# ECON 424 Final Paper
# Spring 2018

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## 1 Introduction

In this paper, we use the techniques learned in this class to analyze a selection of assets and portfolio. We select four public firms from the universe of S&P 1500 firms and compare them to the S&P 500 index in a later section. The firms we choose were part of the index for the entire duration of the above 5-year time frame.

**Alaska Air Group, Inc. (ALK)**, through its subsidiaries, provides passengers and cargo air transportation services. It also focuses on providing ground and ramp handling services to airlines. [1]

**Costco Wholesale Corporation (COST)**, together with its subsidiaries, operates membership warehouses. It offers branded and private-label products in a range of merchandise categories. [2]

**F5 Networks, Inc. (FFIV)** develops, markets, and sells application delivery networking products that optimize the security, performance, and availability of network applications, servers, and storage systems. [3]

**Nordstrom, Inc. (JWN)**, a fashion retailer, provides apparel, shoes, cosmetics, and accessories for women, men, young adults, and children in the United States and Canada. [4]

**Vanguard 500 Index Investor (VFINX)**. The investment seeks to track the performance of a benchmark index that measures the investment return of large-capitalization stocks. The fund employs an indexing investment approach designed to track the performance of the Standard & Poor's 500 Index, a widely recognized benchmark of U.S. stock market performance that is dominated by the stocks of large U.S. companies. [5]

## 2 Descriptive statistics

In this section, we use various tools learned in this class to describe the characteristics of the four assets.

## 2.1 The monthly prices, monthly simple returns, monthly cc returns, and equity curves

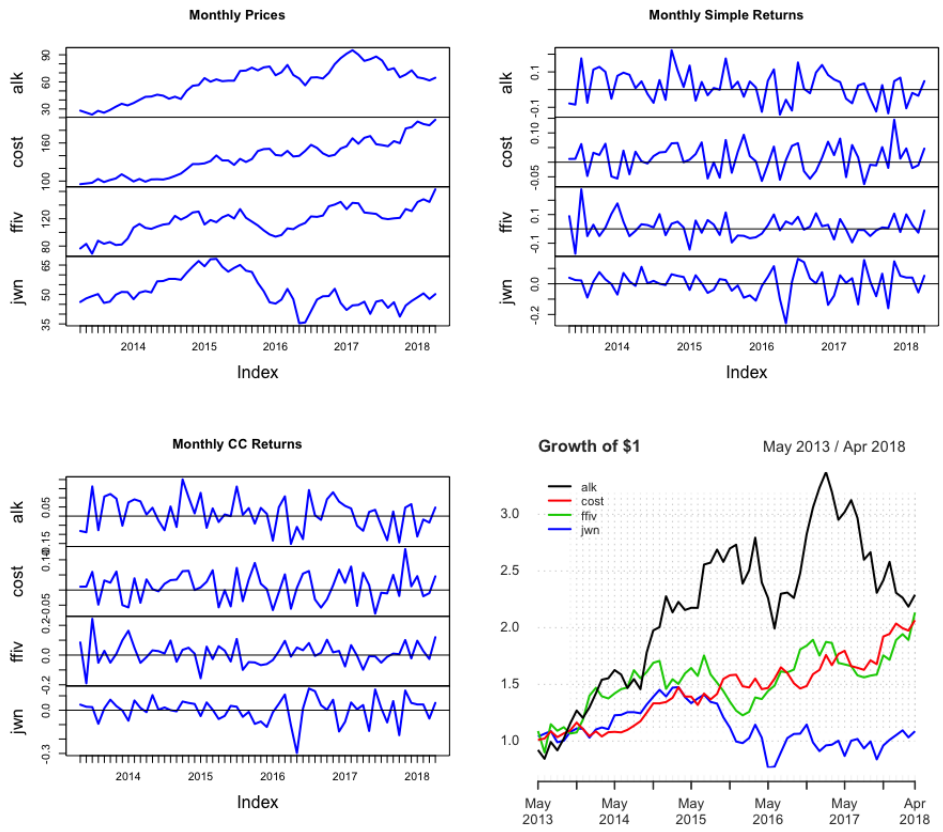



**Figure 1:** The monthly prices, monthly simple returns, monthly cc returns, and equity curves

Stationary and Random Walk:

- The monthly simple returns series and the monthly cc returns series of ALK, COST, and FFIV look stationary. Visually it looks like the mean values are constant over time and the monthly simple returns series and the monthly cc returns series exhibit mean reversion (these three series fluctuate up and down about the mean value). The volatilities look fairly constant over time. Overall, these series look like they could be realizations from a covariance stationary process.

  (The monthly simple returns series and the monthly cc returns series of JWN do not look stationary. The processes appear to have changing means and variances. Clearly the volatilities are higher and the means are lower in 2016.)

- The prices and the equity curves exhibit random walk like behavior since they don't exhibit tendency to revert to a time independent mean.

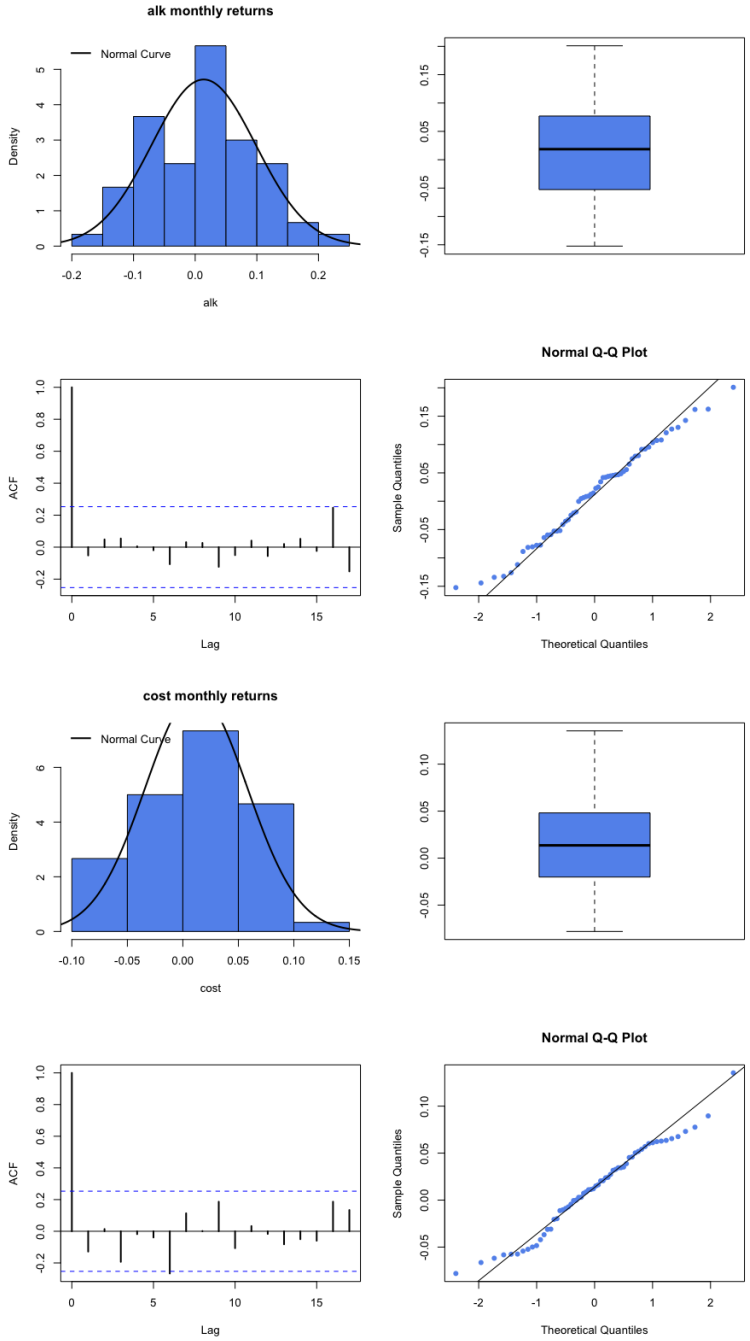
An interesting feature that stands out here is an abnormally large decline of return of JWN during the year of 2016.

The news of Nordstrom sales decline in 2016 might explain the abnormal stock return behavior of JWN.[6] The problem for high-end retailers like Nordstrom was wealthy shoppers were reining in spending and, along with the rest of American consumers, refusing to pay full price for anything.

At first glance, the series seem to covary together.

From the equity curves, we see that a \$1 investment in ALK \$1 grew to above \$2.0, which is the highest. However the volatility of growth of \$1 of ALK is also the highest. For COST and FFIV \$1 grew to about \$2.0, and for JWN \$1 grew to only about \$1.05. Overall, a \$1 investment in COST or FFIV clearly did best.

## 2.2 Four panel diagnostic plots (histograms, boxplots, qq-plots, and SACFs) for each return series



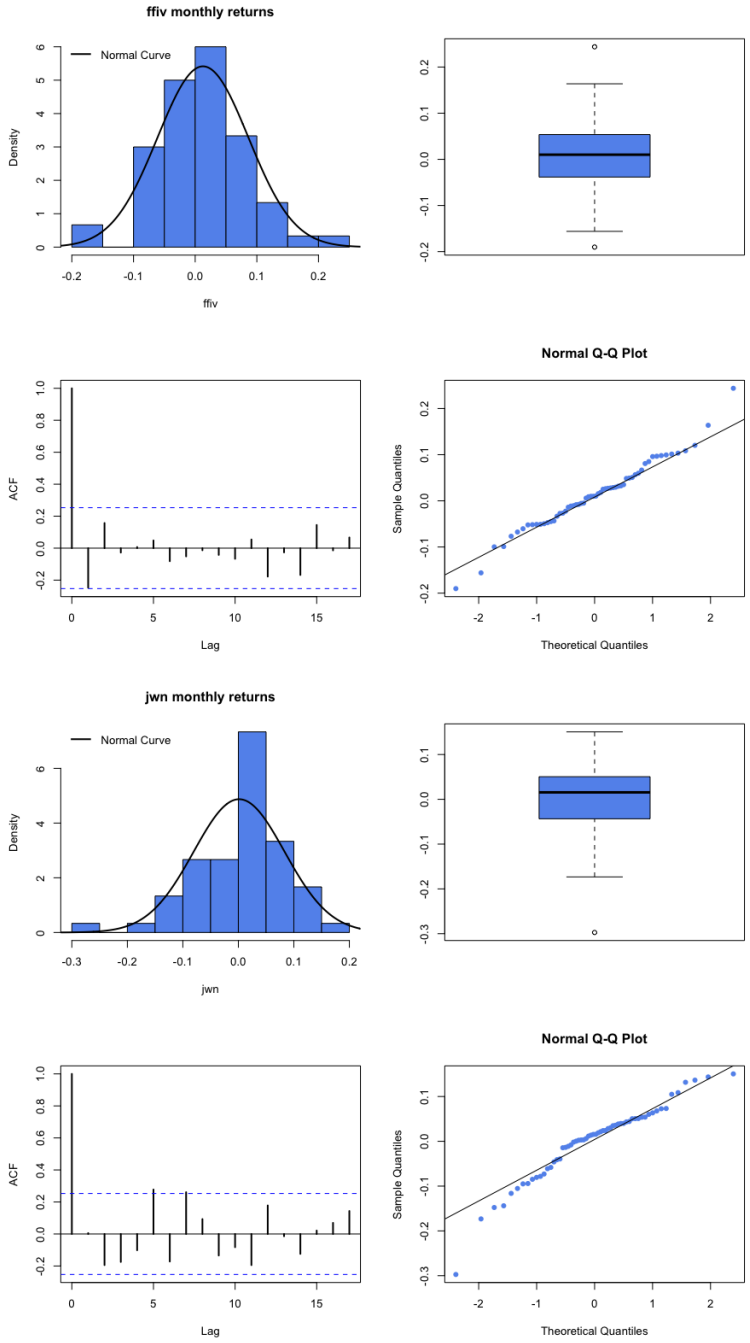



**Figure 2:** Four panel diagnostic plots (histograms, boxplots, qq-plots, and SACFs) of the 4 assets

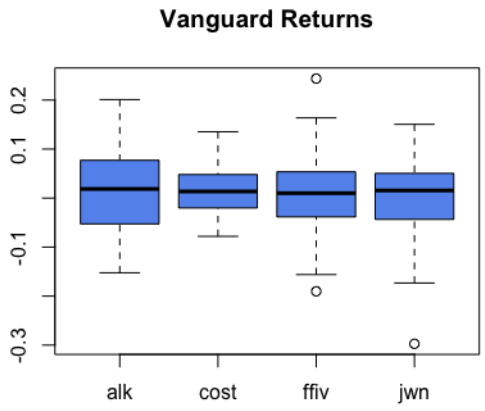



**Figure 3:** The distributions of the 4 assets

The returns on ALK, COST and FFIV look pretty normally distributed. The histograms are roughly bell shaped. Also, the normal qq-plots for these three assets are mostly linear and the boxplots only show two moderate outliers for FFIV.

The returns on JWN exhibit nonnormal behavior. The histogram shows a long left tail (negative skewness) and the boxplot indicates a large negative outlier (fat tails). The normal QQ-plot is not linear in the left tail. All of this is strong evidence against the normal distribution.

There are two outliers in FFIV and one outlier in JWN.

For all of the four series the SACF plots show no significant autocorrelations for lags less than 15 (no bars are above the dotted lines). All of the sample autocorrelations are small (close to zero) and show no distinct pattern over time. Hence, there does not appear to be any linear time dependence in the returns.

### 2.3 Univariate descriptive statistics for return series

| | ALK | COST | FFIV | JWN |
|---|---|---|---|---|
| Mean | 0.0138 | 0.01210 | 0.0126 | 0.00139 |
| Variance | 0.0072 | 0.00211 | 0.0054 | 0.00670 |
| Std Dev | 0.0846 | 0.04595 | 0.0737 | 0.08188 |
| Skewness | -0.0535 | 0.00144 | 0.1405 | -0.93311 |
| Excess Kurtosis | -0.6829 | -0.45492 | 1.1447 | 1.77577 |
| 1% Quantile | -0.1475 | -0.07121 | -0.1700 | -0.22411 |
| 5% Quantile | -0.1325 | -0.05842 | -0.0990 | -0.14411 |

**Table 1:** Univariate descriptive statistics for return series

ALK has the highest average return. JWN has the lowest average return.

ALK has the highest standard deviation. COST has the lowest standard deviation.

Based on Excess Kurtosis, COST looks most normally distributed and JWN looks least normally distributed.

### 2.4 The sample covariance matrix of the returns on the four assets

| | ALK | COST | FFIV | JWN |
|---|---|---|---|---|
| ALK | 0.00716 | 0.001464 | 0.001678 | 0.002465 |
| COST | 0.00146 | 0.002112 | 0.000681 | 0.000761 |
| FFIV | 0.00168 | 0.000681 | 0.005428 | 0.001207 |
| JWN | 0.00247 | 0.000761 | 0.001207 | 0.006705 |

**Table 2:** The sample covariance matrix of the returns on the 4 assets

The directions of linear association between the asset returns are all positive.
There is no surprising relationship.

### 2.5 The sample correlation matrix of the returns on the 4 assets

| | ALK | COST | FFIV | JWN |
|---|---|---|---|---|
| ALK | 1.000 | 0.376 | 0.269 | 0.356 |
| COST | 0.376 | 1.000 | 0.201 | 0.202 |
| FFIV | 0.269 | 0.201 | 1.000 | 0.200 |
| JWN | 0.356 | 0.202 | 0.200 | 1.000 |

**Table 3:** The sample correlation matrix of the returns on the four assets

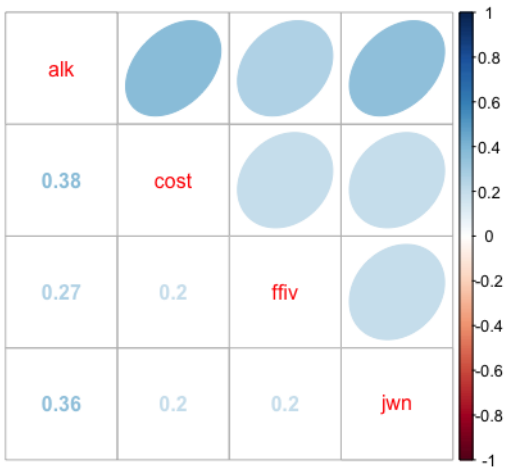



**Figure 4:** Visualization of the sample correlation matrix

ALK and COST are most highly correlated. JWN and FFIV are least correlated.
Based on the estimated correlation values, diversification will reduce risk with these assets. The individual assets have idiosyncratic risk, therefore can be diversified in a portfolio.

## 3 Model Estimation

We use the four selected assets for the following estimations of fit and bootstrap exercises.

### 3.1 Estimated standard errors of the mean and standard deviation and the 95% confidence intervals for the mean and standard deviation

| | $\hat{\mu}$ | SE($\hat{\mu}$) | 95% Lower | 95% Upper | $\hat{\sigma}$ | SE($\hat{\sigma}$) | 95% Lower | 95% Upper |
|---|---|---|---|---|---|---|---|---|
| ALK | 0.01381 | 0.01093 | -0.00804 | 0.0357 | 0.0846 | 0.00773 | 0.0692 | 0.1001 |
| COST | 0.01210 | 0.00593 | 0.00023 | 0.0240 | 0.0460 | 0.00420 | 0.0376 | 0.0543 |
| FFIV | 0.01263 | 0.00951 | -0.00639 | 0.0317 | 0.0737 | 0.00673 | 0.0602 | 0.0871 |
| JWN | 0.00139 | 0.01057 | -0.01975 | 0.0225 | 0.0819 | 0.00747 | 0.0669 | 0.0968 |

**Table 4:** Estimated standard errors of the mean and standard deviation and the 95% CIs

For all series the mean is not estimated very precisely. For ALK, COST and FFIV SE($\hat{\mu}$) is only slightly smaller than $\hat{\mu}$; for JWN, SE($\hat{\mu}$) is much bigger than $\hat{\mu}$ and the range $\hat{\mu} \pm \text{SE}(\hat{\mu})$ contains both negative and positive values.

The standard deviation values, $\sigma$ values, are estimated much more precisely. The values of SE($\hat{\sigma}$) are more than 10 times smaller than the $\sigma$ values.

Recall that 95% confidence intervals, computed using the rule of thumb estimate $\pm 2\,\text{SE}(\hat{\mu})$, are a good way to show the precision of an estimate. Notice that each of the 95% confidence intervals for $\mu$ contain both positive and negative values. This indicates uncertainty about the true value of the expected returns. Here, the 95% confidence intervals for $\sigma$ are fairly narrow. Thus, the estimated standard deviations are more precise.

### 3.2 Bootstrap the standard errors of the estimate of the mean and standard deviation for ALK

| | | Original | Bias | SD | 95% CI Normal | 95% CI Percentile |
|---|---|---|---|---|---|---|
| Mean | 1000 | 0.0138 | -0.000194 | 0.0109 | (-0.0073, 0.0353) | (-0.0082, 0.0353) |
| | 10000 | 0.0138 | 0.000116 | 0.0107 | (-0.0074, 0.0347) | (-0.0071, 0.0351) |
| SD | 1000 | 0.0846 | -0.000832 | 0.0063 | (0.0731, 0.0978) | (0.0717, 0.0969) |
| | 10000 | 0.0846 | -0.000856 | 0.00634 | (0.0731, 0.0979) | (0.0714, 0.0963) |

**Table 5:** Bootstrap estimates of the standard errors of the estimate of the mean and standard deviation for ALK with size 1000 and 10000

The bootstrap SE of the estimate of the mean, 0.0109 and 0.0107, is very close to the analytic SE, 0.01093.

The bootstrap SE of the estimate of the standard deviation, 0.0063 and 0.00634 are a little smaller than the analytic SE, 0.00773. However, recall that the analytic SE for $\hat{\sigma}$ is an approximation based on the CLT. The bootstrap SE should be more accurate.

Using a larger bootstrap size does not make a significant difference. Because a resampling size of 1000 is large enough.

### 3.3 The bootstrap distribution for the mean, from the bootstrap with 1,000 resamples

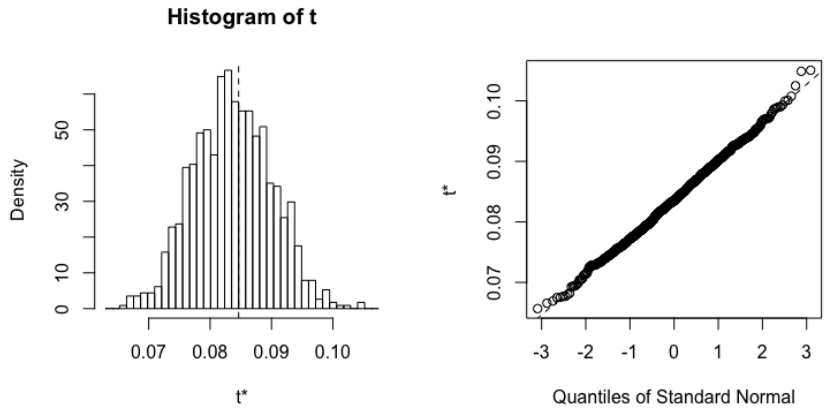



**Figure 5:** Histogram and qq-plot of the estimates of the mean against a normal distribution from the bootstrap with 1,000 resamples

The estimates of the mean are approximately normally distributed. Because the histogram looks normal and the QQ-plot is nice and linear. The bootstrap SE value should be accurate.

The Central Limit Theorem (CLT) applies in this case.

### 3.4 Estimated standard errors of correlation

| | $\hat{\rho}$ | SE($\hat{\rho}$) | LCL (0.95) | UCL (0.95) |
|---|---|---|---|---|
| ALK,COST | 0.376 | 0.111 | 0.1549 | 0.598 |
| ALK,FFIV | 0.269 | 0.120 | 0.0296 | 0.509 |
| ALK,JWN | 0.356 | 0.113 | 0.1301 | 0.581 |
| COST,FFIV | 0.201 | 0.124 | -0.0465 | 0.449 |
| COST,JWN | 0.202 | 0.124 | -0.0455 | 0.450 |
| FFIV,JWN | 0.200 | 0.124 | -0.0478 | 0.448 |

**Table 6:** Estimated standard errors of correlation and the 95% confidence intervals

All of the correlations between two assets are not estimated very precisely: the SE($\hat{\rho}$) values are big compared to the estimates.

Recall that 95% confidence intervals, computed using the rule of thumb estimate $\pm 2\,\text{SE}(\hat{\mu})$, are a good way to show the precision of an estimate. The 95% confidence interval for the first three correlations only contains positive values. The 95% confidence intervals for the last three correlations contain both positive and negative values, indicating uncertainty about the sign of the correlation value. Thus, the estimates of the first three correlations are more precisely estimated and the estimates of the last three correlations are imprecisely estimated.

### 3.5 The 1% and 5% value-at-risk of the $100,000 investment over a one-month investment horizon based on the normal distribution

| | 1% VaR (Normal) | 5% VaR (Normal) |
|---|---|---|
| ALK | -16731 | -11787 |
| COST | -9046 | -6152 |
| FFIV | -14681 | -10287 |
| JWN | -17230 | -12480 |

**Table 7:** VaR over a one-month investment horizon based on the normal distribution

| | 1% VaR (Normal) | 5% VaR (Normal) | $\hat{\sigma}$ |
|---|---|---|---|
| ALK | -16731 | -11787 | 0.0846 |
| COST | -9046 | -6152 | 0.0460 |
| FFIV | -14681 | -10287 | 0.0737 |
| JWN | -17230 | -12480 | 0.0819 |

**Table 8:** VaR and the estimated standard deviations

The values of VaR are positively related to the estimated standard deviations: $\text{VaR}_\alpha = |W_0 \cdot q_\alpha^R| = |W_0 \cdot (\mu_R + \sigma_R \cdot z_\alpha)|$. when $\hat{\sigma}$ gets larger, the values of VaR also gets larger.

### 3.6 The 1% and 5% VaR estimates, the bootstrap standard errors and 95% confidence intervals

| | 1% VaR | SE | LCL (0.95) | UCL (0.95) | 1% VaR | SE | LCL (0.95) | UCL (0.95) |
|---|---|---|---|---|---|---|---|---|
| ALK | -16731 | 1523 | -19913 | -13942 | -11787 | 1393 | -14727 | -9266 |
| COST | -9046 | 959 | -11034 | -7274 | -6152 | 801 | -7811 | -4670 |
| FFIV | -14681 | 1792 | -18456 | -11430 | -10287 | 1454 | -13362 | -7663 |
| JWN | -17230 | 2413 | -22216 | -12759 | -12480 | 2063 | -16823 | -8735 |

**Table 9:** The 1% and 5% VaR estimates, the bootstrap standard errors and 95% confidence intervals

The SE values compared to the values of the VaR are fairly small. The bootstrap confidence intervals (usual and percentile) are fairly narrow. Thus, the estimated VaR are precise.

JWN has the highest VaR at both horizons. COST has the lowest VaR at both horizons.

### 3.7 The VaR analysis using the empirical 1% and 5% quantiles of the return distributions

| | 1% VaR | SE | LCL (0.95) | UCL (0.95) | 1% VaR | SE | LCL (0.95) | UCL (0.95) |
|---|---|---|---|---|---|---|---|---|
| ALK | -13716 | 710 | -15457 | -12674 | -12410 | 1670 | -16399 | -9854 |
| COST | -6873 | 616 | -8258 | -5844 | -5674 | 435 | -6442 | -4737 |
| FFIV | -15636 | 2993 | -23013 | -11282 | -9430 | 2761 | -15394 | -4569 |
| JWN | -20077 | 4705 | -30180 | -11738 | -13420 | 2900 | -19834 | -8467 |

**Table 10:** The VaR analysis using the empirical 1% and 5% quantiles of the return distributions

The VaR of ALK and FFIV I get from normal method and empirical method are very similar, because the returns distributions are fairly normal. The VaR of COST and JWN I get from the two methods are different, because the returns distributions are non-normal.

# 4 Portfolio Theory

We use the four selected assets (except for Q15) and the CER model estimates computed above (from the continuously compounded returns) for the following computations.

## 4.1 Sharpe's ratio and the bootstrap estimates of standard errors

| | Sharpe | SE | LCL (0.95) | UCL (0.95) |
|---|---|---|---|---|
| ALK | 0.1583 | 0.133 | -0.1011 | 0.421 |
| COST | 0.2541 | 0.135 | -0.0148 | 0.512 |
| FFIV | 0.1658 | 0.126 | -0.0862 | 0.408 |
| JWN | 0.0119 | 0.132 | -0.2574 | 0.260 |

**Table 11:** Sharpe's ratio and the bootstrap estimates of standard errors

COST has the highest slope.

For all series the Sharpe slope is not estimated precisely. For ALK, COST and FFIV, $\text{SE}(\widehat{\text{SR}})$ are big compared to the estimates. For JWN, $\text{SE}(\widehat{\text{SR}})$ is much bigger than $\widehat{\text{SR}}$ and the range $\widehat{\text{SR}} \pm \text{SE}(\widehat{\text{SR}})$ contains both negative and positive values.

Recall that 95% confidence intervals, computed using the rule of thumb estimate $\pm 2\,\text{SE}(\widehat{\text{SR}})$, are a good way to show the precision of an estimate. Notice that each of the 95% confidence intervals for $\mu$ contain both positive and negative values. This indicates uncertainty about the true value of the expected returns.

## 4.2 The expected returns and standard deviation of the four chosen assets & S&P 500

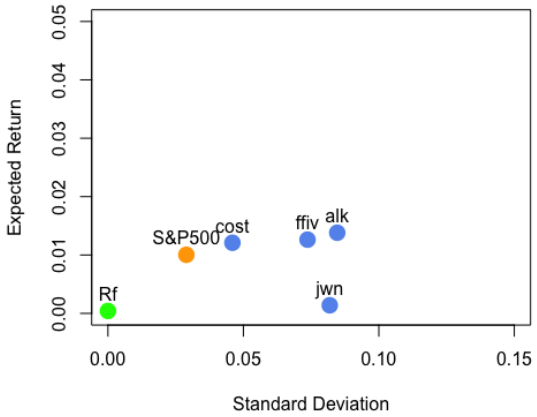



**Figure 6:** Expected return($\mu$)-standard deviation($\sigma$) plane

VFINX has the highest risk-adjusted return. JWN has the lowest risk-adjusted return. It is not surprising that the S&P500 has the highest Sharpe Ratio, which is the risk-adjusted return.

### 4.3 The global minimum variance portfolio based only on the four assets

| Expected Return | Standard Deviation | Sharpe Ratio |
|---|---|---|
| 0.0107 | 0.0407 | 0.254 |

| ALK | COST | FFIV | JWN |
|---|---|---|---|
| 0.0026 | 0.6721 | 0.1897 | 0.1356 |

**Table 12:** The expected return and standard deviation of the global minimum variance portfolio

There is no negative weights in the global minimum variance portfolio.

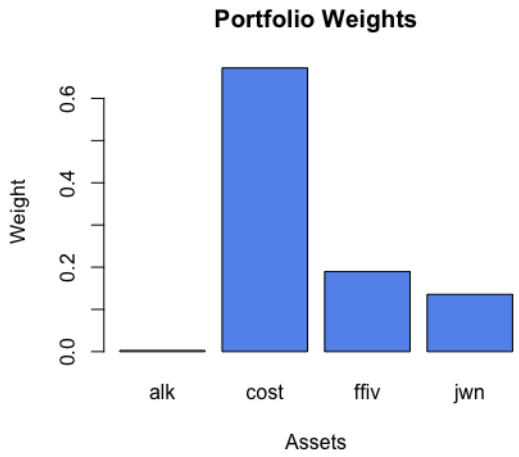



**Figure 7:** The weights of the 4 assets in the global minimum variance portfolio

### 4.4 Value at Risk

Assuming $W_0 = \$100,000$ at January 31, 2018. Using the global minimum variance portfolio, the 1% and 5% value-at-risk of the \$100,000 investment over a one month investment horizon are **\$8048** and **\$5463**, respectively.

Again, the VaR values for the individual assets are:

| | 1% VaR (Normal) | 5% VaR (Normal) |
|---|---|---|
| ALK | -16731 | -11787 |
| COST | -9046 | -6152 |
| FFIV | -14681 | -10287 |
| JWN | -17230 | -12480 |

**Table 13:** The VaR values for the individual assets

The 1% and 5% VaR values using the global minimum variance portfolio are less than the correspondent VaR values for each individual assets.

### 4.5 The global minimum variance portfolio with an added no short-sale constraint

| Expected Return | Standard Deviation | Sharpe Ratio |
|---|---|---|
| 0.0107 | 0.0407 | 0.254 |

| ALK | COST | FFIV | JWN |
|---|---|---|---|
| 0.0026 | 0.6721 | 0.1897 | 0.1356 |

**Table 14:** The expected return and standard deviation of this portfolio

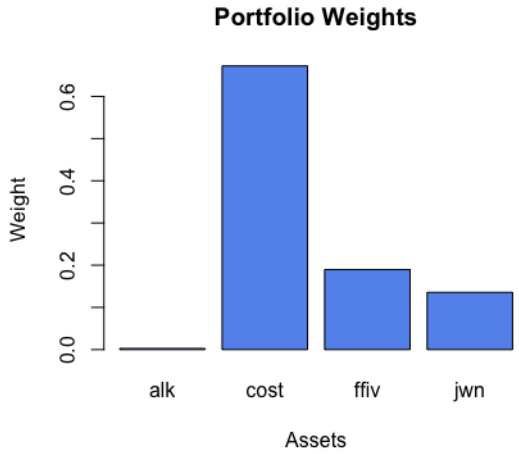



**Figure 8:** The weights of the 4 assets in the global minimum variance portfolio (no short-sale)

### 4.6 The global minimum variance portfolio with no short-sales not allowed II

| | Shorts | No Shorts |
|---|---|---|
| Annual Mean | 0.129 | 0.129 |
| Annual SD | 0.141 | 0.141 |
| 1% VaR | -8048.431 | -8048.431 |
| 5% VaR | -5462.958 | -5462.958 |

**Table 15:** VaR over a one month investment horizon (With short-sale vs. no short-sale)

The results are the same with those for the global minimum variance that allows short sales.

### 4.7 The efficient portfolio frontier, allowing for short sales

Computation steps:

1. Use the global minimum variance portfolio as one efficient portfolio
2. Compute the efficient minimum variance portfolio with a target return equal to the maximum of the average returns for the 4 assets as the second efficient portfolio.

| Expected Return | Standard Deviation | Sharpe Ratio |
|---|---|---|
| 0.0138 | 0.0457 | 0.293 |

| ALK | COST | FFIV | JWN |
|---|---|---|---|
| 0.123 | 0.755 | 0.250 | -0.128 |

**Table 16:** The efficient minimum variance portfolio with a target return

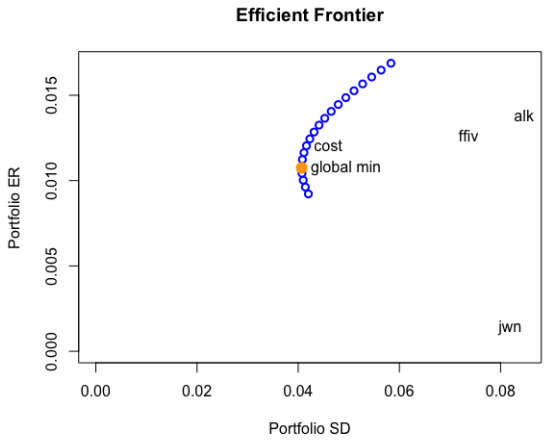



**Figure 9:** The efficient portfolio frontier, allowing for short sales

### 4.8 The tangency portfolio using a monthly risk free rate equal to 0.0004167 per month (which corresponds to an annual rate of 0.5%)

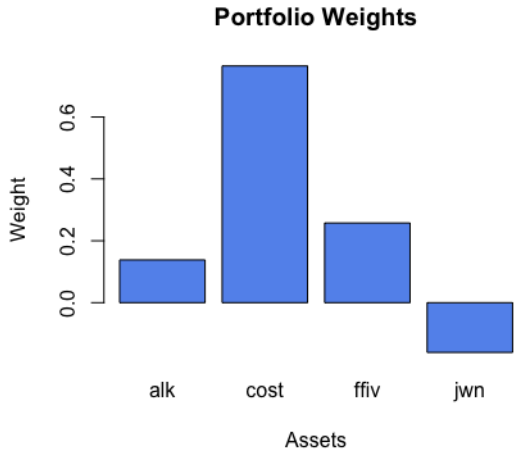



**Figure 10:** The weights of the 4 assets in the tangency portfolio

The weight on JWN is negative.

| Expected Return | Variance | Standard Deviation | Sharpe Ratio |
|---|---|---|---|
| 0.0142 | 0.00221 | 0.047 | 0.293 |

| ALK | COST | FFIV | JWN |
|---|---|---|---|
| 0.138 | 0.765 | 0.258 | -0.161 |

**Table 17:** Summary of the tangency portfolio

Recall that the Sharpe ratios of the individual assets are:

| | Sharpe Ratio |
|---|---|
| ALK | 0.1583 |
| COST | 0.2541 |
| FFIV | 0.1658 |
| JWN | 0.0119 |

**Table 18:** The Sharpe ratios of the individual assets

The Sharpe ratio of the tangency portfolio is 0.293, which is larger than those of the individual assets.

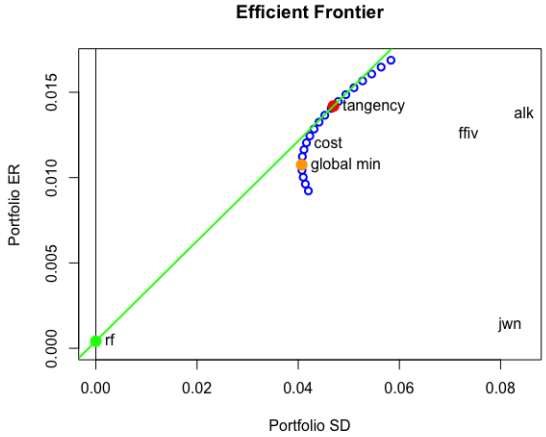



**Figure 11:** The efficient portfolios consisting of T-bills and risky assets

## 4.9 The efficient portfolio frontier not allowing for short sales

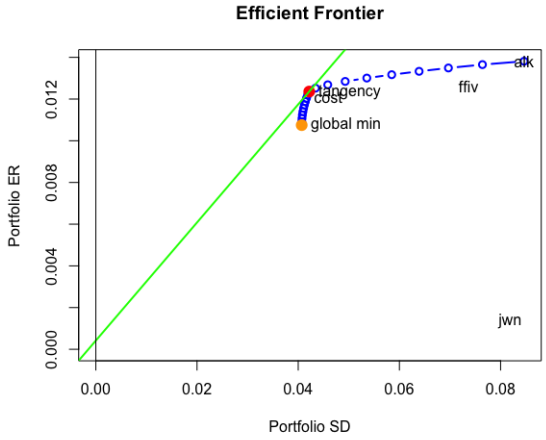



**Figure 12:** The efficient portfolio frontier not allowing for short sales

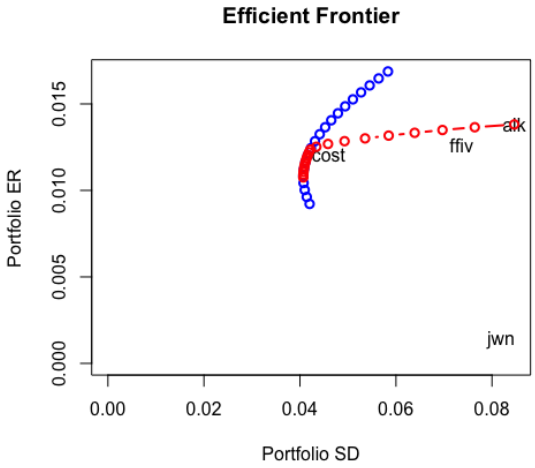



**Figure 13:** The no short sale frontier with the frontier allowing short sales

For these target returns, the no-short sales frontier will lie inside and to the right of the frontier that allows short sales if the no-short sales restrictions are binding for some asset.

Now consider a portfolio with a target volatility of 0.05 or 5% per month . The approximate cost in expected return of investing in a no short sale efficient portfolio versus a short sale efficient portfolio is 0.00202.

(The reason that I don't consider a portfolio with a target volatility of 0.02 or 2% per month: the sd of the global minimum variance portfolio is $0.0407 > 0.02$.)

### 4.10 The tangency portfolio imposing the additional restriction that short-sales are not allowed

| Expected Return | Variance | Standard Deviation | Sharpe Ratio |
|---|---|---|---|
| 0.0124 | 0.00178 | 0.0422 | 0.283 |

| ALK | COST | FFIV | JWN |
|---|---|---|---|
| 0.0848 | 0.6933 | 0.2219 | 0.0000 |

**Table 19:** Summary of The tangency portfolio (no short-sales)

The value of Sharpe's slope for the no-short sales tangency portfolio is 0.283.

The tangency portfolio where short-sales are not allowed has a smaller annual mean and a smaller annual standard deviation than the tangency portfolio where short-sales are allowed.

| | Shorts | No Shorts |
|---|---|---|
| Annual Mean | 0.170 | 0.148 |
| Annual SD | 0.163 | 0.146 |

**Table 20:** Annual mean and annual standard deviation of the tangency portfolio (With short-sale vs. no short-sale)

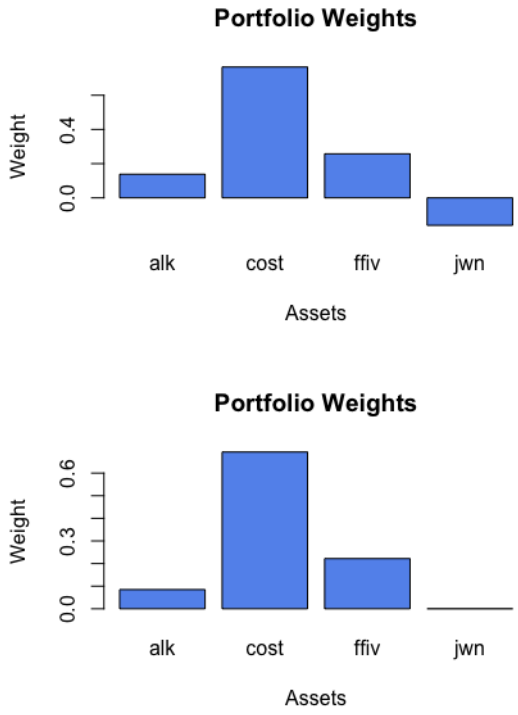



**Figure 14:** The weights of the 4 assets of the tangency portfolio (with short-sale vs. no short-sale)

# 5 Can I beat the S&P 500?

In this section, we construct an efficient portfolio with the same risk-level as the S&P 500 portfolio and see if we could have done better.

## 5.1 Equity curves of the S&P 500 and the tangency portfolio based on an investment timeline of April 2013-April 2018

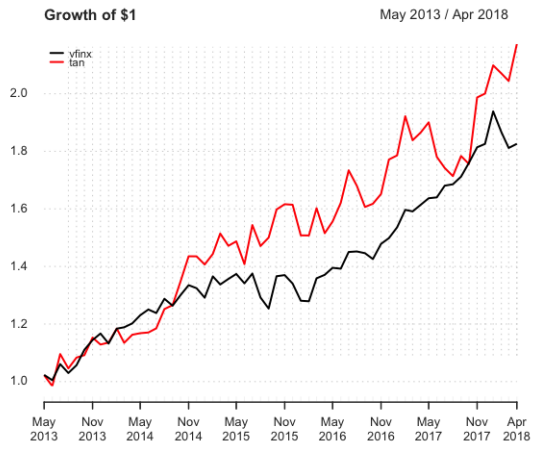



**Figure 15:** Equity curves of the S&P 500 and the tangency portfolio

The equity curves show that a $1 investment in the tangency portfolio did better than a $1 investment in VFINX. For the tangency portfolio $1 grew to about $2.2, and for VFINX $1 grew to only about $1.8.

We are able to outperform the S&P500 portfolio because the tangency portfolio maximizes the Sharpe Ratio, which is the risk-adjusted return. Thus we would expect that $1 grow fastest for the tangency portfolio.

## 5.2 An efficient portfolio (mix of risk-free asset and tangency portfolio) based on the same risk-level as the S&P 500 portfolio

$x_t = 0.616$ and $x_f = 0.384$. The investor that purchases this asset is risk averse.

| | Efficient | S&P500 |
|---|---|---|
| Mean | 0.0089 | 0.0100 |
| Standard Deviation | 0.0289 | 0.0289 |
| Sharpe's Ratio | 0.2932 | 0.3323 |

**Table 21:** Summary of the efficient portfolio and the S&P 500 portfolio

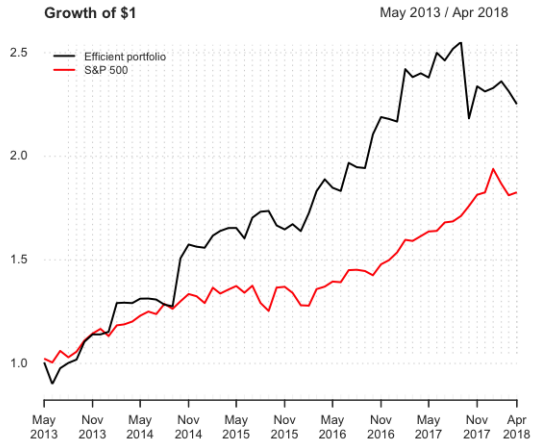



**Figure 16:** Equity chart of the S&P 500 and the new efficient portfolio

From the graph, we are still able to outperform the S&P 500.

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