Projects and Coursework

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Chapter 1

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1.2 About me

I am a First-Year Masters Student at the University of Michigan studying Quantitative Finance and Risk Management. Currently looking for an internship for Summer 2019 as a Quantitative Researcher at an Investment Bank or Hedge Fund.

Chapter 2

Monte Carlo Simulation of Stock Portfolio in R, Matlab, and Python

2.1 Monte Carlo Introduction

The purpose of this tutorial is to demonstrate Monte Carlo Simulation in Matlab, R, and Python. We conduct our Monte Carlo study in the context of simulating daily returns for an investment portfolio.

For simplicity we will only consider three assets: Apple, Google, and Facebook. We will assume an Initial Investment of \$100,000 and allocate our money evenly between the three stocks. In this case the portfolio weights $w_i = 1/3$ for $i = 1, 2, 3$.

Next, we assume that daily returns are distributed Multivariate Normal with mean vector μ and covariance matrix Σ. In other words,

$$R_t \sim MVN(\mu, \Sigma)$$

for $t \in \{1, \ldots, T\}$ where T is the final time horizon.

We will use the Cholesky Factorization in order to find Lower Triangular Matrix L such that $LL' = \Sigma$. Then our returns can be generated by

$$R_t = \mu + LZ_t$$

where

$$Z_t \sim N(0, I)$$

for $t \in \{1, \ldots, T\}$.

The returns will be simulated over a 30-day period, where our 30-day returns can be formulated as,

$$\hat{R}_{30} = \prod_{t=1}^{30} (1 + R_t)$$

Thus our portfolio returns for each Monte Carlo trial m become the inner product between the 30-day returns and our vector of portfolio weights w,

$$P_m = w \cdot \hat{R}_{30}$$

.

2.2 Dataset Summary

We use adjusted-close stock prices for Apple, Google, and Facebook from November 14th, 2017 - November 14th, 2018. Historical stock price data can be found on Yahoo Finance for these companies. Also here is the link to the data set for this tutorial 'Stock Price Data'.

The first ten rows of data look like :

```
##         Date AAPL_Adj_Close GOOG_Adj_Close FB_Adj_Close
##  1: 11/15/17       166.5791        1020.91       177.95
##  2: 11/16/17       168.5693        1032.50       179.59
##  3: 11/17/17       167.6333        1019.09       179.00
##  4: 11/20/17       167.4658        1018.38       178.74
##  5: 11/21/17       170.5791        1034.49       181.86
##  6: 11/22/17       172.3721        1035.96       180.87
##  7: 11/24/17       172.3820        1040.61       182.78
##  8: 11/27/17       171.5150        1054.21       183.03
##  9: 11/28/17       170.5101        1047.41       182.42
## 10: 11/29/17       166.9732        1021.66       175.13
```

2.3 Languages

2.3.1 R

Firstly, we need to load the data

```
stock_Data = fread('./Stats506/Group21_ProjectData.csv')
```

Then we extract the stock price and set initial values for Monte-Carlo parameters

```
stock_Price = as.matrix( stock_Data[ , 2:4] )

mc_rep = 1000 # Number of Monte Carlo Simulations
training_days = 30
```

Get the returns by stock price and set the investment weights

```
# This function returns the first differences of a t x q matrix of data
returns = function(Y){
  len = nrow(Y)
  yDif = Y[2:len, ] / Y[1:len-1, ] - 1
}

# Get the Stock Returns
stock_Returns = returns(stock_Price)

# Suppose we invest our money evenly among all three assets
# We use today's Price 11/14/2018 to find the number of shares each stock
# that we buy
portfolio_Weights = t(as.matrix(rep(1/ncol(stock_Returns), ncol(stock_Returns))))
print(portfolio_Weights)
```

```
##           [,1]      [,2]      [,3]
## [1,] 0.3333333 0.3333333 0.3333333
```

Calculate the Covariance matrix and Mean value of Stock Returns

```
# Get the Variance Covariance Matrix of Stock Returns
coVarMat = cov(stock_Returns)
miu = colMeans(stock_Returns)
# Extend the vector to a matrix
Miu = matrix(rep(miu, training_days), nrow = 3)
```

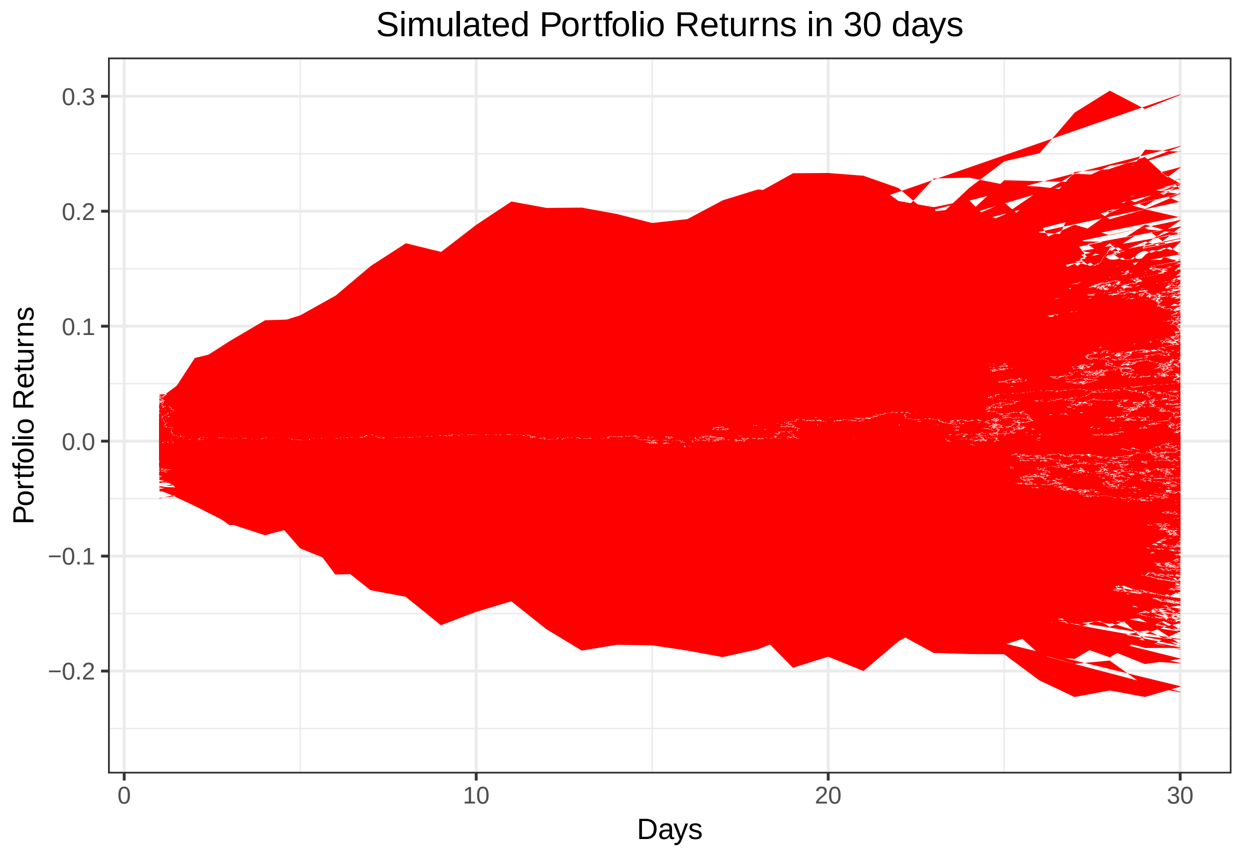
Use Monte-Carlo to simulate the 30-day Portfolio Returns

```
# Initializing simulated 30 day portfolio returns
portfolio_Returns_30_m = matrix(0, training_days, mc_rep)

set.seed(200)
for (i in 1:mc_rep) {
  Z = matrix ( rnorm( dim(stock_Returns)[2] * training_days ), ncol = training_days )
  # Lower Triangular Matrix from our Choleski Factorization
  L = t( chol(coVarMat) )
  # Calculate stock returns for each day
  daily_Returns = Miu + L %*% Z
  # Calculate portfolio returns for 30 days
  portfolio_Returns_30 = cumprod( portfolio_Weights %*% daily_Returns + 1 )
  # Add it to the monte-carlo matrix
  portfolio_Returns_30_m[,i] = portfolio_Returns_30;
}
```

Visualising the result (Simulated Portfolio Returns in 30 days)

```
# Visualising result
x_axis = rep(1:training_days, mc_rep)
y_axis = as.vector(portfolio_Returns_30_m-1)
plot_data = data.frame(x_axis, y_axis)
ggplot(data = plot_data, aes(x = x_axis, y = y_axis)) + geom_path(col = 'red', size = 0.1) +
  xlab('Days') + ylab('Portfolio Returns') +
  ggtitle('Simulated Portfolio Returns in 30 days')+
  theme_bw() +
  theme(plot.title = element_text(hjust = 0.5))
```



Get some useful statistics through the results we get

```
# Porfolio Returns statistics on the 30th day.
Avg_Portfolio_Returns = mean(portfolio_Returns_30_m[30,]-1)
SD_Portfolio_Returns = sd(portfolio_Returns_30_m[30,]-1)
Median_Portfolio_Returns = median(portfolio_Returns_30_m[30,]-1)
print(c(Avg_Portfolio_Returns,SD_Portfolio_Returns,Median_Portfolio_Returns))
```

```
## [1]  0.0009402469  0.0840585273 -0.0015423606
```

```
# Construct a 95% Confidential Interval for average returns
Avg_CI = quantile(portfolio_Returns_30_m[30,]-1, c(0.025, 0.975))
print(Avg_CI)
```

```
##       2.5%      97.5%
## -0.1541318  0.1702711
```

2.3.2 Matlab

Load data and extract stock price

```
stockData = readtable('./Stats506/Group21_ProjectData.csv');
stockPrices = table2array(stockData(:, 2:end));
```

Set Monte_Carlo parameters

```
mc_rep = 1000;
initInvestment = 100000;
numTradingDays = 30
```

Calculate stock returns

```
stock_returns = stock_price(2:end, :) ./ stock_price(1:end-1, :) - 1;
```

Set portfolio weight

```
portfolioWeights = (1/3) * ones(1, size(stockPrices,2));
```

Calculate covariance matrix and mean of the stock returns

```
% Get the Variance Covariance Matrix of our Stock Returns
coVarMat = cov(stockReturns);

% Average returns of each asset
mu = transpose(mean(stockReturns));
mu = repmat(mu, 1, numTradingDays);
```

Then we use Monte-Carlo to simulate the portfolio returns in 30 days

```
for i = 1:mc_rep
    % 'Randomly generated numbers from N(0,1) distribution'
    Z = randn(size(stockReturns,2), numTradingDays);

    % 'Lower Triangular Matrix from Choleski Factorization'
    L = chol(coVarMat, 'lower');

    % 'Calculate daily returns for 30 days'
    dailyReturns = mu + (L * Z);

    % 'Portfolio Returns'
    thirtyDayReturn = transpose(cumprod(portfolioWeights * dailyReturns + 1));

    % 'Add return to the set of all 30-day portfolio returns'
    portfolio30DayReturn_m(:,i) = thirtyDayReturn;
end
```

Visualizing the result

```
plot(portfolio30DayReturn_m - 1, 'LineWidth', 0.5, 'Color', [0,0.7,0.9, 0.2])
title('Simulated Portfolio Returns in 30 days', 'fontsize', 16)
xlabel('Days','fontsize',16)
ylabel('Portfolio Returns','fontsize',16)
```