sold_units_complete

Francisco Finochietto and Jerónimo Pissinis

2/27/2022

Analysis of the factors related with the number of units sold per year

```
#Importing the packages
library(readr)
library(car)
```

```
## Loading required package: carData
```

```
library(glmnet)
```

```
## Loading required package: Matrix
```

```
## Loaded glmnet 4.1-3
```

```
library(leaps)
library(lmvar)
```

Importing the data

```
file_path<-"../raw/sold_units_complete.csv"
sold_units<-read_csv(file_path)
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   Año = col_double(),
##   `Unidades Vendidas` = col_double(),
##   `ITCRB Estados Unidos Promedio` = col_double(),
##   `Importacion de autos` = col_double(),
##   `Crisis Semiconductores` = col_double(),
##   `Devaluacion Interanual` = col_double(),
##   Inflacion = col_double(),
##   `Restriccion de importaciones` = col_double(),
##   `PIB (Millones de US$ a precios actuales)` = col_double(),
##   `Reservas Internacionales` = col_double(),
##   `PIB/reservas` = col_double(),
##   `Brecha Cambiaria` = col_double(),
##   `Diferencia Trade Balance Industria` = col_number()
## )
```

```r
#Dropping the year column.
sold_units<-sold_units[,-1]

#Centering the variables to reduce structural multicolinearity
sold_units[,8]<-scale(sold_units[,8],scale=FALSE)
sold_units[,9]<-scale(sold_units[,9],scale=FALSE)
sold_units[,10]<-scale(sold_units[,10],scale=FALSE)

#Renaming the columns
my_names<-c("num_units", "itcrb", "imported_cars", "semiconductor_crisis",
            "devaluacion_interanual", "inflation", "import_restriction",
            "PIB", "reserves", "PIB_over_reserves", "exchange_difference",
            "industry_trade_balance_difference")
names(sold_units)<-my_names
```

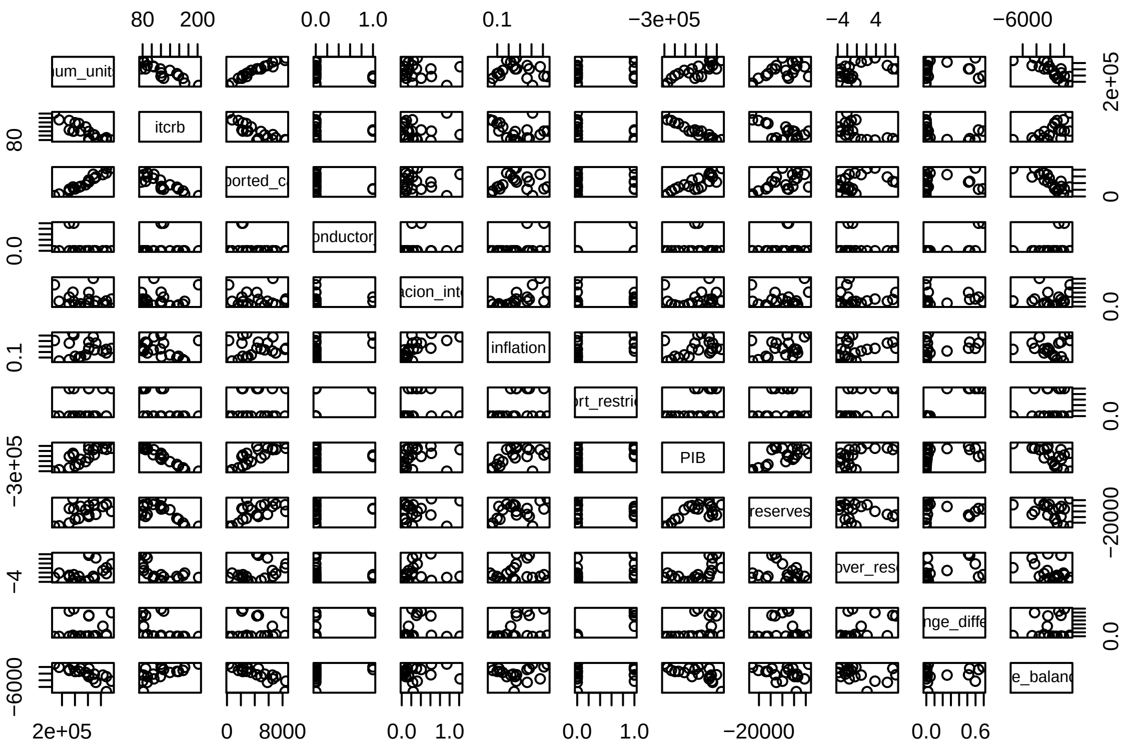
Building the model

```r
sold_units_model<-lm(sold_units, y= TRUE, x = TRUE)
summary(sold_units_model)
```

```
##
## Call:
## lm(formula = sold_units, x = TRUE, y = TRUE)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -62015 -12576  -1454  19485  66203
##
## Coefficients:
##                                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)                        6.445e+05  4.954e+05   1.301   0.2295
## itcrb                             -3.134e+03  3.815e+03  -0.822   0.4351
## imported_cars                      8.011e+01  2.615e+01   3.063   0.0155 *
## semiconductor_crisis              -8.198e+04  1.099e+05  -0.746   0.4770
## devaluacion_interanual            -8.825e+04  5.990e+04  -1.473   0.1789
## inflation                          5.412e+03  1.883e+05   0.029   0.9778
## import_restriction                -3.926e+04  1.058e+05  -0.371   0.7202
## PIB                                5.299e-01  8.115e-01   0.653   0.5321
## reserves                          -8.287e+00  1.045e+01  -0.793   0.4506
## PIB_over_reserves                 -3.020e+04  3.780e+04  -0.799   0.4474
## exchange_difference                8.548e+04  2.097e+05   0.408   0.6942
## industry_trade_balance_difference  1.064e+01  1.747e+01   0.609   0.5594
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 43590 on 8 degrees of freedom
## Multiple R-squared:  0.9866, Adjusted R-squared:  0.9682
## F-statistic: 53.58 on 11 and 8 DF,  p-value: 2.911e-06
```

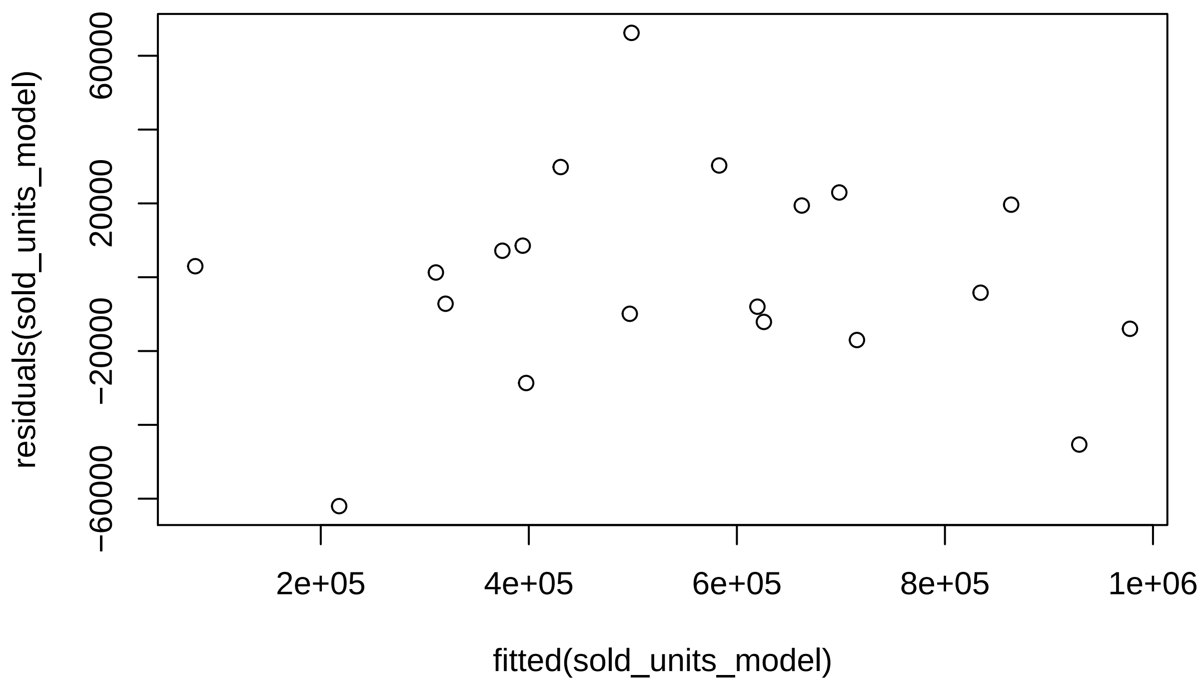
Pairwise plots of the features

```
pairs(sold_units)
```

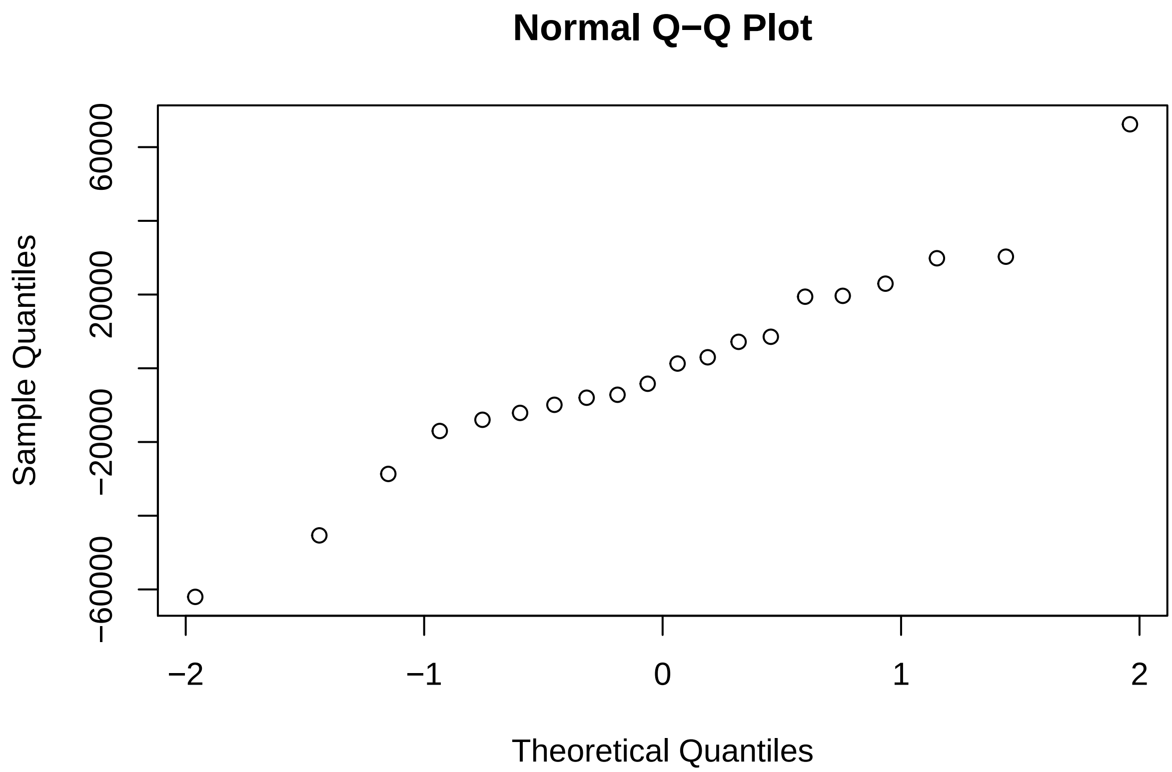


Analyzing the residuals

```
plot(fitted(sold_units_model),residuals(sold_units_model))
```

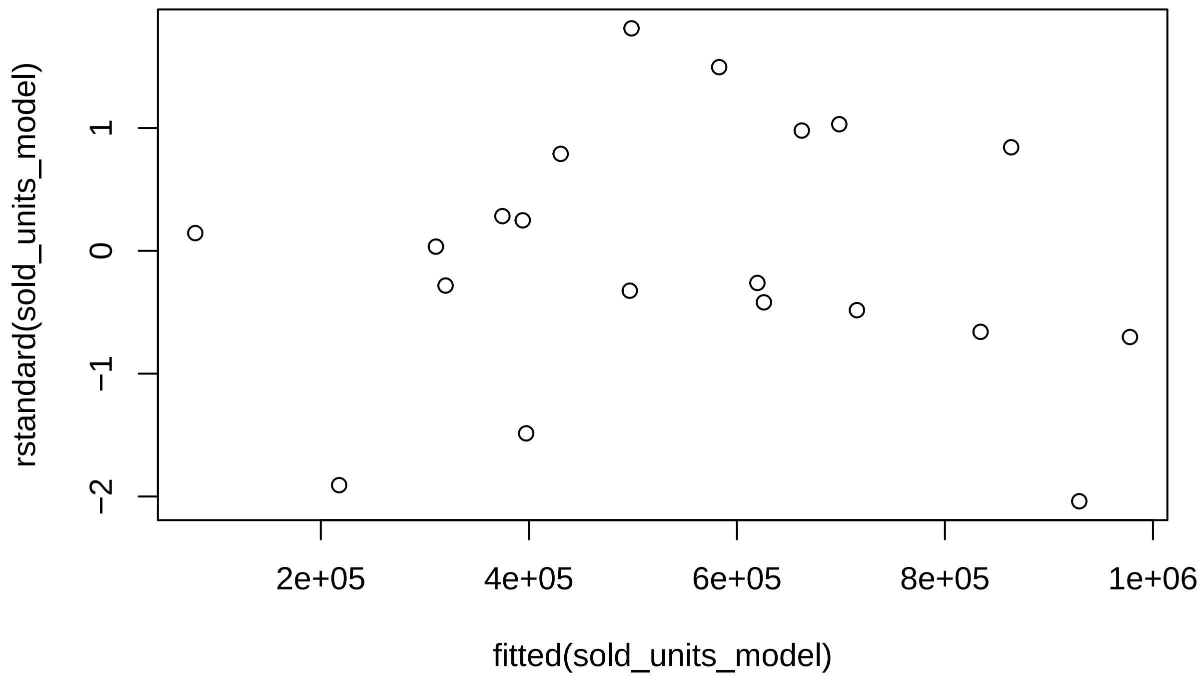



```
qqnorm(residuals(sold_units_model))
```

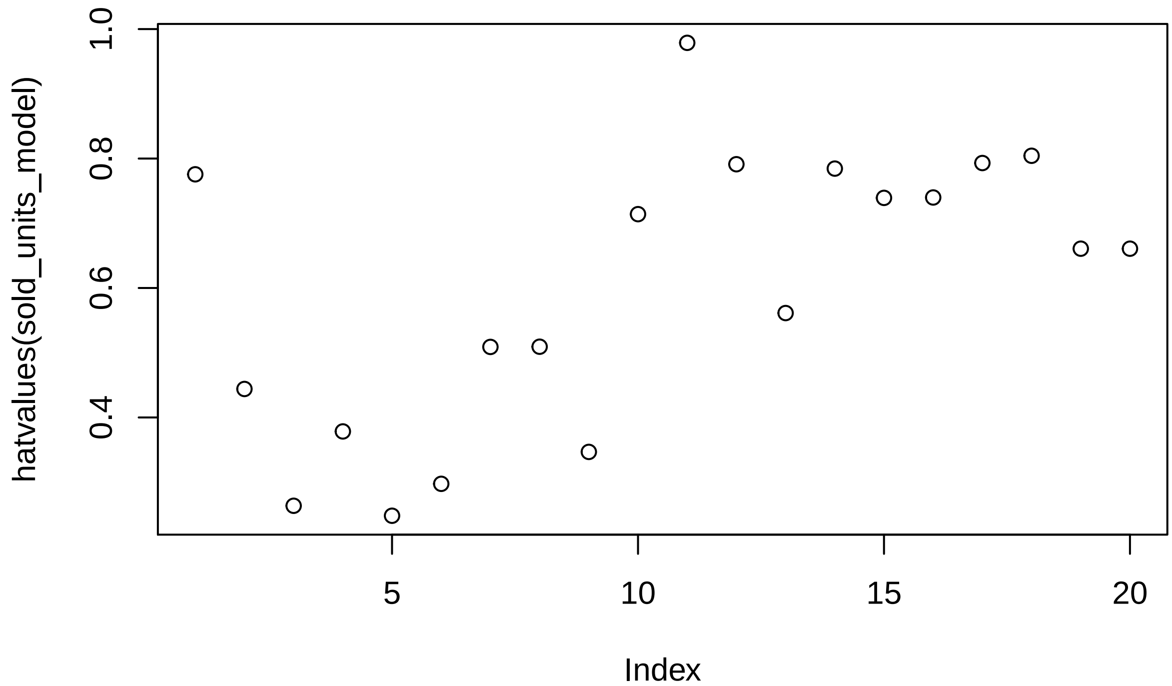


Looking for outliers and high leverage points

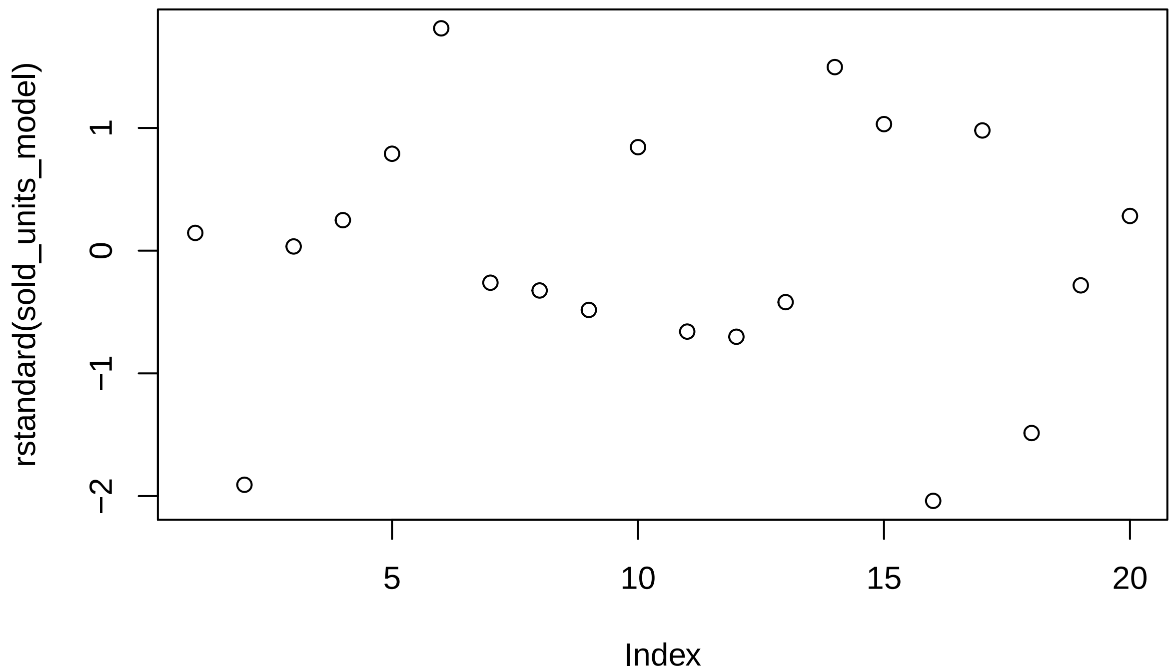
```
plot(fitted(sold_units_model),rstandard(sold_units_model))
```




```
plot(hatvalues(sold_units_model))
abline(h=length(coef(sold_units_model))/nrow(sold_units)*2,
       col = "red",lty = 2)
```




```
high_leverage_points<-hatvalues(sold_units_model)>
  (length(coef(sold_units_model))/nrow(sold_units)*2)
plot(rstandard(sold_units_model),
     col = factor(high_leverage_points))
```



Looking for colinearity Correlation matrix

```
cor(sold_units[,-1])
```

```
##                                        itcrb imported_cars
## itcrb                             1.00000000   -0.84998083
## imported_cars                    -0.84998083    1.00000000
## semiconductor_crisis              0.03102529   -0.27546378
## devaluacion_interanual            0.04051446   -0.02721305
## inflation                        -0.27166538    0.10875007
## import_restriction               -0.45615253    0.15017680
## PIB                              -0.97038025    0.84102366
## reserves                         -0.64341540    0.59313786
## PIB_over_reserves                -0.57391965    0.39056882
## exchange_difference              -0.40454741    0.09171044
## industry_trade_balance_difference  0.62115112   -0.85146240
##                                  semiconductor_crisis devaluacion_interanual
## itcrb                                     0.031025294            0.040514456
## imported_cars                            -0.275463784           -0.027213050
## semiconductor_crisis                      1.000000000            0.005059507
## devaluacion_interanual                    0.005059507            1.000000000
## inflation                                 0.391827027            0.655280837
## import_restriction                        0.509175077            0.060402026
## PIB                                       0.011897026            0.125177055
## reserves                                  0.113498077            0.081914320
## PIB_over_reserves                        -0.123565165            0.092155529
```

```
## exchange_difference                       0.650902612          0.073825750
## industry_trade_balance_difference         0.258351230          0.079954149
##                                    inflation import_restriction        PIB
## itcrb                             -0.27166538        -0.45615253 -0.97038025
## imported_cars                      0.10875007         0.15017680  0.84102366
## semiconductor_crisis               0.39182703         0.50917508  0.01189703
## devaluacion_interanual             0.65528084         0.06040203  0.12517705
## inflation                          1.00000000         0.31212355  0.42376923
## import_restriction                 0.31212355         1.00000000  0.42912174
## PIB                                0.42376923         0.42912174  1.00000000
## reserves                           0.41050289         0.02503357  0.65862991
## PIB_over_reserves                  0.14588345         0.53395398  0.58138567
## exchange_difference                0.38737953         0.95207008  0.39340556
## industry_trade_balance_difference  0.08132427         0.06360759 -0.64427806
##                                     reserves PIB_over_reserves
## itcrb                             -0.64341540       -0.57391965
## imported_cars                      0.59313786        0.39056882
## semiconductor_crisis               0.11349808       -0.12356516
## devaluacion_interanual             0.08191432        0.09215553
## inflation                          0.41050289        0.14588345
## import_restriction                 0.02503357        0.53395398
## PIB                                0.65862991        0.58138567
## reserves                           1.00000000       -0.21014720
## PIB_over_reserves                 -0.21014720        1.00000000
## exchange_difference                0.03724469        0.48228198
## industry_trade_balance_difference -0.33854868       -0.37317620
##                                   exchange_difference
## itcrb                                     -0.40454741
## imported_cars                              0.09171044
## semiconductor_crisis                       0.65090261
## devaluacion_interanual                     0.07382575
## inflation                                  0.38737953
## import_restriction                         0.95207008
## PIB                                        0.39340556
## reserves                                   0.03724469
## PIB_over_reserves                          0.48228198
## exchange_difference                        1.00000000
## industry_trade_balance_difference          0.08784890
##                                   industry_trade_balance_difference
## itcrb                                                    0.62115112
## imported_cars                                           -0.85146240
## semiconductor_crisis                                     0.25835123
## devaluacion_interanual                                   0.07995415
## inflation                                                0.08132427
## import_restriction                                       0.06360759
## PIB                                                     -0.64427806
## reserves                                                -0.33854868
## PIB_over_reserves                                       -0.37317620
## exchange_difference                                      0.08784890
## industry_trade_balance_difference                        1.00000000
```

Variance inflation factors

```r
vif(sold_units_model)
```

```
##                               itcrb                       imported_cars
##                          188.647668                           40.041749
##                semiconductor_crisis               devaluacion_interanual
##                           11.435279                            3.626339
##                           inflation                  import_restriction
##                            7.827097                           24.727457
##                                 PIB                            reserves
##                          182.555051                          224.155138
##                  PIB_over_reserves                 exchange_difference
##                          196.605341                           29.934856
## industry_trade_balance_difference
##                           12.545070
```

Eigenvalues of the correlation matrix

```r
eigen(cor(sold_units[,-1]))$values
```

```
##  [1] 4.518840497 2.690677954 1.652199919 1.222258483 0.450025634 0.278666946
##  [7] 0.121728329 0.033478040 0.023565463 0.007116211 0.001442524
```

Testing the model using cross-validation

```r
cv_sold_units<-cv.lm(sold_units_model, k=5,)
cv_sold_units
```

```
## Mean absolute error        :  119647.7
## Sample standard deviation  :  60554.85
##
## Mean squared error         :  26183733607
## Sample standard deviation  :  22321672589
##
## Root mean squared error    :  147794.4
## Sample standard deviation  :  73659.23
```

Feature selection

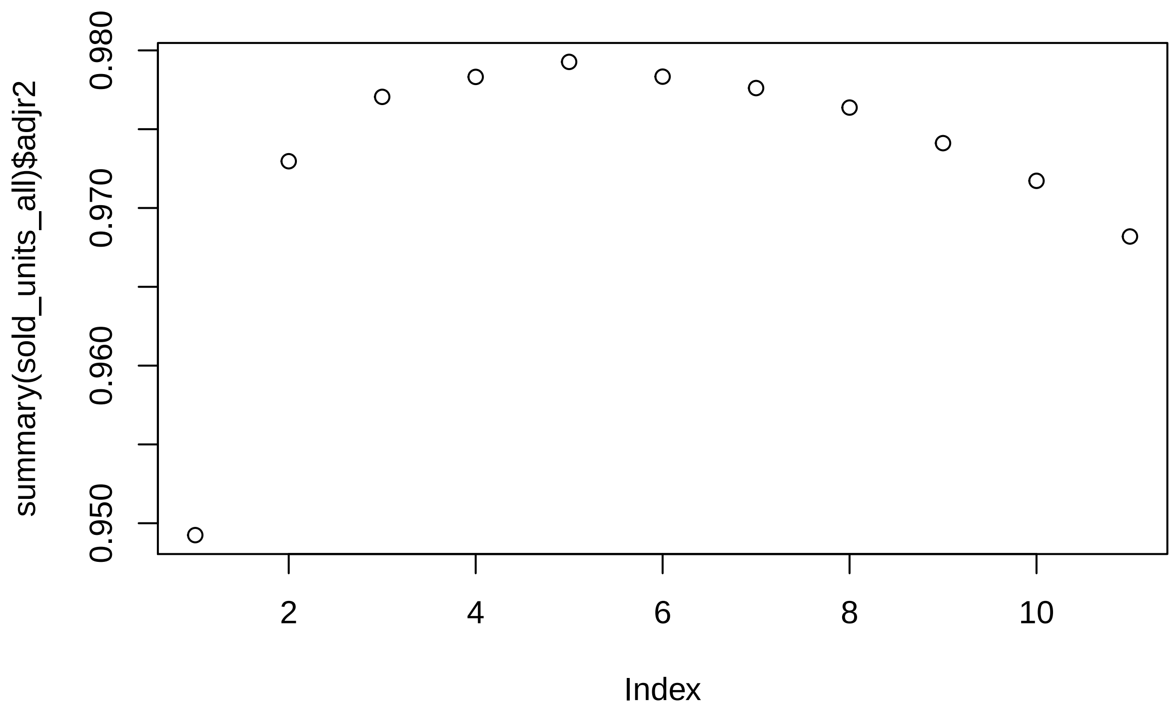
Applying best subset selection

```r
sold_units_all<-regsubsets(sold_units$num_units~.,sold_units,nvmax = 12)
summary(sold_units_all)
```

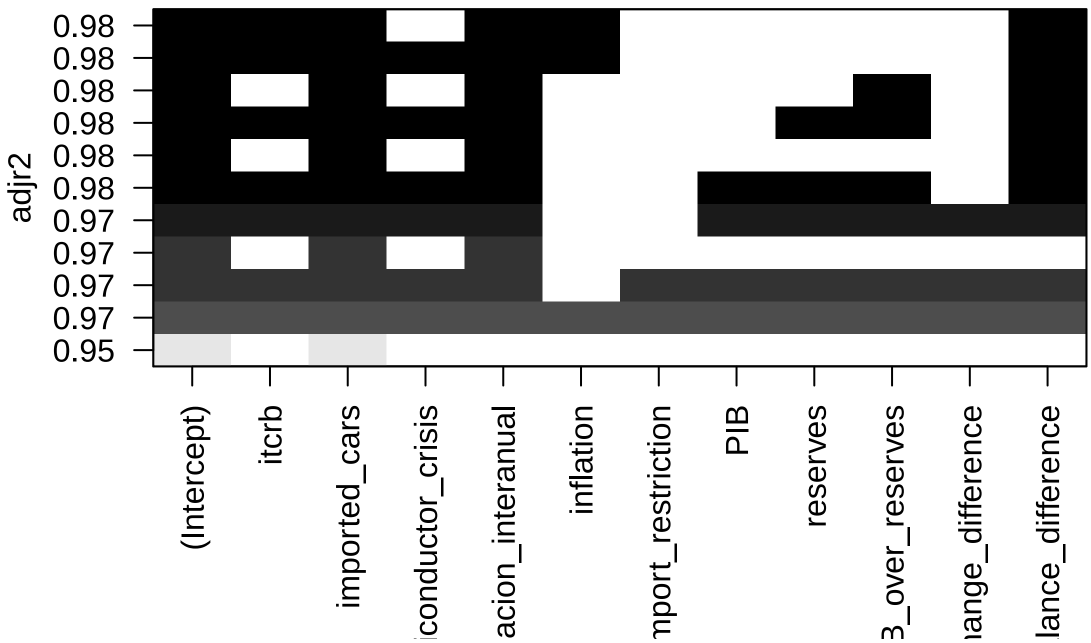
```
## Subset selection object
## Call: regsubsets.formula(sold_units$num_units ~ ., sold_units, nvmax = 12)
## 11 Variables  (and intercept)
##                                   Forced in Forced out
## itcrb                                 FALSE      FALSE
## imported_cars                         FALSE      FALSE
```

```
## semiconductor_crisis                  FALSE      FALSE
## devaluacion_interanual                FALSE      FALSE
## inflation                             FALSE      FALSE
## import_restriction                    FALSE      FALSE
## PIB                                   FALSE      FALSE
## reserves                              FALSE      FALSE
## PIB_over_reserves                     FALSE      FALSE
## exchange_difference                   FALSE      FALSE
## industry_trade_balance_difference     FALSE      FALSE
## 1 subsets of each size up to 11
## Selection Algorithm: exhaustive
##           itcrb imported_cars semiconductor_crisis devaluacion_interanual
## 1  ( 1 )  " "   "*"           " "                  " "
## 2  ( 1 )  " "   "*"           " "                  "*"
## 3  ( 1 )  " "   "*"           " "                  "*"
## 4  ( 1 )  " "   "*"           " "                  "*"
## 5  ( 1 )  "*"   "*"           " "                  "*"
## 6  ( 1 )  "*"   "*"           "*"                  "*"
## 7  ( 1 )  "*"   "*"           "*"                  "*"
## 8  ( 1 )  "*"   "*"           "*"                  "*"
## 9  ( 1 )  "*"   "*"           "*"                  "*"
## 10  ( 1 ) "*"   "*"           "*"                  "*"
## 11  ( 1 ) "*"   "*"           "*"                  "*"
##           inflation import_restriction PIB reserves PIB_over_reserves
## 1  ( 1 )  " "       " "                " " " "      " "
## 2  ( 1 )  " "       " "                " " " "      " "
## 3  ( 1 )  " "       " "                " " " "      " "
## 4  ( 1 )  " "       " "                " " " "      "*"
## 5  ( 1 )  "*"       " "                " " " "      " "
## 6  ( 1 )  "*"       " "                " " " "      " "
## 7  ( 1 )  " "       " "                " " "*"      "*"
## 8  ( 1 )  " "       " "                "*" "*"      "*"
## 9  ( 1 )  " "       " "                "*" "*"      "*"
## 10  ( 1 ) " "       "*"                "*" "*"      "*"
## 11  ( 1 ) "*"       "*"                "*" "*"      "*"
##           exchange_difference industry_trade_balance_difference
## 1  ( 1 )  " "                 " "
## 2  ( 1 )  " "                 " "
## 3  ( 1 )  " "                 "*"
## 4  ( 1 )  " "                 "*"
## 5  ( 1 )  " "                 "*"
## 6  ( 1 )  " "                 "*"
## 7  ( 1 )  " "                 "*"
## 8  ( 1 )  " "                 "*"
## 9  ( 1 )  "*"                 "*"
## 10  ( 1 ) "*"                 "*"
## 11  ( 1 ) "*"                 "*"
```

```
plot(summary(sold_units_all)$adjr2)
```




```
plot(sold_units_all, scale = "adjr2")
```




```r
best_adjr2<-which.max(summary(sold_units_all)$adjr2)
subset_coef<-names(coef(sold_units_all, best_adjr2))
```

Building the selected model

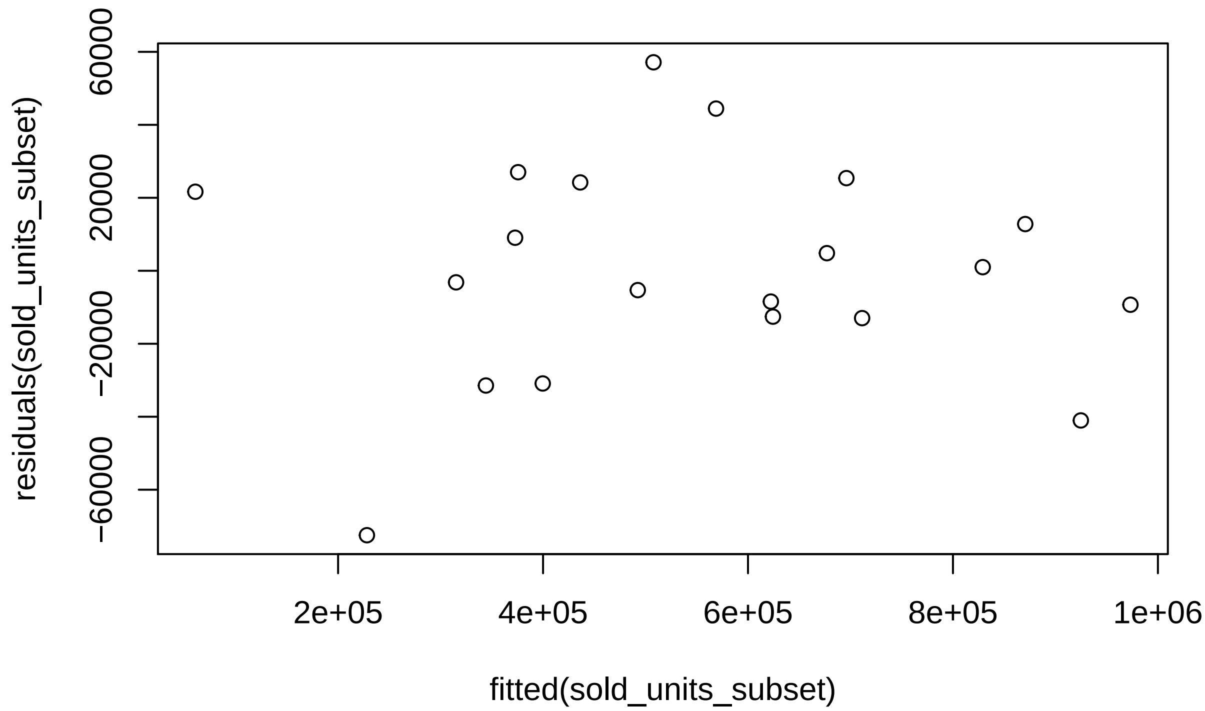
```r
sold_units_subset<-
  lm(sold_units[,names(sold_units)%in%
    c("num_units",subset_coef)], y = TRUE, x = TRUE)
summary(sold_units_subset)
```

```
##
## Call:
## lm(formula = sold_units[, names(sold_units) %in% c("num_units",
##     subset_coef)], x = TRUE, y = TRUE)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -72464 -12668  -1086  22298  57133
##
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                       3.343e+05  9.583e+04   3.489  0.00361 **
## itcrb                            -8.901e+02  5.036e+02  -1.767  0.09894 .
## imported_cars                     9.820e+01  1.028e+01   9.553 1.64e-07 ***
## devaluacion_interanual           -8.505e+04  3.654e+04  -2.327  0.03547 *
```

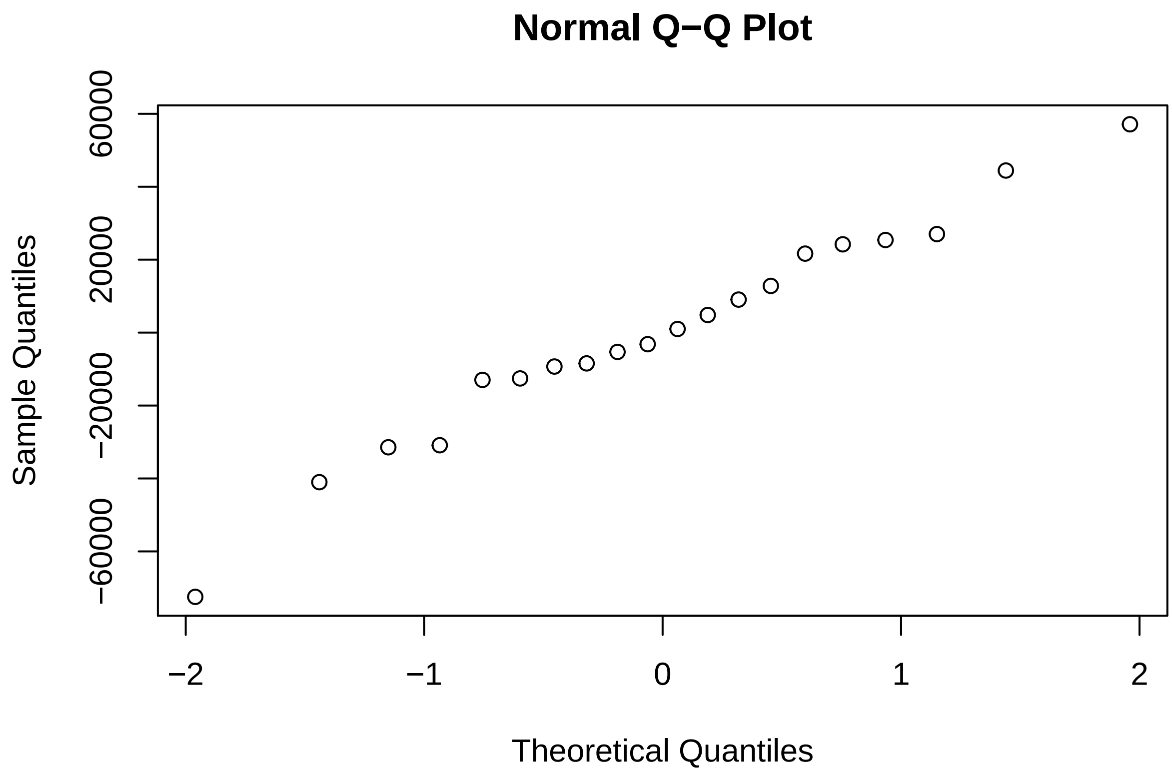
```
## inflation                          -1.214e+05  8.538e+04  -1.421  0.17709
## industry_trade_balance_difference  1.457e+01  8.434e+00   1.728  0.10602
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 35190 on 14 degrees of freedom
## Multiple R-squared:  0.9847, Adjusted R-squared:  0.9793
## F-statistic: 180.5 on 5 and 14 DF,  p-value: 3.385e-12
```

Analyzing the residuals

```
plot(fitted(sold_units_subset),residuals(sold_units_subset))
```

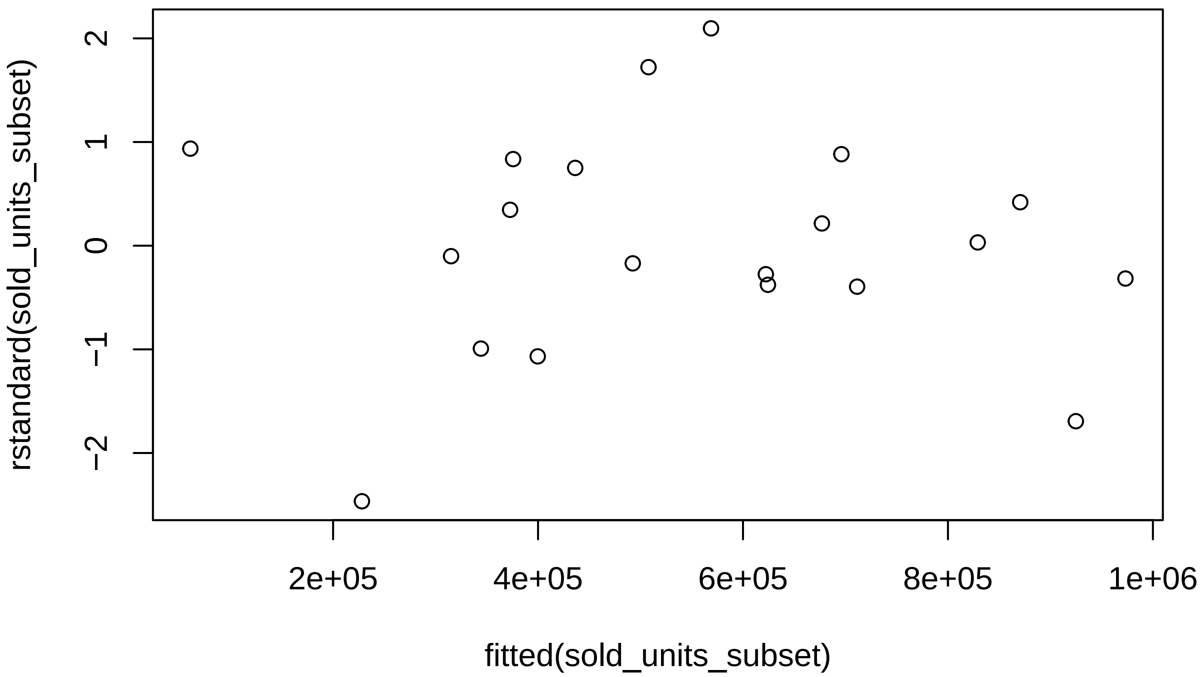



```
qqnorm(residuals(sold_units_subset))
```

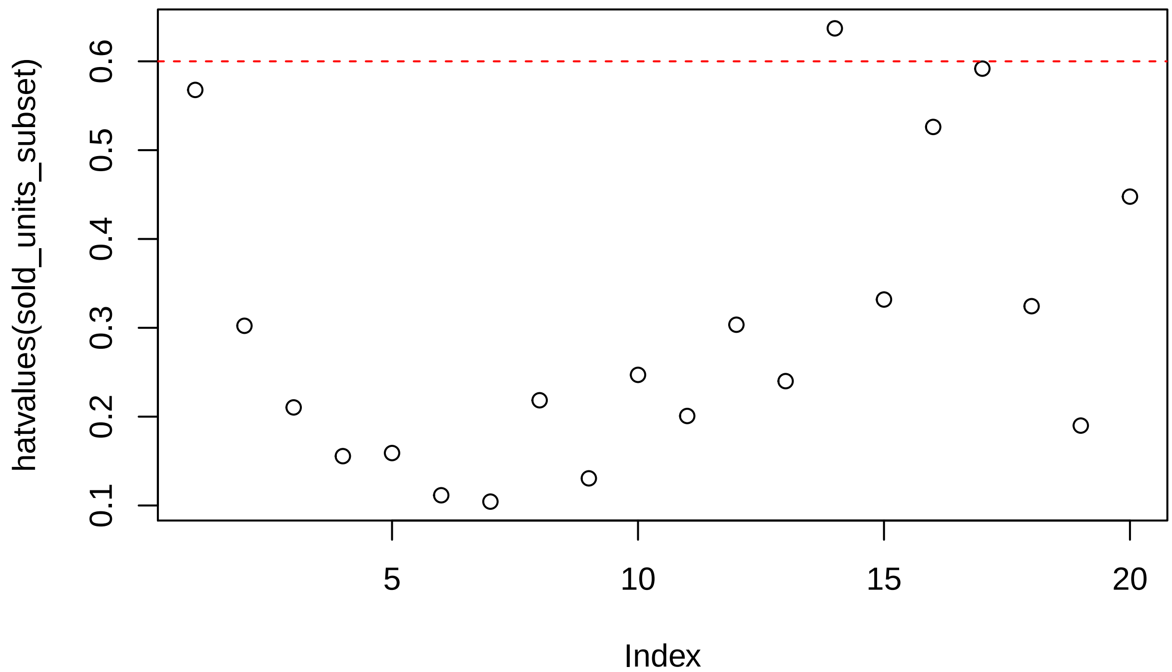


Looking for outliers and high leverage points

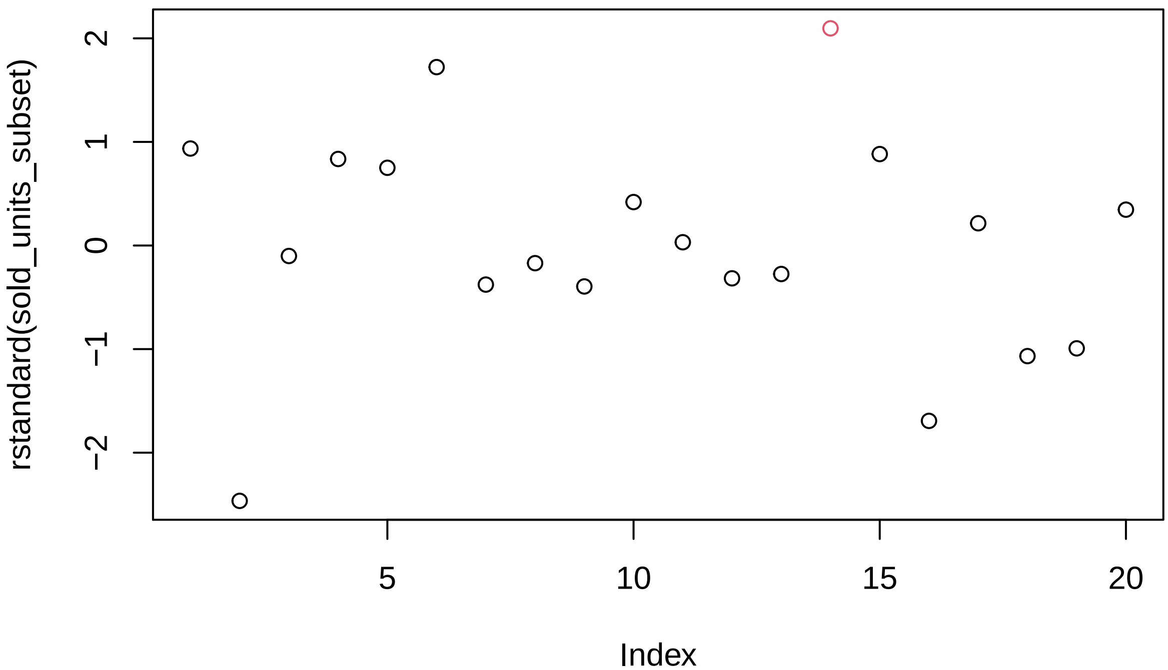
```
plot(fitted(sold_units_subset),rstandard(sold_units_subset))
```




```
plot(hatvalues(sold_units_subset))
abline(h=length(coef(sold_units_subset))/nrow(sold_units)*2,
       col = "red",lty = 2)
```




```
high_leverage_points<-hatvalues(sold_units_subset)>
  (length(coef(sold_units_subset))/nrow(sold_units)*2)
plot(rstandard(sold_units_subset),
     col = factor(high_leverage_points))
```



Looking for colinearity Correlation matrix and its eigen values

```
subset_coef_cor<-cor(sold_units[,names(sold_units)%in%subset_coef])
subset_coef_cor
```

```
##                                        itcrb imported_cars
## itcrb                             1.00000000   -0.84998083
## imported_cars                    -0.84998083    1.00000000
## devaluacion_interanual            0.04051446   -0.02721305
## inflation                        -0.27166538    0.10875007
## industry_trade_balance_difference  0.62115112   -0.85146240
##                                   devaluacion_interanual   inflation
## itcrb                                         0.04051446 -0.27166538
## imported_cars                                -0.02721305  0.10875007
## devaluacion_interanual                        1.00000000  0.65528084
## inflation                                     0.65528084  1.00000000
## industry_trade_balance_difference             0.07995415  0.08132427
##                                   industry_trade_balance_difference
## itcrb                                                    0.62115112
## imported_cars                                           -0.85146240
## devaluacion_interanual                                   0.07995415
## inflation                                                0.08132427
## industry_trade_balance_difference                        1.00000000
```

```r
eigen(subset_coef_cor)$values
```

```
## [1] 2.5725655 1.6807642 0.4957628 0.1849049 0.0660026
```

Variance inflation factors

```r
vif(sold_units_subset)
```

```
##                              itcrb                     imported_cars 
##                           5.045267                          9.491226 
##             devaluacion_interanual                         inflation 
##                           2.071411                          2.468309 
## industry_trade_balance_difference 
##                           4.483669
```

Removing the high leverage outlier

```r
sold_units_subset_rm<-
  lm(sold_units[!(high_leverage_points &
                    (rstandard(sold_units_subset)>2)),
                  names(sold_units)%in% c("num_units",subset_coef)],
     y = TRUE, x = TRUE)
summary(sold_units_subset_rm)
```

```
## 
## Call:
## lm(formula = sold_units[!(high_leverage_points & (rstandard(sold_units_subset) > 
##     2)), names(sold_units) %in% c("num_units", subset_coef)], 
##     x = TRUE, y = TRUE)
## 
## Residuals:
##    Min     1Q Median     3Q    Max 
## -52469 -20381   4372  16455  48379 
## 
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)    
## (Intercept)                       9.729e+04  1.274e+05   0.764  0.45869    
## itcrb                             3.519e+02  6.684e+02   0.527  0.60736    
## imported_cars                     1.172e+02  1.178e+01   9.951  1.9e-07 ***
## devaluacion_interanual           -1.492e+05  4.096e+04  -3.642  0.00298 ** 
## inflation                         8.452e+03  9.066e+04   0.093  0.92715    
## industry_trade_balance_difference 2.090e+01  7.699e+00   2.714  0.01770 *  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 30250 on 13 degrees of freedom
## Multiple R-squared:  0.9895, Adjusted R-squared:  0.9854 
## F-statistic: 244.6 on 5 and 13 DF,  p-value: 2.218e-12
```

```r
summary(sold_units_subset)
```

```
##
## Call:
## lm(formula = sold_units[, names(sold_units) %in% c("num_units",
##     subset_coef)], x = TRUE, y = TRUE)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -72464 -12668  -1086  22298  57133
##
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                       3.343e+05  9.583e+04   3.489  0.00361 **
## itcrb                            -8.901e+02  5.036e+02  -1.767  0.09894 .
## imported_cars                     9.820e+01  1.028e+01   9.553 1.64e-07 ***
## devaluacion_interanual           -8.505e+04  3.654e+04  -2.327  0.03547 *
## inflation                        -1.214e+05  8.538e+04  -1.421  0.17709
## industry_trade_balance_difference  1.457e+01  8.434e+00   1.728  0.10602
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 35190 on 14 degrees of freedom
## Multiple R-squared:  0.9847, Adjusted R-squared:  0.9793
## F-statistic: 180.5 on 5 and 14 DF,  p-value: 3.385e-12
```

```r
vif(sold_units_subset_rm)
```

```
##                             itcrb                     imported_cars
##                         11.106352                         16.856451
##            devaluacion_interanual                         inflation
##                          3.343531                          3.766226
## industry_trade_balance_difference
##                          5.044398
```

Testing the model selected with best subset selection using cross-validation

```r
cv_sold_units_subset<-cv.lm(sold_units_subset, k=5,)
cv_sold_units_subset
```

```
## Mean absolute error        :  29298.56
## Sample standard deviation  :  18657.68
##
## Mean squared error         :  1609635599
## Sample standard deviation  :  1622127045
##
## Root mean squared error    :  35510.34
## Sample standard deviation  :  20876.17
```

Applying LASSO

```r
sold_units_lasso<-glmnet(as.matrix(sold_units[,-1]),
                         as.matrix(sold_units[,1]),alpha=1)
sold_units_lasso
```

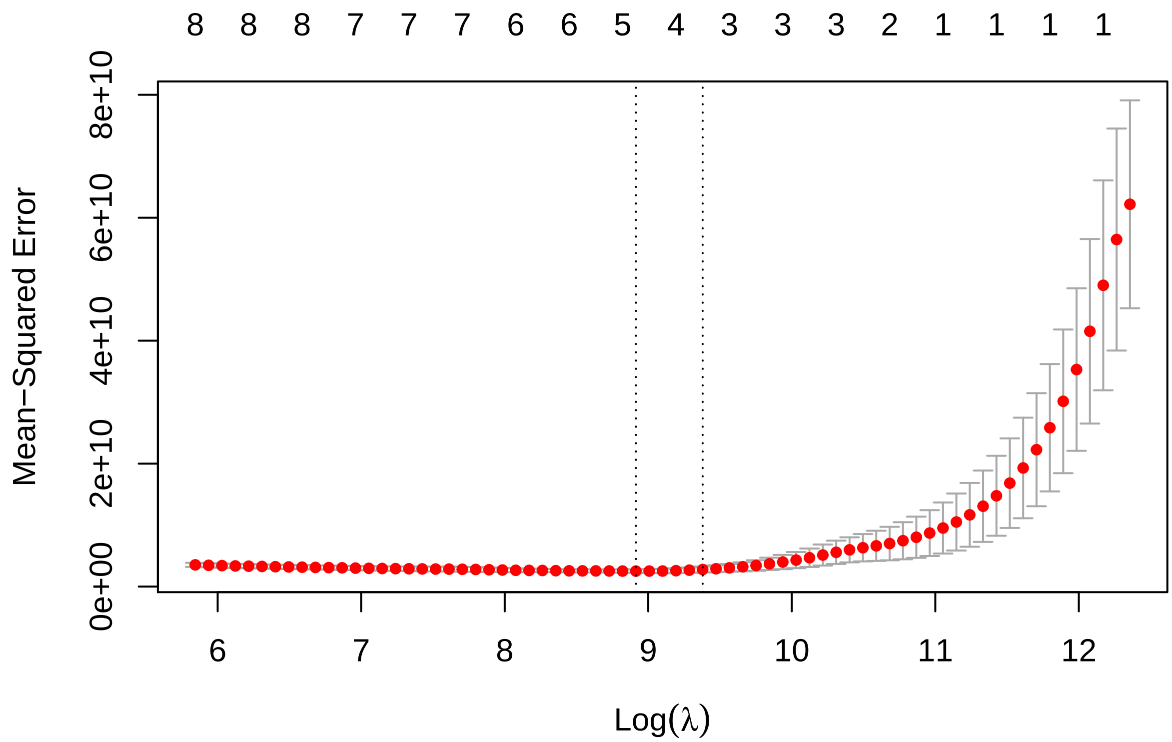
```
##
## Call:  glmnet(x = as.matrix(sold_units[, -1]), y = as.matrix(sold_units[,      1]), alpha = 1)
##
##    Df  %Dev Lambda
## 1   0  0.00 232400
## 2   1 16.16 211800
## 3   1 29.58 193000
## 4   1 40.72 175800
## 5   1 49.97 160200
## 6   1 57.65 146000
## 7   1 64.02 133000
## 8   1 69.31 121200
## 9   1 73.71 110400
## 10  1 77.35 100600
## 11  1 80.38  91680
## 12  1 82.90  83530
## 13  1 84.98  76110
## 14  1 86.72  69350
## 15  1 88.16  63190
## 16  2 89.38  57580
## 17  2 90.45  52460
## 18  2 91.34  47800
## 19  2 92.08  43550
## 20  2 92.69  39680
## 21  3 93.38  36160
## 22  3 94.17  32950
## 23  3 94.82  30020
## 24  3 95.37  27350
## 25  3 95.82  24920
## 26  3 96.19  22710
## 27  3 96.50  20690
## 28  3 96.76  18850
## 29  3 96.97  17180
## 30  3 97.15  15650
## 31  3 97.30  14260
## 32  3 97.42  12990
## 33  4 97.54  11840
## 34  4 97.66  10790
## 35  4 97.76   9830
## 36  4 97.85   8957
## 37  4 97.91   8161
## 38  4 97.97   7436
## 39  5 98.02   6776
## 40  5 98.06   6174
## 41  5 98.10   5625
## 42  6 98.14   5125
## 43  6 98.19   4670
## 44  6 98.22   4255
## 45  6 98.25   3877
```

```
## 46   6 98.28   3533
## 47   6 98.30   3219
## 48   6 98.32   2933
## 49   6 98.33   2672
## 50   7 98.34   2435
## 51   7 98.38   2219
## 52   7 98.41   2022
## 53   7 98.43   1842
## 54   7 98.45   1678
## 55   7 98.47   1529
## 56   7 98.48   1393
## 57   7 98.49   1270
## 58   7 98.50   1157
## 59   7 98.51   1054
## 60   7 98.52    960
## 61   7 98.52    875
## 62   7 98.53    797
## 63   8 98.53    726
## 64   8 98.54    662
## 65   8 98.54    603
## 66   8 98.54    550
## 67   8 98.54    501
## 68   8 98.55    456
## 69   8 98.55    416
## 70   8 98.55    379
## 71   8 98.55    345
```

```r
#selecting lambda using cross-validation
cv_sold_units_lasso<- cv.glmnet(as.matrix(sold_units[,-1]),
                                as.matrix(sold_units[,1]),
                                type.measure = c("mse"),
                                alpha=1,nfolds = 5)
cv_sold_units_lasso
```

```
##
## Call:  cv.glmnet(x = as.matrix(sold_units[, -1]), y = as.matrix(sold_units[,      1]), type.measure =
##
## Measure: Mean-Squared Error
##
##     Lambda Index   Measure        SE Nonzero
## min   7436    38 2.521e+09 284943795       4
## 1se  11840    33 2.777e+09 489821766       4
```

```r
plot(cv_sold_units_lasso)
```




```
best_lambda <- cv_sold_units_lasso$lambda.min
sold_units_lasso_best<-glmnet(as.matrix(sold_units[,-1]),
                              as.matrix(sold_units[,1]), alpha = 1,
                              lambda = best_lambda)
sold_units_lasso_best
```

```
##
## Call:  glmnet(x = as.matrix(sold_units[, -1]), y = as.matrix(sold_units[,      1]), alpha = 1, lambda
##
##   Df  %Dev Lambda
## 1  4 97.97   7436
```

```
coef(sold_units_lasso_best)
```

```
## 12 x 1 sparse Matrix of class "dgCMatrix"
##                                       s0
## (Intercept)                 337228.05398
## itcrb                         -864.76212
## imported_cars                   83.51367
## semiconductor_crisis        -17664.18674
## devaluacion_interanual      -93852.92024
## inflation                          .
## import_restriction                 .
## PIB                                .
## reserves                           .
```

```
## PIB_over_reserves                      .
## exchange_difference                    .
## industry_trade_balance_difference      .
```

Comparing the MSE of the best subset and LASSO models

```
mse_lasso<-min(cv_sold_units_lasso$cvm)
mse_subset<-cv_sold_units_subset$MSE$mean
mse_lasso
```

```
## [1] 2521349932
```

```
mse_subset
```

```
## [1] 1609635599
```

```
sqrt(mse_lasso)
```

```
## [1] 50213.05
```

```
sqrt(mse_subset)
```

```
## [1] 40120.26
```