SCMA 478

PROJECT

MEMBERS

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Executive Summary

Scenario 1: To create an optimal portfolio that will provide the retirees and the disabled with regular streams of monthly income, we must invest into assets that will give us minimum risk. This is why we included into our portfolio a government bond. Also, the reason for selecting these three stocks is because we think that they will give us sustained earnings, due to their credibility and the sector they are in. The results obtained do reflect our objectives for the optimal portfolio.

Scenario 2: The objective is to create an equity fund for investors to have an opportunity to invest in a situation like Covid-19 by selecting stocks which have potential to perform well in COVID-19 situation.
The optimal portfolio contains CPALL.BK, ADVANC.BK, BDMS.BK and EGCO.BK with expected return 9.77% and SD (Volatility) 7.75% .

Scenario 3: As the COVID-19 news caused people to panic until the stock price fell significantly, I chose long-term investing in stocks with good value in the last six months together with the analysis based on Benjamin Graham's methods in order to assess intrinsic value of stocks. I decided to invest in 7 stocks including BDMS, CPALL, CPF, KBANK, SCB, TOP and VGI for the same amount around ฿500,000 to each of them in order to reduce risk. The result is that since the strategy is designed for long-term investment, it is not suitable to measure the performance in a short period. By the way, I can make a realized profit for ฿40,000 which is higher than unrealized loss around 4 times.

Scenario 1

My team task as Actuarial representatives for the Social Security Office (SSO), is to provide the retirees and the disabled with sustainable income when they reach their retirement age or that they have become disabled. These amounts of income will be a regular stream on a monthly basis and will be banked into their accounts.

The investment return target is equivalent to 2%. We project two investment objectives for the portfolio: a target return of 2% and minimum risk (volatility). This to mitigate risk related to loss of principal when the investment matures.

The next task is to select suitable assets for the portfolio that match with our investment objectives. The assets we selected are three stocks and one government bond. The three stocks selected comprises CP All PCL (CPALL), TMT Steel PCL (TMT), and BTS Group Holdings PCL (BTS) and the bond we have chosen is the 1-year Treasury Bill (TBILL1Y).

Justifications for selecting assets

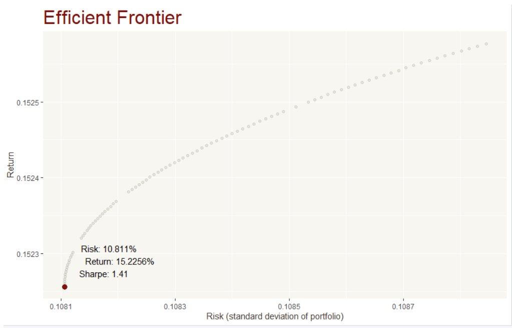
1. CP ALL PCL-CP All is a SET 50 listed company in the retail sector. CP All operates 7-11 which is the first convenience store and has the most branches across Thailand (10,000+), and will soon open up stores in Cambodia. They have had sustained earnings for many years and performed well through many economic crises. Thus, we are confident the company's stock is likely to be less volatile.
2. TMT Steel PCL- TMT is a company that manufactures steel. Steel is a material needed for any type of construction. This commodity product is essential to the country's development of infrastructure including government highways, bridges, metro and also for commercial and resident constructions.
3. BTS Group Holdings PCL- BTS Group operates BTS skytrains, one of Bangkok's mass rapid transits. Due to its high barriers to entry, has given the company almost at a monopoly positioning thus creating its ability to protect its revenues and profits.
4. TBILL1Y- Bonds are considered very low risk investments. Although bonds tend to have low returns, their risk-levels are almost zero.

Analysis: In the analysis process, we will use the R-program to get the adjusted share prices for CPALL, TMT and BTS. By considering the time period between 01/01/2014 and 31/12/2019, we then create an annual return matrix and covariance matrix. The two tables below displays our results:

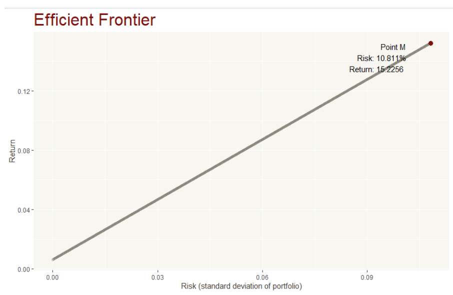
	CPALL	TMT	BTS
2014-12-30	0.08534952	0.06632643	0.235172975
2015-12-30	-0.05885847	-0.01564020	0.001335442
2016-12-30	0.62395820	1.17168489	0.013100830
2017-12-29	0.25219661	0.22864227	0.010423935
2018-12-28	-0.08406150	-0.06900751	0.197091416
2019-12-30	0.06743717	-0.38915150	0.435699131

	CPALL	TMT	BTS
CPALL	0.043922373	0.005876569	0.007512939
TMT	0.005876569	0.038939432	0.004409777
BTS	0.007512939	0.004409777	0.031652372

We then created a plot of the Efficient Frontier (EF), in order to find the point which has the minimum amount of risk.



Note that the Efficient Frontier above has not included the price of the government bond, which is why we still see a high value of risk (10.811%) and a return that is greater than our target (15.2256%). Therefore, the next step is to weigh the three stocks with the 1-Year Treasury Bill (TBILL1Y). Using R, we obtain the capital market line that is shown below. The capital market line passes through the point at which the risk is at zero (the y-intercept) and the point M (point where the line is tangent to the efficient frontier).



The last step, which will give us the optimal portfolio, is to find the point on the capital market line that gives us the target return at 2%. By entering into R the commands,

```
> wopt = (0.02-eff$Exp.Return[j])/(bond.yield-eff$Exp.Return[j])
> Answer = data.frame("CPALL" = (1-wopt)*eff.optimal.point$CPALL,"TMT" = (1-wopt)*eff.optimal.point$TMT,"BTS" = (1-wopt)*eff.
optimal.point$BTS,"T-BILL1Y" = wopt,"Std.Dev" = (1-wopt)*eff$Std.Dev[j],"Exp.Return" = wopt*bond.yield+(1-wopt)*eff$Exp.Retur
n[j])
>
```

we will obtain the standard deviation (risk) of the portfolio and the weights for each of the assets. Below is optimal portfolio:

```
> Answer
  CPALL        TMT        BTS  T.BILL1Y    Std.Dev Exp.Return
1     0 0.01936926 0.07416729 0.9064635 0.01011189       0.02
```

Overall, the optimal portfolio consists of approximately 0% of CPALL, 1.94% of TMT, 7.42% OF BTS, and 90.65% of TBILL1Y. The Standard Deviation is at approximately 1.01%, which is low like what we are looking for. Therefore, we can now say that we are content with our portfolio and will start investing into this portfolio.

Although we are satisfied with our investment portfolio, there is still room for improvement. In the portfolio we created, we did not take into account the inflation rate, which is one of the most important factors when considering and selecting assets for investments as inflation may exceed the estimated 2% return. Therefore, in future, in order to

create a new portfolio for the SSO, we may choose a target return that has real inflation rate accounted for and inclusive, thus in this case, will be higher than 2%.
Another possible adjustment we could make to the portfolio is the selection of the bond. The bond we currently have in our portfolio is the 1-Year Treasury Bill. With the 1-Year Treasury Bill, we would have to wait for 1 year to get the money we invested into the bond back, whilst at the same time we are paying benefits on a monthly basis. Thus, in future, we may consider investing in the 1-Month Treasury Bill instead.

Scenario 2

Investment objective

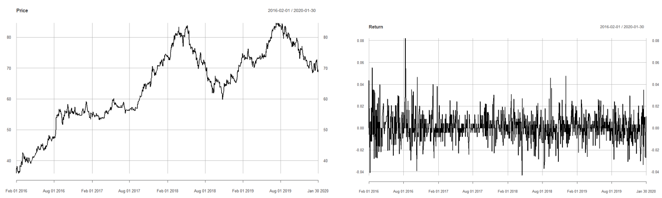
Investors interested in investing need to have the scope and target of investment in order to make the most benefit. Which, according to the problem, requires that the risk margin (volatility) is at most 8% and the return margin is at least 6%. Due to the COVID-19 situation making investment difficult to create less risk and receiving attractive returns. So, we try to create an Equity fund as an alternative for investors to have an opportunity for getting a reasonable level of profit and risk in a situation of COVID-19.

The selected assets

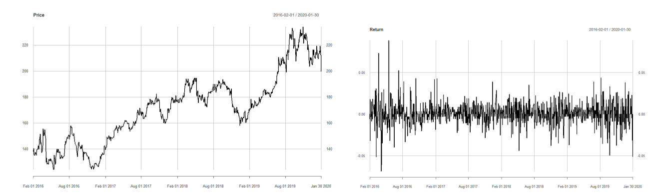
From our investment objective, we select stocks which have potential to perform well in COVID-19 situation. So, we consider stocks from SET50 which is considerably good in many aspects from SET moreover, we also consider the business sector, mean and SD (Volatility) of stocks. In conclusion, we selected stocks from various business sectors which outperform within its own sector to diversify the risk and allow us to take advantage of each business sector. Hence, The selected asset is CPALL.BK, ADVANC.BK, BDMS.BK and EGCO.BK. To reflect the situation in our portfolio, we retrieved stocks data period from 2016-02-01 to 2020-01-31.

Plot of Adjusted close price and Daily return of each stocks (4 years period from 2016-02-01 to 2020-01-30)
We used a plot of Adjusted close price to confirm that the value of each stock exhibits the increasing trend so, we can conclude our selected stock's value is growing over time.
Moreover, we also used a plot of Daily return to get a rough picture of volatility in the return of each stock.

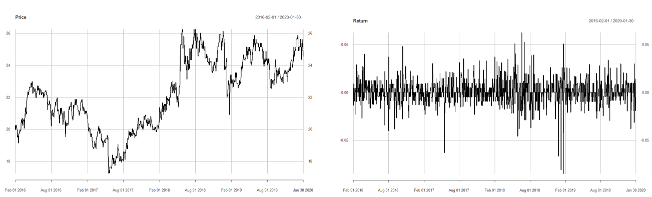
CPALL.BK (COMM / Convenience store company)



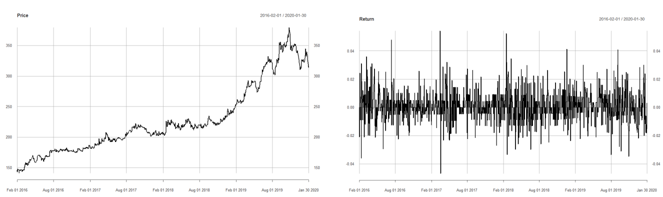
ADVANC.BK (ICT / Mobile phone operator company)

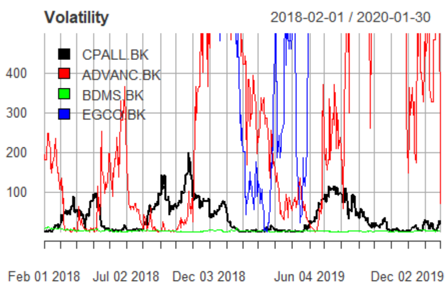


BDMS.BK (HELTH /private healthcare company)



EGCO.BK (ENERG /Electric services company)





Plot of Volatility of each stocks (2 years period from 2018-02-01 to 2020-01-30)

We can see that each stock has significantly different periods for different levels of volatility.

Statistics of stocks (is obtained by using 4 years period from 2016-02-01 to 2020-01-30)

Mean of annualized return of each stocks

```
  CPALL.BK   ADVANC.BK    BDMS.BK    EGCO.BK
0.16245267 0.09092937 0.04688052 0.17204338
```

Our portfolio contains stocks with all positive mean.

Covariance matrix of annualized return of stocks

```
              CPALL.BK      ADVANC.BK       BDMS.BK     EGCO.BK
CPALL.BK    0.0709783012 -0.0004265459 -0.007245439 0.009547561
ADVANC.BK  -0.0004265459  0.0440541860 -0.012014934 0.008948390
BDMS.BK    -0.0072454388 -0.0120149343  0.012004012 0.007370264
EGCO.BK     0.0095475609  0.0089483895  0.007370264 0.020530531
```

ADVANC, CPALL and BDMS have negative covariance taking this advantage to lower the SD (Volatility) i.e. risk diversification of the portfolio.

SD (Volatility) of annualized return of each stocks

```
 CPALL.BK ADVANC.BK   BDMS.BK   EGCO.BK
0.2664175 0.2098909 0.1095628 0.1432848
```

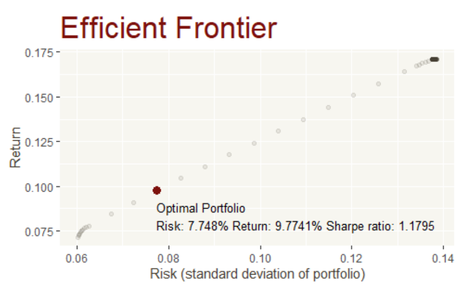
We can see that CPALL exposed to highest risk followed by ADVANC, EGCO exposed to lower level of risk respectively and BDMS exposed to lowest risk under the measurement.

Optimal portfolio under the selected assets

The optimal portfolio is obtained from finding a portfolio on Efficient Frontier having target return and risk as mentioned with giving a maximum sharpe ratio.

Weight of each stocks, Mean and SD

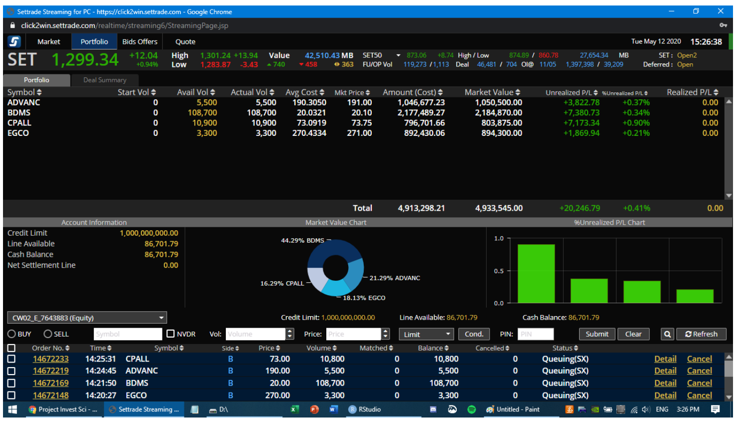
```
    CPALL.BK ADVANC.BK   BDMS.BK   EGCO.BK    Std.Dev Exp.Return   sharpe
13 0.1612611 0.2124235 0.4436248 0.1826906 0.07747719  0.0977409 1.261544
```



Plot of Efficient Frontier of the portfolio and point of the optimal portfolio

The optimal portfolio contain weight of each stock CPALL.BK 16.13% , ADVANC.BK 21.24%, BDMS.BK 44.36% and EGCO.BK 18.27% and have expected return 9.77% and SD (Volatility) 7.75% which can meet the required target return and volatility.

The sharpe ratio is calculated by using yield to maturity (YTM) of the one-year government bond (T-BILL1Y) which is 0.00635268 (retrieved from given bond_gov.csv file). The sharpe ratio of the optimal portfolio is 1.17955 .



Our optimal portfolio on click2win

To see our optimal portfolio in real scenarios, we use suggested information from R to create a portfolio in click2win to see its performance.

Scenario 3

By considering COVID-19 situation, I think it is a good opportunity to make a profit in the stock market since there might be undervalued stocks occurring. From looking at the direction of the stock market over the past 6 months, I find that there are many stocks with high value in the market, reflecting the true potential of stocks ‘pricing along with companies. But I think the COVID-19 news caused people to panic until the stock price fell significantly. Until this time, people begin to adapt to the situation, causing the stock price to rise again. Therefore, I choose to invest in stocks with good value in the last six months together with the analysis based on Benjamin Graham's methods which give me the ways to assess intrinsic value of stocks. Namely, stocks ’price tends to grow in the long term if it follows the methods.

By using the said strategy, I decided to invest in 7 stocks including BDMS, CPALL, CPF, KBANK, SCB, TOP and VGI for the same amount around ฿500,000 to each of them in order to reduce risk.

According to aommoney.com, there are 10 conditions to determine how much a stock follows Benjamin Graham’s methods. The results from the analysis are showed in the table below:

Stocks ‘name / Scenarios	BDMS	CPALL	CPF	KBANK	SCB	TOP	VGI
Not technology	✓	✓	✓	✓	✓	✓	✓
SET 50	✓	✓	✓	✓	✓	✓	✓
Current assets/Current liability > 2				N	N	✓	
Long liability < Current assets		✓		N	N		✓
EPS growth > 10% over 10 years		✓		✓			
Not net loss over 5 years	✓	✓	✓	✓	✓	✓	✓
P/E Ratio < 15			✓	✓	✓	✓	
(P/E Ratio * P/BV) < 22.5			✓	✓	✓	✓	
D/E Ratio < 1 for industrial D/E Ratio < 2.3 for others	✓						✓
Providing consistent dividends	✓	✓	✓	✓	✓	✓	✓
	5	6	7	7	6	7	6

Note
1. The analyzed information refers to settrade.com and finomena.com.
2. N in the table means it can be analyzed, because they don't have that kind of asset in the bank's financial statements.

As you can see from the table, all of them do not follow all conditions. The question begins why do I still invest in them? My answer is that every stock I choose also has a good background in Thailand, and they tend to grow up again when the people start not to panic in the COVID-19 situation, as you can see from the direction of graphs below.

The figures show the direction of the stocks ‘price during the part 6 months to this time:


Figure 1 - BDMS

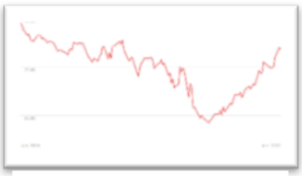


Figure 2 - CPALL


Figure 3 - CPF

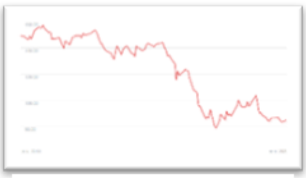


Figure 4 - KBANK

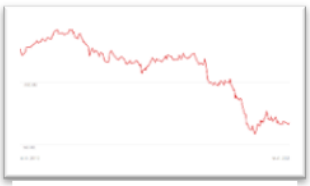


Figure 5 - SCB

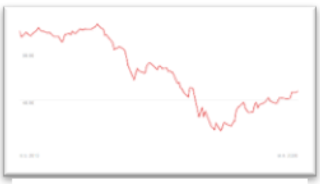


Figure 6 - TOP

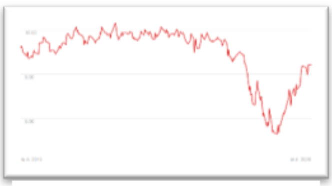
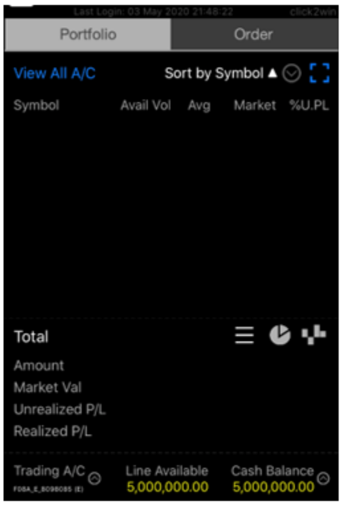


Figure 7 - VGI

Whether you believe it or not, all of the stocks you see here have the lowest point in the middle of March. It was the time that covid-19 became more severe in Thailand, causing many workplaces to declare work from home and students had to study from home as well. But after that, the stocks returned to grow again. Therefore , it might be interpreted that the reason why the stocks fall is due to the panic of people to the unpredictable situation, and when people begin to adjust, the stocks tend to grow up again, and I think it's possible that they are growing up until the price before covid-19 situation begins.

The strategy results



Created a portfolio on 3rd May 2020

The value of portfolio on 13th May 2020

I have spent time trending for 6 days by using this strategy. Since the strategy is designed for long-term investment, it is not suitable to measure the real performance of the strategy by considering the results in a short time period. By the way, there is a good sign that I can make a realized profit for ฿40,000 which is higher than unrealized loss around 4 times

R-Codes

SCENARIO 1

```
##install required packages
install.packages("matlib")
install.packages("autoimage")
install.packages("fPortfolio")
install.packages("timeSeries")
install.packages("ggplot2")
install.packages("reshape2")
install.packages("quadprog")
##Upload required packages
library(quantmod)
library(TTR)
library(matlib)
library(autoimage)
library(fPortfolio)
library(timeSeries)
library(ggplot2)
library(reshape2)
library(quadprog)
##Clear all variables
rm(list = ls(all.names = TRUE))
##Create portfolio
#Stock 1
stockname='CPALL.BK'
startdate='2014-01-01'
enddate='2019-12-31'
stock.info<-getSymbols(c(stockname),src = 'yahoo',from=startdate,to=enddate,auto.assign=FALSE)
stock.info=na.omit(stock.info)
stock.adj.close.price<-stock.info[,6]
port.price<-stock.info[,6]
port.return<-dailyReturn(stock.info[,6])
#Stock 2
stockname='TMT.BK'
startdate='2014-01-01'
enddate='2019-12-31'
stock.info<-getSymbols(c(stockname),src = 'yahoo',from=startdate,to=enddate,auto.assign=FALSE)
stock.info=na.omit(stock.info)
port.price<-cbind(port.price,stock.info[,6])
port.return<-cbind(port.return,dailyReturn(stock.info[,6]))
#Stock 3
stockname='BTS.BK'
startdate='2014-01-01'
enddate='2019-12-31'
stock.info<-getSymbols(c(stockname),src = 'yahoo',from=startdate,to=enddate,auto.assign=FALSE)
stock.info=na.omit(stock.info)
port.price<-cbind(port.price,stock.info[,6])
port.return<-cbind(port.return,dailyReturn(stock.info[,6]))
port.annual.return<-cbind(annualReturn(port.price[,1]),annualReturn(port.price[,2]),annualReturn(port.price [,3]))
```

```
names(port.annual.return) <- c("CPALL", "TMT", "BTS")
covariance.mat<-252*cov(port.return)
rownames(covariance.mat) = c("CPALL", "TMT", "BTS")
colnames(covariance.mat) = c("CPALL", "TMT", "BTS")
##Define function
eff.frontier <- function (returns, short="no", max.allocation=NULL,
                          risk.premium.up=.5, risk.increment=.005){
  covariance <- cov(returns)
  n <- ncol(covariance)
  Amat <- matrix (1, nrow=n)
  bvec <- 1
  meq <- 1
  if(short=="no"){
    Amat <- cbind(1, diag(n))
    bvec <- c(bvec, rep(0, n))
  }
  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
  loop <- 1
  eff <- matrix(nrow=loops, ncol=n+3)
  colnames(eff) <- c(colnames(returns), "Std.Dev", "Exp.Return", "sharpe")
  for (i in seq(from=0, to=risk.premium.up, by=risk.increment)){
    dvec <- colMeans(returns) * i
    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$solution %*% colMeans(returns))
    eff[loop,"sharpe"] <- eff[loop,"Exp.Return"] / eff[loop,"Std.Dev"]
    eff[loop,1:n] <- sol$solution
    loop <- loop+1
  }
  return(as.data.frame(eff))
}
##Find optimal point
#NO Short, Minimized risk, Return >= 0.02
data1<-as.timeSeries(port.annual.return)
eff <- eff.frontier(data1, short="no", max.allocation= NULL, risk.premium.up=0.5, risk.increment=.005)
eff<-subset(eff,eff$CPALL>=0)
eff<-subset(eff,eff$TMT>=0)
eff<-subset(eff,eff$BTS>=0)
eff <- subset(eff,eff$Exp.Return>=0.02)
eff.optimal.point <- subset(eff,eff$Std.Dev==min(eff$Std.Dev))
eff.optimal.point
##Plot 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=3) +
  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$sharpe, digits=2), sep=""),
          hjust=-0.3, vjust=-0.3) +
  ggtitle("Efficient Frontier") +
  labs(x="Risk (standard deviation of portfolio)", y="Return") +
  theme(panel.background=element_rect(fill=eallighttan),
       text=element_text(color=ealdark),
       plot.title=element_text(size=24, color=ealred))
##One government bond
bond.info <- read.csv(file.choose(), head=TRUE, sep=",")
i<-which(bond.info[,1]=="T-BILL1Y")
bond.yield<-bond.info[i,2]
bond.yield<-bond.yield/100
bond.yield.vec<-matrix(bond.yield,nrow=nrow(eff),ncol=1)
tan.theta<-(eff[,6]-bond.yield)/eff[,5]
j<-which(tan.theta==max(tan.theta))
##Plot Efficient Frontier
ggplot(eff, aes(x=Std.Dev, y=Exp.Return)) + coord_cartesian(xlim = c(0.18,0.35),ylim = c(0.15,0.4)) +
geom_point(alpha=.1, color=ealdark) +
  geom_point(data=eff[j,], aes(x=Std.Dev, y=Exp.Return),
           color=ealred, size=3) +
  annotate(geom="text", x=eff.optimal.point$Std.Dev,
          y=eff.optimal.point$Exp.Return,
          label=paste("Risk: ",
                    round(eff$Std.Dev[j]*100, digits=4),"%\nReturn: ",
                    round(eff$Exp.Return[j]*100, digits=4),"%\nSharpe: ",
                    round(eff$sharpe[j], digits=4), sep=""),
          hjust=1, vjust=1) +
  ggtitle("Efficient Frontier") +
  labs(x="Risk (standard deviation of portfolio)", y="Return") +
  theme(panel.background=element_rect(fill=eallighttan),
       text=element_text(color=ealdark),
       plot.title=element_text(size=24, color=ealred))
##Find Weight for Risky and Risk-free Assets
n.point=1000
port.stat.mat.w<-matrix(0,nrow=n.point,ncol=4)
for(i in 1:n.point) {
  w<-i/n.point
  port.stat.mat.w[i,1]<-w
  port.stat.mat.w[i,2]<-1-w
  port.stat.mat.w[i,3]<-w*bond.yield+(1-w)*eff$Exp.Return[j]
  port.stat.mat.w[i,4]<-(1-w)*eff$Std.Dev[j]
}
port.frame<-data.frame(Weight1<-port.stat.mat.w[,1],
                    Weight2<-port.stat.mat.w[,2],
```

```
                    Mean<-port.stat.mat.w[,3],
                    Sd<-port.stat.mat.w[,4])

##Plot Efficient Frontier
ggplot(port.frame, aes(x=Sd, y=Mean)) + geom_point(alpha=.1, color=ealdark) +
  geom_point(data=eff[j,], aes(x=Std.Dev, y=Exp.Return),
             color=ealred, size=3) +
  annotate(geom="text", x=eff$Std.Dev[j],
           y=eff$Exp.Return[j],
           label=paste("Point M    \n", "Risk: ",
                    round(eff$Std.Dev[j]*100, digits=3),"%\nReturn: ",
                    round(eff$Exp.Return[j]*100, digits=4), sep=""),
           hjust=1.5, vjust=1) +
  ggtitle("Efficient Frontier") +
  labs(x="Risk (standard deviation of portfolio)", y="Return") +
  theme(panel.background=element_rect(fill=eallighttan),
        text=element_text(color=ealdark),
        plot.title=element_text(size=24, color=ealred))
##Answer
wopt = (0.02-eff$Exp.Return[j])/(bond.yield-eff$Exp.Return[j])
Answer = data.frame("CPALL" = (1-wopt)*eff.optimal.point$CPALL,"AOT" = (1wopt)*eff.optimal.point$AOT,"BEM" = (1-wopt)*eff.optimal.point$BEM,"T-BILL1Y" = wopt,"Std.Dev" = (1-wopt)*eff$Std.Dev[j],"Exp.Return" = wopt*bond.yield+(1wopt)*eff$Exp.Return[j])
Answer
```

SCENARIO 2

```
rm(list = ls(all.names = TRUE)) #clear objects

library(quantmod)
library(TTR)
library("ggplot2")
library(matlib)

library(autoimage)
library(fPortfolio)
library(timeSeries)
library(ggplot2) # Used to graph efficient frontier
library(reshape2) # Used to melt the data
library(quadprog) # Needed for solve.QP

### graph efficient frontier
# Start with color scheme
ealred <- "#7D110C"
ealtan <- "#CDC4B6"
eallighttan <- "#F7F6F0"
ealdark <- "#423C30"

#par(no.readonly = TRUE)
####

######################  stock info ###########################
```

```
###extract stock info CPALL.BK
stock.info.CPALL.BK <- getSymbols(c('CPALL.BK'),src =
'yahoo',from='2016-02-01',to='2020-01-31',auto.assign=FALSE)
###extract stock info ADVANC.BK
stock.info.ADVANC.BK <- getSymbols(c('ADVANC.BK'),src =
'yahoo',from='2016-02-01',to='2020-01-31',auto.assign=FALSE)
###extract stock info BDMS.BK
stock.info.BDMS.BK <- getSymbols(c('BDMS.BK'),src =
'yahoo',from='2016-02-01',to='2020-01-31',auto.assign=FALSE)
###extract stock info EGCO.BK
stock.info.EGCO.BK <- getSymbols(c('EGCO.BK'),src =
'yahoo',from='2016-02-01',to='2020-01-31',auto.assign=FALSE)

###delete N/A (note: no N/A in this 4 stock)
stock.info.CPALL.BK = na.omit(stock.info.CPALL.BK)
stock.info.ADVANC.BK = na.omit(stock.info.ADVANC.BK)
stock.info.BDMS.BK = na.omit(stock.info.BDMS.BK)
stock.info.EGCO.BK = na.omit(stock.info.EGCO.BK)

### preview stock info
head(stock.info.CPALL.BK)
head(stock.info.ADVANC.BK)
head(stock.info.BDMS.BK)
head(stock.info.EGCO.BK)

###Extract adjusted close price and daily rate of return
#adjusted close price of each asset i.e. consider change in price, dividends and others as a return of a stock
port.price<-cbind(stock.info.CPALL.BK[,6],
          stock.info.ADVANC.BK[,6],
          stock.info.BDMS.BK[,6],
          stock.info.EGCO.BK[,6])
head(port.price)

#dailyReturn of each asset
port.return<-cbind(dailyReturn(stock.info.CPALL.BK[,6]),
           dailyReturn(stock.info.ADVANC.BK[,6]),
           dailyReturn(stock.info.BDMS.BK[,6]),
           dailyReturn(stock.info.EGCO.BK[,6]))
#rename column
names(port.return) <- c("CPALL.BK", "ADVANC.BK", "BDMS.BK", "EGCO.BK");
head(port.return)


################## plot price and dailyReturn of stocks #####################

#### for CPALL.BK of portfolio
plot(port.price[,1],main="Price",xlab='date',type='l')
plot(port.return[,1],main='Return',xlab='time',type='l')

#### for ADVANC.BK of portfolio
plot(port.price[,2],main="Price",xlab='date',type='l')
plot(port.return[,2],main='Return',xlab='time',type='l')
```

```
#### for BDMS.BK of portfolio
plot(port.price[,3],main="Price",xlab='date',type='l')
plot(port.return[,3],main='Return',xlab='time',type='l')

#### for EGCO.BK of portfolio
plot(port.price[,4],main="Price",xlab='date',type='l')
plot(port.return[,4],main='Return',xlab='time',type='l')

#### Volatility of asset price ####
#(2 years period from 2018-02-01 to 2020-01-30)
par(mar=c(1,1,1,1))
port.price.vol = port.price[(nrow(port.price)-488):(nrow(port.price)),]
vol1=volatility(port.price.vol[,1],n=252,N=252,calc="close")
vol1<-na.omit(vol1)
vol2=volatility(port.price.vol[,2],n=252,N=252,calc="close")
vol2<-na.omit(vol2)
vol3=volatility(port.price.vol[,3],n=252,N=252,calc="close")
vol3<-na.omit(vol3)
vol4=volatility(port.price.vol[,4],n=252,N=252,calc="close")
vol4<-na.omit(vol4)
plot(vol1,ylim=c(0,500),main="Volatility",type="l")
lines(vol2, col="Red")
lines(vol3, col="Green")
lines(vol4, col="Blue")
addLegend(legend.loc = "topleft", legend.names = c("CPALL.BK", "ADVANC.BK", "BDMS.BK", "EGCO.BK"), fill =
c("black","red", "green", "blue"),)


##################### prepare data for EF calculation ###########################

#annualized rate of return for each asset in portfolio
port.annual.return <- cbind(annualReturn(port.price[, 1]),
                    annualReturn(port.price[, 2]),
                    annualReturn(port.price[, 3]),
                    annualReturn(port.price[, 4]))
#rename column
names(port.annual.return) <- c("CPALL.BK", "ADVANC.BK", "BDMS.BK", "EGCO.BK");
head(port.annual.return)

###create a time series from port.annual.return
port.annual.return.ts <- as.timeSeries(port.annual.return);


############## statistics of stocks ###########################

#mean of annualized return of each asset in port
mean.asset<-c(mean(annualReturn(port.price[,1])),
        mean(annualReturn(port.price[,2])),
        mean(annualReturn(port.price[,3])),
        mean(annualReturn(port.price[,4])))
#rename column
names(mean.asset) <- c("CPALL.BK", "ADVANC.BK", "BDMS.BK", "EGCO.BK");
mean.asset
```

```
#(trading day = 252 days in 1 years)
#SD = sqrt(var) = volatility
#Annualized Volatility = sqrt(252) * SD(daily rate of return, dailyReturn)
#variance and covariance of Annual return of each asset in port
covariance.mat = cov(port.annual.return)
covariance.mat

#Annualized Volatility of each asset in port
sd.asset = sqrt(diag(covariance.mat))
sd.asset


################ risk-free info ###############
bond.info <- read.csv(file.choose(), head=TRUE, sep=",")
bond.yield<-bond.info[which(bond.info[,1]=="T-BILL1Y"),2] # retrieve bond yield(%) of T-BILL1Y
bond.yield<-bond.yield/100 #convert value to percentage (i.e. Annualized risk-free rate of return)
bond.yield


#### Efficient Frontier function ####

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

  covariance <- cov(returns) #covariance matrix for return rate
  print(covariance)
  n <- ncol(covariance) #number of assets in portfolio

  # Create initial Amat and bvec assuming only equality constraint
  # (short-selling is allowed, no allocation constraints)
  Amat <- matrix (1, nrow=n)
  bvec <- 1
  meq <- 1

  # Then modify the Amat and bvec if short-selling is prohibited
  if(short=="no"){
    Amat <- cbind(1, diag(n))
    bvec <- c(bvec, rep(0, n))
  }

  # And modify Amat and bvec if a max allocation (concentration) is specified
  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))
  }

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

  # Initialize a matrix to contain allocation and statistics
  # This is not necessary, but speeds up processing and uses less memory
  eff <- matrix(nrow=loops, ncol=n+3)
  # Now I need to give the matrix column names
  colnames(eff) <- c(colnames(returns), "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(returns) * 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)))) #Annualized SD (Annualized
volatility) of portfolio = sum of weight vector * sum(covariance matrix * weight vector)
    eff[loop,"Exp.Return"] <- as.numeric(sol$solution %*% colMeans(returns)) #Annualized Mean of portfolio
    eff[loop,"sharpe"] <- eff[loop,"Exp.Return"] / eff[loop,"Std.Dev"] #sharpe ratio where rate of return for risk-free asset
= 0
    eff[loop,1:n] <- sol$solution #weight for each assets in port
    loop <- loop+1
  }

  return(as.data.frame(eff))
}
###### end of the function


################## use EF and shape ratio to find optimal portolio #######################

# Run the eff.frontier function based on no short and no allocation restrictions
eff.port.annual.return.ts <- eff.frontier(port.annual.return.ts, short="no", max.allocation= NULL,
                                          risk.premium.up=0.5, risk.increment=.005)

#make sure no short selling is allowed (use only case which weight of asset >= 0)
eff.port.annual.return.ts<-subset(eff.port.annual.return.ts,eff.port.annual.return.ts$CPALL.BK>=0)
eff.port.annual.return.ts<-subset(eff.port.annual.return.ts,eff.port.annual.return.ts$ADVANC.BK>=0)
eff.port.annual.return.ts<-subset(eff.port.annual.return.ts,eff.port.annual.return.ts$BDMS.BK>=0)
eff.port.annual.return.ts<-subset(eff.port.annual.return.ts,eff.port.annual.return.ts$EGCO.BK>=0)
head(eff.port.annual.return.ts)

### find optimal porfolio ###

#find portfolio with min.target.mean and max.target.sd
# min.target.mean = 0.06
# max.target.sd = 0.08
target.eff.port.annual.return.ts = eff.port.annual.return.ts
target.eff.port.annual.return.ts = subset(target.eff.port.annual.return.ts, target.eff.port.annual.return.ts[,6] >= 0.06)
target.eff.port.annual.return.ts = subset(target.eff.port.annual.return.ts, target.eff.port.annual.return.ts[,5] <= 0.08)
target.eff.port.annual.return.ts
```

```
#recalculate sharpe ratio as risk-free rate = bond.yield for portfolio with min.target.mean and max.target.sd
tan.theta <- (target.eff.port.annual.return.ts[,6] - bond.yield) / target.eff.port.annual.return.ts[,5];#(expect return -
bond.yeild)/Std.Dev
tan.theta

#find portfolio with min.target.mean and max.target.sd and have maximum sharpe ratio i.e. optimal portfolio
target.max.sharpe.index = which(tan.theta == max(tan.theta)) #index of port with max sharpe ratio
target.eff.port.annual.return.ts[target.max.sharpe.index,] #optimal port
tan.theta[target.max.sharpe.index] #sharpe ratio of optimal port


######### plot of efficient frontier and point of optimal portfolio ############

ggplot(eff.port.annual.return.ts, aes(x=Std.Dev, y=Exp.Return)) + geom_point(alpha=.1, color=ealdark) + #plot EF
  geom_point(data=eff.port.annual.return.ts[target.max.sharpe.index,], aes(x=Std.Dev, y=Exp.Return),
             color=ealred, size=3) + #plot point of portfolio M
  annotate(geom="text", x=eff.port.annual.return.ts$Std.Dev[target.max.sharpe.index],
           y=eff.port.annual.return.ts$Exp.Return[target.max.sharpe.index],
           label=paste("Optimal Portfolio    \n", "Risk: ",
                       round(eff.port.annual.return.ts$Std.Dev[target.max.sharpe.index]*100, digits=3),"% Return: ",
                       round(eff.port.annual.return.ts$Exp.Return[target.max.sharpe.index]*100, digits=4),"% Sharpe ratio: ",
                       round(tan.theta[target.max.sharpe.index], digits=4),"", sep=""),
           hjust=0, vjust=1.4, size=3.5) + #label for point M
  ggtitle("Efficient Frontier") +
  labs(x="Risk (standard deviation of portfolio)", y="Return") +
  theme(panel.background=element_rect(fill=eallighttan),
        text=element_text(color=ealdark),
        plot.title=element_text(size=24, color=ealred))
```

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