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Original Research Paper

Computational Approach To Portfolio Optimization of Selected Scripts From Nifty-50 Using R Technology

Computer Science

KEYWORDS : portfolio, expected return, risk, efficient frontier, covariance, regression, Sharpe ratio, R.

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ABSTRACT

The main objective of this paper is to develop a user friendly method for investors and brokers to understand statistical finance to apply the idea of efficient portfolio onto real life data. The proposed Portfolio optimization approach of stock portfolio management, is all about maximizing return and minimizing risk of portfolio through diversification and correct investment decision towards each script under uncertainty. To assess the performance of optimization, monthly closing prices from 2011 to 2015 of five scripts such as, Reliance Industries Ltd, Tata Steel Ltd, Lupin Ltd, HDFCBank Ltd, Dabur India Ltd from different sectors of Nifty-50 sensex has been considered as benchmarks to measure efficient portfolio model when short selling is allowed. This is made possible by statistical software R using stockPortfolio and quadprog packages and different functions of R. The result shows that the proposed portfolio optimization using R produces better results.

Introduction:

In the era of recession in world we make many assumptions that preside over investment management policies which force us to think about portfolio management, a moment in which investors are expressing unique sets of goals and priorities which provide fair return with low risk. portfolio optimization which is also a challenging problem in risk management by considering different types of investors such as , Investors who bear high risk for high returns and low risk and high return follows diversification defined by Markowitz Modern portfolio theory, who think about their investment portfolios based on foundational principals [2].

As the financial system in the world has been shaken due to many reasons like European debt crises, Recession, inflation and the ideological crosscurrents in US and also due to standard of living has made the circumstances for the investors to become conscious, worried and to think about their investment policies and practices.

Considering these investment problems authors have proposed portfolio optimization problem for analysis and risk management, based on Mean –Variance optimization by referring the work of Markowitz [2]. To optimize the investor's portfolio, expected return and the standard deviation are assumed to be estimated from the historical data of Indian stock market. In this paper the Portfolio Optimization problem is formulated as, a set of financial assets are selected from Nifty -50, characterized by their expected return, standard deviation and covariance of excess return of the selected scripts. The optimal solution can be obtained using efficient frontier and solve.QP functions. We have obtained the logical expression of the efficient frontier for a portfolio of five scripts from Indian stock market. An R implementation for the four constraints of several risky common stocks is given.

This paper is organized in seven sections as follows section 1 gives the brief introduction, section 2 reports the prior work, section 3 is about data description, section 4 describes the proposed work and its model, In section 5 Algorithm of the proposed model is given, Experimental Results are given in section 6, section 7 reports conclusion and scope for future work.

Implementation in R language:

The main objective of this paper is to develop a user friendly method for investors and brokers to understand statistical finance to apply the idea of efficient portfolio onto real life data. This is made possible by statistical software R. We have included all the R functions required to get results.

Worldwide, millions of statisticians and data scientists use R to solve their most challenging problems in fields ranging from portfolio management, forecasting of stock prices, risk management, time series analysis and business analytics by using its basic functions and many different packages in Finance for computing Markowitz mean-variance efficient portfolios allowing for short sales. These functions are meant to be used for learning the basics of portfolio theory. [5]

In this paper authors have used four R packages for file Input -output, standard deviation, regression, to find efficient frontier and to plot the graph [6]. The list of packages included is as follows:

Portfolio package for analyzing and implementing equity portfolios, this package is having dependencies of other packages as grid, lattice, nlme.

stockPortfolio to retrieve stock data from online and from excel sheets.

quadprog required for the function solve.QP function.

ggplot2 used in the paper to plot efficient frontier.

reshape2 used to melt the data.

1.2. Statistical Parameters:

Mean-Variance portfolio theory is a statistical framework to allocate assets properly for investment to reduce risk by using diversification method. By combining various assets, it is possible to construct optimal portfolio for risk-averse investors using portfolio with index and group models. There are many models used to calculate expected return such as, Single Model, Constant Correlation Model, Multi-Group model and Multi-Index model requires some assumptions about average return and covariance matrix which is considered as inputs to the portfolio optimization problem which gives a unique result. In This paper authors has used R stockPortfolio package for Single Index Model and constant correlation with or without short selling.

1.2.1. Expected Return:

Expected Return is a weighted-average return of a portfolio. The return of each asset in the portfolio can be the mean of return values of the asset in a past period of time;

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it can be calculated by many other factors but we are using capital asset pricing model (CAPM), which is used to determine a theoretically appropriate required rate of return of an asset (Expected return of each stock). [5]

Capital Asset Pricing Model (CAPM):
The **capital asset pricing model** is used to calculate the require rate of return for any risky asset. [8] CAPM is required to find a relationship between risk and expected return for pricing an individual security or portfolio. The formula of CAPM is in the equation 1.

$$E(R_i) = R_f + \beta_i * (E(R_m) - R_f \qquad (1)$$

Where:

E (R_i) is the expect return of an asset

R_f is the interest rate of T-Bills, referred as risk-free return

E (R_m) is the expected return of the market, Nifty-50 of Indian stock market is considered as indexreturn

β_i is the sensitivity of the expected excess asset return to the expected excess index return. β_i is achieved by calculating regression of excess return of all selected scripts and nifty-50 excess return.

Risk:
Risk is defined as the actual return on investment may vary than the expected return. One way to calculate risk is by finding the standard deviation from the historical excess return data. And also we can find risk by factor models. Here we are using R function and single-factor model to calculate standard deviation and the covariance of two assets in a portfolio.

Sharpe Ratio:
The Sharpe ratio was derived in 1996 by William Sharpe, according to him during investment, investors should consider both risk and return, while return can be easily quantified, but risk cannot [9].

Sharpe ratio is the most preferable risk/return measure. It defines how much excess return an investor can get for high risk assets. The higher the Sharpe ration means the better investment option.

The Sharpe ratio is calculated as given in equation 2.

$$S(x) = (r_x - R_f)/StdDev(x) \qquad (2)$$

Where:

X means assets

r_x expected return of X

R_f is the risk-free return, interest rate of T-Bills

StdDev(x) is the risk of r_x.

Regression:
It is a statistical process to estimate the relationship between one dependent variable and many independent variables. In this paper we have used regression to get the value of βi from the historical data of the excess returns of a five assets and the Nifty-50 index..

Efficient Frontier:
It is defined as the set of optimal portfolios to give highest expected return for a given level of risk or to get low risk for given expected return. Here we have used R function to find the efficient fronrtier.

If the given portfolio lies below the efficient frontier are called as sub-optimal, as these portfolio does not give enough returns. Portfolios that group to the right of the efficient frontier are also sub-optimal, because they have a higher level of risk for the defined rate of return [9].

Literature Review and prior work:
In literature there exists a fistful of papers which deals with portfolio optimization and Risk management. But most of them work with predefined structure and employ some excel, some computational tools and R programming as underlying technology for implementation of optimization.

M. Andrecut has described in his article about portfolio optimization using R by considering the standard risk /return portfolio optimization model, by allowing both long buying and short selling of large number of assets. He has derived analytical expression of the efficient frontier for N risky assets [1].

Marnix Engels has given in his thesis about portfolio optimization models in a mathematical way. He has presented Telser models based on a value at risk constraint. According to him he has considered one-period case but he has suggested considering multi-period case to see the results of optimal solution if a long horizon is chosen [5].

Angela Hei-Yan Leung has written in his thesis about Portfolio Selection and Risk Management in which he introduced and demonstrated about statistical finance theories and their applications with a simple user-friendly stock investment portfolio using R programming.

He has suggested customizing and modifying R environment into an R-Package for educational purposes in the statistical finance area, Researchers can also focus on semi-variance, and geometric mean returns, safety first portfolios, and extreme value theory are some points to be explored [4].

Jeff Enos et al have given information about portfolio package in R used to analyze and to implement equity portfolios [11].

Hemanth Kumar P et al has presented in his paper about Prediction of stock market returns. Using Neuro - Fuzzy technique by taking the low-level of errors in the long and short-term modeling and concluded that stock price behavior is non-linear model and forecasting stock error estimation of the stock price. He explored that price with non-linear methods can decrease the stock price [12].

Data description:
In this paper authors have selected closing prices of five stocks such as Reliance Industries Ltd, Tata Steel Ltd, Lupin Ltd, HDFC Bank Ltd, Dabur India Ltd of different sectors like oil and gas, Steel, Pharmaceuticals, Bank and FMCG from Nifty-50 Sensex through Yahoo Finance from 4th January 2011 to 12th January 2015[8]. Here on the basis of closing prices we have calculated monthly return of each stock, Nifty-50 and T-Bills which can be used as risk free return.

Treasury Bills(T-Bill) are instruments for maturities less than one year borrowing by the Central Government. In

India T-Bills were first issued in the year 1917. Currently T-Bills are 91-days, 182-day and 364-days. The 91 day T-Bills are issued on weekly auction basis while 182 day T-Bill auction is held on Wednesday preceding Non-reporting Friday and 364 day T-Bill auction on Wednesday preceding the Reporting Friday[13]. Auctions of T-Bills are conducted by RBI.

T-Bills are issued on discount to face value, while the holder gets the face value on maturity.If the liquidity position is good then holder can get higher return[8]. The return on T-Bill is calculated using equation 3.

$$T - Bills = issuepriceofstock - facevalueofstock \quad (3)$$

In this paper the portfolio optimization is based on excess return of the portfolio. Excess return is calculated using equation 4.

$$excessreturn = monthlyreturn - monthlyreturnofT - Bill \quad (4)$$

Using excess return of these five scripts of Indian stock market authors have proposed to find whether this portfolio is efficient or not using R Programming tool.

Methodology:

The first step in the portfolio optimization is to acquire stock market data from nifty-50. Whose market return is calculated by considering closing prices of five scripts. By taking return and standard deviation of each stock expected return is calculated using CAPM single factor model and the efficient frontier is obtained using efficient frontier and solve.QP function using R programming tool to get an optimal portfolio. Shown in figure 1:

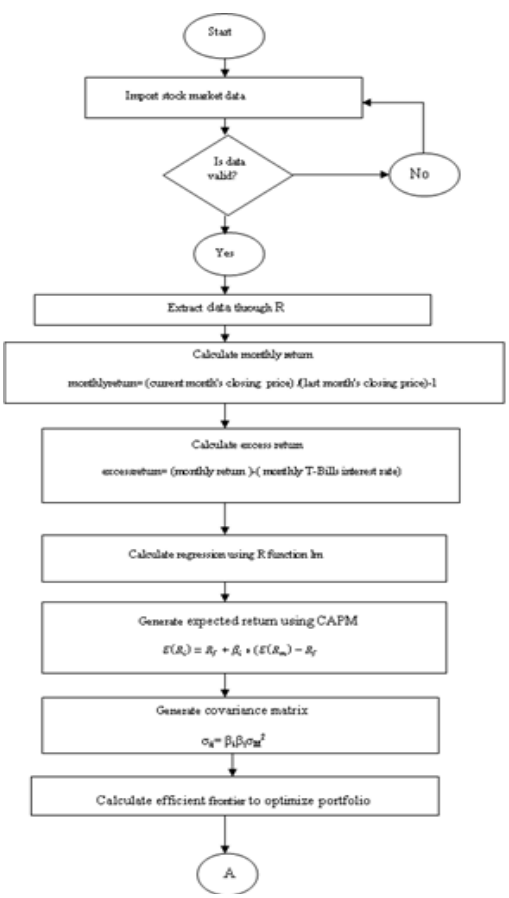



Figure 1: Flow diagram of optimal portfolio model.

Algorithm of Efficient Portfolio:

Step 1: Get the required libraries such as portfolio, Stockportfolio, ggplot2, quadprogpackages installed and loaded in R.

Step 2: create a variable portfolio of five stocks selected from Nifty -50 in Excel.

Reliance Industries Ltd, TataSteel Ltd,Lupin Ltd,HDFCBank Ltd,Dabur India Ltd;

Step 3: obtain a mothly return of each stock and index, store in a monthlyreturnvariable. monthlyreturn=(current month's closing price)/(last month's closing price)-1;

Step 4: extract the monthly return data from .csv file in R

Step 5: obtain excess return of each stock and index.

excessreturn= (monthly return)-(monthly T-Bills interest rate);

Step 6: extractexcessreturn data from .csv file in R

Step 7: clean the data by removing the date column in R.

Step 8: obtain mean and standard deviation of each stock and Nifty-50 index save in the dataframe SD.

Step 9: obtain regression on the excess returns of each stock and the excess return of nifty-50.

Step 10: obtain Expected return for each stock using formula.

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$$E(R_i) = R_f + \beta_i * (E(R_m) - R_f;$$;

Step 11: calculate the covariance of five stocks.

$\sigma_{ij} = \beta_i \beta_j \sigma_M^2$;

Step 12: Define the efficient frontier using R function.

Step 13: Create initial Amat and bvec assuming only equality constraint, ifshort-selling is allowed, no allocation constraints.

Step 14: Then modify the Amat and bvec if short-selling is illicit.

Step 15: modify Amat and bvec if a max allocation (concentration) is specified.

Step 16: Calculate the number of loops in to variable loops.

Step 17: Find the optimal portfolio.

Step 18: plot the efficient frontier graph by installing ggplot2 package.

Experimental Results:
The algorithm proposed above is implemented in R version 3.2.4 technology. To optimize the efficient portfolio we have selected monthly closing prices of five scripts such as Reliance Industries Ltd, TataSteel Ltd, Lupin Ltd, HDFC Bank Ltd, Dabur India Ltd, monthly closing of Nifty-50 and Indian T-Bill from Indian Stock market form 2011to 2015. Monthly return of each script, nifty-50 and till-Bill is calculated and extracted trough R shown in figure 2:

```
> monthlyreturn <- read.csv(file.choose(),header=T)
> head(monthlyreturn)
     Month T.Bills    Nifty.50 Reliance.Industries.Ltd TataSteel.Ltd
1 4/1/2011 0.00790 0.000713706             -0.06229149  -0.009240658
2 5/1/2011 0.01096 0.000762383             -0.03242694  -0.044606650
3 6/1/2011 0.02681 0.000761802             -0.05604875   0.036078099
4 7/1/2011 0.02404 0.000712111             -0.07851975  -0.075788611
5 8/1/2011 0.01435 0.000809756             -0.05477381  -0.169237589
6 9/1/2011 0.00484 0.000735547              0.03290314  -0.113541778
    Lupin.Ltd HDFCBank.Ltd Dabur.India.Ltd
1  0.05808232  0.000713706     0.000713706
2  0.06558954  0.000786976     0.000786976
3 -0.04105193  0.000737209     0.000737209
4  0.01255530  0.000712111     0.000712111
5 -0.01319406  0.000785218     0.000785218
6  0.05704735  0.000760083     0.000760083
```

Figure 2: Monthly return of data

From the available monthly return and T-Bill we have calculated excess return using excel and extracted through R, this excess return is used for further calculation to find the average return shown in figure 3:

```
> excessreturn<- read.csv(file.choose(),header=T)
> head(excessreturn)
     Month    Enifty_50        ERIL ETataSteelLtd   ELupinLtd EHDFCBankLtd
1 4/1/2011 -0.007186294 -0.07019149  -0.017140658  0.05018232  -0.007186294
2 5/1/2011 -0.010197617 -0.04338694  -0.055566650  0.05462954  -0.010173024
3 6/1/2011 -0.026078195 -0.08268875   0.009238099 -0.07089193  -0.026102791
4 7/1/2011 -0.023327889 -0.10255976  -0.099828611 -0.01168470  -0.023327889
5 8/1/2011 -0.013560246 -0.06912386  -0.183587589 -0.02754406  -0.013564782
6 9/1/2011 -0.004104453  0.02806314  -0.118381778  0.05220735  -0.004079917
   EDaburIndia
1 -0.007186294
2 -0.010173024
3 -0.026102791
4 -0.023327889
5 -0.013564782
6 -0.004079917
```

Figure 3: Excess return of all scripts.

On the basis of excess return we have obtained mean and standard deviation using R functions ,We will use mean and standard deviation of Nifty-50 excess returns as the market excess return and risk shown in Figure 4:

```
                X          Mean           SD
    Enifty_50 -1.059646e-02 7.588969e-03
         ERIL -7.177937e-03 7.311204e-02
ETataSteelLtd  1.321671e-01 1.146345e+00
    ELupinLtd -2.060207e+07 1.555422e+08
 EHDFCBankLtd -1.059646e-02 7.590329e-03
  EDaburIndia -1.059646e-02 7.590329e-03
```

Figure 4: Mean and Standard deviation of scripts and Nifty-50.

beta of RIL	2.52081935
The beta of TataSteelLtd	18.7887043
The beta of Lupin LTD	1908243507.9
The beta of HDFC BANK LTD	1.000178e+00
The beta of DaburLtd	1.000178e+00

Table 1: Beta Values of each stock

Residual Standard Error	Value
RIL	0.0712
TataSteelLtd	1.148
Lupin LTD	156300000
HDFC BANK LTD	9.168e-06
DaburIndia Ltd	9.168e-06

Table 2: Residual Error values of each stocks

According to Capital asset Pricing Model formula, we need beta value and residual error value of each stock using regression analysis, which we are using to find Expected Return of each stock and then we find the Covariance matrix of five stocks. After obtaining regression values of each stock we found that each script are not related with each other as we have selected from different sectors.Beta values and Residual error values of five scripts are shown Table 1 and Table 2:

Using Single factor model we have derived the variance of each script. We have extracted each values of scripts required to obtain average return using CAPM formula shown in figure 5:

```
> head(ExpectedReturn)
        ERIL ETataSteelLtd ELupinLtd EHDFCBankLtd EDaburIndia
1 -0.02671176    -0.1348641 252206927    -20602068 -0.01059646
```

Figure 5: Expected Return of Five scripts.

Covariance matrix will be shown in figure 6:

```
head(cov)
                X       ERIL ETataSteelLtd    ELupinLtd EHDFCBankLtd EDaburIndia
        ERIL 0.005345370 2.728105e-03 2.770754e+05  1.45199e-04 1.45199e-04
ETataSteelLtd 0.002728105 1.310000e+00 2.070000e+06  1.08000e-03 1.08000e-03
   ELupinLtd 2.770000000 2.065157e+06 2.420000e+13  1.10000e+05 1.10000e+05
 EHDFCBankLtd 0.000145199 1.082229e-03 1.099148e+05  5.76000e-05 5.76000e-05
  EDaburIndia 0.000145199 1.082229e-03 1.099148e+05  5.76000e-05 5.76000e-05
```

Figure 6: covariance matrix of five scripts.

Based on the expected return and covariance matrix we have obtained efficient frontier using function efficient frontier and solve.QP function by installing quadprog package in R to find efficient optimal portfolio display standard deviation considered as Risk, return which is considered as expected return on investment, and the Sharpe ratio.

Here the better the Sharpe ratio, better the portfolio and vice a versa. We have taken 4 constraints on the portfolio such as, If short selling is allowed then

If short selling is not allowed then

If a maximum allocation is specified and is greater than 1 or less than zero

If a maximum allocation is specified and its value times n is less than 1

From these constraints it has obtained efficient portfolio as shown in figure 7:

```
> eff.optimal.point
  ERIL ETataSteelLtd  ELupinLtd EHDFCBankLtd EDaburIndia    Std.Dev Exp.Return
1  0.5    -2.39e-16 0.02744143    -2.87e-18  0.4725586 0.08594274 0.01563528
      sharpe
1 0.001349739
```

Figure7: optimal efficient portfolio values.

As shown in the graph we obtained that the Risk is 8.594 which is very high and it gives very less return as 1.5635% and according to our calculation Sharpe ratio is also very less that is 0.13%. Considering these results this portfolio is sub-optimal because this portfolio is having high risk with low return which is shown in figure 8:

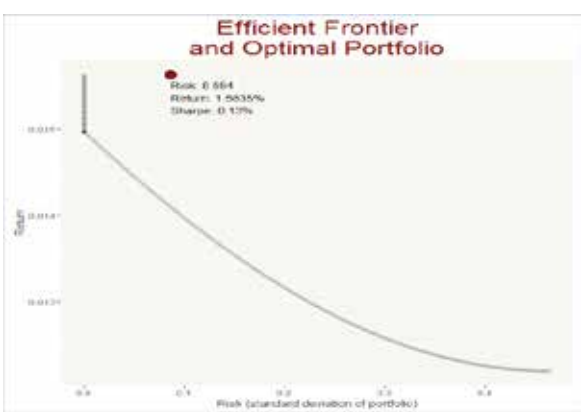

Figure 8: Graph of efficient frontier and optimal portfolio.

Conclusion and scope for future work

Authors have considered the standard risk-return portfolio optimization model, when short selling is allowed. We have consequent analytical expression of the efficient frontier for a portfolio of five scripts of Indian stock market of five years closing price data. The proposed works in this paper is implemented trough R using Efficient frontier and solve.QP functions to find whether the portfolio is optimal or not.

The experimental results show that the portfolio of selected five scripts is sub-optimal as the given portfolio lies below the efficient frontier and do not give enough returns. Because they have a higher level of risk for the defined rate of return.

It is observed through the result as shown in the figure 5. That among the five scripts Lupin Ltd is having high expected return 2552206927% .This is more dominating on other four scripts of the portfolio. Therefore Lupin Ltd is suggestible for investors.

According to authors there is lot of future scope in Indian stock market to find optimal portfolio using R implementation. In this paper we have taken few data to explore result. Researches can take more number of data and can implement fully using R by using some more packages and functions.

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According to authors there is lot of future scope in Indian stock market to find optimal portfolio using R implementation. In this paper we have taken few data to explore result. Researches can take more number of data and can implement fully using R by using some more packages and functions.

Appendix A

```
# To get expected Return of the portfolio

library(portfolio) # Classes for analysing and implementing equity portfolios

monthlyreturn<- read.csv(file.choose(),header=T) #read the historical return data from .csv file

head(monthlyreturn) # to display all column name and first 6 lines of dataset monthly return.

excessreturn<- read.csv(file.choose(),header=T)# read the excess return from .csv file

head(excessreturn)

excessreturn<- excessreturn[,-1] # remove the date column

Mean=sapply(excessreturn,mean) #  to get mean and standard deviation

SD=sapply(excessreturn,sd)

head(SD)
```

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```
meansd<-cbind(Mean,SD)# to get both mean and standard deviation

write.csv(meansd, file="d:/meansd.csv")#write meansd in to csv file

var<- read.csv(file.choose(),header=T)

head(var)

# conduct the regression to get the beta of RIL

Reliance<- lm(ERIL ~ Enifty_50, excessreturn)

summary(Reliance)

head(Reliance)

plot(Reliance)

# conduct the regression to get the beta of ETataSteelLtd

TataSteelLtd<- lm(ETataSteelLtd ~ Enifty_50, excessreturn)

summary(TataSteelLtd)

head(TataSteelLtd)

plot(TataSteelLtd)

# conduct the regression to get the beta of ELupinLtd

lm.lupin<- lm(ELupinLtd ~ Enifty_50, excessreturn)

summary(lm.lupin)

head(lm.lupin)

plot(lm.lupin)

 # conduct the regression to get the beta of EHDFCBankLtd

lm.hdfc<- lm(EHDFCBankLtd ~ Enifty_50, excessreturn)

summary(lm.hdfc)

head(lm.hdfc)

plot(lm.hdfc)

# conduct the regression to get the beta of EDaburIndiaLtd

lm.dabur<-lm(EDaburIndia ~ Enifty_50, excessreturn)

summary(lm.dabur)

head(lm.dabur)

plot(lm.dabur)

# The beta of RIL is 2.52081935

# The beta of TataSteelLtd 18.7887043

# The beta of Lupin LTD 1908243507.9

# The beta of HDFC BANK LTD  1.000178e+00

# The beta of DaburLtd  1.000178e+00

# The residual standard error of RIL is 0.0712

# The residual standard error of TataSteelLtd 1.148

# The residual standard error of Lupin LTD 156300000

# The residual standard error of HDFC BANK LTD 9.168e-06

# The residual standard error of DaburLtd  9.168e-06

#Single-Factor Model, the variance of RIL is

#sRIL2= ßRIL2sEnifty_502+ s2(e)

ExpectedReturn<- read.csv(file.choose(),header=T)

head(ExpectedReturn)

ExpectedReturn<- ExpectedReturn[,-3]

ExpectedReturn

write.csv(ExpectedReturn,file="d:/return.csv") # write Expected return in .csv file

return<- read.csv(file.choose(),header=T)#read rerun from .csv file

head(return)

#covariance of five scripts using sij= ßißjsM2 .

cov<- read.csv(file.choose(),header=T)#read covariance matrix from .csv file

head(cov).
```

 # Appendix B

```
# To get Efficient Frontier

eff.frontier<- function (returns, short="no", max.allocation=NULL, risk.premium.up=.5, risk.increment=.005)

{

# return argument should be a m x n matrix with one column per security

# short argument is whether short-selling is allowed; default is no (short

# selling prohibited)max.allocation is the maximum % allowed for any one

# security (reduces concentration) risk.premium.up is the upper limit of the

# risk premium modeled (see for loop below) and risk.increment is the

# increment (by) value used in the for loop

cov<- read.csv(file.choose(),header=T)#read covariance matrix from .csv file

n <- ncol(covariance)

# Create initial Amat and bvec assuming only equality constraint  if short-selling is allowed, and no allocation con-
```

straints are passed

Amat<- matrix (1, nrow=n)

bvec<- 1

meq<- 1

modify the Amat and bvec if short-selling is prohibited

if(short=="no")

{

Amat<- cbind(1, diag(n))

bvec<- c(bvec, rep(0, n))

}

also modify Amat and bvec if a max allocation is allowed

if(!is.null(max.allocation)){

if(max.allocation> 1 | max.allocation<0){

stop("max.allocation must be greater than 0 and less than 1")

}

if(max.allocation * n < 1){

stop("Need to set max.allocation higher; not enough assets to add to 1")

}

Amat<- cbind(Amat, -diag(n))

bvec<- c(bvec, rep(-max.allocation, n))

}

loops<- risk.premium.up / risk.increment + 1 # Calculate the number of loops

loop<- 1

eff<- matrix(nrow=loops, ncol=n+2) # Initialize a matrix to contain allocation and statistics

colnames(eff) <- c(colnames(return), "Std.Dev", "Exp.Return", "sharpe")

Loop through the quadratic program solver

for (i in seq(from=0, to=risk.premium.up, by=risk.increment)){

dvec<- colMeans(return) * i # This moves the solution along the EF

sol<- solve.QP(covariance, dvec=dvec, Amat=Amat, bvec=bvec, meq=meq)

eff[loop,"Std.Dev"] <- sqrt(sum(sol$solution*colSums((covariance*sol$solution))))

eff[loop,"Exp.Return"] <- as.numeric(sol$solution %*% colMeans(return))

eff[loop,"sharpe"] <- eff[loop,"Exp.Return"] / eff[loop,"Std.Dev"]

eff[loop,1:n] <- sol$solution

loop<- loop+1

}

return(as.data.frame(eff))

}

Run the eff.frontier function based on no short and 50% alloc. restrictions

eff<- eff.frontier(return=return$R, short="no", max.allocation=.50,

risk.premium.up=1, risk.increment=.001)

Find the optimal portfolio

eff.optimal.point<- eff[eff$sharpe==max(eff$sharpe),]

write.csv(eff.optimal.point, file="d:/eff.optimal.point.csv")

eff.optimal.point<- read.csv(file.choose(),header=T)

eff.optimal.point

Appendix c

To plot the Graph of Efficient Frontier

ealred<- "#7D110C"

ealtan<- "#CDC4B6"

eallighttan<- "#F7F6F0"

ealdark<- "#423C30"

ggplot(eff, aes(x=Std.Dev, y=Exp.Return)) + geom_point(alpha=.1, color=ealdark) +

geom_point(data=eff.optimal.point, aes(x=Std.Dev, y=Exp.Return, label=sharpe),

color=ealred, size=5) +

annotate(geom="text", x=eff.optimal.point$Std.Dev,

y=eff.optimal.point$Exp.Return,

label=paste("Risk: ",

round(eff.optimal.point$Std.Dev*100, digits=3),"\nReturn: ",

round(eff.optimal.point$Exp.Return*100, digits=4),"%\nSharpe: ",

round(eff.optimal.point$sharpe*100, digits=2), "%", sep=""),

hjust=0, vjust=1.2) +

ggtitle("Efficient Frontier\nand Optimal Portfolio") +

labs(x="Risk (standard deviation of portfolio)", y="Return")

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+

theme(panel.background=element_rect(fill=eallighttan),

text=element_text(color=ealdark),

plot.title=element_text(size=24, color=ealred))

References:

[1] M. Andrecut, "Portfolio Optimization in R"

[2] H. Markowitz, *Portfolio selection: Efficient Diversification of Investments*, Wiley, New York, 1959.

[3] Leslie E. Christian, cfa, "A New Foundation for Portfolio Management", 2011, rsf social finance, version 2.

[4] Luo, Rui," R functions development for stockPortfolio package", University of California, Los Angeles,2013

[5] MarnixEngels,"Portfolio optimization beyond Markowitz" January 13, 2004

[6] http://www.r-bloggers.com/investment-portfolio-analysis-with-r-language/

[7] http://www.r-project.org

[8] http://finance.yahoo.com

[9] http://www.zenwealth.com/businessfinanceonline/RR/CAPMExercise.html

[10] http://www.investopedia.com/articles/07/sharpe_ratio.asp

[11] Jeff Enos, David Kane, Daniel Gerlanc and Kyle Campbell, "Analysing equity portfolios", February 20, 2015

[12] Hemanth Kumar P, Prashanth K. B, Nirmala T V, S. Basavaraj patil,"Neuro Fuzzy based Techniques for Predicting StockTrends", IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 4, No 3, July 2012,ISSN (Online): 1694-0814

[13] http://www.gktoday.in/blog/key-facts-about-treasury-bills-in-india/