Descriptive Statistics for Financial Time Series

Econ 424
Winter 201
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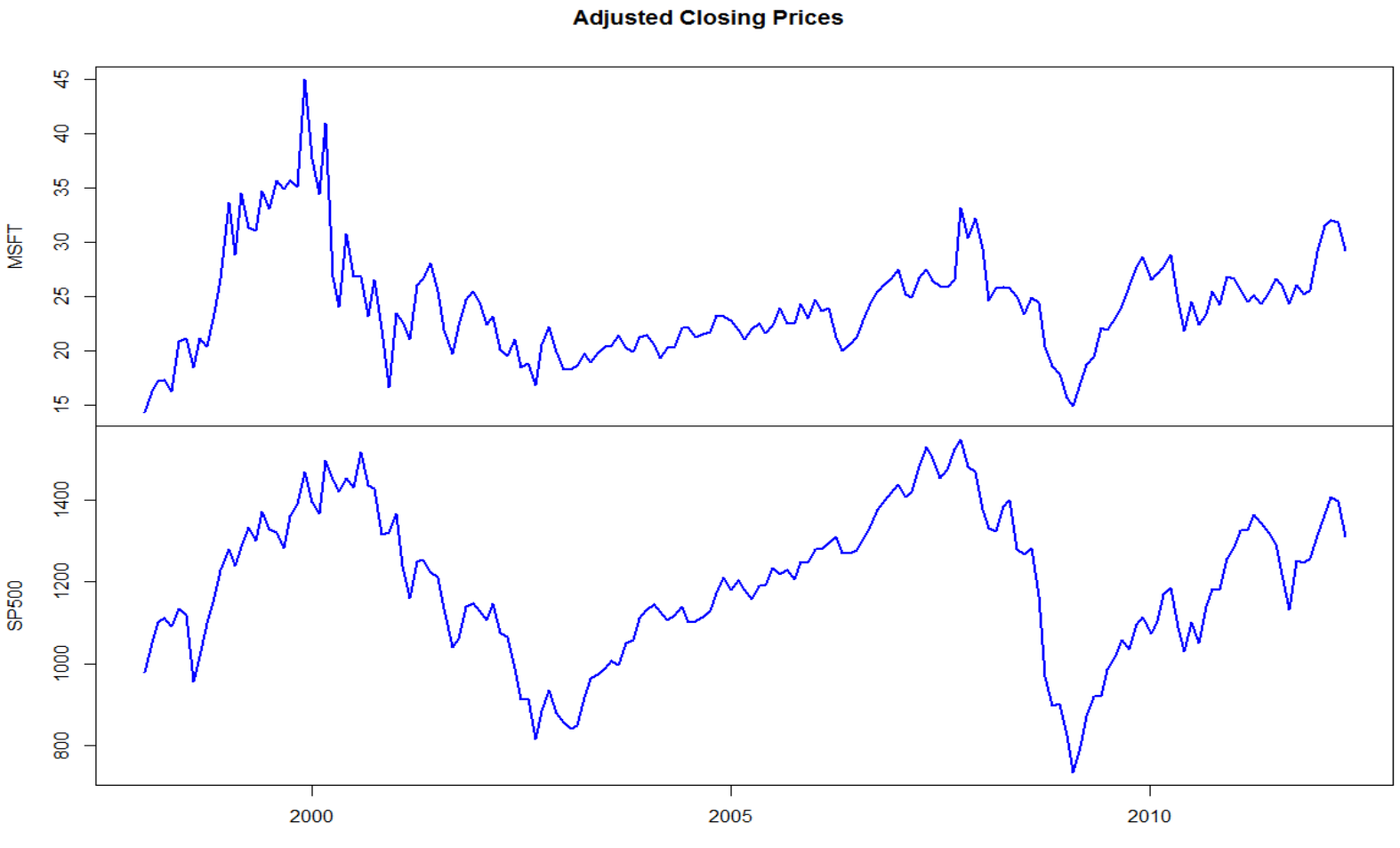
Updated: January 26, 2015

Data for Examples

```
# Load libraries
> library(tseries)
> library(PerformanceAnalytics)

# Get adjusted closing price data from Yahoo!
> MSFT.prices = get.hist.quote(instrument="msft", start="1998-01-01",
+                              end="2012-05-31", quote="AdjClose",
+                              provider="yahoo", origin="1970-01-01",
+                              compression="m", retclass="zoo")

> SP500.prices = get.hist.quote(instrument="^gspc", start="1998-01-01",
+                              end="2012-05-31", quote="AdjClose",
+                              provider="yahoo", origin="1970-01-01",
+                              compression="m", retclass="zoo")
```

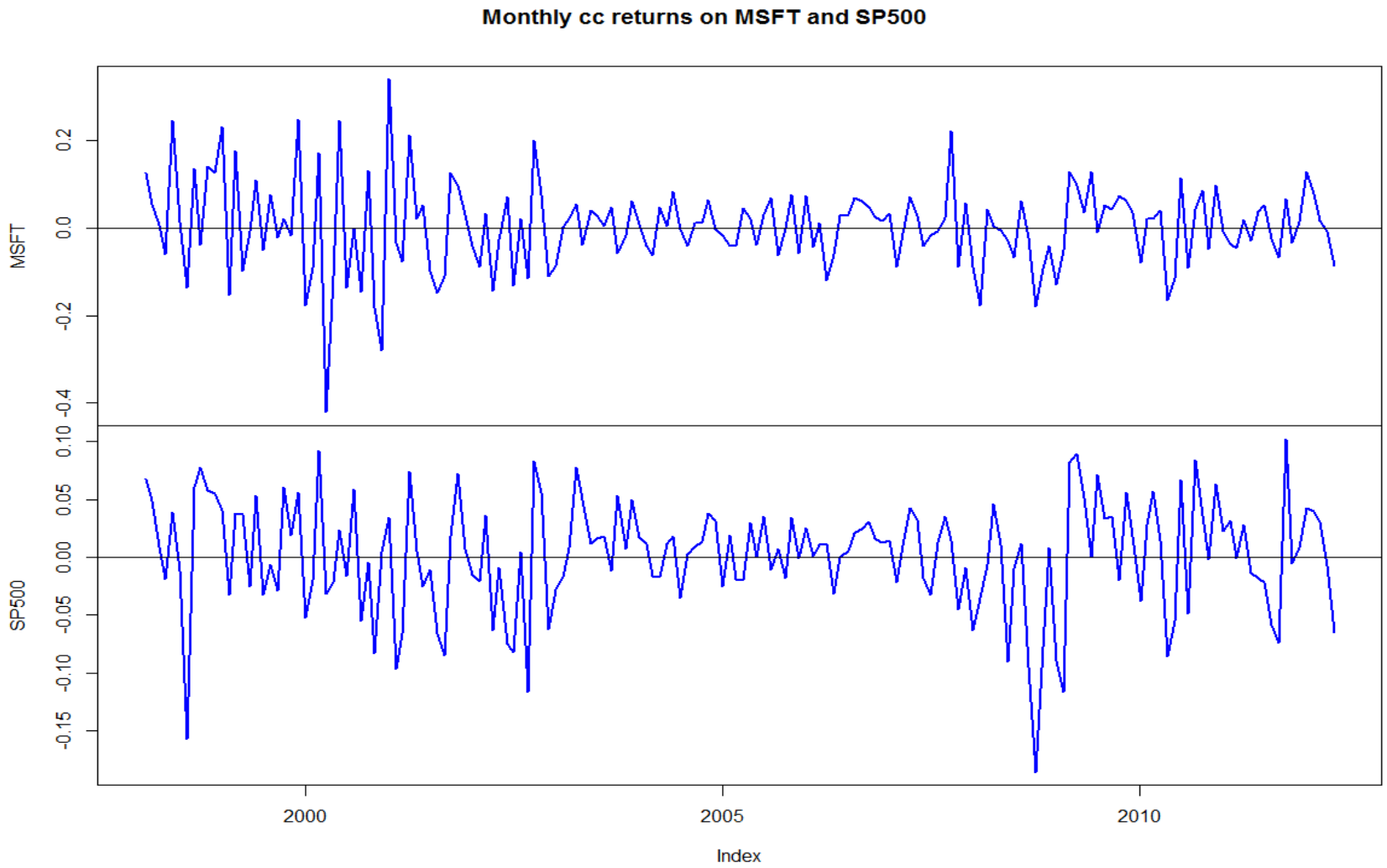
- Note: **`MSFT.prices`** and **`SP500.prices`** are "zoo" objects. "zoo" is a special time series class (from the **zoo** package) that is very useful for financial data.
- See the document "Working with Financial Time Series Data in R" on the class syllabus page.

Price Data

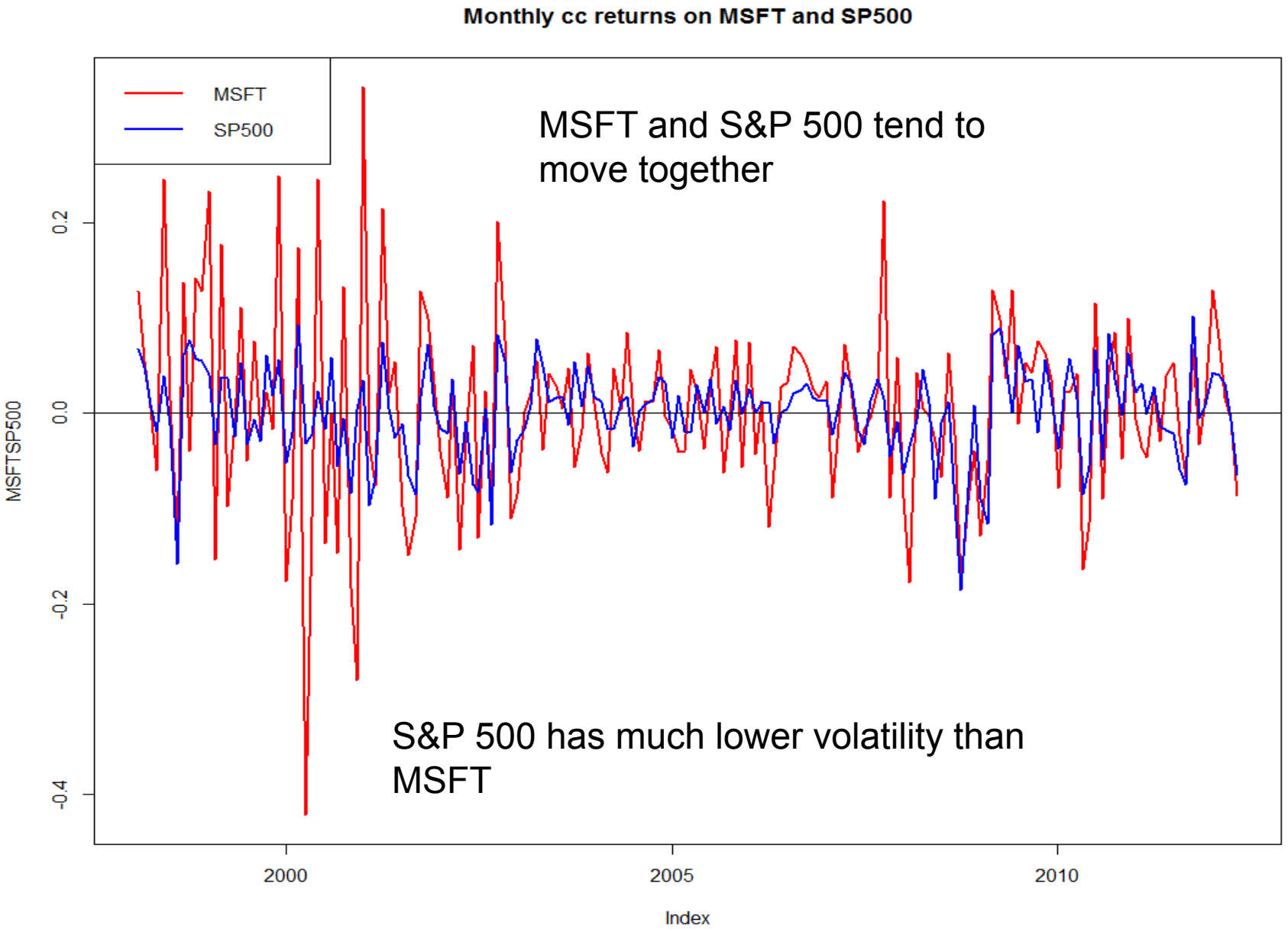



```
> plot(MSFTSP500.prices, main="Adjusted Closing Prices",
     lwd=2, col="blue")
```

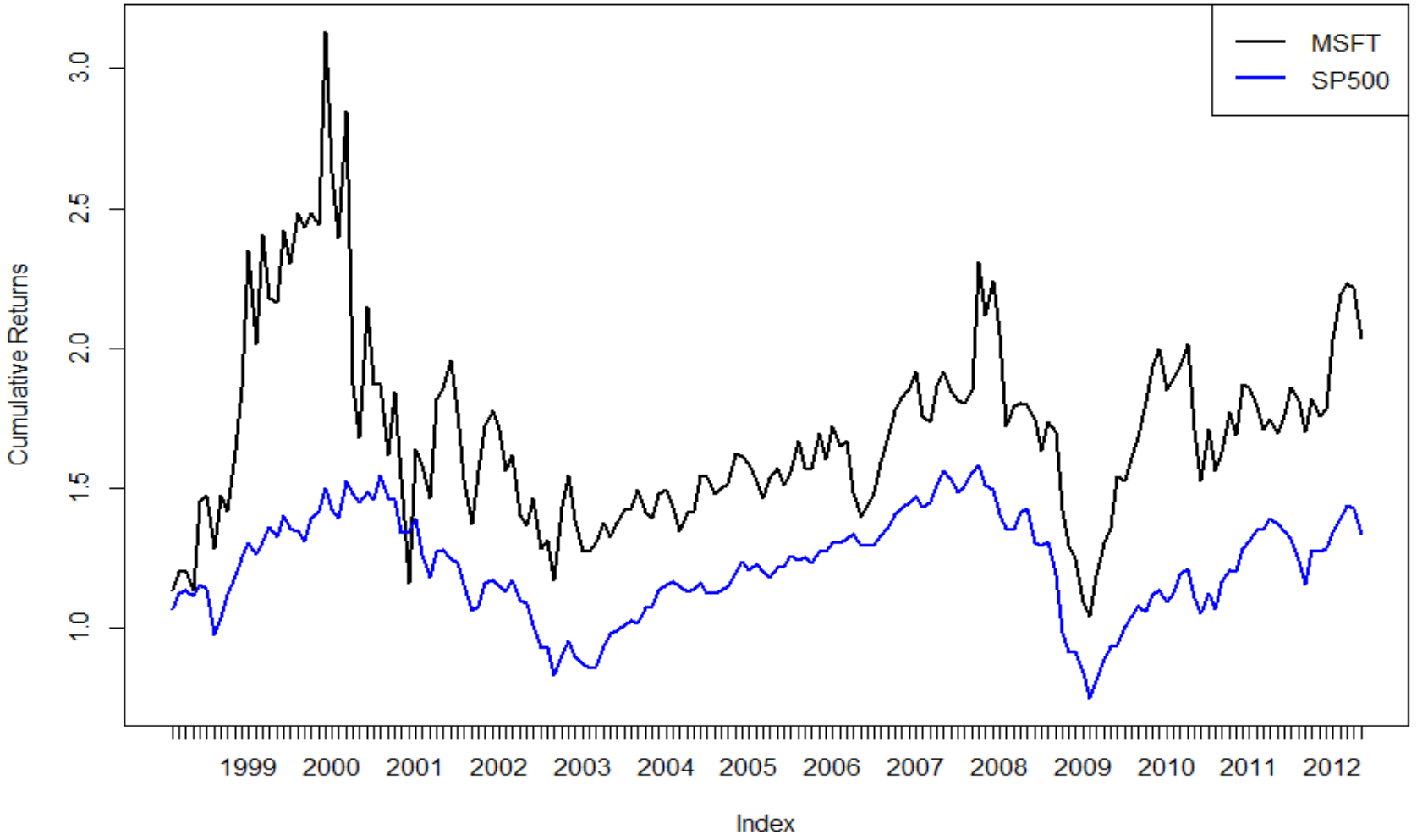
Monthly Continuously Compounded Returns



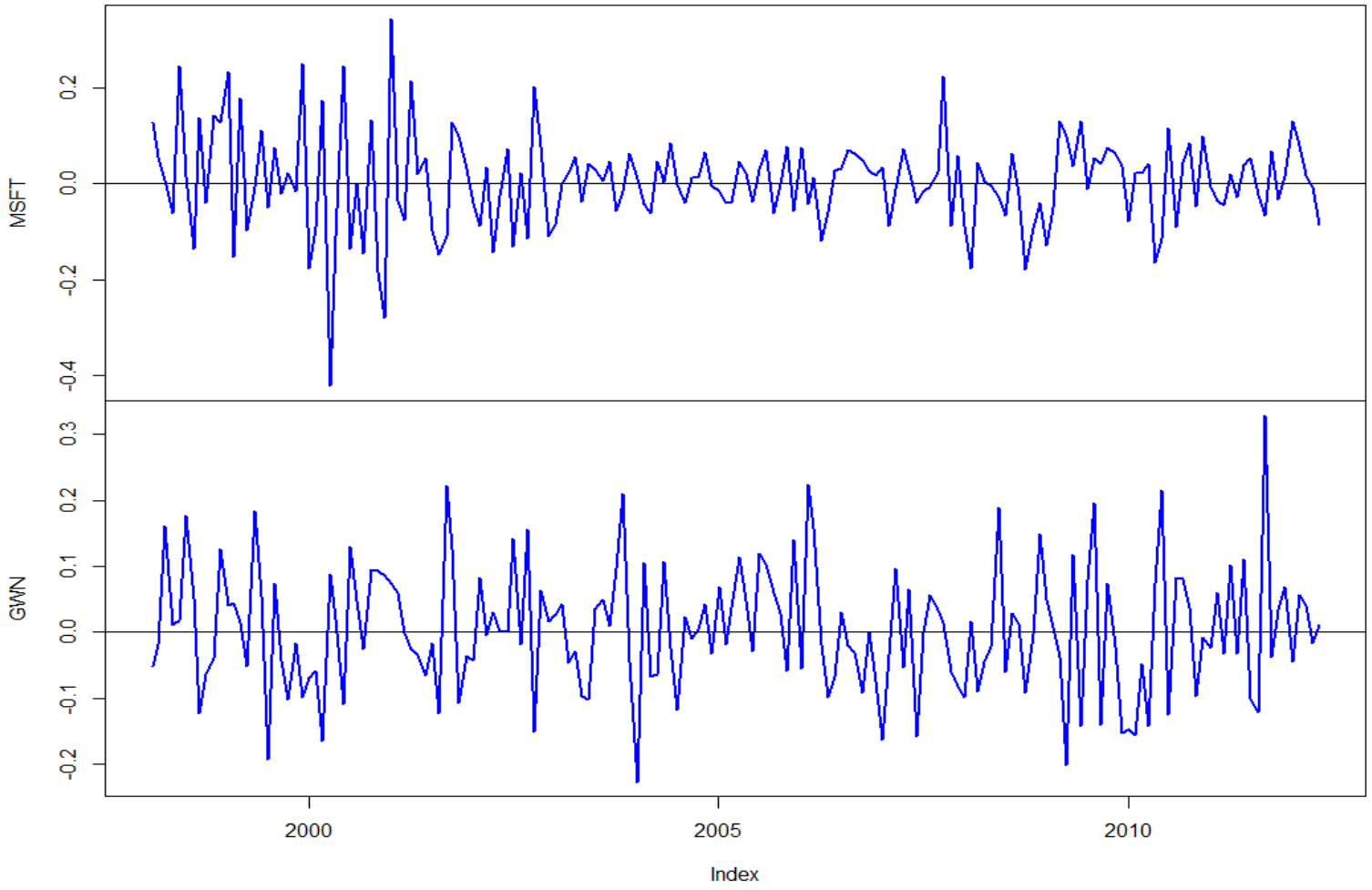
Q: What common features do you see?



Compare Cumulative Returns: Equity Curve

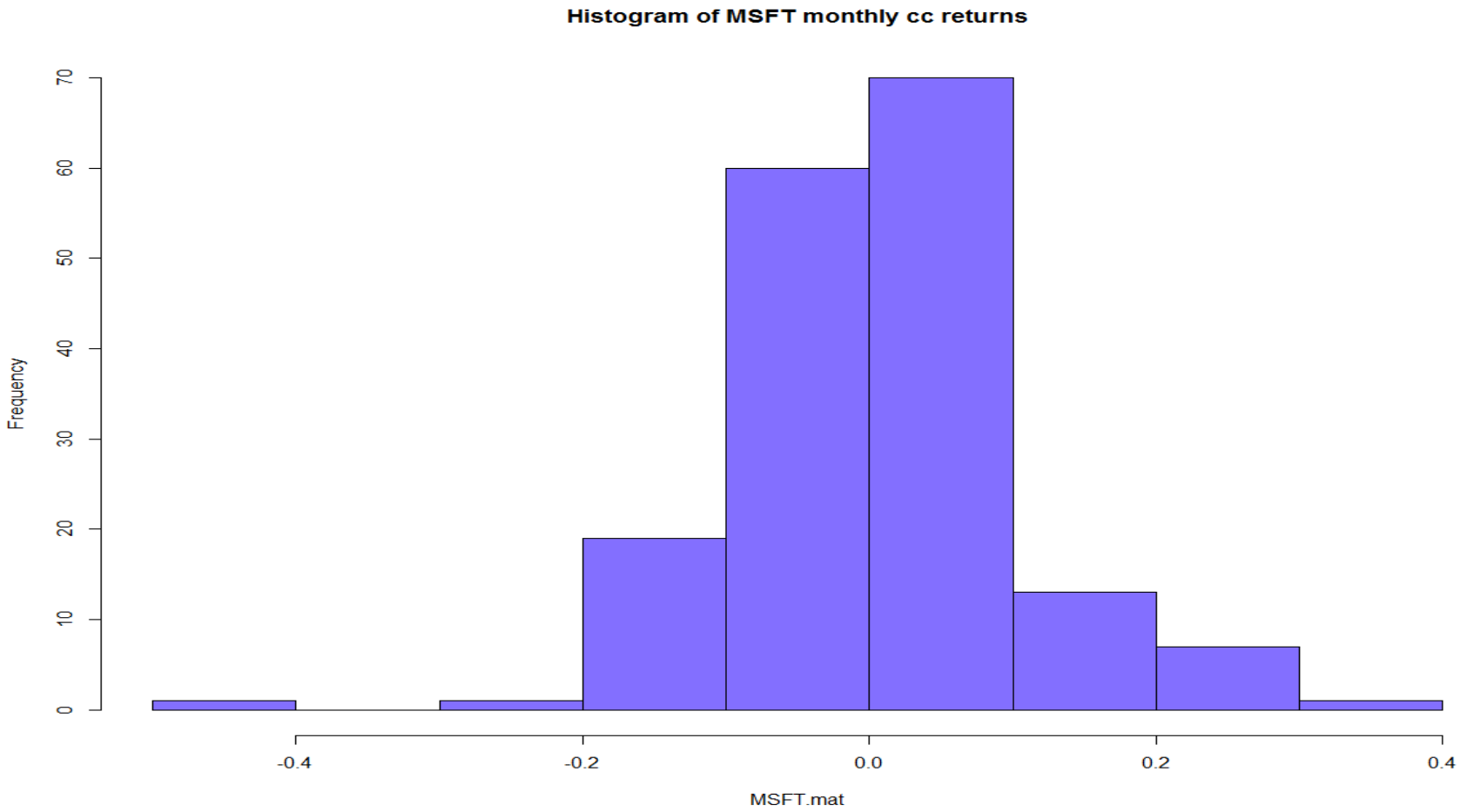


Are Monthly Returns Gaussian White Noise?

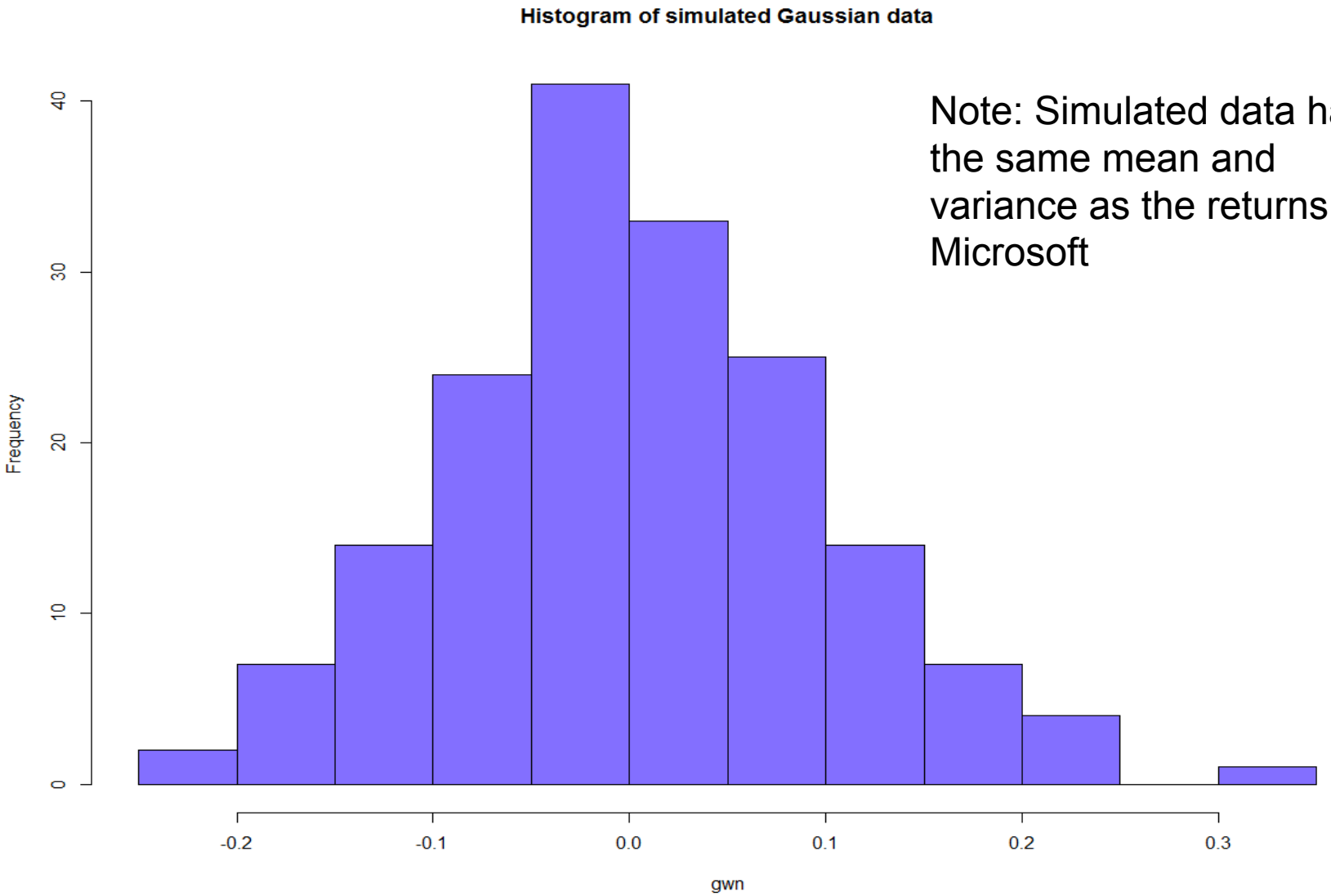



```
> set.seed(123)
> gwn = rnorm(length(MSFT),mean=mean(MSFT),sd=std(MSFT))
```

Estimating the pdf: Histogram

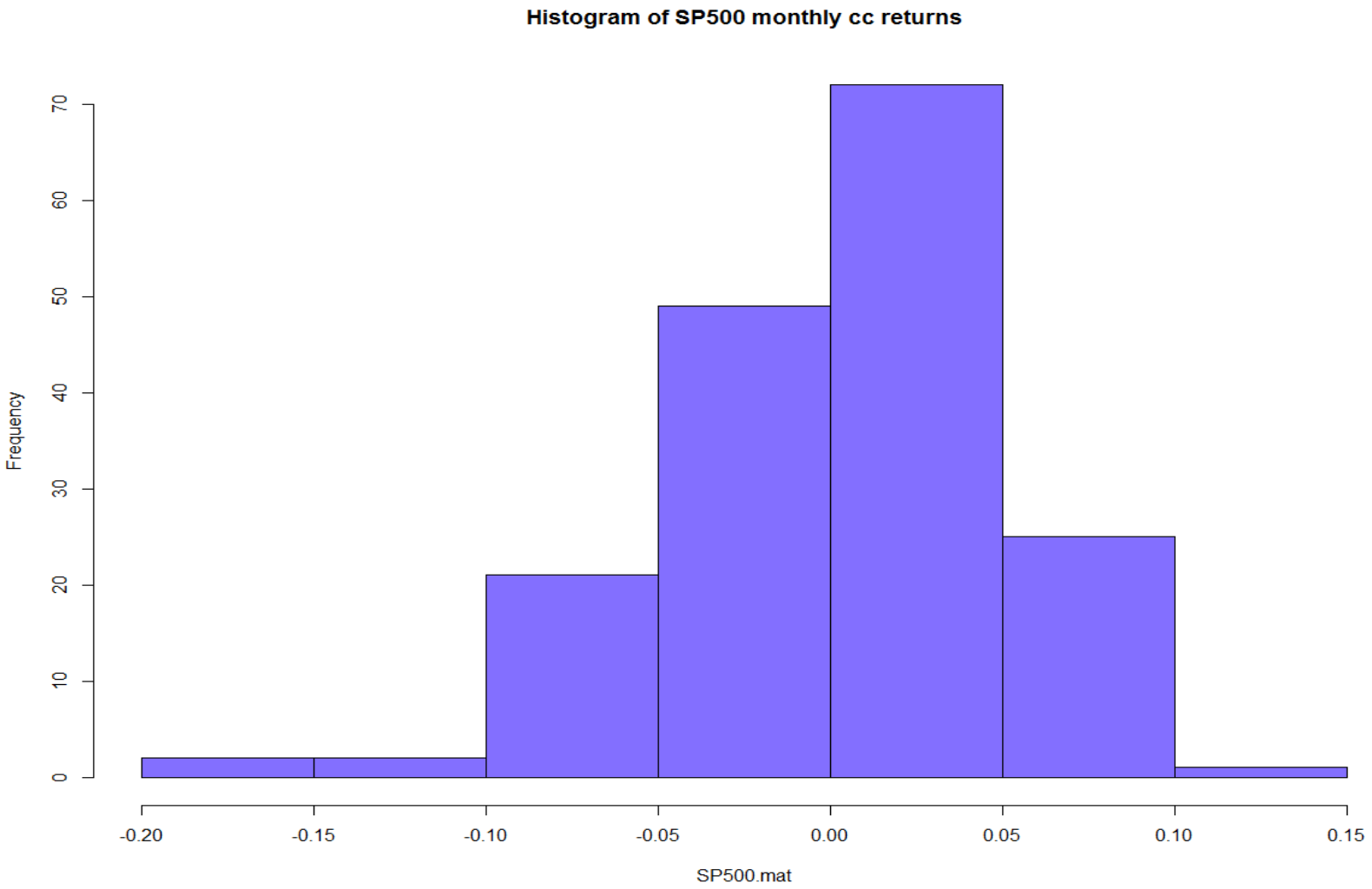



```
> hist(MSFT,main="Histogram of MSFT monthly cc returns“,
+      col=“slateblue1”)
```



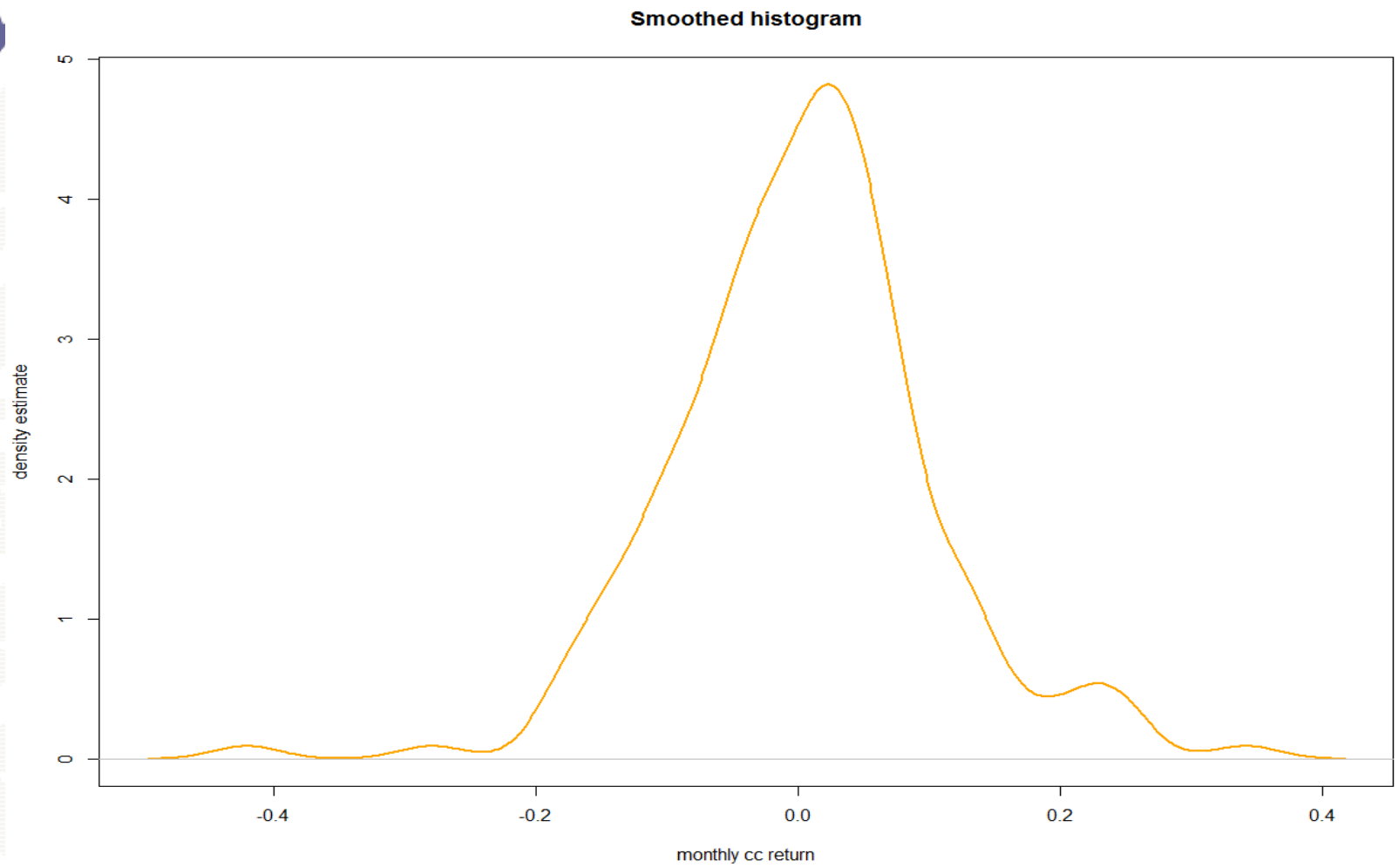
Note: Simulated data has the same mean and variance as the returns on Microsoft

```
> hist(gwn,main="Histogram of simulated Gaussian data“,
+      col=“slateblue1”)
```

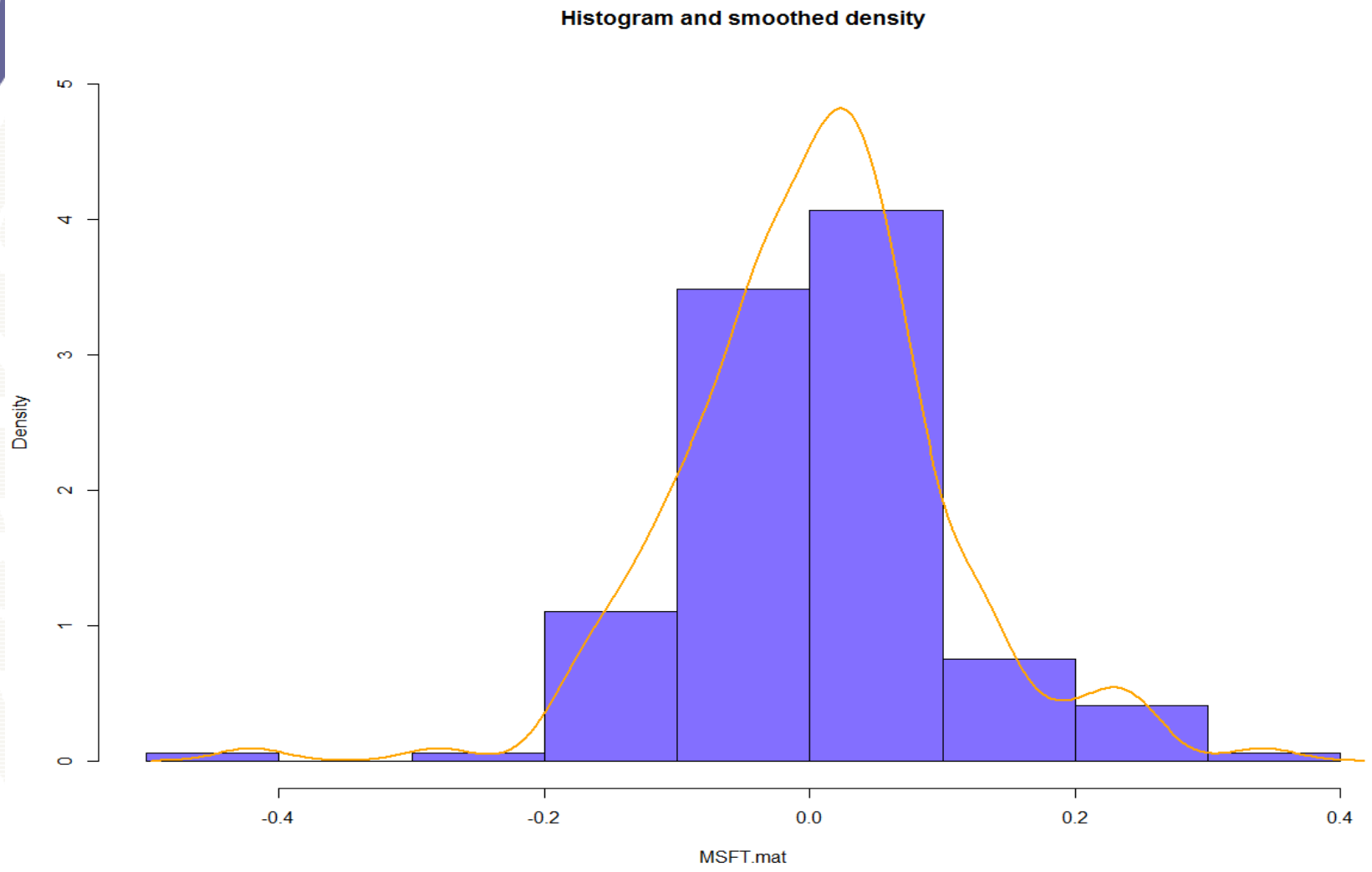



```
> hist(SP500,main="Histogram of SP500 monthly cc returns“,
+       col=“slateblue1”)
```

Note: MSFT has larger SD (volatility) than S&P 500




```
> MSFT.density = density(MSFT)
> plot(MSFT.density,type="l",xlab="monthly return",
+      ylab="density estimate",main="Smoothed histogram for MSFT
+      monthly cc returns“, col=“orange”, lwd=2)
```




```
> hist(MSFT,main="Histogram and smoothed density of MSFT
+      monthly returns", probability=T, col="slateblue1",
+      ylim=c(0,5))
> points(MSFT.density, type="l", col="orange", lwd=2)
```

Computing quantiles

```
> quantile(MSFT.ret.mat)
       0%        25%        50%        75%       100%
-0.421081 -0.050019  0.008343  0.055535  0.342188

# 1% and 5% empirical quantiles
> quantile(MSFT.ret.mat,probs=c(0.01,0.05))
      1%      5%
 -0.2110 -0.1473
# compare to 1% and 5% normal quantiles
> qnorm(p=c(0.01,0.05), mean=mean(MSFT.ret.mat),
+       sd=sd(MSFT.ret.mat))
[1] -0.2291 -0.1608
# SP500 empirical and normal quantiles
> quantile(SP500.ret.mat,probs=c(0.01,0.05))
      1%       5%
-0.12846 -0.08538
> qnorm(p=c(0.01,0.05), mean=mean(SP500.ret.mat),
+       sd=sd(SP500.ret.mat))
[1] -0.11107 -0.07804
```

1% and 5% quantiles are used for Value-at-Risk calculations

Monthly VaR Using Empirical Quantiles

```
> q.01 = quantile(MSFT.ret.mat, probs=0.01)
> q.05 = quantile(MSFT.ret.mat, probs=0.05)
> q.01
     1%
-0.211
> q.05
     5%
-0.1473

# Monthly VaR on $100,000 investment
> VaR.01 = 100000*(exp(q.01) - 1)
> VaR.05 = 100000*(exp(q.05) - 1)
> VaR.01
    1%
-19020

> VaR.05
    5%
-13694
```

Summary Statistics

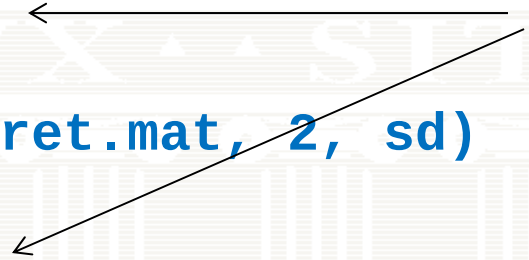
```
> mean(MSFT.ret.mat)
     MSFT
0.004127

> var(MSFT.ret.mat)
          MSFT
MSFT 0.01005

> sd(MSFT.ret.mat)
   MSFT
0.1003

> skewness(MSFT.ret.mat)
[1] -0.09073

> kurtosis(MSFT.ret.mat)
[1] 2.082
```

`Skewness()` function is in package PerformanceAnalytics

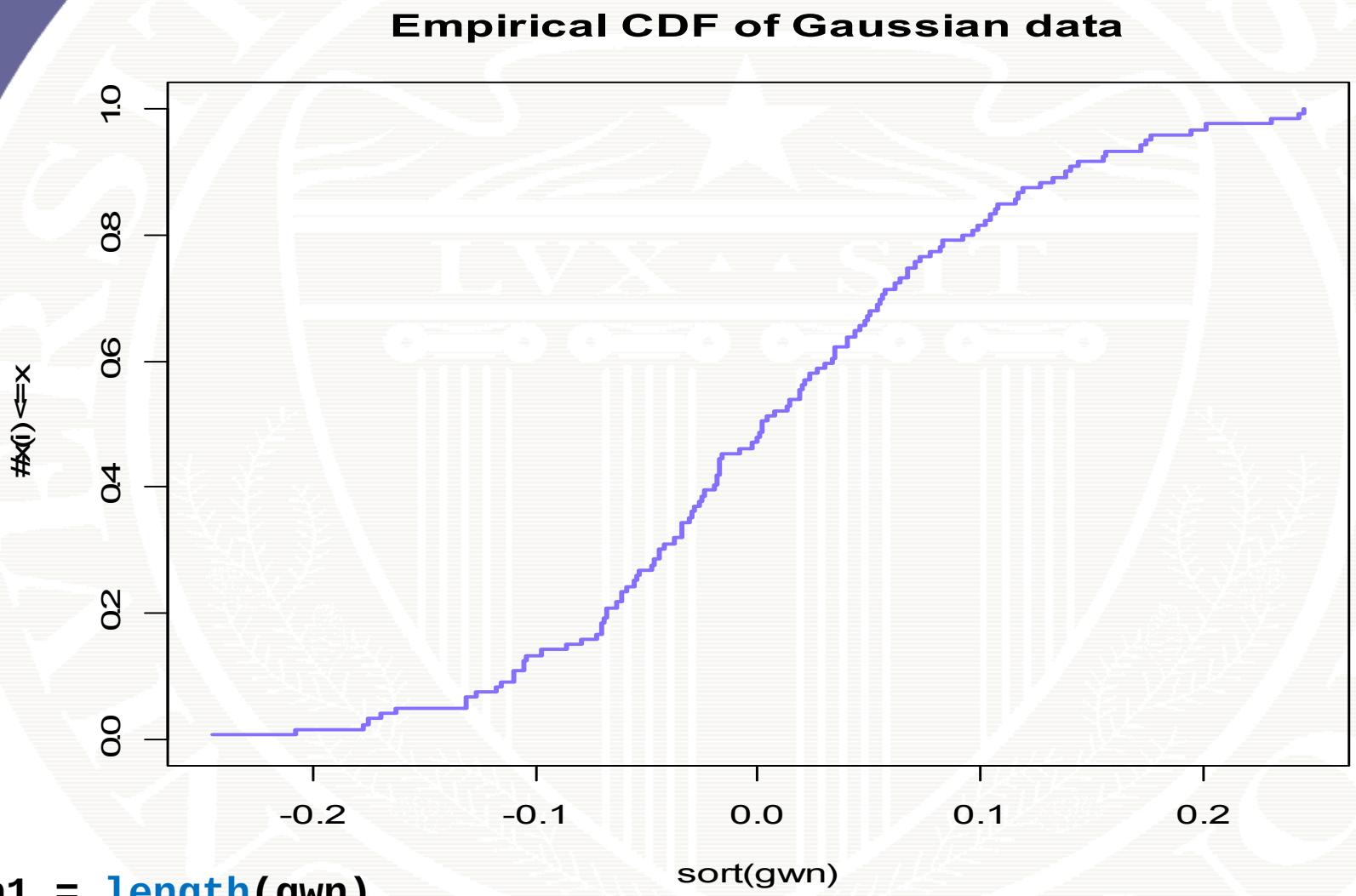
`kurtosis()` function is in package PerformanceAnalytics and computes *excess kurtosis*

Summary Statistics by Column

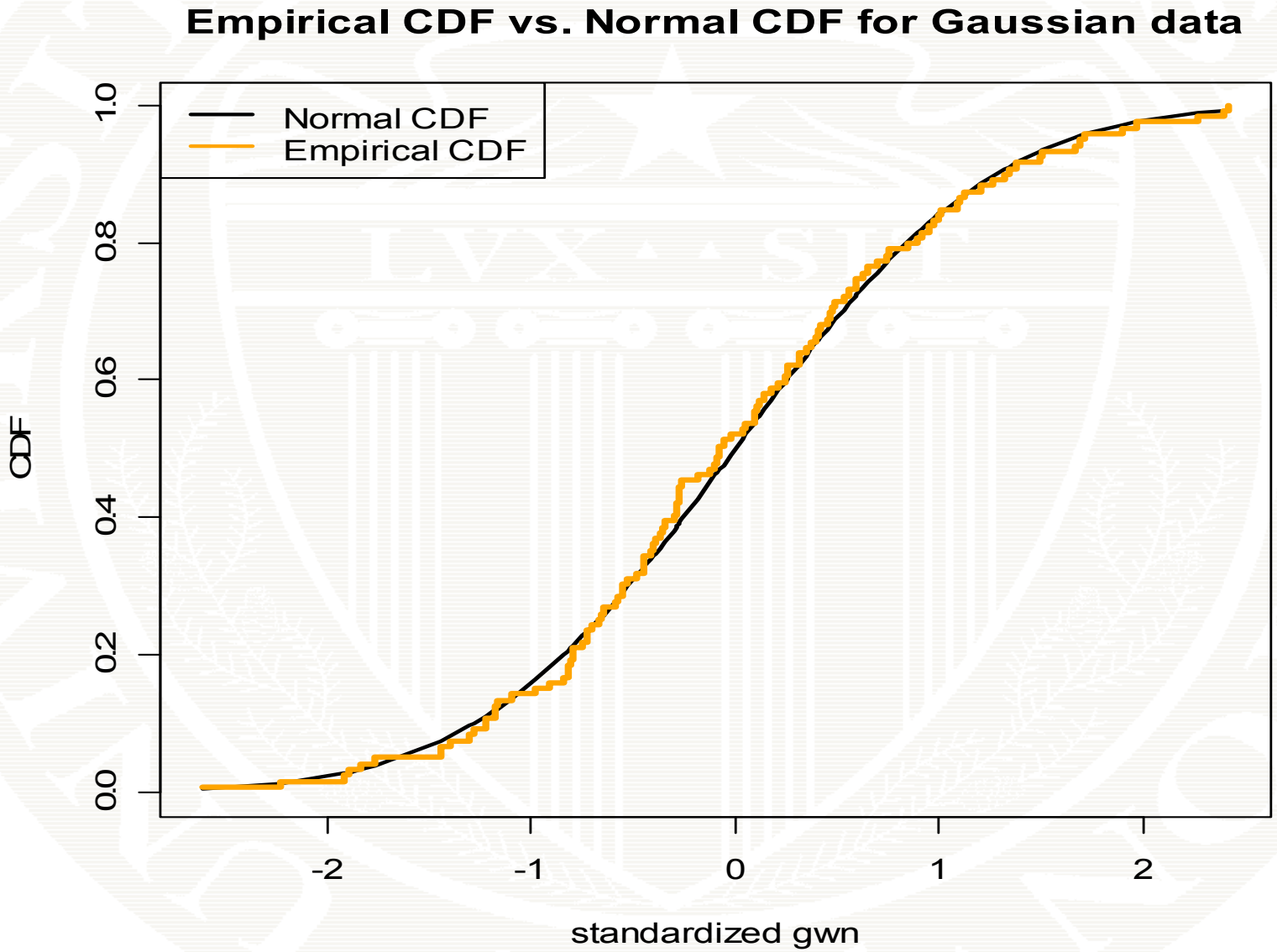
```
> apply(MSFTSP500.ret.mat, 2, mean)
     MSFT     SP500
0.004127 0.001687

> apply(MSFTSP500.ret.mat, 2, sd)
    MSFT    SP500
0.10026 0.04847

> apply(MSFTSP500.ret.mat, 2, skewness)
     MSFT     SP500
-0.09073 -0.73988

> apply(MSFTSP500.ret.mat, 2, kurtosis)
 MSFT SP500
2.082 1.068
```



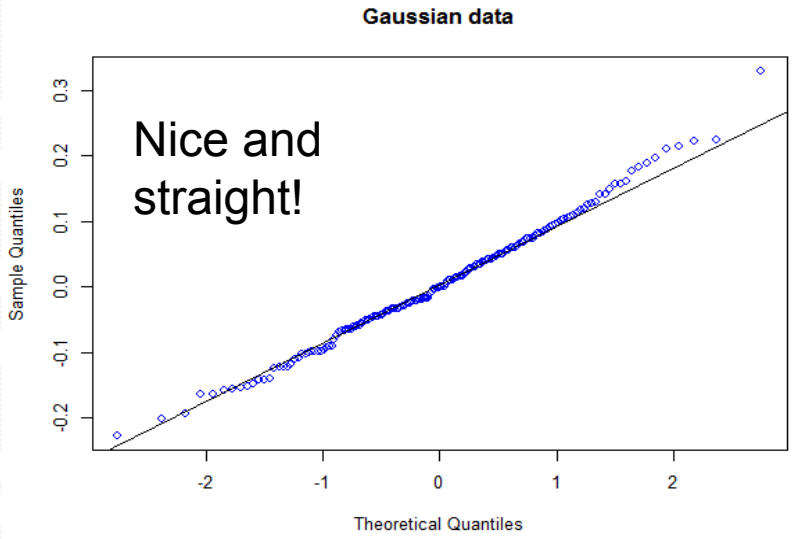
Note: MSFT has a higher mean and higher SD than SP500

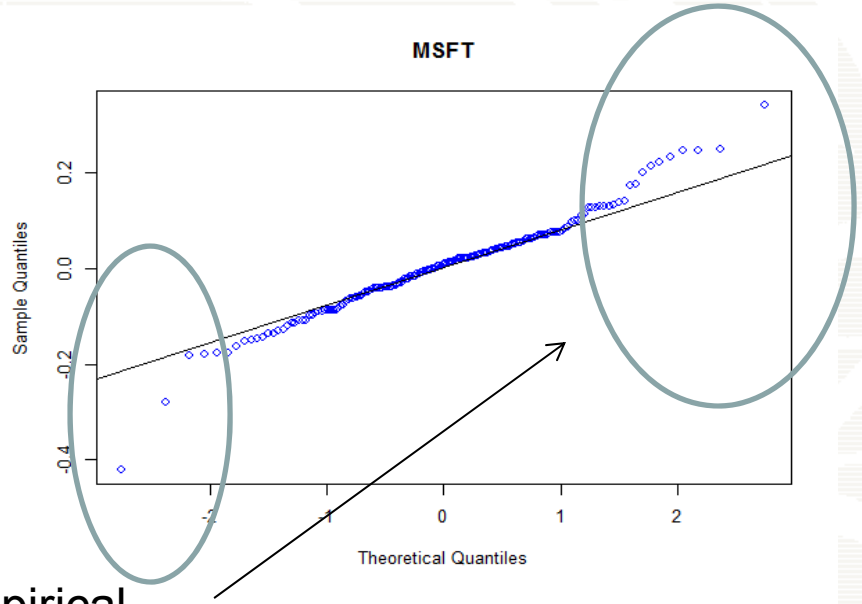


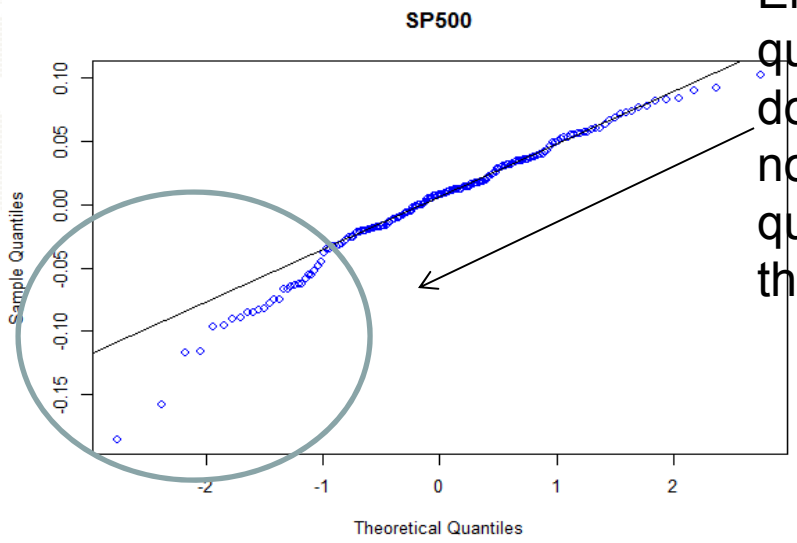

```
> n1 = length(gwn)
> plot(sort(gwn),(1:n1)/n1,type="s",ylim=c(0,1), col="slateblue1"
+ main="Empirical CDF of Gaussian data", ylab="#x(i) <= x")
```



QQ-plots against Normal Distribution



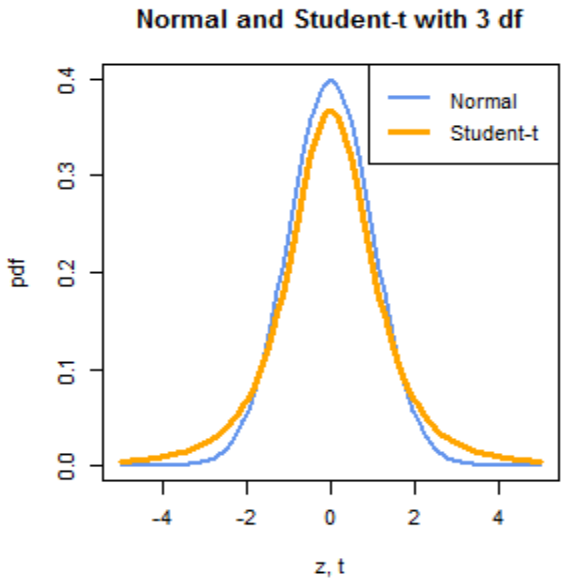


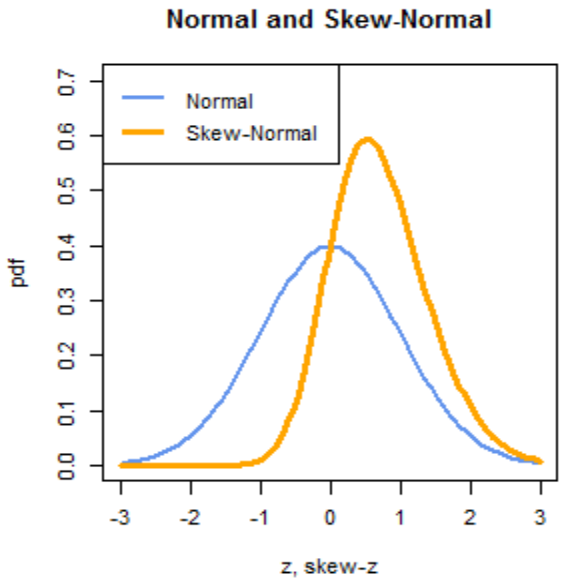


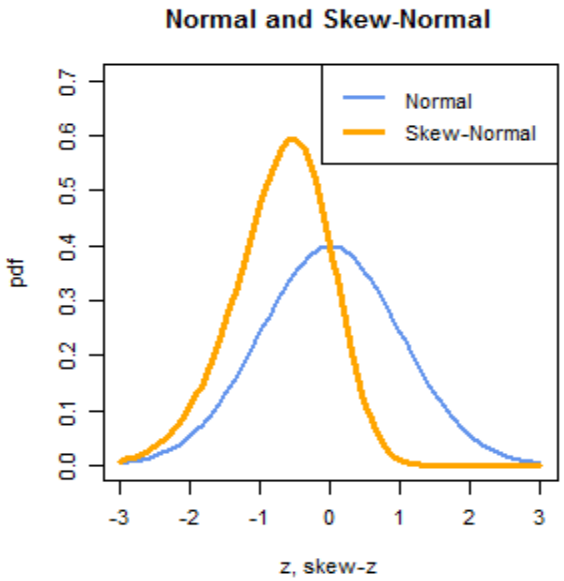
Empirical quantiles don't match normal quantiles in the tails!

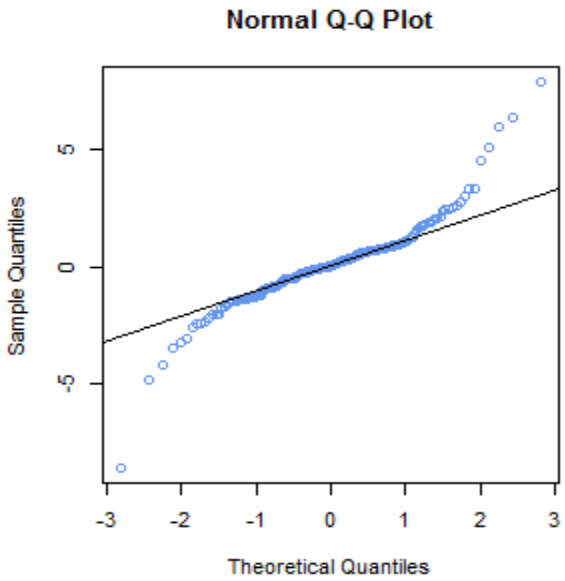
```
> par(mfrow=c(2,2))
>     qqnorm(gwn)
>     qqline(gwn)
>     qqnorm(MSFT.ret)
>     qqline(MSFT.ret)
>     qqnorm(SP500.ret)
>     qqline(SP500.ret)
> par(mfrow=c(1,1))
```

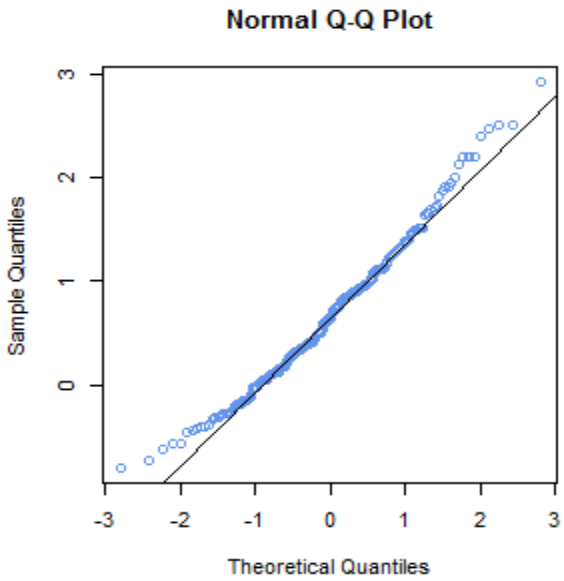
QQ-Plots for Fat-tailed and Skewed Data

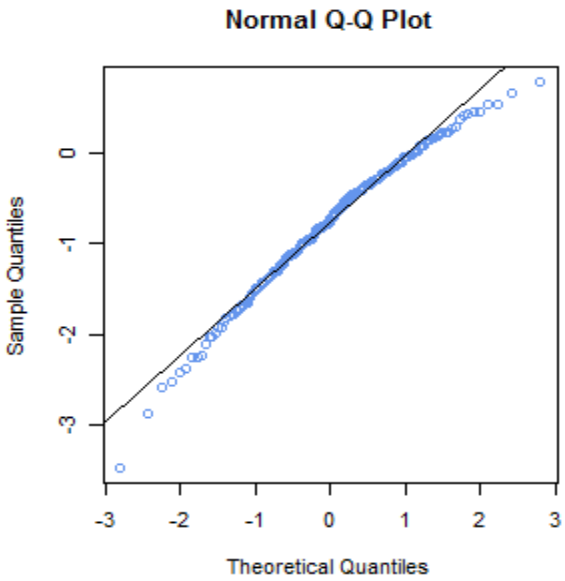


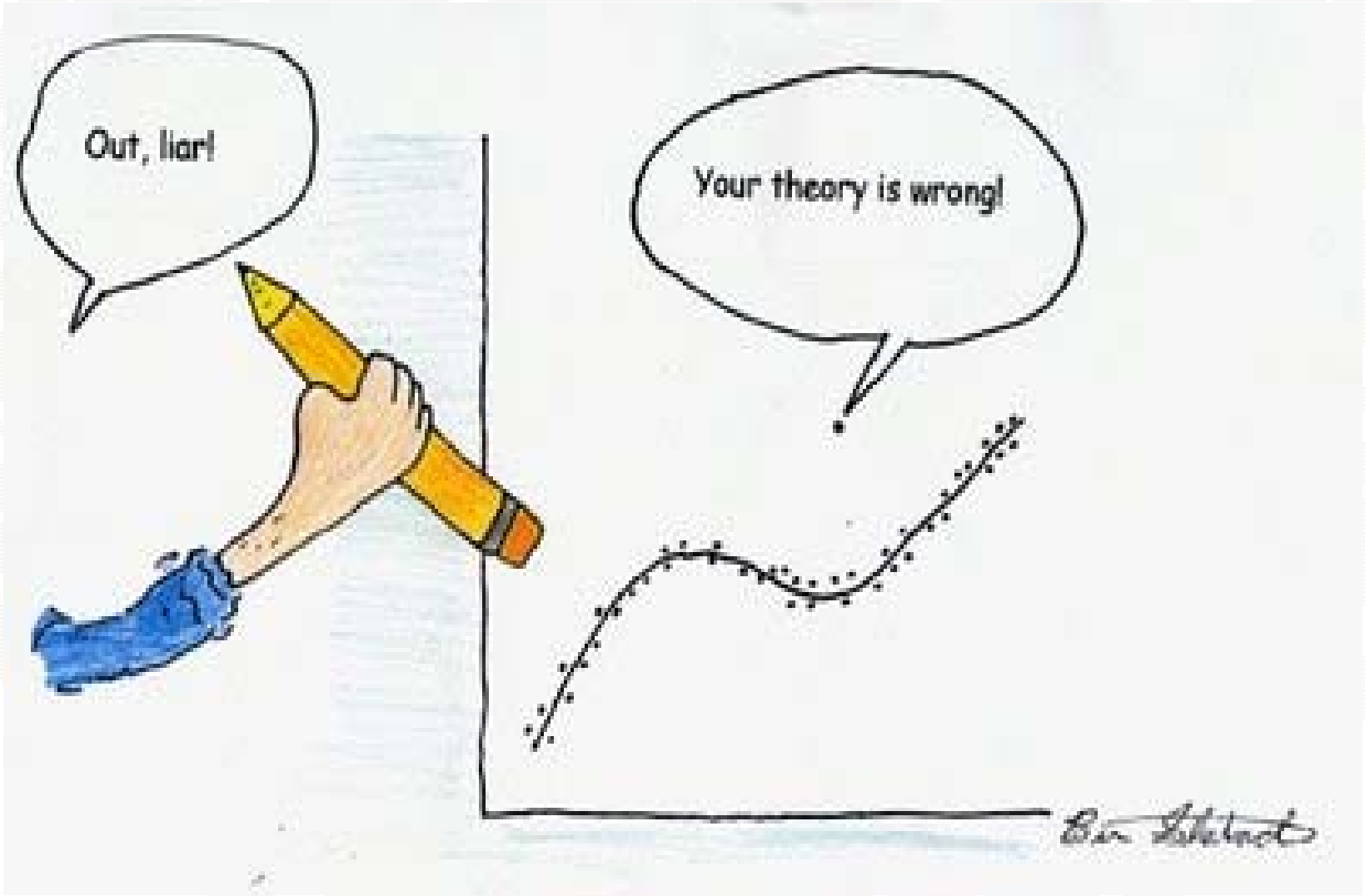




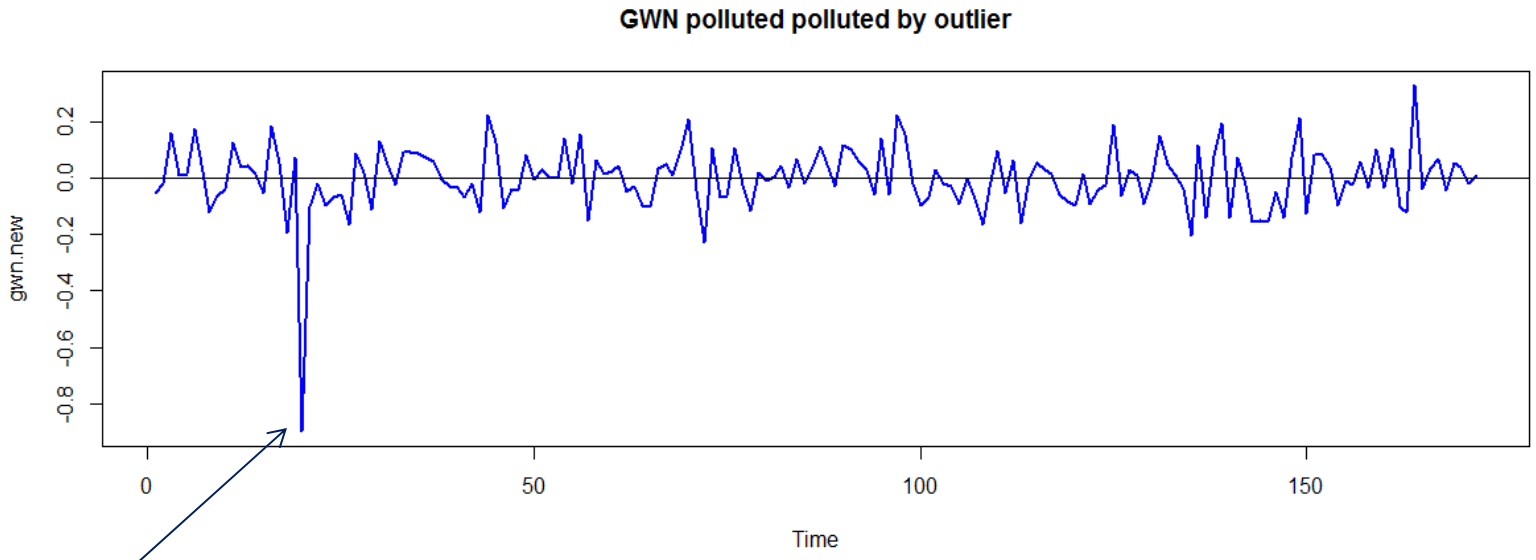




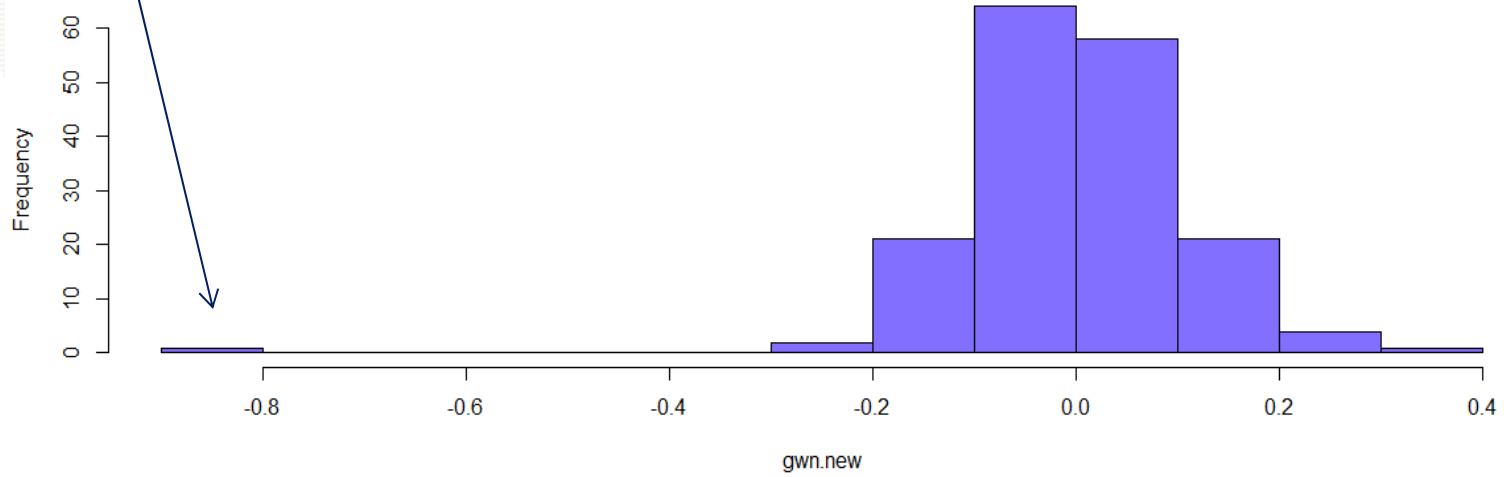




Effect of Outliers on Descriptive Statistics



Outlier

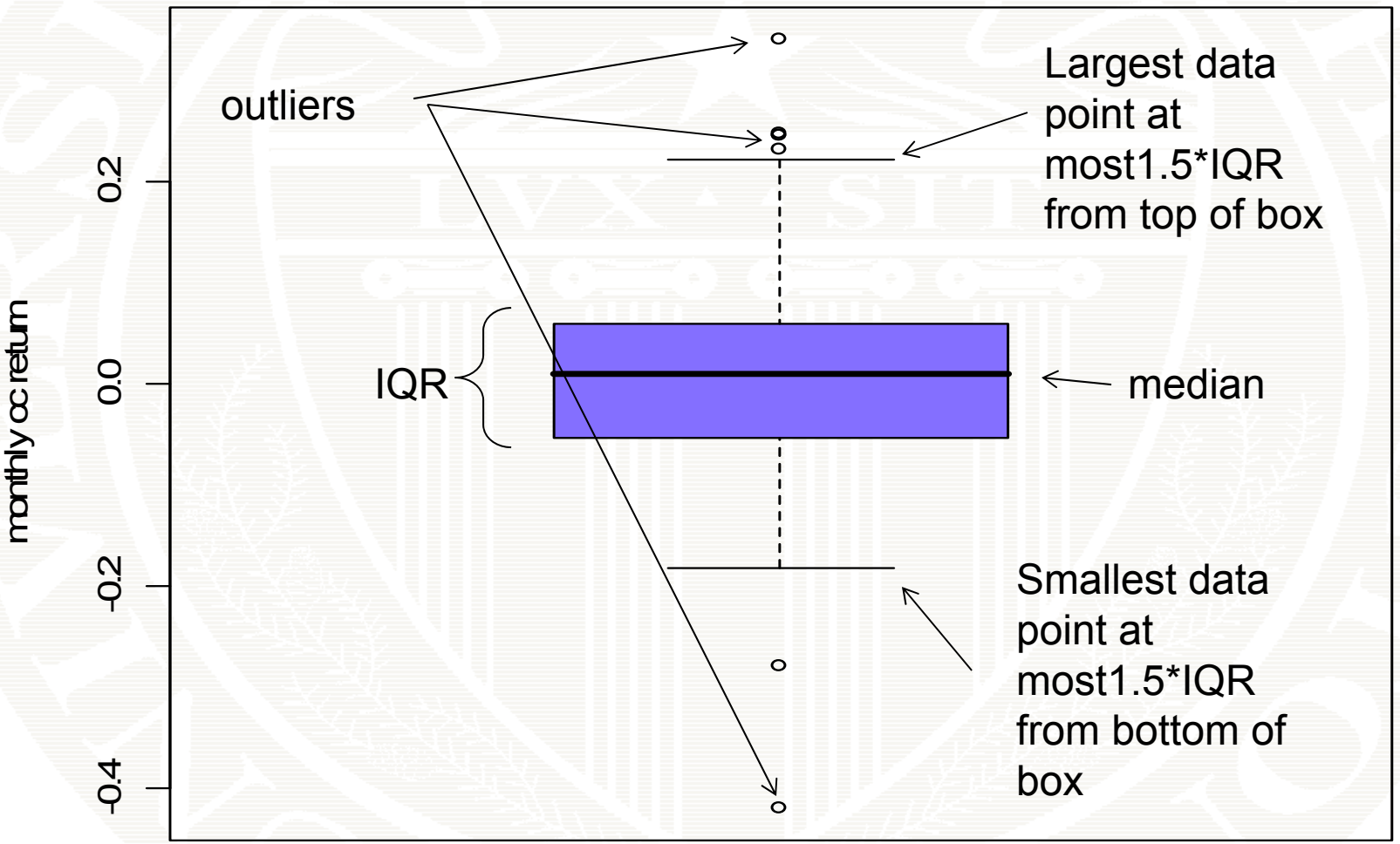


Summary statistics of polluted data

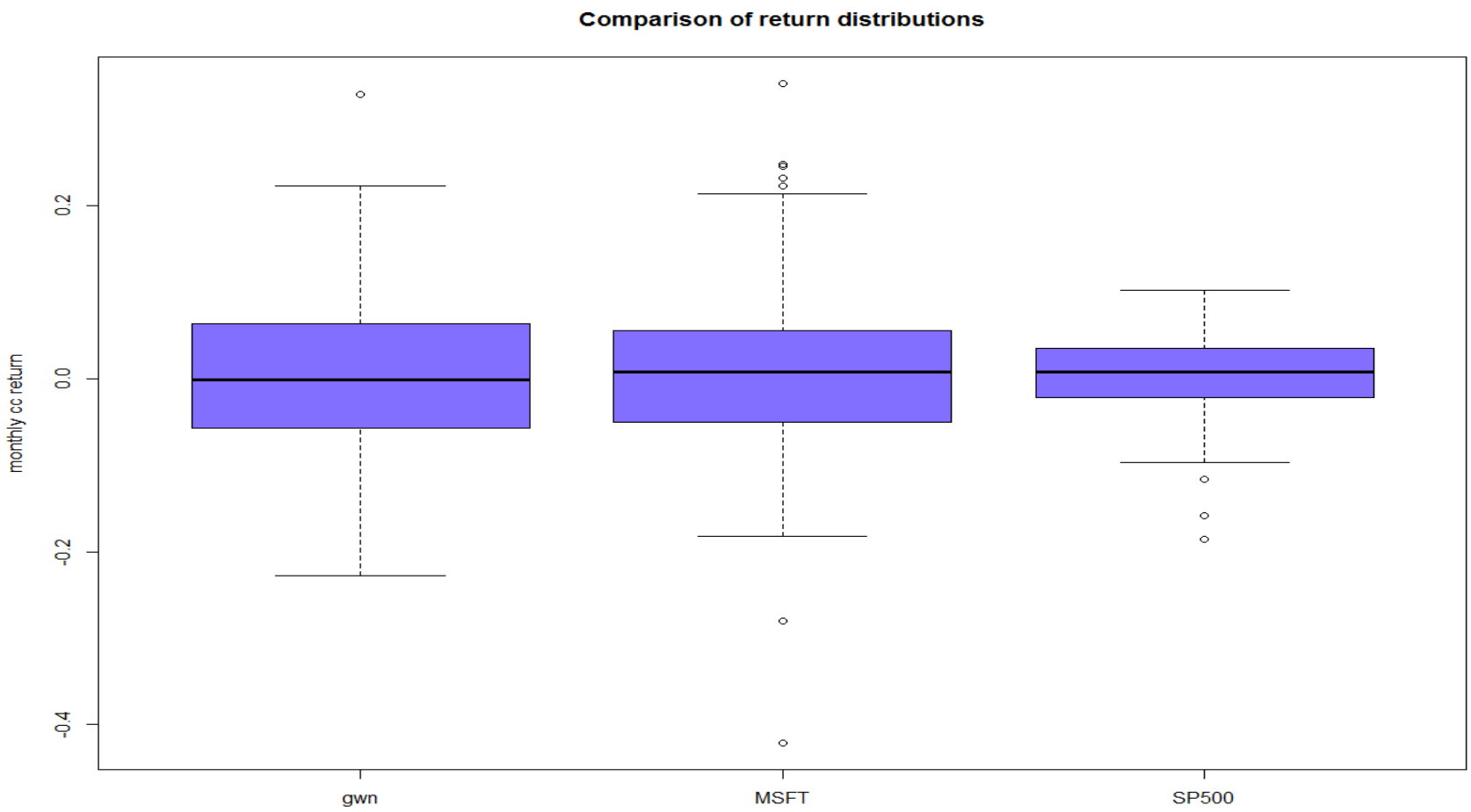
```
> tmp = cbind(gwn, gwn.new)
> apply(tmp, 2, mean)
       gwn    gwn.new
 0.0043420 -0.0006391

> apply(tmp, 2, sd)
     gwn gwn.new
0.09515 0.11746

> apply(tmp, 2, skewness)
     gwn gwn.new
 0.2842 -2.3751

> apply(tmp, 2, kurtosis)
     gwn gwn.new
 0.1557 18.3707
```

Notice how sample statistics are influenced by the single outlier

```
# outlier robust measures
> apply(tmp, 2, median)
       gwn    gwn.new
-0.0009163 -0.0009163

> apply(tmp, 2, IQR)
     gwn gwn.new
  0.1200  0.1219
```




```
> boxplot(MSFT,outchar=T,main="Boxplot of monthly cc
+ returns on Microsoft",ylab="monthly cc return")
```

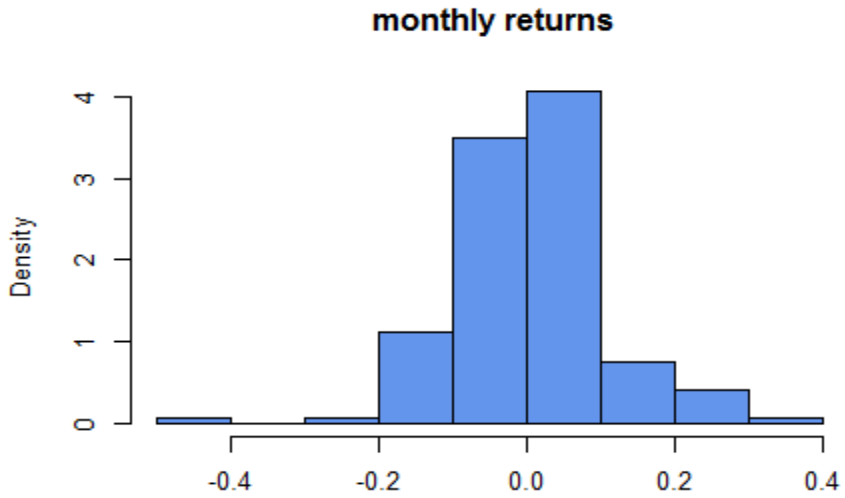


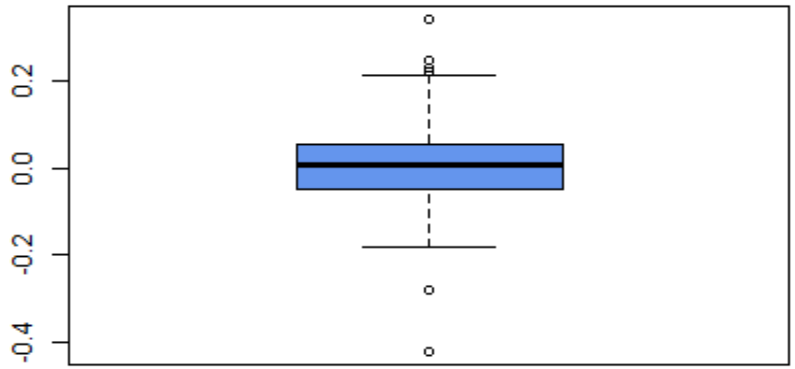

```
> boxplot(gwn,MSFT,SP500,names=c("gwn","MSFT","SP500"),outchar=T,
+ main="Comparison of return distributions", ylab="monthly cc
+ return")
```

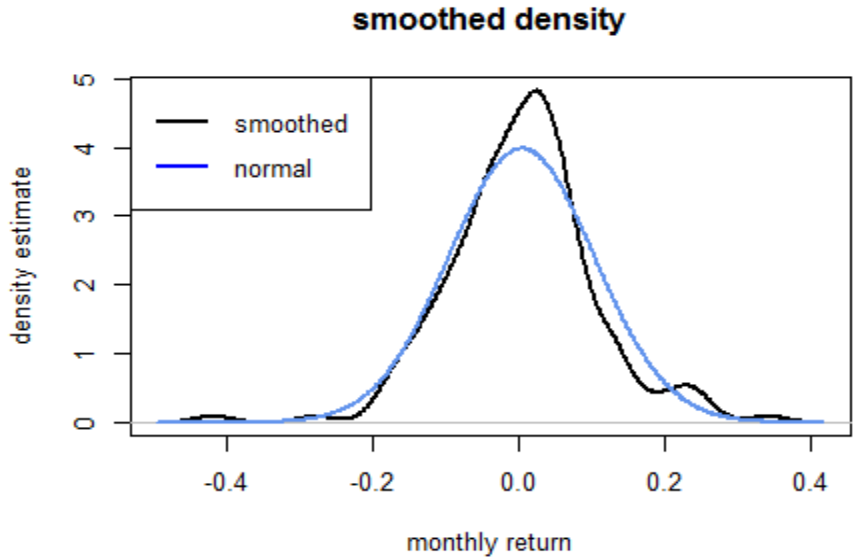
Four Graph Summary

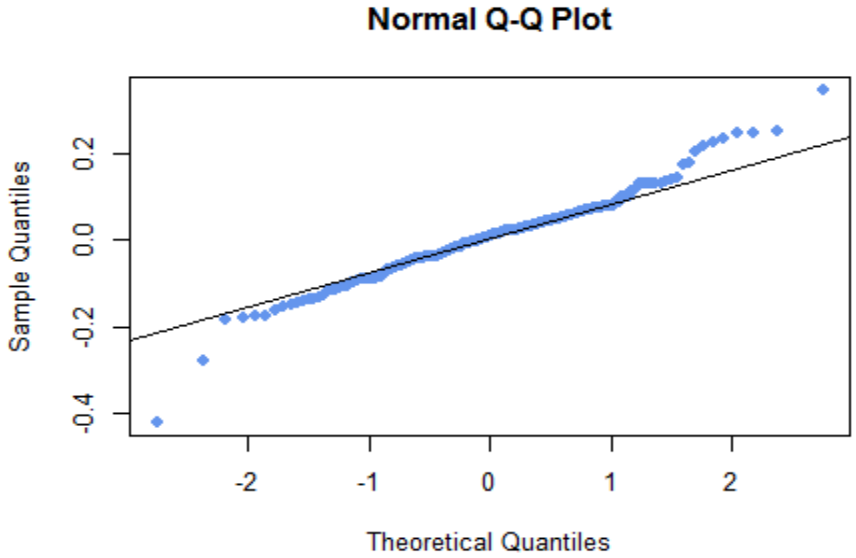
```
fourPanelPlot = function(ret) {
retName = colnames(ret)
  ret.den = density(ret)
  par(mfrow=c(2,2))
  hist(ret, main=paste(retName, " monthly returns", sep=""),
       xlab=retName, probability=T, col="cornflowerblue")
  boxplot(ret, outchar=T,col="cornflowerblue")
  plot(ret.den, main="smoothed density",
       type="l", lwd=2, xlab="monthly return",
       ylab="density estimate")
  lines(ret.den$x, dnorm(ret.den$x, mean=mean(ret), sd=sd(ret)),
        col="cornflowerblue", lwd=2)
  legend(x="topleft", legend=c("smoothed", "normal"),
         lty=c(1,1), col=c("black", "blue"), lwd=2)
  qqnorm(ret, col="cornflowerblue", pch=16)
  qqline(ret)
  par(mfrow=c(1,1))
}
```

> fourPanelPlot(MSFT)

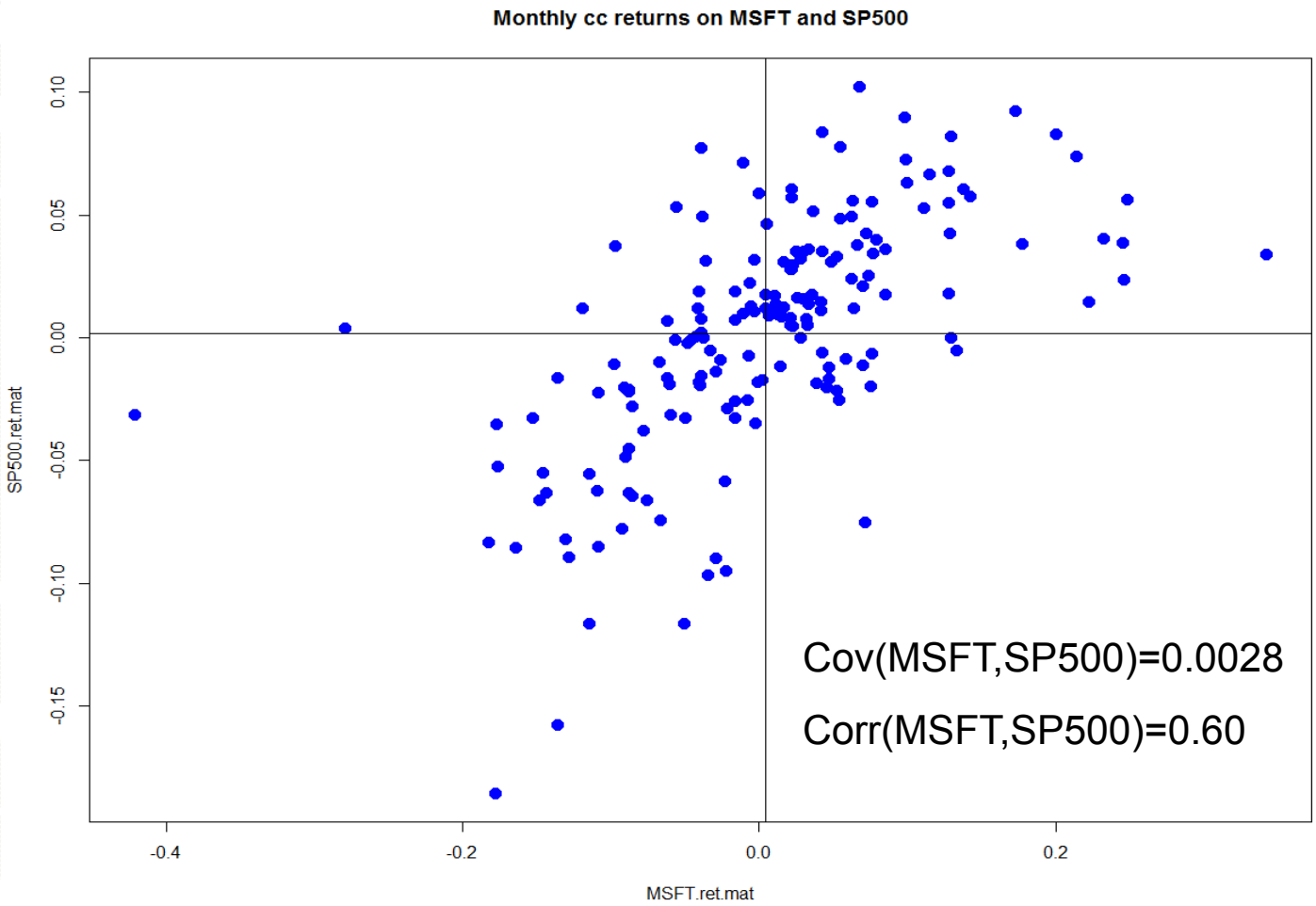






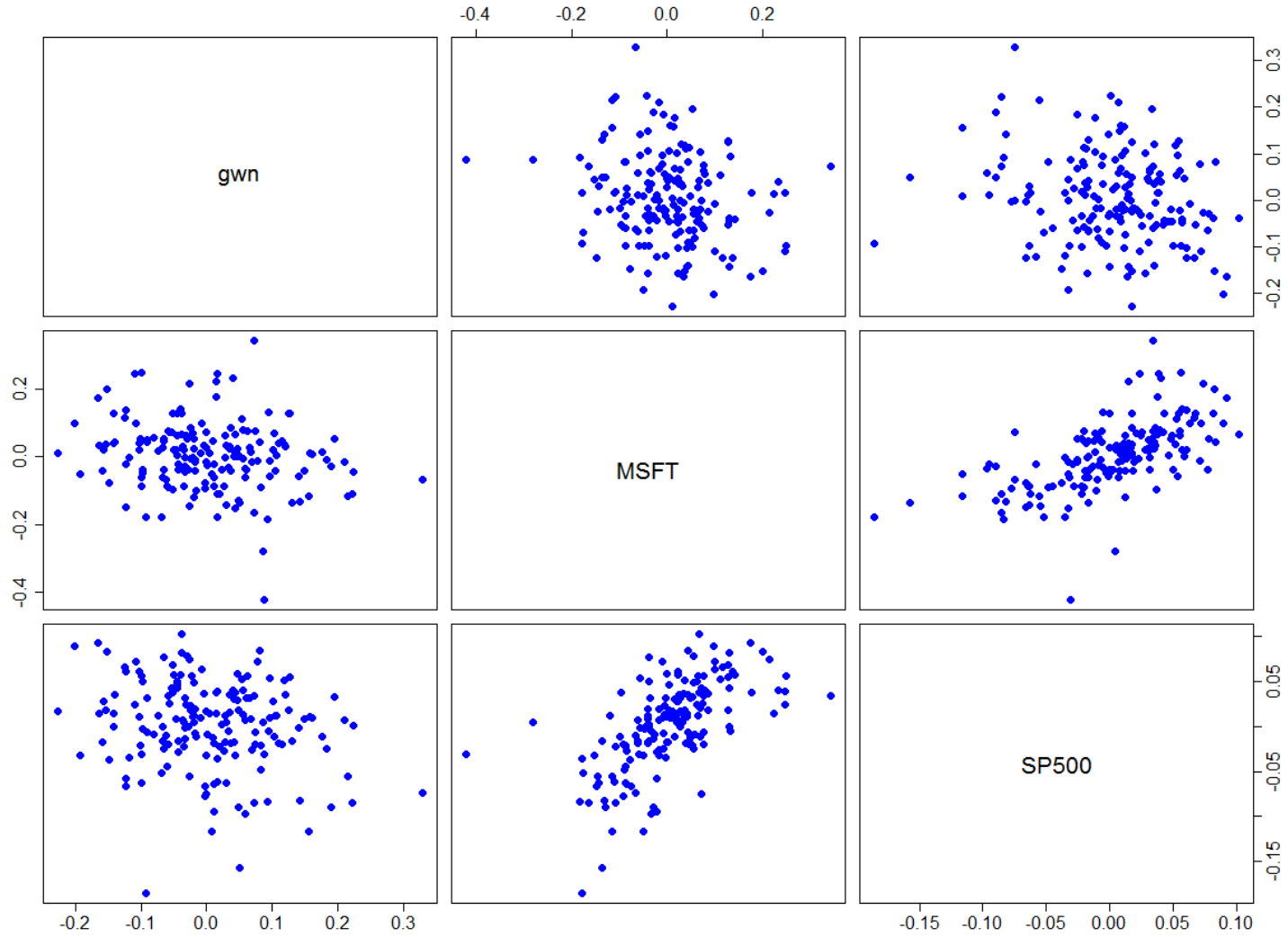


Scatterplot




```
> plot(MSFT.mat,SP500.mat,main="Monthly cc returns on MSFT
+      and SP500“, pch=16, cex=1.5, col=“blue”)
> abline(h=mean(SP500))    # horizontal line at SP500 mean
> abline(v=mean(MSFT))     # vertical line at MSFT mean
```

Pairwise Scatterplots

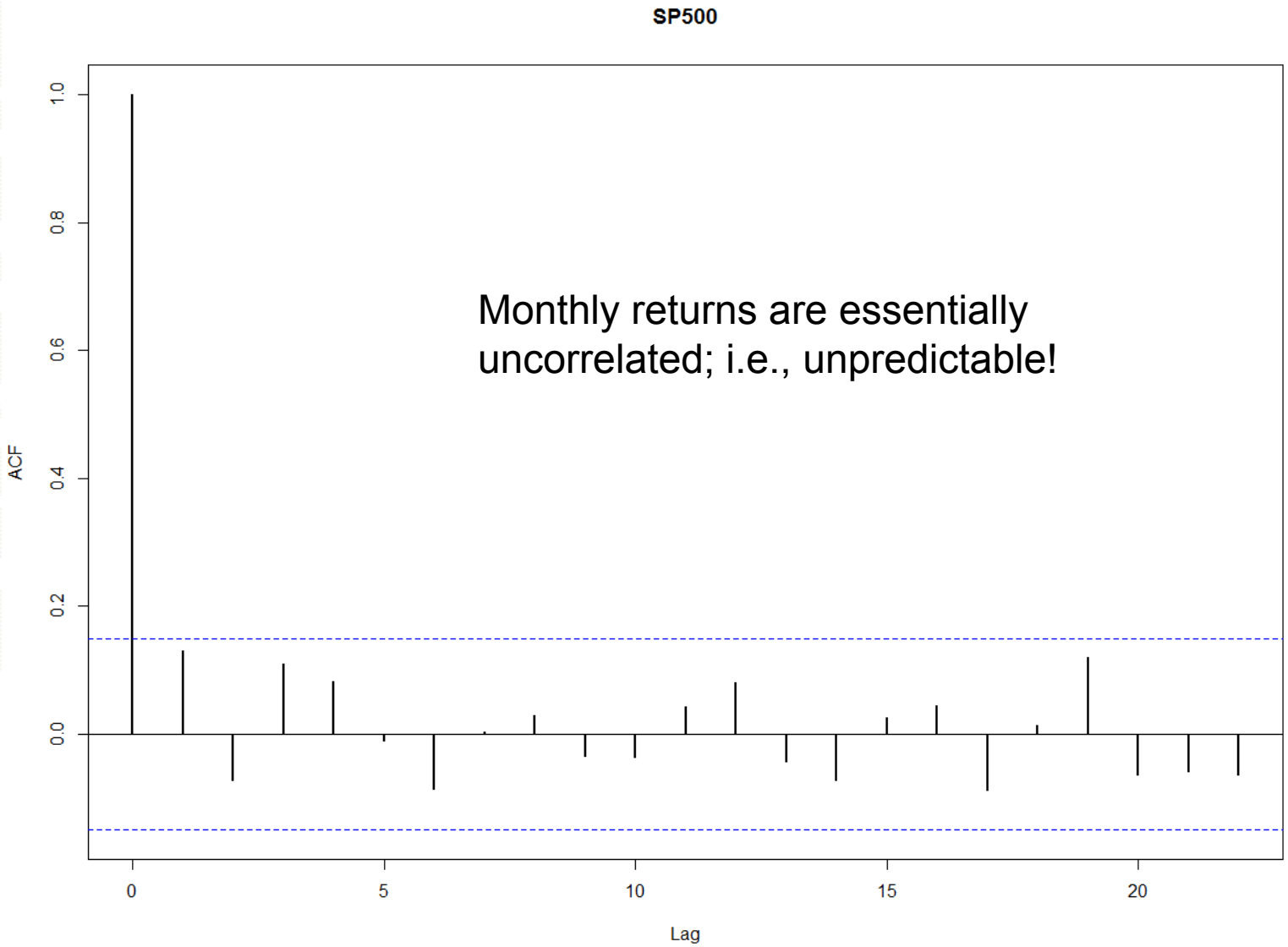



```
> pairs(cbind(gwn,MSFT,SP500), col="blue", pch=16,
+       cex=1.5, cex.axis=1.5)
```

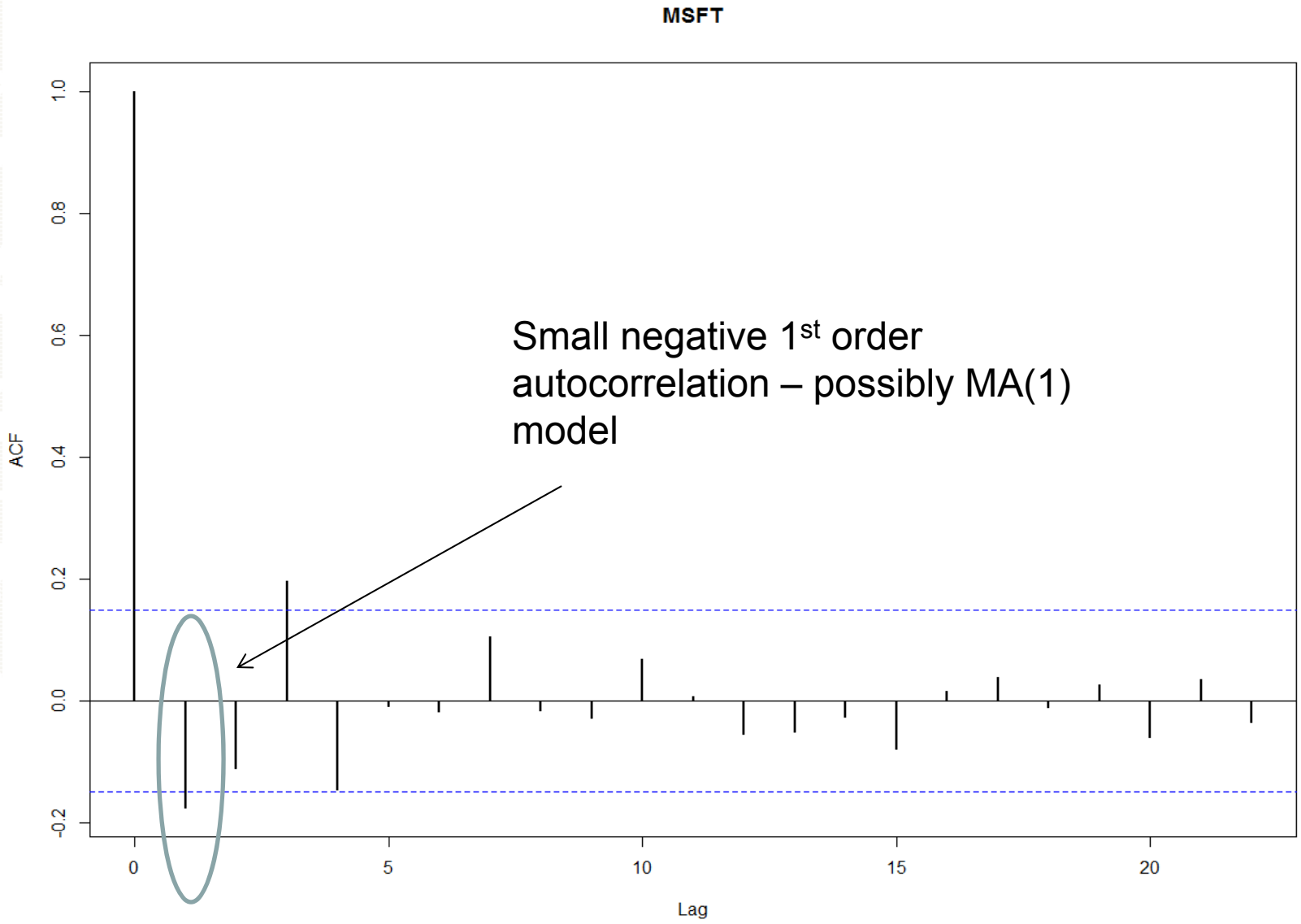
Sample Covariances and Correlations

```
> var(cbind(gwn,MSFT.mat,SP500.mat))
              gwn      MSFT      SP500
gwn     0.0090534 -0.001856 -0.0009685
MSFT   -0.0018563  0.010044  0.0029993
SP500  -0.0009685  0.002999  0.0023494

> cor(cbind(gwn,MSFT.mat,SP500.mat))
             gwn    MSFT   SP500
gwn     1.0000 -0.1947 -0.2100
MSFT   -0.1947  1.0000  0.6174
SP500  -0.2100  0.6174  1.0000
```

Sample ACF for S&P 500



Sample ACF for MSFT



Stylized Facts for Monthly CC Returns

- Returns appear to be approximately normally distributed
  - Some noticeable negative skewness and excess kurtosis
- Individual asset returns have higher SD than diversified portfolios
- Many assets are contemporaneously correlated
- Assets are approximately uncorrelated over time (no serial correlation)