Project 2 - Stock portfolio

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1 Introduction

This paper analyzes the historical performance of eight stocks across different sectors of industry and derives various optimal portfolios in accordance with Markowitz portfolio theory. The performance of the derived portfolios are then analyzed using more current stock market data.

2 Data Presentation

The chosen stocks for this paper are as follows: Cisco Systems, Inc. (CSX), FedEx Corporation (FDX), Alphabet Inc. Class C (GOOG), JPMorgan Chase & Co. (JPM), Coca-Cola Co (KO), Newmont Goldcorp Corp (NME), Pfizer Inc. (PFE), Phillips 66 (PSX). The stocks were chosen for their spread across the Global Industry Classification Standard (GICS) groups and their relatively stable and positive returns.

Historical price and returns data for the eight stocks was collected from January 1, 2014 until January 1, 2019 and used to approximate future performance and derive optimal portfolios. That historical data is shown below.

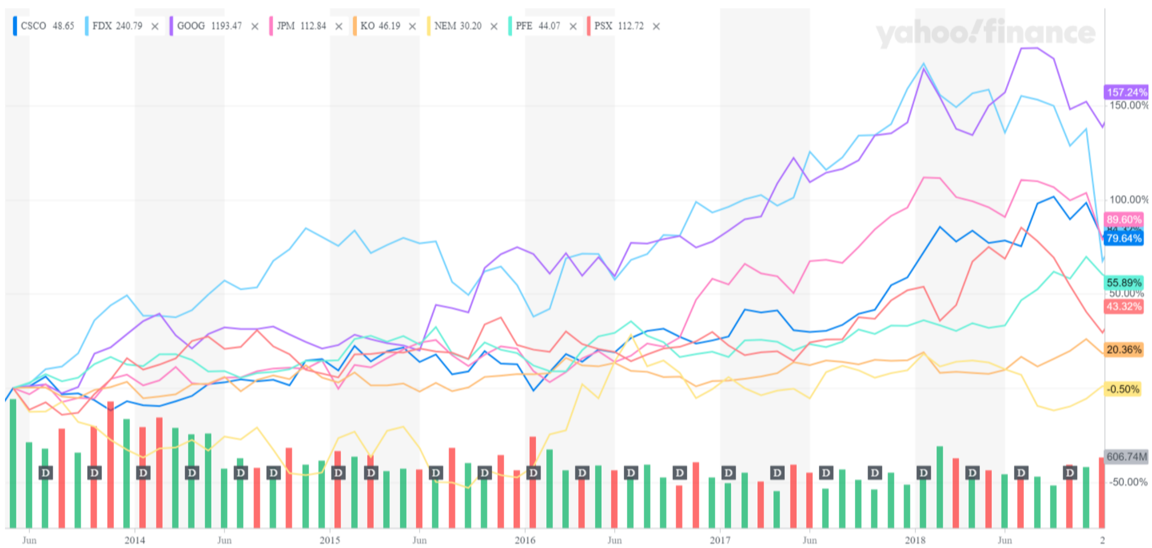

Figure 1: Historical performance of the 8 stocks

2.1 Summary of General Statistics

Ticker	Name	Industry	Annualized Return	Annualized Risk
CSCO	Cisco Systems	Information Technology	.1783	.2111
FDX	FedEx Corporation	Industrials	.0313	.2236
GOOG	Alphabet Inc. Class C	Communication services	.1318	.2344
JPM	JPMorgan Chase & Co.	Financials	.1381	.2083
KO	Coca-Cola Company	Consumer Staples	.0615	.1369
NEM	Newmont Goldcorp	Materials	.0952	.3773
PFE	Pfizer Inc.	Health Care	.1126	.1745
PSX	Phillips 66	Energy	.0523	.2425

Of the chosen stocks, all have positive annualized returns and risk less than 0.4. The tech and financial stocks - Cisco, Google, and JPMorgan - seem to offer the highest average annual rates of return, though they are relatively more risky. The Coca-Cola company offers the lowest returns but least amount of risk.

2.2 Correlation Matrix

Stock	CSCO	FDX	GOOG	JPM	KO	NEM	PFE	PSX
CSCO	1	.4795	.4656	.5121	.3353	.0854	.4137	.3927
FDX	.4795	1	.4010	.5377	.3489	.0403	.3916	.4068
GOOG	.4656	.4010	1	.4196	.2689	.0369	.3602	.3584
JPM	.5121	.5377	.4196	1	.2962	-.0096	.4658	.4844
KO	.3353	.3489	.2689	.2962	1	.1065	.3288	.2562
NEM	.0854	.0403	.0369	-.0096	.1065	1	.0471	.1274
PFE	.4137	.3916	.3602	.4658	.3288	.0471	1	.3429
PSX	.3927	.4068	.3584	.4844	.2562	.1274	.3429	1

None of the chosen stocks are correlated with a ρ value more than 0.7. This is good because less correlation translates to more diversification which generally minimizes riskiness. This should lead to more interesting, profitable portfolios.

2.3 Distribution of Returns

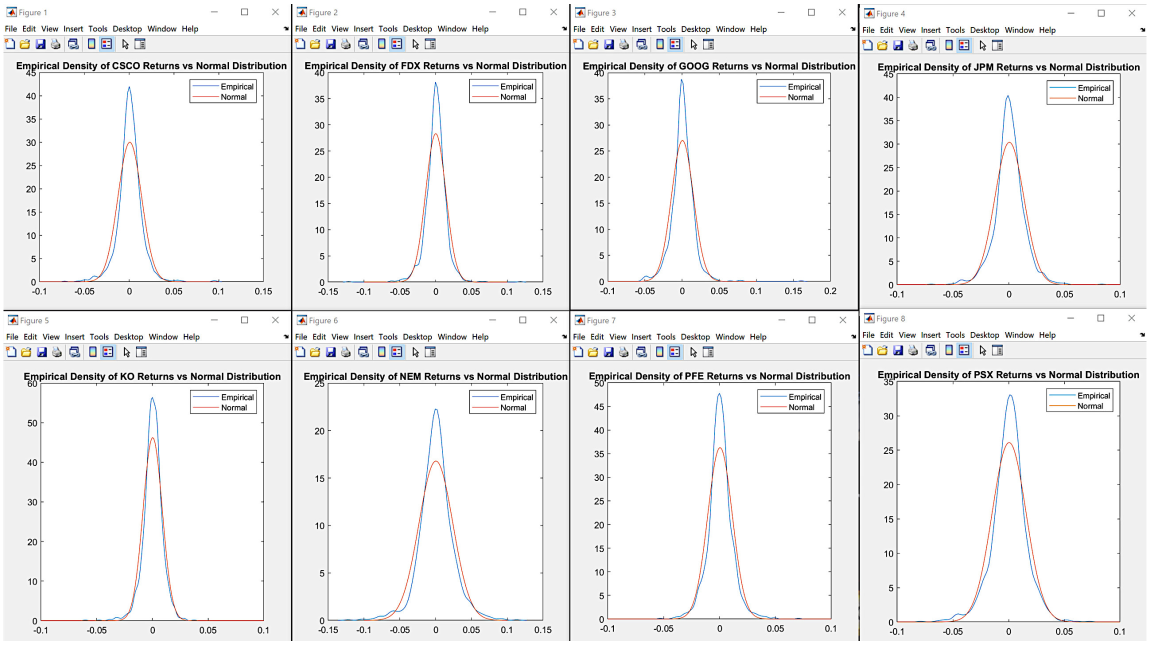

Figure 2: Distribution of actual daily returns versus normal returns

The above figure shows the distribution of each stock's returns compared to an approximated normal distribution. Each stock's returns are more concentrated around the average with less spread. This looks promising, as less variation of returns is more desirable in an investment.

2.4 Secondary Statistics

Stock	Range	Skewness	Kurtosis	Autocorrelation	Sharpe Ratio
CSCO	.1685	.2845	9.4961	-0.0358	.7499
FDX	.2399	-.2801	12.8425	.0140	.0507
GOOG	.2137	.9582	15.9611	.0369	.4768
JPM	.1528	-.0161	6.2222	.0070	.5669
KO	.0977	-.7254	7.2475	.0253	.3029
NEM	.2354	-.1172	5.7967	-.0455	.1994
PFE	.1237	.2779	6.3971	.0395	.5304
PSX	.1516	-.3371	5.3808	.0244	.1333

Range refers to the absolute difference between the highest and lowest daily return rates of each stock. Lower values are generally more desirable, as they indicate less variation of returns. While some of the range values are somewhat high (take FDX and NEM for instance), the above distribution charts indicate that returns are mostly clustered around the average and that the high range values can be attributed to outliers.

Skewness refers to the symmetry of a returns distribution. Generally values between -0.5 and 0.5 indicate fairly symmetric, less volatile returns. GOOG has a skewness value of .9582, but since the value is positive, one can expect the distribution of returns to be more biased towards positive returns, which is desirable. KO has a skewness of -.7254, which is undesirable (One can expect the distribution of returns to be more biased towards negative returns).

Kurtosis refers to the probability of more extreme outliers in the returns distributions. All of the stocks analyzed exhibit kurtosis over 3, which indicates more likelihood of extreme positive and negative returns. This makes the chosen stocks more risky but potentially more profitable.

Autocorrelation refers to the degree of similarity between a stock's returns over time and a lagged version of those returns. It is useful for measuring how much past prices will effect the future price of a stock. This is more useful for technical analysis and since all of the eight stocks have low absolute autocorrelations, this statistic is not very relevant.

The Sharpe Ratio is a measure of investment return relative to risk. Higher values are better, as they indicate a good balance between the potential reward of an investment relative to its risk. CSCO, GOOG, and JPM - the stocks with the highest returns - have relatively higher Sharpe Ratios. KO, the stock with the lowest risk, also has a relatively high Sharpe Ratio.

3 Portfolio theory

Based upon the eight chosen stocks, seven portfolios have been made in order to investigate different investments strategies. The seven portfolios are:

P1 - Risky-assets only global minimum variance
P2 - The tangent portfolio
P3 - Risky-assets only minimum variance, but no shortselling
P4 - Risky-assets only maximum return, but no shortselling
P5 - Equal weights of each risky-asset
P6 - Risky-assets only minimum variance, but $w_i \leq 20\%$ for i $\in \{1, 8\}$.
P7 - Risky-assets only minimum variance, but $w_i \geq 8\%$ for i $\in \{1, 8\}$.

The portfolios from above are constructed using the portfolio theory derived by Harry Markowitz and given a risk free rate of return of 2%. The expected return of each portfolio is calculated by: $\mathbf{w}\mu$, were μ is a vector containing the expected return of each stock. The variance of the portfolios is defined as $\sigma_P^2 = \mathbf{w}^T \Sigma \mathbf{w}$.

The weights w_i of each stock in portfolio P2 - the tangent portfolio are found analytically by using the following formulas:

$$\mathbf{w}_{tan} = \frac{\Sigma^{-1}\mu^e}{\mathbf{1}'\Sigma^{-1}\mu^e}, \qquad \text{were } \mu^e = \mu - 0.02 \text{ and } \Sigma \text{ is the correlation matrix from above.}$$

The weights of portfolio P4 is chosen to maximize the return with no shortselling. This is simply done by investing all capital into the stock with highest expected annual return. In this case CSCO (Cisco Systems). Since the portfolio only consists of one stock the expected return of P4 is equal the expected return of CSCO and the variance the same.

In P5 each stock have the same weight of $\frac{1}{8}$, which makes the calculations quite easy. Since the weights are already given.

The weights of each stock in the rest of the portfolios (P1,P3,P6,P7) are found by an iterative procedure, were a chosen expected return between $\min(\mu)$ and $\max(\mu)$ is chosen and the minimum variance is found by using the optimality-solver in Matlab called, "fmincon". The different parameters of the portfolios are defined as $\text{sum}(w_i) = 1$ for P1 and $\text{sum}(w_i) = 1 \wedge w_i \geq 0$, $\text{sum}(w_i) = 1 \wedge 0 \leq w_i \leq 20\%$, $\text{sum}(w_i) = 1 \wedge w_i \geq 8\%$ for P3,P6 and P7 respectively. Portfolio P6 doesn't have an optimal solutions that meets all restrictions, which is why the sum of weights doesn't sum to 1. See summary of the portfolios down below:

""	"p1"	"p2"	"p3"	"p4"	"p5"	"p6"	"p7"
"CSCO"	"0.04589"	"0.66783"	"0.045893"	"1"	"0.125"	"2.5759e-12"	"0.080005"
"FDX"	"0.076083"	"-0.57372"	"0.076085"	"0"	"0.125"	"0.2"	"0.080116"
"GOOG"	"0.13353"	"0.28609"	"0.13353"	"0"	"0.125"	"9.1303e-12"	"0.11802"
"JPM"	"0.089173"	"0.4851"	"0.089172"	"0"	"0.125"	"6.8746e-12"	"0.080028"
"KO"	"0.14853"	"-0.063987"	"0.14853"	"0"	"0.125"	"0.2"	"0.14695"
"NEM"	"0.30273"	"0.34393"	"0.30273"	"0"	"0.125"	"0.2"	"0.29873"
"PFE"	"0.11463"	"0.15198"	"0.11463"	"0"	"0.125"	"0.087718"	"0.10564"
"PSX"	"0.089419"	"-0.29723"	"0.08942"	"0"	"0.125"	"0.2"	"0.090512"
"Return"	"0.09602"	"0.23616"	"0.09602"	"0.17833"	"0.10014"	"0.057949"	"0.09749"
"Variance"	"0.34642"	"0.9945"	"0.34642"	"0.21112"	"0.39688"	"0.30955"	"0.34732"

Figure 3: Portfolio weights, expected return and variance

4 Performance

Portfolio performance was measured by analyzing each stock's performance from January 1st, 2019 to October 31st, 2019. This data was recorded and weighted in accordance with the derived portfolios described above.

A simplistic view that looks at the percentage change of each stock from the first date of the specified time period to the last yields the following data.

Stock	CSCO	FDX	GOOG	JPM	KO	NEM	PFE	PSX
Percentage Change	0.1374	-0.0536	0.2049	0.2972	0.1877	0.1950	-0.0887	0.3630
Ranking	6	7	3	2	5	4	8	1

Applying the above stock data to the 7 chosen portfolios yields the following returns.

Stock	P1	P2	P3	P4	P5	P6	P7
Percentage Change	0.1653	0.2590	0.1653	0.1374	0.1553	0.1307	0.1640
Ranking	2	1	3	7	5	7	4

For a more complicated calculation that shows portfolio return over time, each stock's daily percentage increase or decrease from its January 1st value is recorded. Applying the portfolio weights to this data and plotting the results over time yields the following figure.

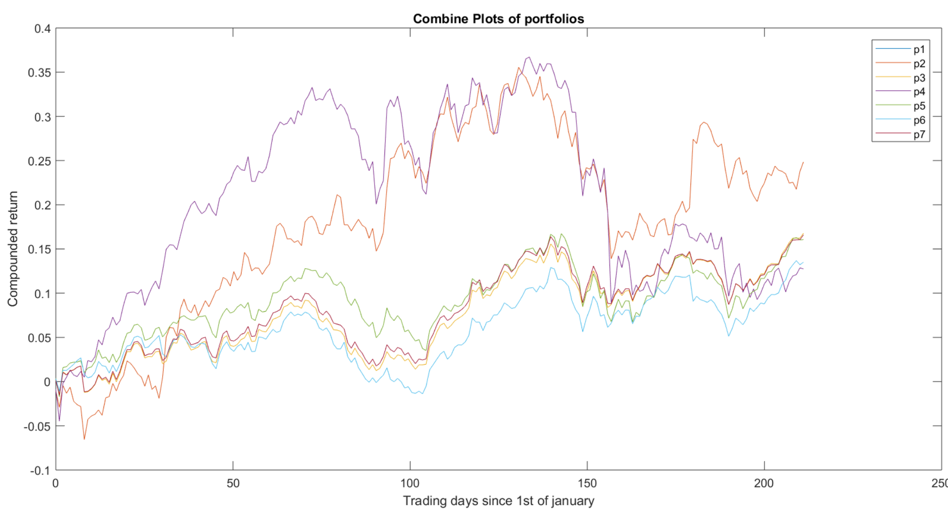

Figure 4: 2019 performance of the 7 portfolios

In both instances, the second portfolio / the tangent portfolio performs the best.