This report will be divided into several sections, each section corresponding to a particular model. A final section will be dedicated to monitoring portfolio performance. I selected sector, each from the S&P 500, for this project. Each sector consisted of 4 stocks. The sectors and stocks I selected for this project are the following:

- Money Center Banks
  - JP Morgan (JPM)
  - Wells Fargo (WFC)
  - Citigroup (C)
  - Goldman Sachs (GS)

- Oil and Gas
  - Shell (ADR)
  - Chevron and Texaco (CVX)
  - Exxon-Mobil (XOM)
  - Valero (VLO)

- Telecommunications and Wireless Services
  - Verizon (VZ)
  - AT&T (T)
  - Sprint (S)
  - T-Mobil (TMUS)

- Biotechnology
  - Amgen (AMGN)
  - Gilead Sciences (GILD)
  - Celgene Corporation (CELG)
  - Regeneron (REGN)

- Commercial Airlines
  - Delta Airlines (DAL)
  - United Airlines (UAL)
  - American Airlines (AAL)
  - Southwest Airlines (LUV)

- Software Applications and Services
  - Apple (AAPL)
  - Microsoft (MSFT)
  - Yahoo (YHOO)
  - Amazon (AMZN)

Part 1: The Classical Markowitz Model

Assuming short selling is allowed, optimizing the portfolio based on the Classical Markowitz Model yields the following result. I chose Rf = 0.001:

Model: no model specified. (indicating Classical Markowitz was used)
Expected return: 0.08980839
Risk estimate: 0.1247406

Portfolio allocation:

JPM	WFC	C	GS	ADR	CVX
0.24386655	0.77241269	-0.39738106	-0.03310107	0.33928853	3.26726082

XOM	VLO	VZ	T	S	TMUS
-1.80836481	-0.77089403	0.16824124	-1.09667946	0.13101953	-0.14963564

AMGN	GILD	CELG	REGN	DAL	UAL
0.24551888	0.60037347	-0.01958043	0.33413525	0.05833928	0.25694517

LUV	AAL	AAPL	MSFT	YHOO	AMZN
-1.07021172	-0.01205129	0.42054289	-1.35899565	0.25597640	0.62297445

Graphing this portfolio on the PPC with respect to the stocks that compose it, the following chart is produced:

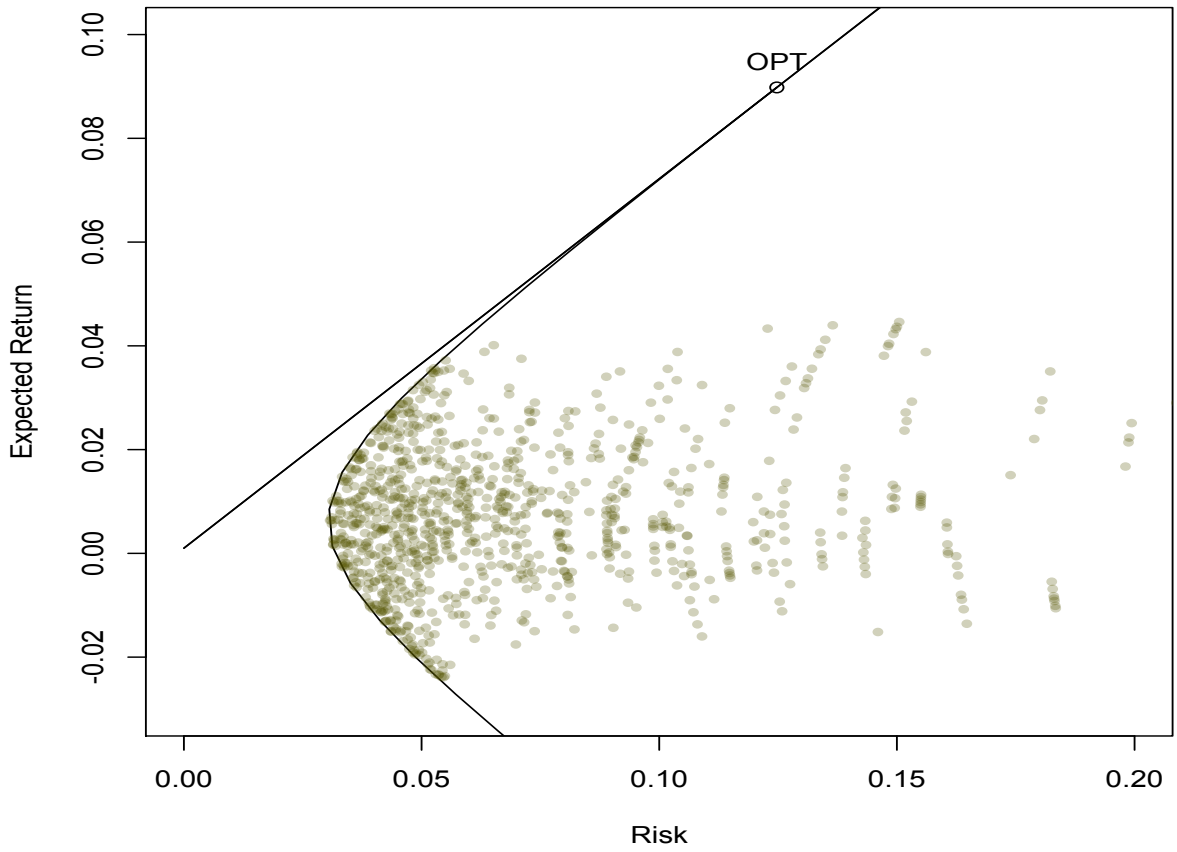

Figure 1

Figure 1 shows the PPC with the optimal portfolio as the point of tangency to the curve as well of a cloud of other possible portfolio allocations.

The next part requires tracing out the efficient frontier of the portfolio constructed in the previous part. Normally we could do this by choosing a second portfolio of another risk free asset, but it turns out that this can also be done very easily with the effFrontier parameter of the portPossCurve function in the stockPortfolio package. The following graph displays only the efficient frontier with the optimal portfolio clearly marked. Again, the Rf = 0.001:

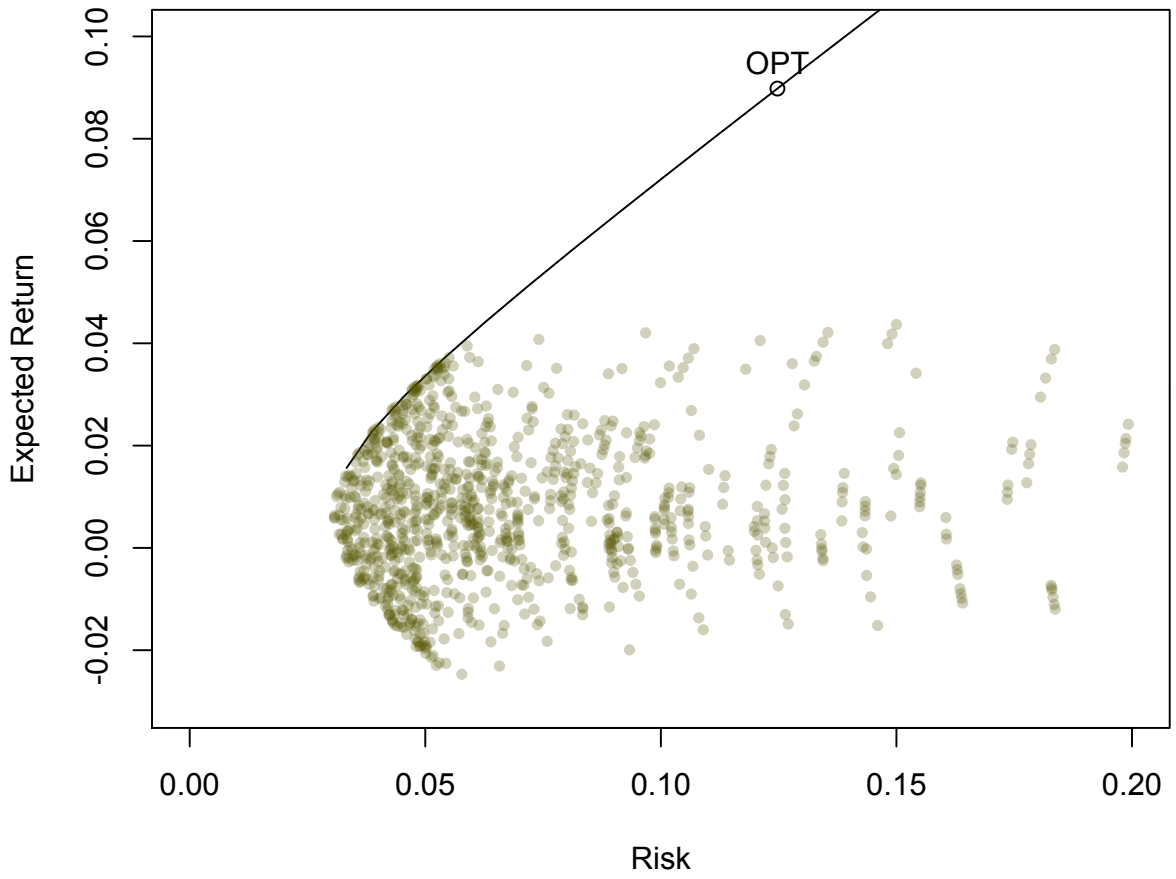

Figure 2

Notice that in Figure 2 half of the PPC is missing, which of course is to be expected as the efficient frontier only contains all portfolios with expected returns higher than the minimum risk portfolio.

Next we consider the risk and expected return of the equal allocation portfolio. Assuming each stock received 1/24 of the total allocation, the equal allocation portfolio yields the following results:

Equal Allocation Portfolio Expected Return: 0.009761762
Equal Allocation Portfolio Risk: 0.06323093

Note that while the equal allocation portfolio has considerably lower risk than the optimal portfolio, the expected return is rather pitiful. This of course is not unexpected seeing that low risk and low return often accompany one another.

Part 2: The Single Index Model

We now shift gears to the Single Index Model. For all SIM calculations, I chose to adjust all the betas using the Vasiceck technique.

Assuming short selling is NOT allowed, optimizing the portfolio based on the Single Index Model yields the following result:

Model: single index model
Expected return: 0.02400483
Risk estimate: 0.06311228

Portfolio allocation:

JPM	WFC	C	GS	ADR	CVX
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
XOM	VLO	VZ	T	S	TMUS
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
AMGN	GILD	CELG	REGN	DAL	UAL
0.22144360	0.08871701	0.10104072	0.21562363	0.00000000	0.02813369
LUV	AAL	AAPL	MSFT	YHOO	AMZN
0.00000000	0.04922418	0.13415315	0.00000000	0.00000000	0.16166402

It is clear here that MANY of the stocks did not appear to be incorporated into the portfolio as the excess return to beta ratio did not allow so. It appears that the biotechnology companies are the optimal investments based on this model. The alpha and the beta of this portfolio are listed below (opVas is the optimal portfolio in this case):

Alpha of opVas: 0.02318751
Beta of opVas: 0.7864346

If this experiment were be to repeated with short selling allowed, the following alternate portfolio would be constructed. In this case, Rf = 0.001:

Model: single index model
Expected return: 0.04758214

Risk estimate: 0.08810703

Portfolio allocation:

JPM	WFC	C	GS	ADR
0.015292229	0.072945809	-0.167199957	-0.250543493	0.001741242

CVX	XOM	VLO	VZ	T
0.165651139	-0.154567441	-0.182724366	0.250641516	-0.085464630

S	TMUS	AMGN	GILD	CELG
-0.020439844	-0.045116892	0.363220353	0.237649239	0.237408276

REGN	DAL	UAL	LUV	AAL
0.270386847	0.035056741	0.048279196	-0.117357380	0.063325569

AAPL	MSFT	YHOO	AMZN
0.387984046	-0.395579348	-0.038244133	0.307655281

The alpha and beta of this new portfolio are listed below (opVas2 is the optimal portfolio in this case):

Alpha of opVas2: 0.04745353
Beta of opVas2: 0.1237529

This new portfolio does allow for the incorporation of more stocks into the portfolio and has a slightly higher return than the previous portfolio (albeit a higher risk as well).

Part 3: The Constant Correlation Model

We now shift gears to the Constant Correlation Model.

Assuming short selling is NOT allowed, optimizing the portfolio based on the Constant Correlation Model yields the following result:

Model: constant correlation model
Expected return: 0.02542954
Risk estimate: 0.07287318

Portfolio allocation:

JPM	WFC	C	GS	ADR	CVX
0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000

XOM	VLO	VZ	T	S	TMUS
0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000

AMGN	GILD	CELG	REGN	DAL	UAL
0.210855619	0.030943361	0.059236283	0.254951810	0.000000000	0.000000000

LUV	AAL	AAPL	MSFT	YHOO	AMZN
0.000000000	0.006289386	0.228566256	0.000000000	0.000000000	0.209157285

It is clear here that MANY of the stocks did not appear to be incorporated into the portfolio as the excess return to standard deviation ratio did not allow so. It appears that the biotechnology companies are the optimal investments based on this model.

If this experiment were be to repeated with short selling allowed, the following alternate portfolio would be constructed. In this case, Rf = 0.001:

Model: constant correlation model
Expected return: 0.07798569
Risk estimate: 0.1601093

Portfolio allocation:

JPM	WFC	C	GS	ADR
-0.0002463151	0.0810932797	-0.2569807076	-0.3546944737	-0.1678786254

CVX	XOM	VLO	VZ	T
0.2309096977	-0.3835271800	-0.3102483623	0.3725203783	-0.2440293850

S	TMUS	AMGN	GILD	CELG
-0.1314533016	-0.2042085526	0.6754234417	0.3848477422	0.3990455284

REGN	DAL	UAL	LUV	AAL
0.5406537886	-0.0165828370	0.0432936736	-0.2342713964	0.0929698965

AAPL	MSFT	YHOO	AMZN
0.5855191736	-0.4710001705	-0.1819232502	0.5507679572

This new portfolio does allow for the incorporation of more stocks into the portfolio and has a slightly higher return than the previous portfolio (albeit a higher risk as well).

Part 4: The Multi-Group Model

We now shift gears to the Multi-Group Model. The stocks are grouped into their corresponding industries as outlined in the beginning of the report.

Assuming short selling is allowed, optimizing the portfolio based on the Constant Correlation Model yields the following result. In this case, Rf = 0.001:

Model: multigroup model
Expected return: 0.06862788
Risk estimate: 0.1361673

Portfolio allocation:

JPM	WFC	C	GS	ADR	CVX
0.19468648	0.30850983	-0.32225001	-0.39332024	0.03691075	0.48115399

XOM	VLO	VZ	T	S	TMUS
-0.08351911	-0.19107437	0.53420425	-0.12134948	-0.09594342	-0.16425842

AMGN	GILD	CELG	REGN	DAL	UAL
0.28553286	-0.04029720	0.02000417	0.42465313	-0.06844550	0.05006007

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      LUV       AAL       AAPL       MSFT       YHOO       AMZN
-0.48535788  0.14305224  0.57343350 -0.45267609 -0.17325554  0.53954598
```

This portfolio indeed has a fairly high expected return, but a significantly high risk as well.

Part 5: Bringing It All Together

The last part before actually monitoring portfolio performance is to see where these optimal portfolios stand in relation to one another from a risk and expected return standpoint. If we were to plot them all on the same space in addition to the stocks that compromise them, the following chart is constructed. In this case, NSS means no short selling while SS means short selling. Each allocation is marked above by what portfolio it corresponds to. All portfolios with short selling had a risk-free rate of 0.001 except for Markowitz2, which has a risk-free rate of 0.002:

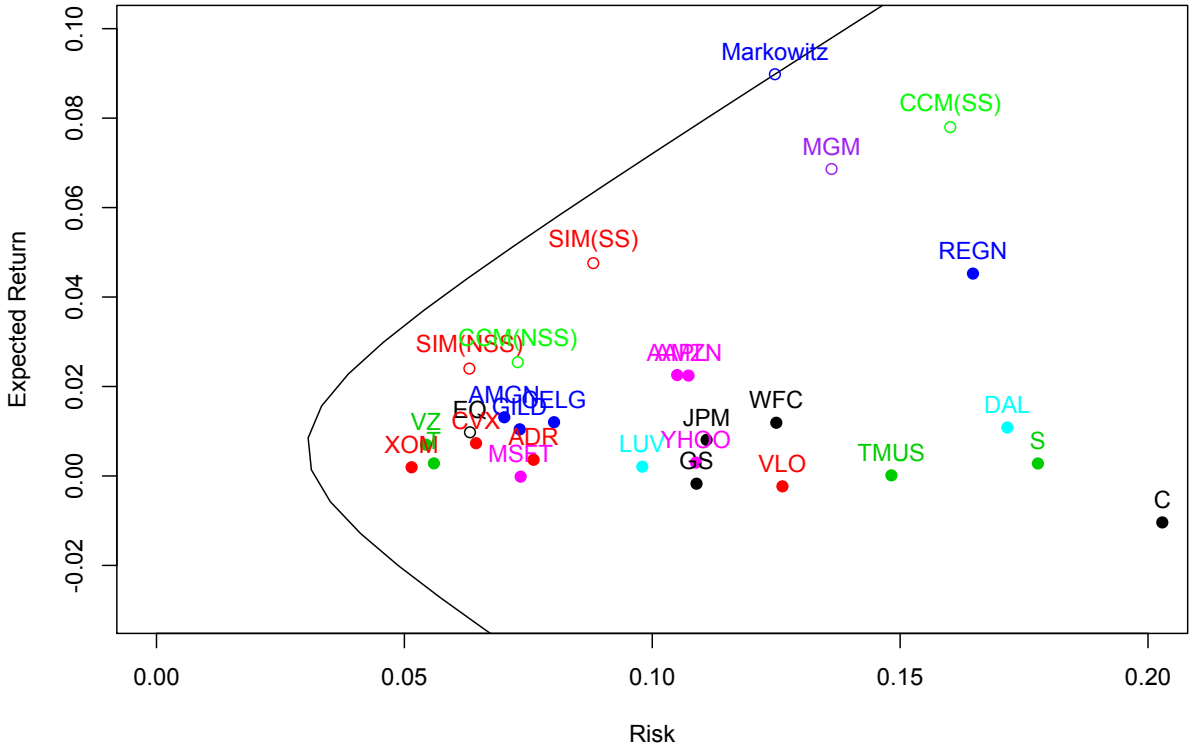

Figure 4

The space appears to fairly cluttered near the risk rate of 0.075. From observing Figure 4, it appears the Classical Markowitz portfolio appears to have the highest expected return, while the Exxon-Mobil stock alone appears to have the lowest risk. Finding out how accurate these predictions are, however, requires portfolio performance analysis. This task will be tackled in the next section of the project.

Part 6: Monitoring Performance

Now comes the exciting part of actually seeing how these optimal portfolio allocations actually perform! Though the project only asks for the plotting of 5 portfolios, I decided to plot all of them out of curiosity. Displayed below is the graph:

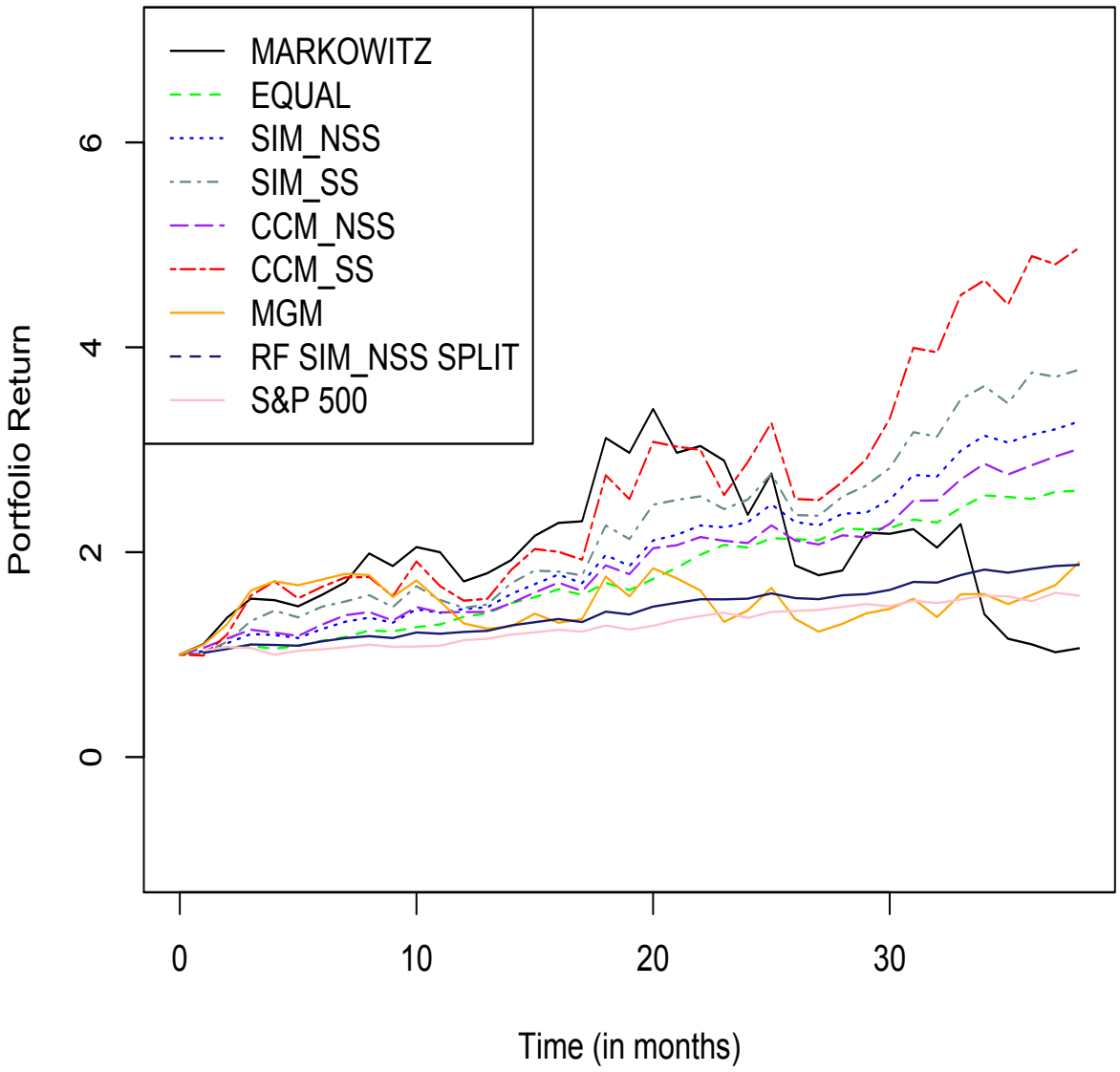

Figure 5

Clearly there is a lot to be said about Figure 5. To add to this information, the average return of each portfolio over this 38-month time period is displayed below:

Average Markowitz Returns: 0.01159391
Average Equal Allocation Returns: 0.02546623
Average SIM_NSS Returns: 0.03293808
Average SIM_SS Returns: 0.03863768
Average CCM_NSS Returns: 0.03042083
Average CCM_SS Returns: 0.05131048
Average MGM Returns: 0.01502756
Average 50-50 SIM_NSS and RF Returns: 0.01696904

Based off what we heard in class, it indeed appears to be the case in this plot that the Classical Markowitz Model appears to perform the worst of the lot. In addition to having the lowest average return, it also ended up at the lowest ending price compared to all other portfolios, and it is the only portfolio to actually perform worse than the market index itself. Though the Markowitz appeared to promise the highest expected return in the previous part, it turns out this was far from the truth. Therefore, one must exercise caution if planning to allocate based on this model.

The Multi-Group Model and the 50-50 split between the risk-free asset and the Single Index Model with no short selling appeared to perform around the level of the market itself. The Mutli-Group model did initially significantly outperform the market, but in the end the fluctuations of up and down were fairly even and it ended up only slightly above the market index. The 50-50 split portfolio, on the other hand, always slightly outperformed the market constantly, and thus appears to be more stable than the MGM portfolio in this time period. It ended up ultimately performing better than the MGM portfolio as well.

The remainder of the portfolios significantly outperformed the market. Ranking "worst" among these exceptional portfolios is the equal allocation portfolio, and highest being the Constant Correlation Model with short selling portfolio. The Single Index Model and Constant Correlation Models appeared to perform very well in this time period, and for this reason I will probably investigate these models in a bit more detail in the future. In either case, short selling portfolios seemed to outperform no short selling portfolios – in fact the Single Index Model would have outperformed the Constant Correlation Model if short selling was not allowed.

Overall, this project was extremely interesting and worthwhile, and I look forward to improving these models with additional parameters myself in the future. After all, if these appear to constantly show outperforming of the market, why not try investing some real money using these allocations?