Stat 897 Fall 2017 Data Analysis Assignment 5

Penn State

Due September 24, 2017

(1) In the first part of this assignment we will use the College data found in the ISLR library. Split the data into a training set of size 100 and test set with the rest. Your goal is to predict the number of applications received using the other variables in the data set.

```r
library(leaps)
library(ISLR)
library(quantmod)
```

```
## Loading required package: xts

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

## Loading required package: TTR

## Version 0.4-0 included new data defaults. See ?getSymbols.
```

```r
library(glmnet)
```

```
## Loading required package: Matrix

## Loading required package: foreach

## Loaded glmnet 2.0-12
```

```r
#install.packages('plotmo')
library(plotmo)
```

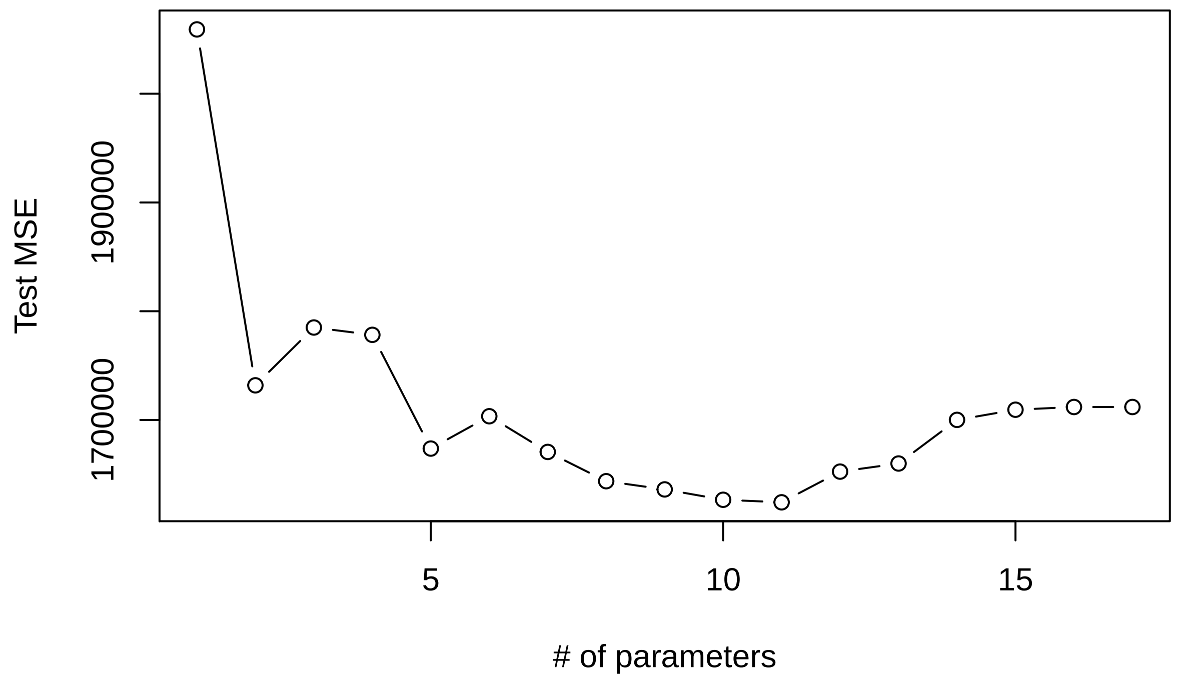
```
## Loading required package: plotrix

## Loading required package: TeachingDemos
```

```r
data("College")

set.seed (1)
trainingRows=sample (nrow(College), 100, replace = FALSE)
train = College[trainingRows,]
test = College[-trainingRows,]
```

(a) Fit a "best" model obtained from your previous assignment on the training set and report the test error for this model.

We will use the test MSE to find the best model

```
regfit.best=regsubsets (Apps~.,data=train, nvmax=17)
test.mat=model.matrix (Apps~.,data=test)
test.val.errors =rep(NA ,17)
for(i in 1:17){
  coefi=coef(regfit.best ,id=i)
  pred=test.mat [,names(coefi)] %*% coefi
  test.val.errors [i]= mean(( test$Apps-pred)^2)
}
plot(test.val.errors ,type='b', xlab='# of parameters', ylab='Test MSE')
```



We see that we get the lowest test MSE for model with 11 parameters:

```
which.min(test.val.errors)
```

```
## [1] 11
```

```
test.val.errors[11]
```

```
## [1] 1624278
```

The test MSE is reported to be 1624278

(b) Fit a ridge regression model on the training set, with λ chosen by cross-validation. Report the test error obtained.

```
train.mat <- model.matrix(Apps ~ ., data = train)
test.mat <- model.matrix(Apps ~ ., data = test)
```

```r
cv.ridge <- cv.glmnet(train.mat, train$Apps, alpha = 0)
bestlam.ridge <- cv.ridge$lambda.min
bestlam.ridge
```

```
## [1] 634.627
```

We see that the value of lambda a that results in the smallest crossvalidation error is 635. The test MSE associated with this value of lambda is:

```r
grid =10^ seq (10,-2, length =100)
fit.ridge =glmnet(train.mat, train$Apps, alpha = 0, lambda = grid, thresh = 1e-12)
pred.ridge = predict (fit.ridge, s=bestlam.ridge, newx=test.mat)
mean(( pred.ridge - test$Apps)^2)
```

```
## [1] 1680229
```

The test MSE with ridge is: 1680229

(c) Fit a lasso model on the training set, with λ chosen by cross-validation. Report the test error obtained.

```r
cv.lasso <- cv.glmnet(train.mat, train$Apps, alpha = 1)
bestlam.lasso <- cv.lasso$lambda.min
bestlam.lasso
```

```
## [1] 72.96669
```

We see that the value of lambda a that results in the smallest crossvalidation error is 73 The test MSE associated with this value of lambda is:

```r
fit.lasso <- glmnet(train.mat, train$Apps, alpha = 1, lambda = grid, thresh = 1e-12)
pred.lasso=predict (fit.lasso, s=bestlam.lasso, newx=test.mat)
mean(( pred.lasso - test$Apps)^2)
```

```
## [1] 1621135
```

The test MSE with lasso is: 1621135

(d) Compare the result obtained in (a) – (c). How accurately can we predict the number of college applications? Is there much difference among the test errors resulting from different approaches?

We find that: Best model with 11 parameters test MSE: 1624278 Ridge regression test MSE: 1680229 Lasso test MSE: 1621135

The test MSE is lowest for lasso, closely followed by best model with 11 parameters. Ridge regression has the highest MSE.

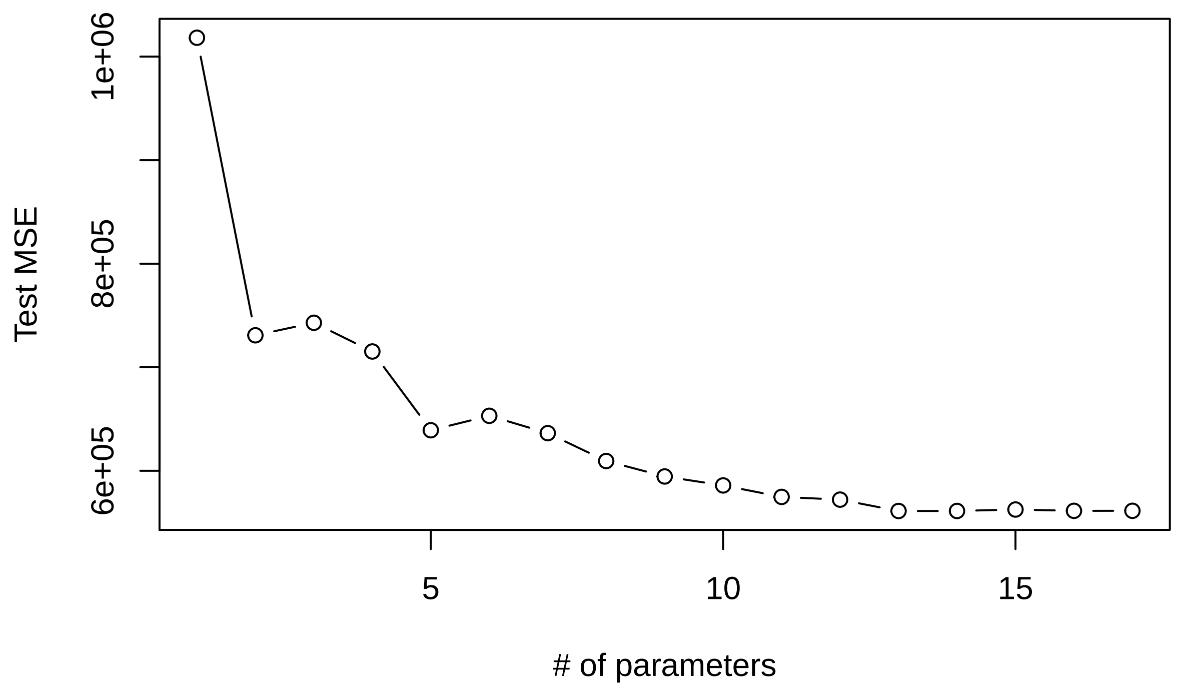
MSE for lasso and best model are relatively close than the ridge test MSE.

(e) Now partition the data into a training set of size 600 and a test set with the rest. Compare the test errors from the "best" linear regression model, ridge and lasso models. Note that, the "best" model here may not be the "best" model obtained before.

```
trainingRows=sample (nrow(College), 600, replace = FALSE)
train = College[trainingRows,]
test = College[-trainingRows,]
```

We will use the test MSE to find the best model

```
regfit.best=regsubsets (Apps~.,data=train, nvmax=17)
test.mat=model.matrix (Apps~.,data=test)
test.val.errors =rep(NA ,17)
for(i in 1:17){
  coefi=coef(regfit.best ,id=i)
  pred=test.mat [,names(coefi)] %*% coefi
  test.val.errors [i]= mean(( test$Apps-pred)^2)
}
plot(test.val.errors ,type='b', xlab='# of parameters', ylab='Test MSE')
```



```
which.min(test.val.errors)
```

```
## [1] 13
```

```
test.val.errors[which.min(test.val.errors)]
```

```
## [1] 561171.9
```

We see that we get the lowest test MSE for model with 13 parameters. It is a different result than the last time.

The test MSE for the selected model is: 561171.9

(b) Fit a ridge regression model on the training set, with λ chosen by cross-validation. Report the test error obtained.

```
train.mat <- model.matrix(Apps ~ ., data = train)
test.mat <- model.matrix(Apps ~ ., data = test)
cv.ridge <- cv.glmnet(train.mat, train$Apps, alpha = 0)
bestlam.ridge <- cv.ridge$lambda.min
bestlam.ridge
```

```
## [1] 413.419
```

We see that the value of lambda a that results in the smallest crossvalidation error is 413. The test MSE associated with this value of lambda is:

```
fit.ridge =glmnet(train.mat, train$Apps, alpha = 0, lambda = grid, thresh = 1e-12)
pred.ridge = predict (fit.ridge, s=bestlam.ridge, newx=test.mat)
mean(( pred.ridge - test$Apps)^2)
```

```
## [1] 691818.8
```

The test MSE: 691818.8

(c) Fit a lasso model on the training set, with λ chosen by cross-validation. Report the test error obtained.

```
cv.lasso <- cv.glmnet(train.mat, train$Apps, alpha = 1)
bestlam.lasso <- cv.lasso$lambda.min
bestlam.lasso
```

```
## [1] 2.657488
```

We see that the value of lambda a that results in the smallest crossvalidation error is 3. The test MSE associated with this value of lambda is:

```
fit.lasso <- glmnet(train.mat, train$Apps, alpha = 1, lambda = grid, thresh = 1e-12)
pred.lasso=predict (fit.lasso, s=bestlam.lasso, newx=test.mat)
mean(( pred.lasso - test$Apps)^2)
```

```
## [1] 561649.3
```

The test MSE: 561649.3

(f) Do you see any difference between the two sets of results? Comment.

We find that (600 training set): Best model with 13 parameters test MSE: 561171.9 Ridge regression test MSE: 691818.8 Lasso test MSE: 561649.3

The overall MSE has reduced but we observe a similar pattern as before with the diff that the test MSE is lowest for best model, closely followed by lasso. Ridge regression has the highest MSE.

MSE for lasso and best model are relatively close than the ridge test MSE.

(100 training set): Best model with 11 parameters test MSE: 1624278 Ridge regression test MSE: 1680229 Lasso test MSE: 1621135

(2) The file Sp.Rdv contains daily returns for 501 stocks in 2016. It was created as follows.

(You don't need to run this, i.e. leave eval=FALSE)

```r
library("quantmod")
sp = read.csv("SP500HistoricalComponents.csv")
Symbols = sp[which(sp$X12.31.2016 == "X"), "Ticker"]
StartDate = '2016-01-01'
EndDate = '2016-12-31'

Stocks = lapply(Symbols, function(sym) {
  print(sym)
  dailyReturn(na.omit(getSymbols(as.character(sym), from = StartDate, to = EndDate,
                                 auto.assign = FALSE, src = "yahoo")))
})

SPreturns = do.call(merge, Stocks)
colnames(SPreturns) = Symbols

#Clean out cols with NA
spreturns = SPreturns[ , colSums(is.na(SPreturns)) == 0]
save(spreturns, file = "spreturns.Rda")
```

Make sure you downloaded the data from the assignment page, and you can load it using:

```r
load("hw5_spreturns.Rda")
```

I have constructed a secret long-only portfolio chosen from these stocks. It contains between five and twenty stocks. The daily return of this portfolio for each trading day of 2016 is in the object `portfolioreturns` which you can load from file with:

```r
load("hw5_portfolioreturnsstatic.Rda")
dim(spreturns)
```

```
## [1] 252 501
```

```r
dim(portfolioreturns)
```

```
## [1] 252   1
```

Your goal is to recover the stocks and weights of the secret portfolio.

Note that you can think of a portfolio as a vector of nonnegative weights that sum to one. For simplicity, we are assuming that this portfolio is rebalanced daily at the closing prices. Then if the daily returns vector on date d is r_d and the weight vector is w_d, the daily return for the portfolio is the dot product $r_d \cdot w_d$. If this were a buy-and-hold portfolio, we would have to back into the returns more carefully.

(a) First try to fit an ordinary regression (lm) with `portfolioreturns` as the response and `spreturns` as the predictors. What happens? What problem do you run into?

```
options(max.print=1000000)
portWithReturnsAndStocks <- cbind(portfolioreturns, spreturns)
dim(portWithReturnsAndStocks)
```

```
## [1] 252 502
```

```
colnames(portWithReturnsAndStocks)[1] <- "portfolioreturns"

lm.fit=lm(portfolioreturns~., data=portWithReturnsAndStocks)
summary(lm.fit)
```

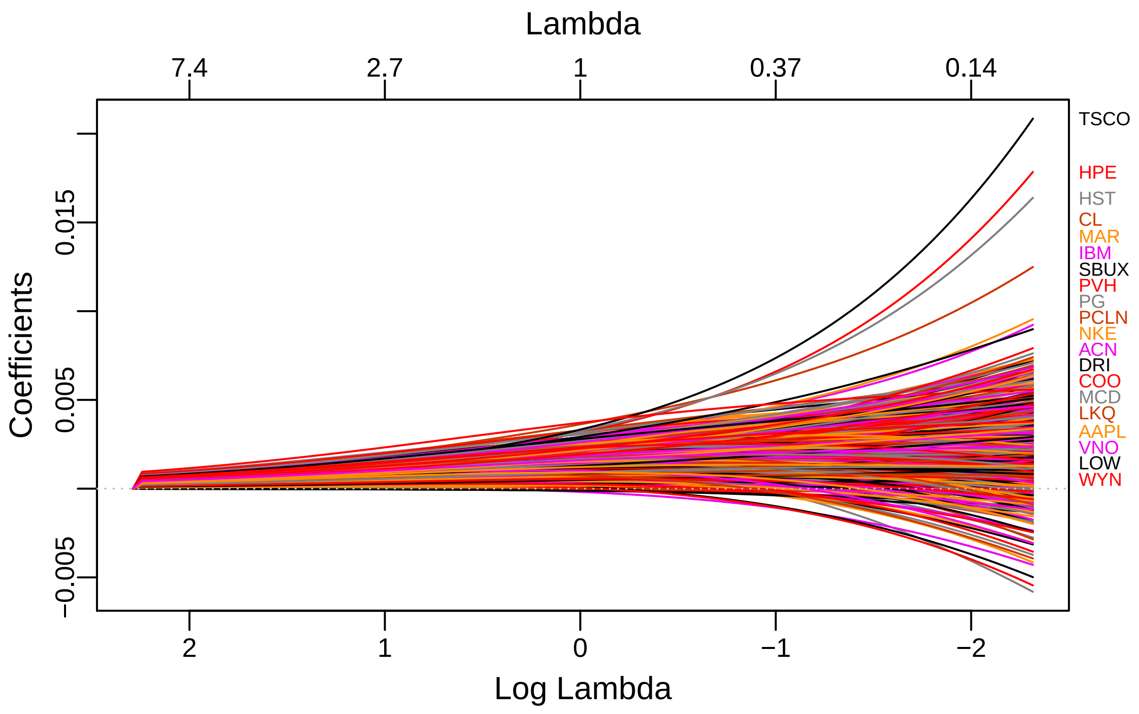
```
##
## Call:
## lm(formula = portfolioreturns ~ ., data = portWithReturnsAndStocks)
##
## Residuals:
## ALL 252 residuals are 0: no residual degrees of freedom!
##
## Coefficients: (250 not defined because of singularities)
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.001525         NA      NA       NA
## A           -0.752916         NA      NA       NA
## AAL         -0.057577         NA      NA       NA
## AAP         -0.094218         NA      NA       NA
## AAPL         0.060840         NA      NA       NA
## ABBV         0.461477         NA      NA       NA
## ABC         -0.240886         NA      NA       NA
## ABT          1.247800         NA      NA       NA
## ACN         -0.449216         NA      NA       NA
## ADBE         0.060757         NA      NA       NA
## ADI         -0.329032         NA      NA       NA
## ADM          0.038342         NA      NA       NA
## ADP          0.908372         NA      NA       NA
## ADS         -0.128100         NA      NA       NA
## ADSK         0.132905         NA      NA       NA
## AEE         -2.217198         NA      NA       NA
## AEP          2.235636         NA      NA       NA
## AES          0.057907         NA      NA       NA
## AET          0.192574         NA      NA       NA
## AFL          1.537212         NA      NA       NA
## AGN         -0.264545         NA      NA       NA
## AIG          0.425684         NA      NA       NA
## AIV          0.349113         NA      NA       NA
## AIZ         -0.095779         NA       NA        NA
## AJG          0.006105         NA       NA        NA
## AKAM        -0.213798         NA       NA        NA
## ALB         -0.540041         NA       NA        NA
## ALK          0.362265         NA       NA        NA
## ALL         -0.303270         NA       NA        NA
## ALLE         0.078936         NA       NA        NA
## ALXN        -0.583297         NA       NA        NA
## AMAT        -0.584111         NA       NA        NA
## AME         -0.823864         NA       NA        NA
## AMG          0.413978         NA       NA        NA
## AMGN        -0.177249         NA       NA        NA
## AMP          0.384805         NA       NA        NA
## AMT          0.195539         NA       NA        NA
## AMZN        -0.219948         NA       NA        NA
## AN           0.345714         NA       NA        NA
## ANTM         0.729511         NA       NA        NA
## AON          1.196071         NA       NA        NA
## APA         -0.488080         NA       NA        NA
## APC          0.104617         NA       NA        NA
## APD          0.467921         NA       NA        NA
## APH          0.236326         NA       NA        NA
## ARNC        -0.007023         NA       NA        NA
## ATVI        -0.409678         NA       NA        NA
## AVB          0.296708         NA       NA        NA
## AVGO         0.204381         NA       NA        NA
## AVY          0.393299         NA       NA        NA
## AWK          0.028447         NA       NA        NA
## AXP          0.627870         NA       NA        NA
## AYI          0.147942         NA       NA        NA
## AZO          0.468430         NA       NA        NA
## BA          -0.682487         NA       NA        NA
## BAC          0.186240         NA       NA        NA
## BAX         -0.737112         NA       NA        NA
## BBBY        -0.216040         NA       NA        NA
## BBT         -1.653938         NA       NA        NA
## BBY          0.104649         NA       NA        NA
## BCR          0.481008         NA       NA        NA
## BDX         -0.587362         NA       NA        NA
## BEN         -0.728245         NA       NA        NA
## BF.B        -0.144899         NA       NA        NA
## BHI          0.154007         NA       NA        NA
## BIIB         0.440162         NA       NA        NA
## BK          -0.855546         NA       NA        NA
## BLK          0.109083         NA       NA        NA
## BLL         -0.329718         NA       NA        NA
## BMY         -0.068873         NA       NA        NA
## BRK.B        0.760065         NA       NA        NA
## BSX         -0.135188         NA       NA        NA
## BWA         -0.210303         NA       NA        NA
## BXP         -0.003172         NA       NA        NA
## C            0.204513         NA       NA        NA
## CA          -0.183412         NA       NA        NA
## CAG          0.234695         NA       NA        NA
## CAH          -0.031444         NA       NA        NA
## CAT           0.703032         NA       NA        NA
## CB            0.354181         NA       NA        NA
## CBG           0.101964         NA       NA        NA
## CBS          -0.034096         NA       NA        NA
## CCI          -0.227332         NA       NA        NA
## CCL          -0.058523         NA       NA        NA
## CELG         -0.396638         NA       NA        NA
## CERN         -0.076368         NA       NA        NA
## CF            0.207523         NA       NA        NA
## CFG          -0.189083         NA       NA        NA
## CHD          -0.072280         NA       NA        NA
## CHK           0.090957         NA       NA        NA
## CHRW         -0.336519         NA       NA        NA
## CHTR         -0.649265         NA       NA        NA
## CI           -0.511516         NA       NA        NA
## CINF         -0.015048         NA       NA        NA
## CL           -0.220169         NA       NA        NA
## CLX           1.075131         NA       NA        NA
## CMA           0.785082         NA       NA        NA
## CMCSA        -0.442488         NA       NA        NA
## CME           0.404537         NA       NA        NA
## CMG          -0.035822         NA       NA        NA
## CMI          -0.426753         NA       NA        NA
## CMS          -1.160802         NA       NA        NA
## CNC           0.144513         NA       NA        NA
## CNP          -0.287291         NA       NA        NA
## COF           0.093460         NA       NA        NA
## COG          -0.070436         NA       NA        NA
## COH           0.276752         NA       NA        NA
## COL          -0.715455         NA       NA        NA
## COO          -0.102564         NA       NA        NA
## COP           0.112794         NA       NA        NA
## COST         -0.430260         NA       NA        NA
## COTY         -0.076408         NA       NA        NA
## CPB          -0.986939         NA       NA        NA
## CRM           0.311644         NA       NA        NA
## CSCO         -0.420070         NA       NA        NA
## CSRA         -0.318300         NA       NA        NA
## CSX          -0.050329         NA       NA        NA
## CTAS          0.127489         NA       NA        NA
## CTL          -0.347094         NA       NA        NA
## CTSH          0.177388         NA       NA        NA
## CTXS          0.664393         NA       NA        NA
## CVS           0.577500         NA       NA        NA
## CVX          -0.077712         NA       NA        NA
## CXO           0.898262         NA       NA        NA
## D            -0.389992         NA       NA        NA
## DAL           0.379405         NA       NA        NA
## DD            0.619175         NA       NA        NA
## DE            0.172169         NA       NA        NA
## DFS          -1.076650         NA       NA        NA
## DG           -0.122964         NA       NA        NA
## DGX          -0.098586         NA       NA        NA
## DHI          0.155587         NA       NA        NA
## DHR         -0.053931         NA       NA        NA
## DIS          0.767953         NA       NA        NA
## DISCA        0.466659         NA       NA        NA
## DISCK       -0.821751         NA       NA        NA
## DLPH        -0.016282         NA       NA        NA
## DLR          0.232095         NA       NA        NA
## DLTR        -0.145634         NA       NA        NA
## DNB          0.110330         NA       NA        NA
## DOV          0.478662         NA       NA        NA
## DOW         -0.891012         NA       NA        NA
## DPS          0.495028         NA       NA        NA
## DRI          0.047791         NA       NA        NA
## DTE          1.987056         NA       NA        NA
## DUK         -1.285035         NA       NA        NA
## DVA          0.174313         NA       NA        NA
## DVN          0.116323         NA       NA        NA
## EA           0.306731         NA       NA        NA
## EBAY        -0.184828         NA       NA        NA
## ECL          0.084057         NA       NA        NA
## ED           0.114259         NA       NA        NA
## EFX         -0.154614         NA       NA        NA
## EIX          0.115249         NA       NA        NA
## EL           0.409133         NA       NA        NA
## EMN         -0.350901         NA       NA        NA
## EMR         -0.346147         NA       NA        NA
## ENDP         0.115596         NA       NA        NA
## EOG         -0.782028         NA       NA        NA
## EQIX         0.575762         NA       NA        NA
## EQR         -0.073419         NA       NA        NA
## EQT          0.319864         NA       NA        NA
## ES           1.214052         NA       NA        NA
## ESRX        -0.698489         NA       NA        NA
## ESS          0.377826         NA       NA        NA
## ETFC         0.137954         NA       NA        NA
## ETN         -0.479066         NA       NA        NA
## ETR         -0.598589         NA       NA        NA
## EVHC         0.031668         NA       NA        NA
## EW           0.137961         NA       NA        NA
## EXC          0.237056         NA       NA        NA
## EXPD        -0.492622         NA       NA        NA
## EXPE         0.309651         NA       NA        NA
## EXR         -0.395261         NA       NA        NA
## F           -0.291823         NA       NA        NA
## FAST         0.353287         NA       NA        NA
## FB          -0.196186         NA       NA        NA
## FBHS         0.010088         NA       NA        NA
## FCX          0.046338         NA       NA        NA
## FDX          0.454865         NA       NA        NA
## FE          -0.088282         NA       NA        NA
## FFIV         0.050890         NA       NA        NA
## FIS         -0.423613         NA       NA        NA
## FISV         0.059242         NA       NA        NA
## FITB         0.443553         NA       NA        NA
## FL           0.035503         NA       NA       NA
## FLIR        -0.166893         NA       NA       NA
## FLR         -0.472372         NA       NA       NA
## FLS          0.704143         NA       NA       NA
## FMC          0.107565         NA       NA       NA
## FOX         -0.882660         NA       NA       NA
## FOXA         1.087309         NA       NA       NA
## FRT         -0.198502         NA       NA       NA
## FSLR         0.013091         NA       NA       NA
## FTI         -0.563737         NA       NA       NA
## FTR          0.162302         NA       NA       NA
## GD          -0.173312         NA       NA       NA
## GE           0.691920         NA       NA       NA
## GGP         -0.856091         NA       NA       NA
## GILD         0.259934         NA       NA       NA
## GIS          0.791991         NA       NA       NA
## GLW         -0.186643         NA       NA       NA
## GM           0.207095         NA       NA       NA
## GOOG        -0.371412         NA       NA       NA
## GOOGL        0.595635         NA       NA       NA
## GPC         -0.463923         NA       NA       NA
## GPN          0.178230         NA       NA       NA
## GPS          0.245789         NA       NA       NA
## GRMN        -0.137435         NA       NA       NA
## GS           0.110510         NA       NA       NA
## GT          -0.348271         NA       NA       NA
## GWW          0.207698         NA       NA       NA
## HAL         -0.263731         NA       NA       NA
## HAR          0.263477         NA       NA       NA
## HAS          0.046177         NA       NA       NA
## HBAN         0.350658         NA       NA       NA
## HBI         -0.055808         NA       NA       NA
## HCA         -0.662768         NA       NA       NA
## HCN          0.336948         NA       NA       NA
## HCP         -0.275236         NA       NA       NA
## HD          -0.790137         NA       NA       NA
## HES         -0.408293         NA       NA       NA
## HIG         -0.212661         NA       NA       NA
## HOG         -0.018744         NA       NA       NA
## HOLX        -0.668797         NA       NA       NA
## HON          0.018582         NA       NA       NA
## HP           0.239023         NA       NA       NA
## HPE          0.289372         NA       NA       NA
## HPQ          0.313270         NA       NA       NA
## HRB          0.406856         NA       NA       NA
## HRL         -0.042603         NA       NA       NA
## HRS         -0.225242         NA       NA       NA
## HSIC         0.330772         NA       NA       NA
## HST          0.016855         NA       NA       NA
## HSY         -0.051291         NA       NA       NA
## HUM         -0.373588         NA       NA       NA
## IBM          0.002144         NA       NA       NA
## ICE         -0.081279         NA       NA       NA
## IFF         -0.130718         NA       NA       NA
## ILMN         0.328409          NA       NA        NA
## INTC        -0.253233          NA       NA        NA
## INTU        -0.057137          NA       NA        NA
## IP          -0.724142          NA       NA        NA
## IPG          0.351920          NA       NA        NA
## IR          -0.954283          NA       NA        NA
## IRM         -0.481459          NA       NA        NA
## ISRG         0.595607          NA       NA        NA
## ITW          0.321038          NA       NA        NA
## IVZ          0.105643          NA       NA        NA
## JBHT         0.354974          NA       NA        NA
## JCI          0.217565          NA       NA        NA
## JEC          0.937129          NA       NA        NA
## JNJ                NA          NA       NA        NA
## JNPR               NA          NA       NA        NA
## JPM                NA          NA       NA        NA
## JWN                NA          NA       NA        NA
## K                  NA          NA       NA        NA
## KEY                NA          NA       NA        NA
## KHC                NA          NA       NA        NA
## KIM                NA          NA       NA        NA
## KLAC               NA          NA       NA        NA
## KMB                NA          NA       NA        NA
## KMI                NA          NA       NA        NA
## KMX                NA          NA       NA        NA
## KO                 NA          NA       NA        NA
## KORS               NA          NA       NA        NA
## KR                 NA          NA       NA        NA
## KSS                NA          NA       NA        NA
## KSU                NA          NA       NA        NA
## L                  NA          NA       NA        NA
## LB                 NA          NA       NA        NA
## LEG                NA          NA       NA        NA
## LEN                NA          NA       NA        NA
## LH                 NA          NA       NA        NA
## LKQ                NA          NA       NA        NA
## LLL                NA          NA       NA        NA
## LLTC               NA          NA       NA        NA
## LLY                NA          NA       NA        NA
## LMT                NA          NA       NA        NA
## LNC                NA          NA       NA        NA
## LNT                NA          NA       NA        NA
## LOW                NA          NA       NA        NA
## LRCX               NA          NA       NA        NA
## LUK                NA          NA       NA        NA
## LUV                NA          NA       NA        NA
## LVLT               NA          NA       NA        NA
## LYB                NA          NA       NA        NA
## M                  NA          NA       NA        NA
## MA                 NA          NA       NA        NA
## MAA                NA          NA       NA        NA
## MAC                NA          NA       NA        NA
## MAR                NA          NA       NA        NA
## MAS                NA          NA       NA        NA
## MAT                    NA          NA       NA        NA
## MCD                    NA          NA       NA        NA
## MCHP                   NA          NA       NA        NA
## MCK                    NA          NA       NA        NA
## MCO                    NA          NA       NA        NA
## MDLZ                   NA          NA       NA        NA
## MDT                    NA          NA       NA        NA
## MET                    NA          NA       NA        NA
## MHK                    NA          NA       NA        NA
## MJN                    NA          NA       NA        NA
## MKC                    NA          NA       NA        NA
## MLM                    NA          NA       NA        NA
## MMC                    NA          NA       NA        NA
## MMM                    NA          NA       NA        NA
## MNK                    NA          NA       NA        NA
## MNST                   NA          NA       NA        NA
## MO                     NA          NA       NA        NA
## MON                    NA          NA       NA        NA
## MOS                    NA          NA       NA        NA
## MPC                    NA          NA       NA        NA
## MRK                    NA          NA       NA        NA
## MRO                    NA          NA       NA        NA
## MS                     NA          NA       NA        NA
## MSFT                   NA          NA       NA        NA
## MSI                    NA          NA       NA        NA
## MTB                    NA          NA       NA        NA
## MTD                    NA          NA       NA        NA
## MU                     NA          NA       NA        NA
## MUR                    NA          NA       NA        NA
## MYL                    NA          NA       NA        NA
## NAVI                   NA          NA       NA        NA
## NBL                    NA          NA       NA        NA
## NDAQ                   NA          NA       NA        NA
## NEE                    NA          NA       NA        NA
## NEM                    NA          NA       NA        NA
## NFLX                   NA          NA       NA        NA
## NFX                    NA          NA       NA        NA
## NI                     NA          NA       NA        NA
## NKE                    NA          NA       NA        NA
## NLSN                   NA          NA       NA        NA
## NOC                    NA          NA       NA        NA
## NOV                    NA          NA       NA        NA
## NRG                    NA          NA       NA        NA
## NSC                    NA          NA       NA        NA
## NTAP                   NA          NA       NA        NA
## NTRS                   NA          NA       NA        NA
## NUE                    NA          NA       NA        NA
## NVDA                   NA          NA       NA        NA
## NWL                    NA          NA       NA        NA
## NWS                    NA          NA       NA        NA
## NWSA                   NA          NA       NA        NA
## O                      NA          NA       NA        NA
## OKE                    NA          NA       NA        NA
## OMC                    NA          NA       NA        NA
## ORCL                 NA          NA       NA       NA
## ORLY                 NA          NA       NA       NA
## OXY                  NA          NA       NA       NA
## PAYX                 NA          NA       NA       NA
## PBCT                 NA          NA       NA       NA
## PBI                  NA          NA       NA       NA
## PCAR                 NA          NA       NA       NA
## PCG                  NA          NA       NA       NA
## PCLN                 NA          NA       NA       NA
## PDCO                 NA          NA       NA       NA
## PEG                  NA          NA       NA       NA
## PEP                  NA          NA       NA       NA
## PFE                  NA          NA       NA       NA
## PFG                  NA          NA       NA       NA
## PG                   NA          NA       NA       NA
## PGR                  NA          NA       NA       NA
## PH                   NA          NA       NA       NA
## PHM                  NA          NA       NA       NA
## PKI                  NA          NA       NA       NA
## PLD                  NA          NA       NA       NA
## PM                   NA          NA       NA       NA
## PNC                  NA          NA       NA       NA
## PNR                  NA          NA       NA       NA
## PNW                  NA          NA       NA       NA
## PPG                  NA          NA       NA       NA
## PPL                  NA          NA       NA       NA
## PRGO                 NA          NA       NA       NA
## PRU                  NA          NA       NA       NA
## PSA                  NA          NA       NA       NA
## PSX                  NA          NA       NA       NA
## PVH                  NA          NA       NA       NA
## PWR                  NA          NA       NA       NA
## PX                   NA          NA       NA       NA
## PXD                  NA          NA       NA       NA
## PYPL                 NA          NA       NA       NA
## QCOM                 NA          NA       NA       NA
## QRVO                 NA          NA       NA       NA
## R                    NA          NA       NA       NA
## RAI                  NA          NA       NA       NA
## RCL                  NA          NA       NA       NA
## REGN                 NA          NA       NA       NA
## RF                   NA          NA       NA       NA
## RHI                  NA          NA       NA       NA
## RHT                  NA          NA       NA       NA
## RIG                  NA          NA       NA       NA
## RL                   NA          NA       NA       NA
## ROK                  NA          NA       NA       NA
## ROP                  NA          NA       NA       NA
## ROST                 NA          NA       NA       NA
## RRC                  NA          NA       NA       NA
## RSG                  NA          NA       NA       NA
## RTN                  NA          NA       NA       NA
## SBUX                 NA          NA       NA       NA
## SCG                  NA          NA       NA       NA
## SCHW                 NA          NA       NA        NA
## SE                   NA          NA       NA        NA
## SEE                  NA          NA       NA        NA
## SHW                  NA          NA       NA        NA
## SIG                  NA          NA       NA        NA
## SJM                  NA          NA       NA        NA
## SLB                  NA          NA       NA        NA
## SLG                  NA          NA       NA        NA
## SNA                  NA          NA       NA        NA
## SNI                  NA          NA       NA        NA
## SO                   NA          NA       NA        NA
## SPG                  NA          NA       NA        NA
## SPGI                 NA          NA       NA        NA
## SPLS                 NA          NA       NA        NA
## SRCL                 NA          NA       NA        NA
## SRE                  NA          NA       NA        NA
## STI                  NA          NA       NA        NA
## STJ                  NA          NA       NA        NA
## STT                  NA          NA       NA        NA
## STX                  NA          NA       NA        NA
## STZ                  NA          NA       NA        NA
## SWK                  NA          NA       NA        NA
## SWKS                 NA          NA       NA        NA
## SWN                  NA          NA       NA        NA
## SYF                  NA          NA       NA        NA
## SYK                  NA          NA       NA        NA
## SYMC                 NA          NA       NA        NA
## SYY                  NA          NA       NA        NA
## T                    NA          NA       NA        NA
## TAP                  NA          NA       NA        NA
## TDC                  NA          NA       NA        NA
## TDG                  NA          NA       NA        NA
## TEL                  NA          NA       NA        NA
## TGNA                 NA          NA       NA        NA
## TGT                  NA          NA       NA        NA
## TIF                  NA          NA       NA        NA
## TJX                  NA          NA       NA        NA
## TMK                  NA          NA       NA        NA
## TMO                  NA          NA       NA        NA
## TRIP                 NA          NA       NA        NA
## TROW                 NA          NA       NA        NA
## TRV                  NA          NA       NA        NA
## TSCO                 NA          NA       NA        NA
## TSN                  NA          NA       NA        NA
## TSO                  NA          NA       NA        NA
## TSS                  NA          NA       NA        NA
## TWX                  NA          NA       NA        NA
## TXN                  NA          NA       NA        NA
## TXT                  NA          NA       NA        NA
## UAL                  NA          NA       NA        NA
## UDR                  NA          NA       NA        NA
## UHS                  NA          NA       NA        NA
## ULTA                 NA          NA       NA        NA
## UNH                  NA          NA       NA        NA
## UNM                 NA          NA      NA       NA
## UNP                 NA          NA      NA       NA
## UPS                 NA          NA      NA       NA
## URBN                NA          NA      NA       NA
## URI                 NA          NA      NA       NA
## USB                 NA          NA      NA       NA
## UTX                 NA          NA      NA       NA
## V                   NA          NA      NA       NA
## VAR                 NA          NA      NA       NA
## VFC                 NA          NA      NA       NA
## VIAB                NA          NA      NA       NA
## VLO                 NA          NA      NA       NA
## VMC                 NA          NA      NA       NA
## VNO                 NA          NA      NA       NA
## VRSK                NA          NA      NA       NA
## VRSN                NA          NA      NA       NA
## VRTX                NA          NA      NA       NA
## VTR                 NA          NA      NA       NA
## VZ                  NA          NA      NA       NA
## WAT                 NA          NA      NA       NA
## WBA                 NA          NA      NA       NA
## WDC                 NA          NA      NA       NA
## WEC                 NA          NA      NA       NA
## WFC                 NA          NA      NA       NA
## WFM                 NA          NA      NA       NA
## WHR                 NA          NA      NA       NA
## WM                  NA          NA      NA       NA
## WMB                 NA          NA      NA       NA
## WMT                 NA          NA      NA       NA
## WRK                 NA          NA      NA       NA
## WU                  NA          NA      NA       NA
## WY                  NA          NA      NA       NA
## WYN                 NA          NA      NA       NA
## WYNN                NA          NA      NA       NA
## XEC                 NA          NA      NA       NA
## XEL                 NA          NA      NA       NA
## XL                  NA          NA      NA       NA
## XLNX                NA          NA      NA       NA
## XOM                 NA          NA      NA       NA
## XRAY                NA          NA      NA       NA
## XRX                 NA          NA      NA       NA
## XYL                 NA          NA      NA       NA
## YHOO                NA          NA      NA       NA
## YUM                 NA          NA      NA       NA
## ZBH                 NA          NA      NA       NA
## ZION                NA          NA      NA       NA
## ZTS                 NA          NA      NA       NA
##
## Residual standard error: NaN on 0 degrees of freedom
## Multiple R-squared:      1,  Adjusted R-squared:    NaN
## F-statistic:   NaN on 251 and 0 DF,  p-value: NA
```

```
options(max.print=252)
```

There is a clear problem of not having any significant parameter in the model. More variables than observations, so linear regression will not give a unique solution!

(b) Now use elasticnet (Lasso, Ridge, or a combination, i.e. glmnet) instead of linear regression to model the secret portfolio. Once get a smaller set of variables from the shrinkage, refit a linear model with only those predictors. [Note, you may want to check out the `plotmo` and `pander` packages for nice plots and outputs for your models.]

```
x=model.matrix (portfolioreturns~., portWithReturnsAndStocks)[,-1];
y=portWithReturnsAndStocks$portfolioreturns
grid =10^ seq (10,-2, length =100)
port.ridge =glmnet (x, y,alpha =0, thresh =1e-12)
plot_glmnet(port.ridge, label=20)
```



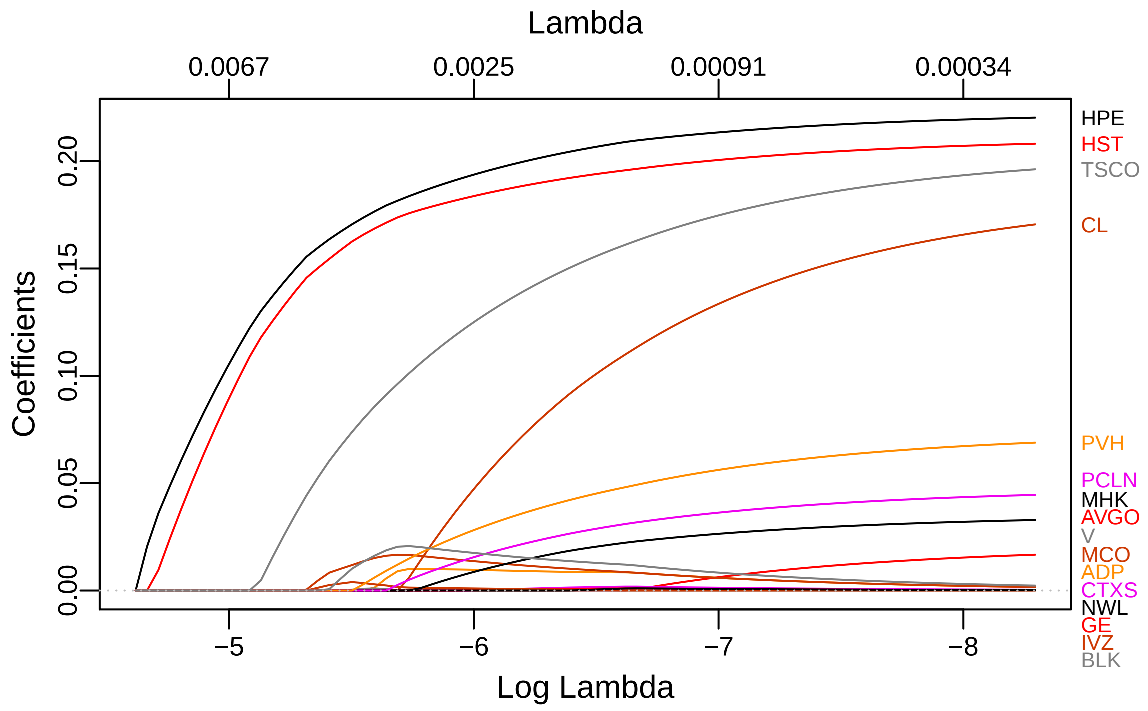
```
### Use lasso with CV
cv.lasso <- cv.glmnet(x, y, alpha = 1)
bestlam.lasso <- cv.lasso$lambda.min
bestlam.lasso
```

```
## [1] 0.009865088
```

```
port.lasso =glmnet (x, y, alpha =1, thresh =1e-12)
lasso.coef=predict (port.lasso, type ="coefficients", s=bestlam.lasso )[0:502,]

lasso.coef[lasso.coef !=0]
```

```
##  (Intercept)
## 0.0007774937
```

```
plot_glmnet(port.lasso, label=20)
```



The list of parameters that we find significant from lasso are: ADP + AVGO + CL + CTXS + GE + HPE + HST + MCO + MHK + NWL + PCLN + PVH + TSCO + V

Lets use these to perform linear regressions.

```
lm.fit=lm(portfolioreturns ~ ADP + AVGO +   CL + CTXS +   GE +  HPE +  HST  + MCO +  MHK +  NWL + PCLN +
summary(lm.fit)
```

```
## Warning in summary.lm(lm.fit): essentially perfect fit: summary may be
## unreliable

##
## Call:
## lm(formula = portfolioreturns ~ ADP + AVGO + CL + CTXS + GE +
##     HPE + HST + MCO + MHK + NWL + PCLN + PVH + TSCO + V, data = portWithReturnsAndStocks)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.496e-17 -2.359e-18 -9.540e-19  5.220e-19  7.741e-17
##
## Coefficients:
##               Estimate Std. Error    t value Pr(>|t|)
## (Intercept) -2.512e-19  4.641e-19 -5.410e-01    0.589
## ADP          5.671e-16  6.831e-17  8.302e+00 7.85e-15 ***
## AVGO         2.066e-02  3.743e-17  5.519e+14  < 2e-16 ***
## CL           1.845e-01  6.587e-17  2.801e+15  < 2e-16 ***
## CTXS         3.996e-17  4.221e-17  9.470e-01    0.345
## GE          -6.976e-17  6.445e-17 -1.082e+00    0.280
## HPE          2.229e-01  2.767e-17  8.056e+15  < 2e-16 ***
## HST          2.110e-01  3.203e-17  6.588e+15  < 2e-16 ***
## MCO         -5.847e-17  4.912e-17 -1.190e+00    0.235
## MHK          3.527e-02  4.782e-17  7.375e+14  < 2e-16 ***
## NWL         -5.484e-17  4.257e-17 -1.288e+00    0.199
## PCLN         4.767e-02  3.429e-17  1.390e+15  < 2e-16 ***
## PVH          7.369e-02  2.768e-17  2.662e+15  < 2e-16 ***
## TSCO         2.043e-01  2.966e-17  6.888e+15  < 2e-16 ***
## V            1.359e-17  5.363e-17  2.530e-01    0.800
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.259e-18 on 237 degrees of freedom
## Multiple R-squared:      1,  Adjusted R-squared:      1
## F-statistic: 5.138e+31 on 14 and 237 DF,  p-value: < 2.2e-16
```

We get much better results in this case.

(c) Here is how the portfolio was created. We're essentially randomly sampling columns from spreturns to have non-zero coefficients (portfoliowts) and then generating returns from that.

```r
t = runif(ncol(spreturns))
thresh = .98
mask = t > thresh
w = runif(ncol(spreturns))
sum(mask) # number of chosen coefficients
portfoliowts = w * mask / sum(w * mask)
myportfolioreturns = spreturns %*% portfoliowts
```

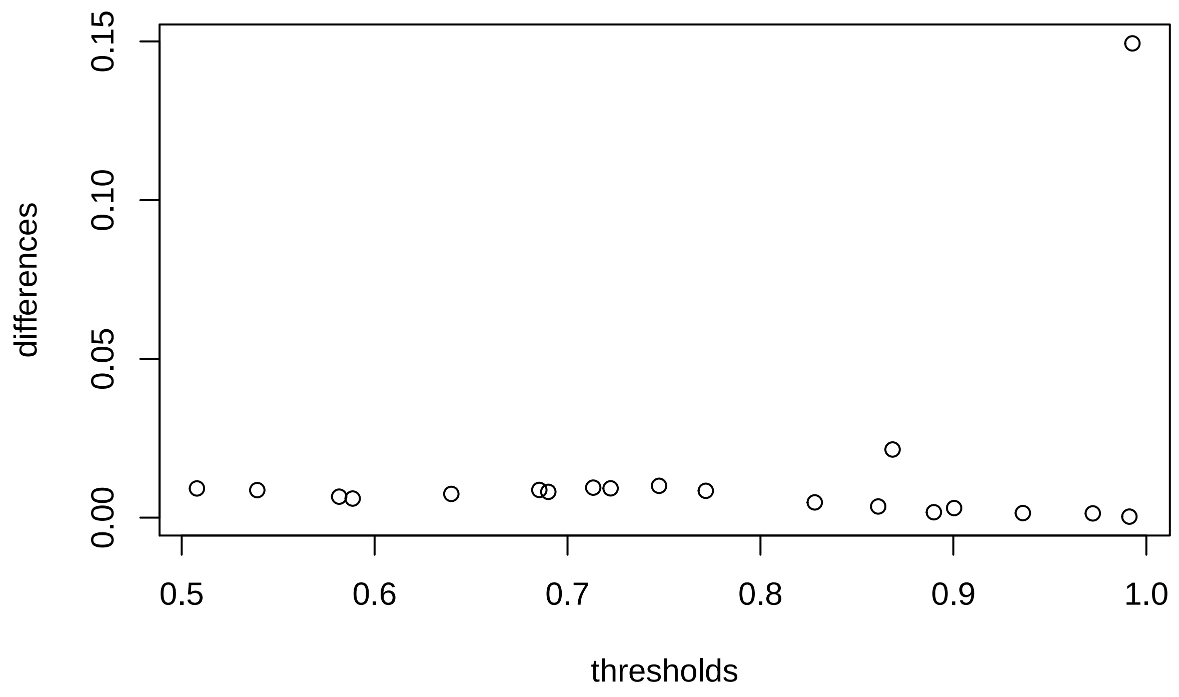
Write a function that takes a threshold as input and produces the total error for estimated weights from lasso to the true weights. To do this you will need (1) a function that generates weights and returns for a given threshold function, (2) a function that takes the the returns and outputs the estimated coefficeints from a lasso, and (3) a function that takes the estimated coefficients and returns the error relative to the true weights. Plot the errors for a variety of different thresholds between 0.5 and 1.

```r
generateWeightsAndReturns <- function(threshold) {
  t = runif(ncol(spreturns))
  mask = t > threshold
  w = runif(ncol(spreturns))
  portfoliowts = w * mask / sum(w * mask)
  list(Returns=spreturns %*% portfoliowts, Weights=portfoliowts)
}

estimateLassoCoef <- function(returns) {
  portWithReturnsAndStocks <- cbind(returns, spreturns)
  dim(portWithReturnsAndStocks)
  colnames(portWithReturnsAndStocks)[1] <- "portfolioreturns"
  x=model.matrix (portfolioreturns ~ ., data = portWithReturnsAndStocks)[,-1]
  y=portWithReturnsAndStocks$portfolioreturns
  cv.lasso <- cv.glmnet(x,y, alpha = 1)
  bestlam.lasso <- cv.lasso$lambda.min

  lasso.mod =glmnet (x,y,alpha =1)
  lasso.coef  <- predict(lasso.mod, type = 'coefficients', s = bestlam.lasso)
  lasso.coef
}

# find squared differences
squaredDifferenceBetweenEstimatedAndTrueWeights <- function(estCoef, trueCoef) {
  # The est coef include the intercept that we have to remove
  sum((estCoef[2:502] - trueCoef)^2)
}

wrapper <- function(threshold) {
  weightsAndReturns = generateWeightsAndReturns(threshold)
  squaredDifferenceBetweenEstimatedAndTrueWeights(estimateLassoCoef(weightsAndReturns$Returns), weights
}

emitID <- local({
    idCounter <- 0
    function(){
        idCounter <<- idCounter + 1L                      # increment
        formatC(idCounter, width=9, flag=0, format="d")  # format & return
    }
})

df <- data.frame(thresholds=numeric(0), differences=numeric(0))
lapply(runif(20, min = 0.5, max = 1), function(x) { df[emitID(),] <<- c(x, wrapper(x))  } )
```

```
## [[1]]
## [1] 0.68537505 0.00872213
##
## [[2]]
## [1] 0.935989883 0.001428347
##
## [[3]]
## [1] 0.900380798 0.003004168
##
## [[4]]
## [1] 0.588642272 0.006010504
##
## [[5]]
## [1] 0.581638846 0.006605068
##
## [[6]]
## [1] 0.97224455 0.00133598
##
## [[7]]
## [1] 0.722318801 0.009222658
##
## [[8]]
## [1] 0.539196295 0.008665269
##
```

```
## [[9]]
## [1] 0.9927858 0.1493764
##
## [[10]]
## [1] 0.507919109 0.009190536
##
## [[11]]
## [1] 0.74744125 0.01002822
##
## [[12]]
## [1] 0.713313122 0.009444134
##
## [[13]]
## [1] 0.690032717 0.008117933
##
## [[14]]
## [1] 0.86847219 0.02145733
##
## [[15]]
## [1] 0.639769176 0.007469914
##
## [[16]]
## [1] 0.828141936 0.004796263
##
## [[17]]
## [1] 0.889863051 0.001697387
##
## [[18]]
## [1] 0.861026253 0.003509371
##
## [[19]]
## [1] 0.9912030222 0.0003198741
##
## [[20]]
## [1] 0.77166136 0.00844408
```

```r
plot(df)
```


differences
0.00
0.05
0.10
0.15
0.5
0.6
0.7
0.8
0.9
1.0
thresholds