPL.csv'	-0.00189	-0.0017	0.00098	-6.70E-05	-0.00016	-0.00266	-0.0003	-0.00123	0.000503	0.000882	0.004308	1.048E-03	-0.00158	-0.00071	0.000165	-0.00039	-0.00063	-0.00176	-0.00104	0.001124
'IBM.csv'	-0.00017	-0.00028	-0.0002	-7.98E-05	1.2869E-05	-0.00045	0.000367	0.000305	-0.00022	0.000135	0.001048	5.622E-04	-0.00073	0.000122	0.00013	-0.00049	-0.00017	-0.00052	-0.00041	0.000707
'PFE.csv'	1.63E-03	0.001821	0.001598	-4.17E-05	0.0002191	0.001581	6.32E-05	8.67E-05	-0.0003	0.000629	-0.00158	-7.254E-04	0.002408	0.000972	0.000948	0.001833	0.000531	0.001703	0.000989	5.98E-05
'JNJ.csv'	0.001584	0.00035	0.000839	0.000284	-0.000263	0.001562	0.000816	0.001244	-0.0011	0.000335	-0.00071	1.219E-04	0.000972	0.002431	0.001206	9.83E-05	0.000479	0.000383	-0.00019	0.00112
'XOM.csv'	0.000688	0.001584	0.001969	-2.50E-05	0.0001576	0.000371	-0.00029	0.001152	-0.00038	0.001077	0.000165	1.299E-04	0.000948	0.001206	0.001631	0.000986	0.000108	0.000467	0.000491	0.00097
'MRO.csv'	0.000715	0.001919	0.001975	-0.0002	0.000377	0.000435	-0.0005	-0.00016	0.000161	0.00098	-0.00039	-4.879E-04	0.001833	9.83E-05	0.000986	0.001935	0.000193	0.001281	0.001039	9.68E-05
'ED.csv'	0.000576	0.000177	5.85E-05	5.49E-05	-3.47E-05	0.000647	0.000256	9.42E-05	-0.00023	-4.89E-05	-0.00063	-1.707E-04	0.000531	0.000479	0.000108	0.000193	0.000201	0.000378	9.08E-05	2.34E-05
'T.csv'	0.001498	0.001904	0.00051	-0.00022	0.000385	0.001452	0.000315	0.000399	-0.00031	0.000237	-0.00176	-5.160E-04	0.001703	0.000383	0.000467	0.001281	0.000378	0.001584	0.000948	-3.51E-05
'VZ.csv'	0.000469	0.001672	0.000766	-0.00018	0.0003499	0.000471	-0.00046	0.000413	0.000134	0.000362	-0.00104	-4.056E-04	0.000989	-0.00019	0.000491	0.001039	9.08E-05	0.000948	0.000899	-0.00027
'NEM.csv'	0.000752	0.000479	0.000682	-0.00013	9.78E-05	0.00017	0.000821	0.000787	-0.00073	0.000686	0.001124	0.0007075	5.98E-05	0.00112	0.00097	9.68E-05	2.34E-05	-3.51E-05	-0.00027	0.001567

Table 33: Mean-variance optimization (MVO) for data from Jan 2011 to July 2011

Stocks	Weights
Ford Motor Co. (F)	-8.30E+07
Caterpillar Inc. (CAT)	3.40E+07
Walt Disney Co. (DIS)	-2.57E+07
McDonald's Corp. (MCD)	4.56E+07
Coca-Cola Co. (KO)	2.63E+07
PepsiCo Inc. (PEP)	1.09E+07
Walmart Inc. (WMT)	-2.20E+07
Citigroup Inc. (C)	-3.40E+07
Wells Fargo & Co. (WFC)	-7.05E+07
JPMorgan Chase & Co. (JPM)	-4.57E+07
Apple Inc. (AAPL)	1.11E+07
IBM Corp. (IBM)	3.82E+07
Pfizer Inc. (PFE)	5.33E+06
Johnson & Johnson (JNJ)	3.62E+07
Exxon Mobil Corp. (XOM)	2.24E+06
Marathon Oil Corp. (MRO)	2.38E+07
Consolidated Edison Inc. (ED)	1.33E+07
AT&T Inc. (T)	2.74E+07
Verizon Communications Inc. (VZ)	2.34E+06
Newmont Corp. (NEM)	4.06E+06

Table 34: Robust mean-variance optimization (CL=95%) for data from Jan 2011 to July 2011

Stocks	Weights
Ford Motor Co. (F)	-5.02E+05
Caterpillar Inc. (CAT)	1.30E-01
Walt Disney Co. (DIS)	-1.14E-02
McDonald's Corp. (MCD)	5.24E+05
Coca-Cola Co. (KO)	4.45E+05
PepsiCo Inc. (PEP)	1.64E-02
Walmart Inc. (WMT)	-2.14E-01
Citigroup Inc. (C)	-8.45E+04
Wells Fargo & Co. (WFC)	-6.84E+05
JPMorgan Chase & Co. (JPM)	-2.62E+04
Apple Inc. (AAPL)	-6.19E-02
IBM Corp. (IBM)	4.67E-02
Pfizer Inc. (PFE)	1.16E-01
Johnson & Johnson (JNJ)	-4.29E-02

Exxon Mobil Corp. (XOM)	-5.10E-02
Marathon Oil Corp. (MRO)	8.84E-01
Consolidated Edison Inc. (ED)	6.09E-02
AT&T Inc. (T)	3.28E+05
Verizon Communications Inc. (VZ)	1.71E-01
Newmont Corp. (NEM)	-2.71E-01

Table 35: Robust mean-variance optimization (CL=90%) for data from Jan 2011 to July 2011

Stocks	Weights
Ford Motor Co. (F)	-9.22E+04
Caterpillar Inc. (CAT)	3.89E-01
Walt Disney Co. (DIS)	-9.00E-02
McDonald's Corp. (MCD)	9.62E+04
Coca-Cola Co. (KO)	8.17E+04
PepsiCo Inc. (PEP)	7.48E-02
Walmart Inc. (WMT)	-3.59E-01
Citigroup Inc. (C)	-1.55E+04
Wells Fargo & Co. (WFC)	-1.26E+05
JPMorgan Chase & Co. (JPM)	-4.81E+03
Apple Inc. (AAPL)	-1.49E-01
IBM Corp. (IBM)	2.78E-01
Pfizer Inc. (PFE)	2.82E-01
Johnson & Johnson (JNJ)	-8.51E-02
Exxon Mobil Corp. (XOM)	-1.29E-01
Marathon Oil Corp. (MRO)	1.23E+00
Consolidated Edison Inc. (ED)	1.02E-01
AT&T Inc. (T)	6.02E+04
Verizon Communications Inc. (VZ)	4.00E-01
Newmont Corp. (NEM)	-4.35E-01

Table 36: Risk Parity optimization with no short selling for data from January 2011 to July 2011

Stocks	Weights
Ford Motor Co. (F)	0.0499
Caterpillar Inc. (CAT)	0.0499
Walt Disney Co. (DIS)	0.0499
McDonald's Corp. (MCD)	0.0499
Coca-Cola Co. (KO)	0.0499
PepsiCo Inc. (PEP)	0.0499
Walmart Inc. (WMT)	0.0499

Citigroup Inc. (C)	0.0499
Wells Fargo & Co. (WFC)	0.0499
JPMorgan Chase & Co. (JPM)	0.0499
Apple Inc. (AAPL)	0.0499
IBM Corp. (IBM)	0.0499
Pfizer Inc. (PFE)	0.05
Johnson & Johnson (JNJ)	0.05
Exxon Mobil Corp. (XOM)	0.05
Marathon Oil Corp. (MRO)	0.05
Consolidated Edison Inc. (ED)	0.05
AT&T Inc. (T)	0.05
Verizon Communications Inc. (VZ)	0.05
Newmont Corp. (NEM)	0.05

Table 37: Market Capitalizations of July 2011 [4]

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	\$46.37	0.016723
Caterpillar Inc. (CAT)	\$63.66	0.022958
Walt Disney Co. (DIS)	\$72.99	0.026323
McDonald's Corp. (MCD)	\$89.72	0.032356
Coca-Cola Co. (KO)	\$155.69	0.056147
PepsiCo Inc. (PEP)	\$101.35	0.03655
Walmart Inc. (WMT)	\$183.03	0.066007
Citigroup Inc. (C)	\$111.97	0.04038
Wells Fargo & Co. (WFC)	\$147.77	0.053291
JPMorgan Chase & Co. (JPM)	\$160.73	0.057965
Apple Inc. (AAPL)	\$362.01	0.130554
IBM Corp. (IBM)	\$217.17	0.078319
Pfizer Inc. (PFE)	\$152.08	0.054846
Johnson & Johnson (JNJ)	\$177.59	0.064045
Exxon Mobil Corp. (XOM)	\$393.05	0.141748
Marathon Oil Corp. (MRO)	\$22.05	0.007952
Consolidated Edison Inc. (ED)	\$15.38	0.005547
AT&T Inc. (T)	\$173.27	0.062487
Verizon Communications Inc. (VZ)	\$99.89	0.036024
Newmont Corp. (NEM)	\$27.11	0.009777

Appendix Part 2 b) – January 2011 to August 2011

Table 38: Sample Mean for each stock for data from Jan 2011 to Aug 2011

Stocks	Sample Mean
Ford Motor Co. (F)	-4.90E-02
Caterpillar Inc. (CAT)	-5.77E-03
Walt Disney Co. (DIS)	-1.64E-02
McDonald's Corp. (MCD)	3.31E-02
Coca-Cola Co. (KO)	1.87E-02
PepsiCo Inc. (PEP)	4.64E-03
Walmart Inc. (WMT)	-3.80E-03
Citigroup Inc. (C)	-5.81E-02
Wells Fargo & Co. (WFC)	-2.84E-02
JPMorgan Chase & Co. (JPM)	-2.31E-02
Apple Inc. (AAPL)	1.99E-02
IBM Corp. (IBM)	1.09E-02
Pfizer Inc. (PFE)	1.14E-02
Johnson & Johnson (JNJ)	1.87E-02
Exxon Mobil Corp. (XOM)	-8.79E-03
Marathon Oil Corp. (MRO)	2.75E-03
Consolidated Edison Inc. (ED)	2.25E-02
AT&T Inc. (T)	1.10E-02
Verizon Communications Inc. (VZ)	6.30E-03
Newmont Corp. (NEM)	2.10E-02

Table 39: Sample Variance for each stock for data from Jan 2011 to Aug 2011

Stocks	Sample Variance
Ford Motor Co. (F)	0.002277
Caterpillar Inc. (CAT)	0.00424
Walt Disney Co. (DIS)	0.004734
McDonald's Corp. (MCD)	2.11E-04
Coca-Cola Co. (KO)	0.000271
PepsiCo Inc. (PEP)	0.00213
Walmart Inc. (WMT)	0.001476
Citigroup Inc. (C)	0.004998
Wells Fargo & Co. (WFC)	0.000818
JPMorgan Chase & Co. (JPM)	0.001241
Apple Inc. (AAPL)	0.00389
IBM Corp. (IBM)	0.001111
Pfizer Inc. (PFE)	0.002098
Johnson & Johnson (JNJ)	0.00209

Exxon Mobil Corp. (XOM)	0.001947
Marathon Oil Corp. (MRO)	0.004415
Consolidated Edison Inc. (ED)	0.000737
AT&T Inc. (T)	0.001595
Verizon Communications Inc. (VZ)	0.000829
Newmont Corp. (NEM)	0.003182

Table 40: Sample Covariance for each stock for data from Jan 2011 to Aug 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.002277	0.001811	0.000737	-0.00022	6.85E-05	0.001848	0.000967	0.001779	-0.0007	0.000395	-0.00139	0.0002672	0.001492	0.001318	0.000974	0.001475	0.000104	0.001536	0.000277	-5.96E-05
'CAT.csv'	0.001811	0.00424	0.002611	-0.00066	0.0005042	0.00092	-0.0005	0.003136	0.000137	0.001468	-0.00104	0.0005065	0.001736	0.000228	0.002057	0.003211	-0.00056	0.002091	0.001207	-0.00087
'DIS.csv'	0.000737	0.002611	0.004734	-2.98E-04	-0.000189	-0.00045	-0.00137	2.38E-03	0.000752	0.002289	0.001423	8.70E-04	0.001615	0.000618	0.002661	0.003873	-0.00094	0.001076	0.000341	-0.0012
'MCD.csv'	-0.00022	-0.00066	-0.0003	2.11E-04	-1.14E-04	7.31E-05	-1.78E-05	-4.90E-04	-0.00011	-0.00025	-0.00017	-2.68E-04	-8.25E-05	0.000263	-0.00021	-0.00059	0.000236	-0.00031	-9.43E-05	0.000231
'KO.csv'	6.85E-05	0.000504	-0.00019	-1.14E-04	2.71E-04	8.35E-05	6.23E-05	-1.82E-04	-8.84E-05	1.87E-05	-0.00024	-1.65E-04	0.000146	-0.00021	-2.95E-05	-4.56E-05	0.000137	0.000222	0.000353	0.000385
'PEP.csv'	0.001848	0.00092	-0.00045	7.31E-05	8.35E-05	0.00213	0.000952	6.80E-04	-0.00089	-0.00035	-0.00234	-4.85E-04	0.001332	0.001348	0.000227	0.000169	0.000647	0.001185	4.33E-04	0.000313
'WMT.csv'	0.000967	-0.0005	-0.00137	-1.78E-05	6.23E-05	0.000952	0.001476	-2.56E-04	-0.00086	-0.0005	-0.00037	1.08E-04	5.53E-06	0.000719	-0.00044	-0.00086	0.000415	0.000143	-0.00034	0.001058
'C.csv'	0.001779	0.003136	0.002375	-4.90E-04	-1.82E-04	0.00068	-0.00026	5.00E-03	5.54E-05	0.001262	-0.00029	1.61E-03	0.000392	0.000935	0.002251	0.002689	-0.0012	0.001171	-5.58E-05	-0.00164
'WFC.csv'	-0.0007	0.000137	0.000752	-1.14E-04	-8.84E-05	-0.00089	-0.00086	5.54E-05	0.000818	0.000287	0.000622	1.54E-04	-0.00018	-0.00098	-8.08E-06	0.000853	-0.00052	-5.94E-05	1.16E-05	-0.00121
'JPM.csv'	0.000395	0.001468	0.002289	-2.52E-04	1.87E-05	-0.00035	-0.0005	1.26E-03	2.87E-04	0.001241	0.001033	6.11E-04	0.000655	2.39E-04	0.001386	0.001877	-5.11E-04	0.000507	0.00016	-2.59E-04
'AAPL.csv'	-0.00139	-0.00104	0.001423	-1.69E-04	-2.36E-04	-0.00234	-0.00037	-2.93E-04	0.000622	0.001033	0.00389	1.25E-03	-0.00127	-6.46E-04	0.00047	0.000399	-8.71E-04	-0.0013	-0.001	3.61E-04
'IBM.csv'	0.000267	0.000506	0.00087	-2.68E-04	-1.65E-04	-0.00049	0.000108	1.61E-03	0.000154	0.000611	0.00125	1.11E-03	-0.00047	4.34E-05	0.000699	0.000899	-7.42E-04	-5.65E-05	-0.00054	-4.69E-04
'PFE.csv'	0.001492	0.001736	0.001615	-8.25E-05	1.46E-04	0.001332	5.53E-06	3.92E-04	-0.00018	0.000655	-0.00127	-4.74E-04	0.002098	8.19E-04	0.000951	0.00188	3.15E-04	0.00155	0.000803	-2.01E-04
'JNJ.csv'	0.001318	0.000228	0.000618	2.63E-04	-2.08E-04	0.001348	0.000719	9.35E-04	-0.00098	0.000239	-0.00065	4.34E-05	0.000819	2.09E-03	0.000977	-4.34E-05	4.68E-04	0.000291	-0.00014	1.06E-03
'XOM.csv'	0.000974	0.002057	0.002661	-2.07E-04	-2.95E-05	0.000227	-0.00044	2.25E-03	-8.08E-06	0.001386	0.00047	6.99E-04	0.000951	9.77E-04	0.001947	0.002075	-4.64E-04	0.000761	0.000242	-1.73E-04
'MRO.csv'	0.001475	0.003211	0.003873	-5.91E-04	-4.56E-05	0.000169	-0.00086	2.69E-03	0.000853	0.001877	0.000399	8.99E-04	0.00188	-4.34E-05	0.002075	0.004415	-1.08E-03	0.001905	0.000491	-2.17E-03
'ED.csv'	0.000104	-0.00056	-0.00094	2.36E-04	1.37E-04	0.000647	0.000415	-1.20E-03	-0.00052	-0.00051	-0.00087	-7.42E-04	0.000315	4.68E-04	-0.00046	-0.00108	7.37E-04	-4.14E-05	0.000259	1.04E-03
'T.csv'	0.001536	0.002091	0.001076	-3.07E-04	2.22E-04	0.001185	0.000143	1.17E-03	-5.94E-05	0.000507	-0.0013	-5.65E-05	0.00155	2.91E-04	0.000761	0.001905	-4.14E-05	0.001595	0.000695	-6.89E-04
'VZ.csv'	0.000277	0.001207	0.000341	-9.43E-05	3.53E-04	0.000433	-0.00034	-5.58E-05	1.16E-05	0.00016	-0.001	-5.38E-04	0.000803	-1.41E-04	0.000242	0.000491	2.59E-04	0.000695	0.000829	9.08E-05
'NEM.csv'	-5.96E-05	-0.00087	-0.0012	2.31E-04	3.85E-04	0.000313	0.001058	-1.64E-03	-0.00121	-0.00026	0.000361	-4.69E-04	-0.0002	1.06E-03	-0.00017	-0.000217	1.04E-03	-0.00069	9.08E-05	3.18E-03

Table 41: Mean-variance optimization (MVO) for data from Jan 2011 to Aug 2011

Stocks	Weights
Ford Motor Co. (F)	-7.44E+07
Caterpillar Inc. (CAT)	2.95E+07
Walt Disney Co. (DIS)	-2.27E+07
McDonald's Corp. (MCD)	4.17E+07
Coca-Cola Co. (KO)	1.88E+07
PepsiCo Inc. (PEP)	1.13E+07
Walmart Inc. (WMT)	-1.65E+07
Citigroup Inc. (C)	-2.12E+07
Wells Fargo & Co. (WFC)	-6.86E+07
JPMorgan Chase & Co. (JPM)	-4.59E+07
Apple Inc. (AAPL)	1.64E+07
IBM Corp. (IBM)	4.85E+07
Pfizer Inc. (PFE)	3.52E+06
Johnson & Johnson (JNJ)	3.45E+07
Exxon Mobil Corp. (XOM)	8.40E+05
Marathon Oil Corp. (MRO)	3.83E+07
Consolidated Edison Inc. (ED)	2.80E+06
AT&T Inc. (T)	3.05E+07
Verizon Communications Inc. (VZ)	-1.00E+07
Newmont Corp. (NEM)	-1.73E+07

Table 42: Robust mean-variance optimization (CL=95%) for data from Jan 2011 to Aug 2011

Stocks	Weights
Ford Motor Co. (F)	-5.86E+00
Caterpillar Inc. (CAT)	1.31E-13
Walt Disney Co. (DIS)	-6.72E-14
McDonald's Corp. (MCD)	6.73E+00
Coca-Cola Co. (KO)	2.23E-11
PepsiCo Inc. (PEP)	-3.48E-13
Walmart Inc. (WMT)	-1.16E-13
Citigroup Inc. (C)	2.07E-13
Wells Fargo & Co. (WFC)	-6.70E+00
JPMorgan Chase & Co. (JPM)	-8.21E-13
Apple Inc. (AAPL)	-1.13E-13
IBM Corp. (IBM)	1.71E+00
Pfizer Inc. (PFE)	1.45E-13
Johnson & Johnson (JNJ)	4.97E-14
Exxon Mobil Corp. (XOM)	-6.74E-14
Marathon Oil Corp. (MRO)	9.28E-01

Consolidated Edison Inc. (ED)	-4.01E-13
AT&T Inc. (T)	4.19E+00
Verizon Communications Inc. (VZ)	-3.72E-13
Newmont Corp. (NEM)	-1.09E-13

Table 43: Robust mean-variance optimization (CL=90%) for data from Jan 2011 to Aug 2011

Stocks	Weights
Ford Motor Co. (F)	-9.28E+04
Caterpillar Inc. (CAT)	-7.70E-03
Walt Disney Co. (DIS)	-3.53E-02
McDonald's Corp. (MCD)	6.89E+04
Coca-Cola Co. (KO)	-1.10E-01
PepsiCo Inc. (PEP)	1.87E-04
Walmart Inc. (WMT)	3.03E-02
Citigroup Inc. (C)	-2.11E+03
Wells Fargo & Co. (WFC)	-9.57E+04
JPMorgan Chase & Co. (JPM)	-4.10E+04
Apple Inc. (AAPL)	9.77E-02
IBM Corp. (IBM)	5.39E+04
Pfizer Inc. (PFE)	1.71E-01
Johnson & Johnson (JNJ)	-1.37E-01
Exxon Mobil Corp. (XOM)	-5.12E-01
Marathon Oil Corp. (MRO)	3.42E+04
Consolidated Edison Inc. (ED)	-1.83E-01
AT&T Inc. (T)	7.47E+04
Verizon Communications Inc. (VZ)	-3.05E-01
Newmont Corp. (NEM)	-2.60E+01

Table 44: Risk Parity optimization with no short selling for data from January 2011 to August 2011

Stocks	Weights
Ford Motor Co. (F)	0.05
Caterpillar Inc. (CAT)	0.05
Walt Disney Co. (DIS)	0.05
McDonald's Corp. (MCD)	0.05
Coca-Cola Co. (KO)	0.05
PepsiCo Inc. (PEP)	0.05
Walmart Inc. (WMT)	0.05

Citigroup Inc. (C)	0.05
Wells Fargo & Co. (WFC)	0.05
JPMorgan Chase & Co. (JPM)	0.05
Apple Inc. (AAPL)	0.05
IBM Corp. (IBM)	0.0499
Pfizer Inc. (PFE)	0.05
Johnson & Johnson (JNJ)	0.05
Exxon Mobil Corp. (XOM)	0.05
Marathon Oil Corp. (MRO)	0.05
Consolidated Edison Inc. (ED)	0.05
AT&T Inc. (T)	0.05
Verizon Communications Inc. (VZ)	0.05
Newmont Corp. (NEM)	0.05

Table 45: Market Capitalizations of August 2011[4]

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	\$42.25	0.015833
Caterpillar Inc. (CAT)	\$58.79	0.022031
Walt Disney Co. (DIS)	\$63.21	0.023688
McDonald's Corp. (MCD)	\$93.28	0.034956
Coca-Cola Co. (KO)	\$161.76	0.060619
PepsiCo Inc. (PEP)	\$101.96	0.038209
Walmart Inc. (WMT)	\$184.70	0.069215
Citigroup Inc. (C)	\$90.60	0.033952
Wells Fargo & Co. (WFC)	\$137.80	0.05164
JPMorgan Chase & Co. (JPM)	\$146.44	0.054878
Apple Inc. (AAPL)	\$356.77	0.133698
IBM Corp. (IBM)	\$205.30	0.076935
Pfizer Inc. (PFE)	\$148.08	0.055492
Johnson & Johnson (JNJ)	\$180.31	0.06757
Exxon Mobil Corp. (XOM)	\$359.89	0.134867
Marathon Oil Corp. (MRO)	\$19.22	0.007203
Consolidated Edison Inc. (ED)	\$16.46	0.006168
AT&T Inc. (T)	\$168.77	0.063246
Verizon Communications Inc. (VZ)	\$102.36	0.038359
Newmont Corp. (NEM)	\$30.53	0.011441

Appendix Part 2 b) – January 2011 to September 2011

Table 46: Sample Mean for each stock for data from Jan 2011 to Sept 2011

Stocks	Sample Mean
Ford Motor Co. (F)	-5.92E-02
Caterpillar Inc. (CAT)	-2.86E-02
Walt Disney Co. (DIS)	-2.86E-02
McDonald's Corp. (MCD)	2.54E-02
Coca-Cola Co. (KO)	1.20E-02
PepsiCo Inc. (PEP)	-8.53E-04
Walmart Inc. (WMT)	-6.36E-03
Citigroup Inc. (C)	-7.27E-02
Wells Fargo & Co. (WFC)	-3.43E-02
JPMorgan Chase & Co. (JPM)	-4.49E-02
Apple Inc. (AAPL)	1.63E-02
IBM Corp. (IBM)	1.17E-02
Pfizer Inc. (PFE)	1.41E-03
Johnson & Johnson (JNJ)	1.23E-02
Exxon Mobil Corp. (XOM)	-1.00E-02
Marathon Oil Corp. (MRO)	-2.24E-02
Consolidated Edison Inc. (ED)	2.15E-02
AT&T Inc. (T)	9.81E-03
Verizon Communications Inc. (VZ)	7.69E-03
Newmont Corp. (NEM)	1.97E-02

Table 47: Sample Variance for each stock for data from Jan 2011 to Sept 2011

Stocks	Sample Variance
Ford Motor Co. (F)	2.72E-03
Caterpillar Inc. (CAT)	7.36E-03
Walt Disney Co. (DIS)	5.20E-03
McDonald's Corp. (MCD)	6.01E-04
Coca-Cola Co. (KO)	5.46E-04
PepsiCo Inc. (PEP)	2.07E-03
Walmart Inc. (WMT)	1.34E-03
Citigroup Inc. (C)	5.87E-03
Wells Fargo & Co. (WFC)	9.62E-04
JPMorgan Chase & Co. (JPM)	4.44E-03
Apple Inc. (AAPL)	3.50E-03
IBM Corp. (IBM)	9.77E-04

Pfizer Inc. (PFE)	2.53E-03
Johnson & Johnson (JNJ)	2.11E-03
Exxon Mobil Corp. (XOM)	1.71E-03
Marathon Oil Corp. (MRO)	8.29E-03
Consolidated Edison Inc. (ED)	6.52E-04
AT&T Inc. (T)	1.41E-03
Verizon Communications Inc. (VZ)	7.39E-04
Newmont Corp. (NEM)	2.80E-03

Table 48: Sample Covariance for each stock for data from Jan 2011 to Sept 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.002716	3.21E-03	0.001518	0.000354	5.33E-04	2.01E-03	0.001028	0.002596	-0.00019	0.001903	-0.00095	0.0001777	0.002017	1.60E-03	0.000941	0.00308	1.63E-04	0.00143	0.000144	4.63E-05
'CAT.csv'	0.003211	7.36E-03	4.25E-03	0.000658	1.50E-03	1.68E-03	-3.11E-05	0.005079	0.001069	0.004784	-0.00033	0.000317	0.003117	1.21E-03	0.001999	0.006831	-3.26E-04	0.002022	0.000833	-5.39E-04
'DIS.csv'	0.001518	4.25E-03	0.005196	0.000402	4.05E-04	7.34E-05	-0.00098	0.003332	0.001168	3.88E-03	0.001557	0.0006935	0.00227	1.09E-03	0.002436	0.005548	-7.33E-04	0.001044	0.000179	-9.28E-04
'MCD.csv'	0.000354	6.58E-04	0.000402	0.000601	2.59E-04	3.60E-04	0.000122	0.00036	0.000221	9.61E-04	4.84E-05	-0.000277	0.000467	5.73E-04	-0.00011	0.000841	2.61E-04	-0.0002	-0.00016	2.76E-04
'KO.csv'	0.000533	1.50E-03	0.000405	0.000259	5.46E-04	3.28E-04	0.000173	0.00052	0.000199	1.03E-03	-3.72E-05	-0.000181	0.000593	1.13E-04	3.22E-05	0.001129	1.67E-04	0.00025	0.000245	4.01E-04
'PEP.csv'	0.002007	1.68E-03	7.34E-05	0.00036	3.28E-04	2.07E-03	0.000931	0.001156	-0.00055	5.32E-04	-0.0019	-0.000455	0.001549	1.42E-03	0.000246	0.001113	6.05E-04	0.001083	0.000326	3.27E-04
'WMT.csv'	0.001028	-3.11E-05	-0.00098	0.000122	1.73E-04	9.31E-04	0.001337	3.70E-05	-0.00065	-4.98E-05	-0.00026	8.00E-05	0.000184	7.43E-04	-0.00036	-0.0003	3.81E-04	0.000147	-0.00032	9.50E-04
'C.csv'	0.002596	5.08E-03	0.003332	0.00036	5.20E-04	1.16E-03	3.70E-05	0.005865	0.000655	3.34E-03	0.000115	0.0013319	0.001363	1.47E-03	0.002097	0.004922	-0.00095	0.001147	-0.00019	-0.00129
'WFC.csv'	-0.00019	1.07E-03	0.001168	0.000221	1.99E-04	-5.52E-04	-0.00065	0.000655	0.000962	1.16E-03	0.000695	0.0001018	0.000257	-5.90E-04	4.48E-05	0.001791	-0.00042	-2.12E-06	-4.76E-05	-0.001
'JPM.csv'	0.001903	4.78E-03	0.003881	0.000961	1.03E-03	5.32E-04	-4.98E-05	0.00334	0.00116	4.44E-03	0.00146	0.0004141	0.002103	1.18E-03	0.001404	0.005492	-0.00029	0.000627	-7.31E-05	-1.47E-05
'AAPL.csv'	-0.00095	-3.25E-04	0.001557	4.84E-05	-3.72E-05	-1.90E-03	-0.00026	0.000115	0.000695	1.46E-03	0.003496	0.001074	-0.00086	-4.04E-04	0.000443	0.000989	-0.00074	-0.0011	-0.00091	0.000351
'IBM.csv'	0.000178	3.17E-04	0.000693	-0.00028	-1.81E-04	-4.55E-04	8.00E-05	0.001332	0.000102	4.14E-04	0.001074	0.0009768	-0.00047	2.99E-06	0.000605	0.000648	-0.00066	-5.61E-05	-0.00046	-0.00042
'PFE.csv'	0.002017	3.12E-03	0.00227	0.000467	5.93E-04	1.55E-03	0.000184	0.001363	0.000257	2.10E-03	-0.00086	-0.00047	0.002534	1.16E-03	0.000919	0.003403	0.000347	0.001441	0.000606	-7.95E-05
'JNJ.csv'	0.001605	1.21E-03	0.001085	0.000573	1.13E-04	1.42E-03	0.000743	0.001466	-0.00059	1.18E-03	-0.0004	2.99E-06	0.00116	2.11E-03	0.00091	0.001078	0.000454	0.000308	-0.00019	0.000992
'XOM.csv'	0.000941	2.00E-03	0.002436	-0.00011	3.22E-05	2.46E-04	-0.00036	0.002097	4.48E-05	1.40E-03	0.000443	0.000605	0.000919	9.10E-04	0.001715	0.002036	-0.0004	0.000676	0.0002	-0.00014
'MRO.csv'	0.00308	6.83E-03	0.005548	0.000841	1.13E-03	1.11E-03	-0.0003	0.004922	0.001791	5.49E-03	0.000989	0.0006479	0.003403	1.08E-03	0.002036	0.008287	-0.00077	0.001878	0.000185	-0.00165
'ED.csv'	0.000163	-3.26E-04	-0.00073	0.000261	1.67E-04	6.05E-04	0.000381	-0.00095	-0.00042	-2.93E-04	-0.00074	-0.000655	0.000347	4.54E-04	-0.0004	-0.00077	0.000652	-2.78E-05	0.000216	0.000919
'T.csv'	0.00143	2.02E-03	0.001044	-0.0002	2.50E-04	1.08E-03	0.000147	0.001147	-2.12E-06	6.27E-04	-0.0011	-5.61E-05	0.001441	3.08E-04	0.000676	0.001878	-2.78E-05	0.001405	0.000597	-0.00059
'VZ.csv'	0.000144	8.33E-04	0.000179	-0.00016	2.45E-04	3.26E-04	-0.00032	-0.00019	-4.76E-05	-7.31E-05	-0.00091	-0.000464	0.000606	-1.85E-04	0.0002	0.000185	0.000216	0.000597	0.000739	6.60E-05
'NEM.csv'	4.63E-05	-0.00054	-0.00093	0.000276	0.0004011	0.000327	0.00095	-0.00129	-0.001	-1.47E-05	0.000351	-0.000418	-7.95E-05	9.92E-04	-0.00014	-0.00165	0.000919	-0.00059	6.60E-05	0.002797

Table 49: Mean-variance optimization (MVO) for data from Jan 2011 to Sept 2011

Stocks	Weights
Ford Motor Co. (F)	-3.68E+05
Caterpillar Inc. (CAT)	1.62E+05
Walt Disney Co. (DIS)	-1.23E+05
McDonald's Corp. (MCD)	2.26E+05
Coca-Cola Co. (KO)	9.86E+04
PepsiCo Inc. (PEP)	5.76E+04
Walmart Inc. (WMT)	-8.08E+04
Citigroup Inc. (C)	-1.00E+05
Wells Fargo & Co. (WFC)	-3.37E+05
JPMorgan Chase & Co. (JPM)	-1.95E+05
Apple Inc. (AAPL)	7.75E+04
IBM Corp. (IBM)	2.19E+05
Pfizer Inc. (PFE)	1.58E+04
Johnson & Johnson (JNJ)	1.78E+05
Exxon Mobil Corp. (XOM)	-2.48E+04
Marathon Oil Corp. (MRO)	2.09E+05
Consolidated Edison Inc. (ED)	1.52E+04
AT&T Inc. (T)	1.23E+05
Verizon Communications Inc. (VZ)	-7.17E+04
Newmont Corp. (NEM)	-8.13E+04

Table 50: Robust mean-variance optimization (CL=95%) for data from Jan 2011 to Sept 2011

Stocks	Weights
Ford Motor Co. (F)	2.69E-02
Caterpillar Inc. (CAT)	4.74E-02
Walt Disney Co. (DIS)	4.42E-02
McDonald's Corp. (MCD)	6.43E-02
Coca-Cola Co. (KO)	5.82E-02
PepsiCo Inc. (PEP)	5.31E-02
Walmart Inc. (WMT)	4.78E-02
Citigroup Inc. (C)	2.18E-02
Wells Fargo & Co. (WFC)	3.38E-02
JPMorgan Chase & Co. (JPM)	3.66E-02
Apple Inc. (AAPL)	5.88E-02
IBM Corp. (IBM)	5.64E-02
Pfizer Inc. (PFE)	5.70E-02
Johnson & Johnson (JNJ)	6.04E-02
Exxon Mobil Corp. (XOM)	4.90E-02
Marathon Oil Corp. (MRO)	5.09E-02

Consolidated Edison Inc. (ED)	6.06E-02
AT&T Inc. (T)	5.80E-02
Verizon Communications Inc. (VZ)	5.44E-02
Newmont Corp. (NEM)	6.05E-02

Table 51: Robust mean-variance optimization (CL=90%) for data from Jan 2011 to Sept 2011

Stocks	Weights
Ford Motor Co. (F)	2.69E-02
Caterpillar Inc. (CAT)	4.74E-02
Walt Disney Co. (DIS)	4.42E-02
McDonald's Corp. (MCD)	6.43E-02
Coca-Cola Co. (KO)	5.82E-02
PepsiCo Inc. (PEP)	5.31E-02
Walmart Inc. (WMT)	4.78E-02
Citigroup Inc. (C)	2.18E-02
Wells Fargo & Co. (WFC)	3.38E-02
JPMorgan Chase & Co. (JPM)	3.66E-02
Apple Inc. (AAPL)	5.88E-02
IBM Corp. (IBM)	5.64E-02
Pfizer Inc. (PFE)	5.70E-02
Johnson & Johnson (JNJ)	6.04E-02
Exxon Mobil Corp. (XOM)	4.90E-02
Marathon Oil Corp. (MRO)	5.09E-02
Consolidated Edison Inc. (ED)	6.06E-02
AT&T Inc. (T)	5.80E-02
Verizon Communications Inc. (VZ)	5.44E-02
Newmont Corp. (NEM)	6.05E-02

Table 52: Risk Parity optimization with no short selling for data from January 2011 to September 2011

Stocks	Weights
Ford Motor Co. (F)	0.05
Caterpillar Inc. (CAT)	0.05
Walt Disney Co. (DIS)	0.05
McDonald's Corp. (MCD)	0.0499
Coca-Cola Co. (KO)	0.0499
PepsiCo Inc. (PEP)	0.05
Walmart Inc. (WMT)	0.05

Citigroup Inc. (C)	0.05
Wells Fargo & Co. (WFC)	0.05
JPMorgan Chase & Co. (JPM)	0.0499
Apple Inc. (AAPL)	0.05
IBM Corp. (IBM)	0.0499
Pfizer Inc. (PFE)	0.05
Johnson & Johnson (JNJ)	0.0499
Exxon Mobil Corp. (XOM)	0.05
Marathon Oil Corp. (MRO)	0.0499
Consolidated Edison Inc. (ED)	0.05
AT&T Inc. (T)	0.0499
Verizon Communications Inc. (VZ)	0.05
Newmont Corp. (NEM)	0.0499

Table 53: Market Capitalizations of September 2011 [4]

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	\$36.74	0.014428
Caterpillar Inc. (CAT)	\$47.70	0.018733
Walt Disney Co. (DIS)	\$55.97	0.02198
McDonald's Corp. (MCD)	\$90.60	0.03558
Coca-Cola Co. (KO)	\$155.12	0.060918
PepsiCo Inc. (PEP)	\$97.96	0.03847
Walmart Inc. (WMT)	\$178.88	0.070249
Citigroup Inc. (C)	\$74.75	0.029356
Wells Fargo & Co. (WFC)	\$127.34	0.050008
JPMorgan Chase & Co. (JPM)	\$117.43	0.046117
Apple Inc. (AAPL)	\$353.50	0.138825
IBM Corp. (IBM)	\$208.84	0.082015
Pfizer Inc. (PFE)	\$137.94	0.054171
Johnson & Johnson (JNJ)	\$174.53	0.068541
Exxon Mobil Corp. (XOM)	\$353.13	0.13868
Marathon Oil Corp. (MRO)	\$15.40	0.006048
Consolidated Edison Inc. (ED)	\$16.69	0.006554
AT&T Inc. (T)	\$169.00	0.066369
Verizon Communications Inc. (VZ)	\$104.16	0.040905
Newmont Corp. (NEM)	\$30.69	0.012052

Appendix Part 2 b) – January 2011 to October 2011

Table 54: Sample Mean for each stock for data from Jan 2011 to Oct 2011

Stocks	Sample Mean
Ford Motor Co. (F)	-2.95E-02
Caterpillar Inc. (CAT)	6.37E-03
Walt Disney Co. (DIS)	-8.06E-03
McDonald's Corp. (MCD)	2.89E-02
Coca-Cola Co. (KO)	1.19E-02
PepsiCo Inc. (PEP)	1.13E-03
Walmart Inc. (WMT)	4.67E-03
Citigroup Inc. (C)	-3.87E-02
Wells Fargo & Co. (WFC)	-2.23E-02
JPMorgan Chase & Co. (JPM)	-2.17E-02
Apple Inc. (AAPL)	2.13E-02
IBM Corp. (IBM)	1.66E-02
Pfizer Inc. (PFE)	1.12E-02
Johnson & Johnson (JNJ)	1.22E-02
Exxon Mobil Corp. (XOM)	-5.73E-04
Marathon Oil Corp. (MRO)	3.01E-03
Consolidated Edison Inc. (ED)	2.08E-02
AT&T Inc. (T)	1.41E-02
Verizon Communications Inc. (VZ)	8.94E-03
Newmont Corp. (NEM)	2.43E-02

Table 55: Sample Variance for each stock for data from Jan 2011 to Oct 2011

Stocks	Sample Variance
Ford Motor Co. (F)	9.46E-03
Caterpillar Inc. (CAT)	1.63E-02
Walt Disney Co. (DIS)	8.00E-03
McDonald's Corp. (MCD)	6.35E-04
Coca-Cola Co. (KO)	4.86E-04
PepsiCo Inc. (PEP)	1.88E-03
Walmart Inc. (WMT)	2.16E-03
Citigroup Inc. (C)	1.44E-02
Wells Fargo & Co. (WFC)	2.02E-03
JPMorgan Chase & Co. (JPM)	8.26E-03
Apple Inc. (AAPL)	3.31E-03

IBM Corp. (IBM)	1.06E-03
Pfizer Inc. (PFE)	3.02E-03
Johnson & Johnson (JNJ)	1.88E-03
Exxon Mobil Corp. (XOM)	2.24E-03
Marathon Oil Corp. (MRO)	1.25E-02
Consolidated Edison Inc. (ED)	5.84E-04
AT&T Inc. (T)	1.40E-03
Verizon Communications Inc. (VZ)	6.69E-04
Newmont Corp. (NEM)	2.66E-03

Table 56: Sample Covariance for each stock for data from Jan 2011 to Oct 2011

Assets	'F.csv'	'CAT.csv'	'DIS.csv'	'MCD.csv'	'KO.csv'	'PEP.csv'	'WMT.csv'	'C.csv'	'WFC.csv'	'JPM.csv'	'AAPL.csv'	'IBM.csv'	'PFE.csv'	'JNJ.csv'	'XOM.csv'	'MRO.csv'	'ED.csv'	'T.csv'	'VZ.csv'	'NEM.csv'
'F.csv'	0.009459	1.12E-02	0.006233	0.001157	0.0004531	2.25E-03	0.003531	0.010371	2.69E-03	0.007208	0.000345	0.0013216	0.004113	1.39E-03	0.003085	0.008768	-2.88E-05	0.002299	0.000423	0.001149
'CAT.csv'	1.12E-02	1.63E-02	0.009533	0.001578	0.0013126	2.05E-03	0.003059	0.014024	4.33E-03	0.010759	0.001118	0.001654	0.005506	0.001037	0.004428	0.013183	-0.00049	0.00301	0.001089	0.000827
'DIS.csv'	6.23E-03	9.53E-03	0.008003	0.000941	0.000346	3.91E-04	0.000946	0.008551	3.02E-03	0.007274	0.002211	0.001423	0.003626	0.00094	0.003723	0.009111	-0.00077	0.001641	0.000364	-5.69E-05
'MCD.csv'	1.16E-03	1.58E-03	0.000941	0.000635	0.0002279	3.76E-04	4.22E-04	0.001283	5.38E-04	0.001514	0.000186	-0.000107	0.000692	0.000505	0.000167	0.001468	0.000211	-5.79E-05	-0.0001	0.000378
'KO.csv'	4.53E-04	1.31E-03	0.000346	0.000228	0.0004856	2.90E-04	1.46E-04	0.000439	1.68E-04	0.000903	-3.66E-05	-0.000164	0.00052	0.0001	2.21E-05	0.000986	0.000149	0.000219	0.000216	0.000353
'PEP.csv'	2.25E-03	2.05E-03	0.000391	0.000376	0.0002904	1.88E-03	1.00E-03	0.001566	-2.99E-04	0.000841	-0.00161	-0.000327	0.001532	0.001263	0.000369	0.001392	0.000526	0.001031	0.000309	0.000364
'WMT.csv'	3.53E-03	3.06E-03	0.000946	0.000422	0.0001465	1.00E-03	2.16E-03	0.003029	4.86E-04	0.002006	0.00021	0.0005034	0.001025	0.000647	0.000513	0.001972	0.000275	0.000513	-0.00017	0.001256
'C.csv'	1.04E-02	1.40E-02	0.008551	0.001283	0.0004386	1.57E-03	3.03E-03	0.014444	3.86E-03	0.009284	0.001467	0.0025158	0.003868	0.001263	0.004437	0.011277	-0.00104	0.002197	0.000168	0.00012
'WFC.csv'	2.69E-03	4.33E-03	0.003022	0.000538	0.0001682	-2.99E-04	4.86E-04	0.003859	2.02E-03	0.003273	0.001103	0.0005633	0.001172	-0.00054	0.000953	0.004042	-0.00044	0.000416	7.77E-05	-0.00044
'JPM.csv'	7.21E-03	1.08E-02	0.007274	0.001514	0.0009029	8.41E-04	2.01E-03	0.009284	3.27E-03	0.008264	0.002232	0.0012793	0.003686	0.001022	0.003008	0.009604	-0.0004	0.001363	0.000166	0.000854
'AAPL.csv'	3.45E-04	1.12E-03	0.002211	0.000186	-3.66E-05	-1.61E-03	2.10E-04	0.001467	1.10E-03	0.002232	0.003309	0.0011517	-0.00037	-0.00036	0.000774	0.0019	-0.00068	-0.00081	-0.00076	0.0005
'IBM.csv'	1.32E-03	1.65E-03	0.001423	-0.00011	-0.000164	-3.27E-04	5.03E-04	0.002516	5.63E-04	0.001279	0.001152	0.0010604	-3.44E-05	-3.19E-06	0.000909	0.001572	-0.00061	0.00012	-0.00036	-0.00019
'PFE.csv'	4.11E-03	5.51E-03	0.003626	0.000692	0.00052	1.53E-03	1.03E-03	0.003868	1.17E-03	0.003686	-0.00037	-3.44E-05	0.003017	0.001019	0.001557	0.00501	0.000251	0.001619	0.000636	0.000294
'JNJ.csv'	1.39E-03	1.04E-03	0.00094	0.000505	0.0001004	1.26E-03	6.47E-04	0.001263	-5.39E-04	0.001022	-0.00036	-3.19E-06	0.001019	0.001876	0.000798	0.000928	0.000405	0.000269	-0.00017	0.000877
'XOM.csv'	3.08E-03	4.43E-03	0.003723	0.000167	2.21E-05	3.69E-04	5.13E-04	0.004437	9.53E-04	0.003008	0.000774	0.000909	0.001557	0.000798	0.002242	0.003734	-0.00041	0.000929	0.000272	0.000229
'MRO.csv'	8.77E-03	1.32E-02	0.009111	0.001468	0.0009863	1.39E-03	1.97E-03	0.011277	4.04E-03	0.009604	0.0019	0.0015719	0.00501	0.000928	0.003734	0.012528	-0.00083	0.00255	0.000418	-0.00052
'ED.csv'	-2.88E-05	-4.95E-04	-0.00077	0.000211	0.000149	5.26E-04	2.75E-04	-0.00104	-4.40E-04	-0.0004	-0.00068	-0.000611	0.000251	0.000405	-0.00041	-0.00083	0.000584	-5.00E-05	0.000185	0.000789
'T.csv'	2.30E-03	3.01E-03	0.001641	-5.79E-05	0.0002193	1.03E-03	5.13E-04	0.002197	4.16E-04	0.001363	-0.00081	0.00012	0.001619	0.000269	0.000929	0.00255	-5.00E-05	0.001399	0.000574	-0.00036
'VZ.csv'	4.23E-04	1.09E-03	0.000364	-0.0001	0.0002165	3.09E-04	-1.73E-04	0.000168	7.77E-05	0.000166	-0.00076	-0.000363	0.000636	-0.00017	0.000272	0.000418	0.000185	0.000574	0.000669	0.000105
'NEM.csv'	1.15E-03	0.000827	-5.69E-05	0.000378	0.0003533	0.000364	1.26E-03	0.00012	-0.00044	0.000854	0.0005	-0.000189	0.000294	0.000877	0.000229	-0.00052	0.000789	-0.00036	0.000105	0.002661

Table 57: Mean-variance optimization (MVO) for data from Jan 2011 to Oct 2011

Stocks	Weights
Ford Motor Co. (F)	-1.06E+07
Caterpillar Inc. (CAT)	3.33E+07
Walt Disney Co. (DIS)	2.23E+06
McDonald's Corp. (MCD)	4.99E+07
Coca-Cola Co. (KO)	-2.86E+07
PepsiCo Inc. (PEP)	-1.93E+07
Walmart Inc. (WMT)	2.86E+06
Citigroup Inc. (C)	-6.01E+06
Wells Fargo & Co. (WFC)	-2.48E+07
JPMorgan Chase & Co. (JPM)	-4.24E+07
Apple Inc. (AAPL)	5.68E+06
IBM Corp. (IBM)	1.82E+07
Pfizer Inc. (PFE)	7.50E+06
Johnson & Johnson (JNJ)	-2.63E+06
Exxon Mobil Corp. (XOM)	-6.85E+06
Marathon Oil Corp. (MRO)	1.17E+07
Consolidated Edison Inc. (ED)	1.56E+07
AT&T Inc. (T)	2.65E+06
Verizon Communications Inc. (VZ)	-9.91E+06
Newmont Corp. (NEM)	1.37E+06

Table 58: Robust MVO (CL=95%) for data from Jan 2011 to Oct 2011

Stocks	Weights
Ford Motor Co. (F)	-2.68E-08
Caterpillar Inc. (CAT)	-1.21E-09
Walt Disney Co. (DIS)	-1.66E-09
McDonald's Corp. (MCD)	1.28E+00
Coca-Cola Co. (KO)	1.36E-09
PepsiCo Inc. (PEP)	-7.61E-10
Walmart Inc. (WMT)	-1.14E-09
Citigroup Inc. (C)	-1.41E-08
Wells Fargo & Co. (WFC)	-2.78E-01
JPMorgan Chase & Co. (JPM)	-1.08E-08
Apple Inc. (AAPL)	4.38E-10
IBM Corp. (IBM)	2.89E-10
Pfizer Inc. (PFE)	-9.64E-10
Johnson & Johnson (JNJ)	-6.94E-11
Exxon Mobil Corp. (XOM)	-1.82E-09
Marathon Oil Corp. (MRO)	-1.14E-09

Consolidated Edison Inc. (ED)	8.11E-09
AT&T Inc. (T)	-5.53E-10
Verizon Communications Inc. (VZ)	2.83E-10
Newmont Corp. (NEM)	2.54E-10

Table 59: Robust MVO (CL=90%) for data from Jan 2011 to Oct 2011

Stocks	Weights
Ford Motor Co. (F)	-3.19E-14
Caterpillar Inc. (CAT)	1.69E-14
Walt Disney Co. (DIS)	-1.17E-14
McDonald's Corp. (MCD)	1.75E+00
Coca-Cola Co. (KO)	-3.41E-14
PepsiCo Inc. (PEP)	-2.64E-14
Walmart Inc. (WMT)	9.53E-14
Citigroup Inc. (C)	8.50E-15
Wells Fargo & Co. (WFC)	-7.46E-01
JPMorgan Chase & Co. (JPM)	-5.79E-14
Apple Inc. (AAPL)	6.17E-15
IBM Corp. (IBM)	9.58E-14
Pfizer Inc. (PFE)	1.06E-14
Johnson & Johnson (JNJ)	-1.34E-14
Exxon Mobil Corp. (XOM)	1.57E-14
Marathon Oil Corp. (MRO)	8.13E-15
Consolidated Edison Inc. (ED)	-2.21E-14
AT&T Inc. (T)	1.81E-14
Verizon Communications Inc. (VZ)	6.71E-15
Newmont Corp. (NEM)	5.98E-14

Table 60: Risk Parity optimization with no short selling for data from January 2011 to October 2011

Stocks	Weights
Ford Motor Co. (F)	0.05
Caterpillar Inc. (CAT)	0.05
Walt Disney Co. (DIS)	0.0499
McDonald's Corp. (MCD)	0.05
Coca-Cola Co. (KO)	0.05
PepsiCo Inc. (PEP)	0.05
Walmart Inc. (WMT)	0.05

Citigroup Inc. (C)	0.05
Wells Fargo & Co. (WFC)	0.05
JPMorgan Chase & Co. (JPM)	0.05
Apple Inc. (AAPL)	0.05
IBM Corp. (IBM)	0.05
Pfizer Inc. (PFE)	0.0499
Johnson & Johnson (JNJ)	0.0499
Exxon Mobil Corp. (XOM)	0.0499
Marathon Oil Corp. (MRO)	0.0499
Consolidated Edison Inc. (ED)	0.0499
AT&T Inc. (T)	0.0499
Verizon Communications Inc. (VZ)	0.0499
Newmont Corp. (NEM)	0.0499

Table 61: Market Capitalizations of October 2011 [4]

Stocks	Market Capitalization (Billions USD)	Market Capitalization Weights
Ford Motor Co. (F)	\$44.38	0.016279
Caterpillar Inc. (CAT)	\$61.02	0.022383
Walt Disney Co. (DIS)	\$64.73	0.023743
McDonald's Corp. (MCD)	\$95.79	0.035137
Coca-Cola Co. (KO)	\$155.17	0.056918
PepsiCo Inc. (PEP)	\$98.41	0.036098
Walmart Inc. (WMT)	\$195.49	0.071707
Citigroup Inc. (C)	\$92.17	0.033809
Wells Fargo & Co. (WFC)	\$136.80	0.050179
JPMorgan Chase & Co. (JPM)	\$135.53	0.049714
Apple Inc. (AAPL)	\$376.22	0.138001
IBM Corp. (IBM)	\$217.60	0.079817
Pfizer Inc. (PFE)	\$150.26	0.055117
Johnson & Johnson (JNJ)	\$176.45	0.064723
Exxon Mobil Corp. (XOM)	\$379.68	0.13927
Marathon Oil Corp. (MRO)	\$18.58	0.006815
Consolidated Edison Inc. (ED)	\$16.94	0.006214
AT&T Inc. (T)	\$173.69	0.063711
Verizon Communications Inc. (VZ)	\$104.69	0.038401
Newmont Corp. (NEM)	\$32.62	0.011965