sold_units_complete

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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_diference")
names(sold_units)<-my_names
```

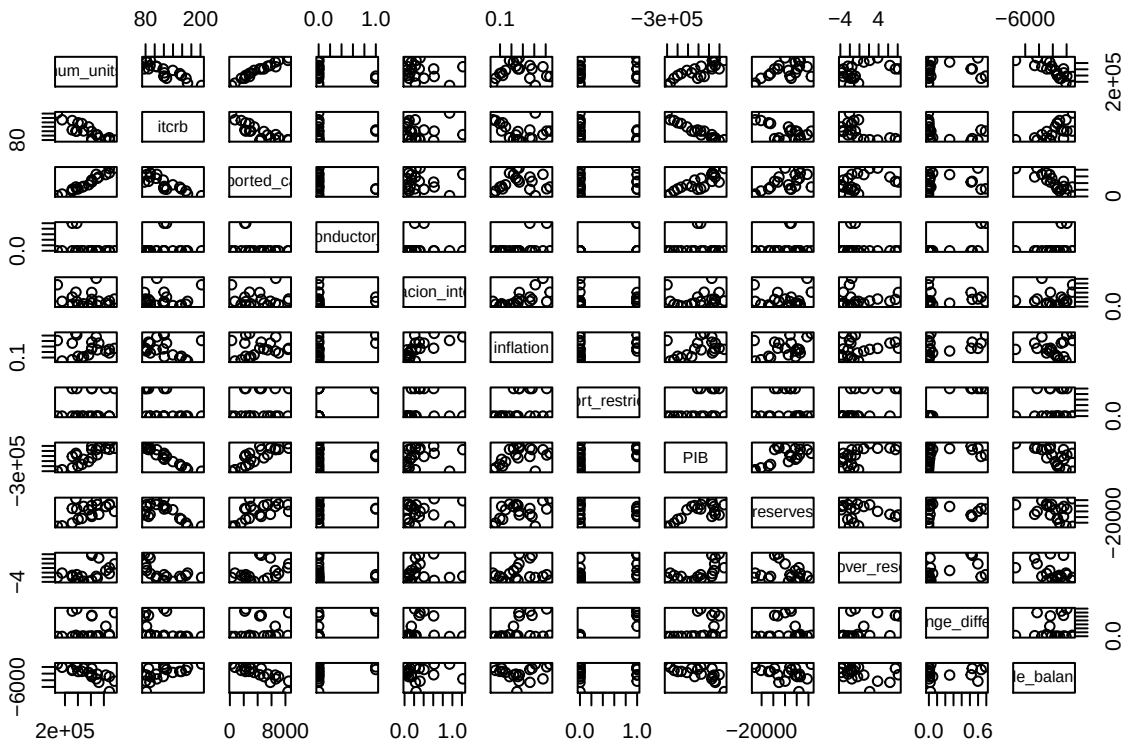
Building the model

```r
sold_units_model<-lm(sold_units)
summary(sold_units_model)
```

```
##
## Call:
## lm(formula = sold_units)
##
## 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_diference 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
```

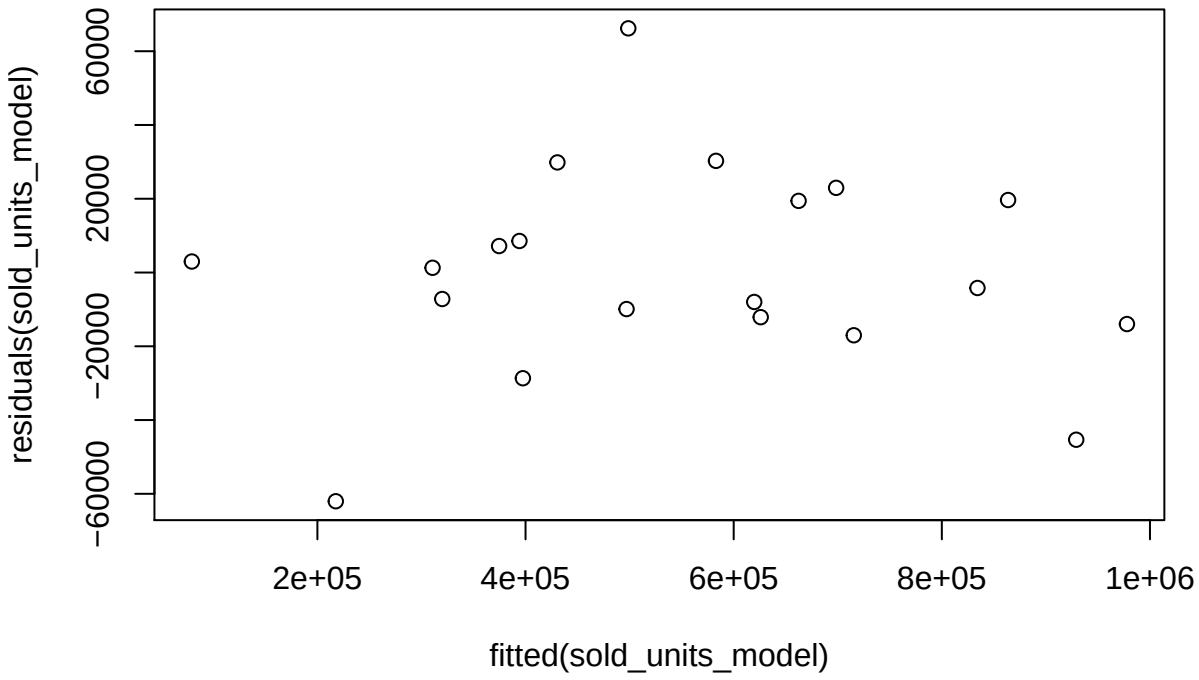
Pairwise plots of the features

```
pairs(sold_units)
```

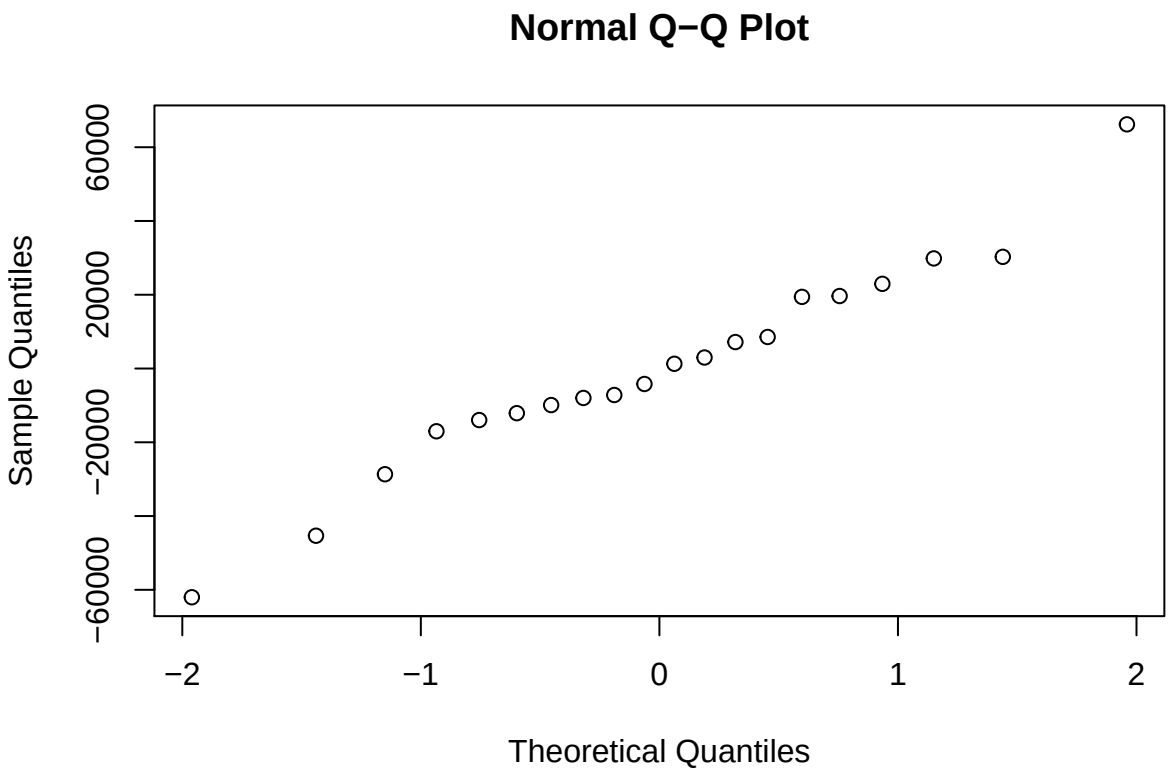


Analyzing the residuals

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

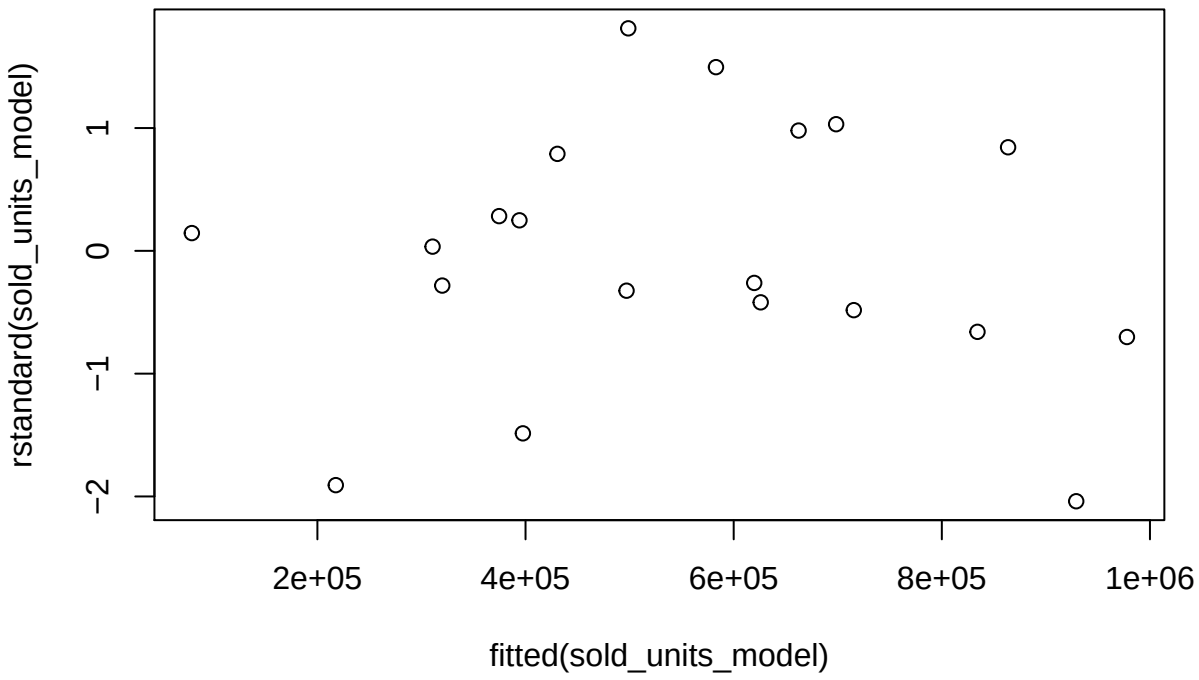



```
qqnorm(residuals(sold_units_model))
```

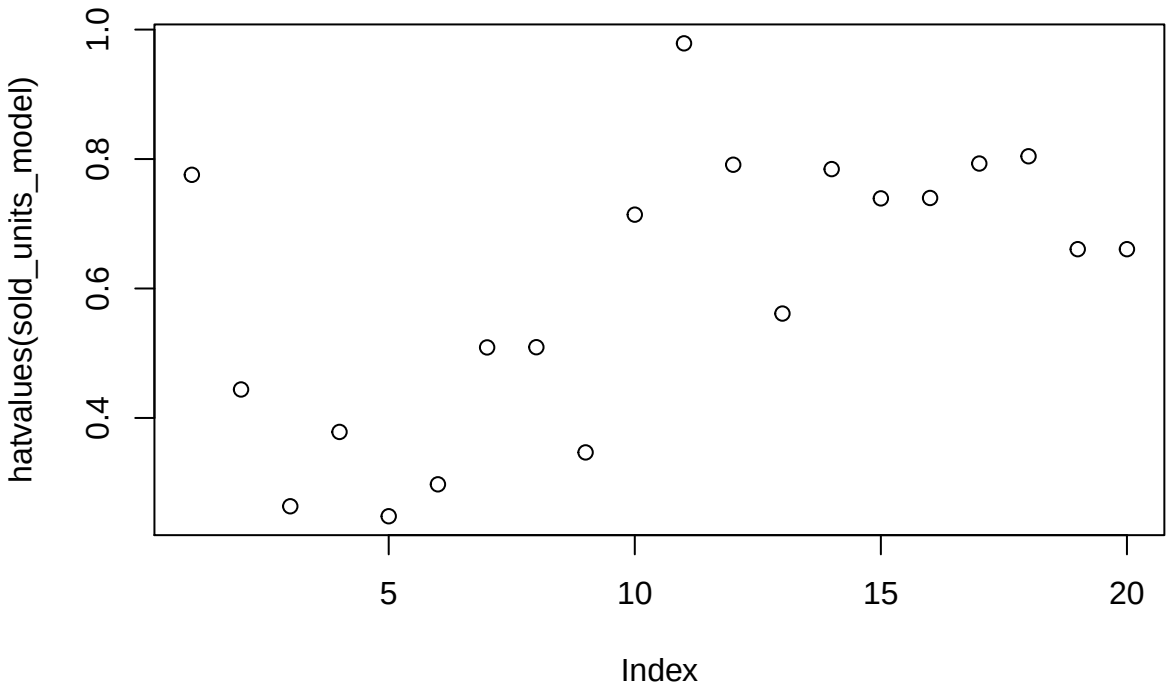


Looking for outliers and high leverage points

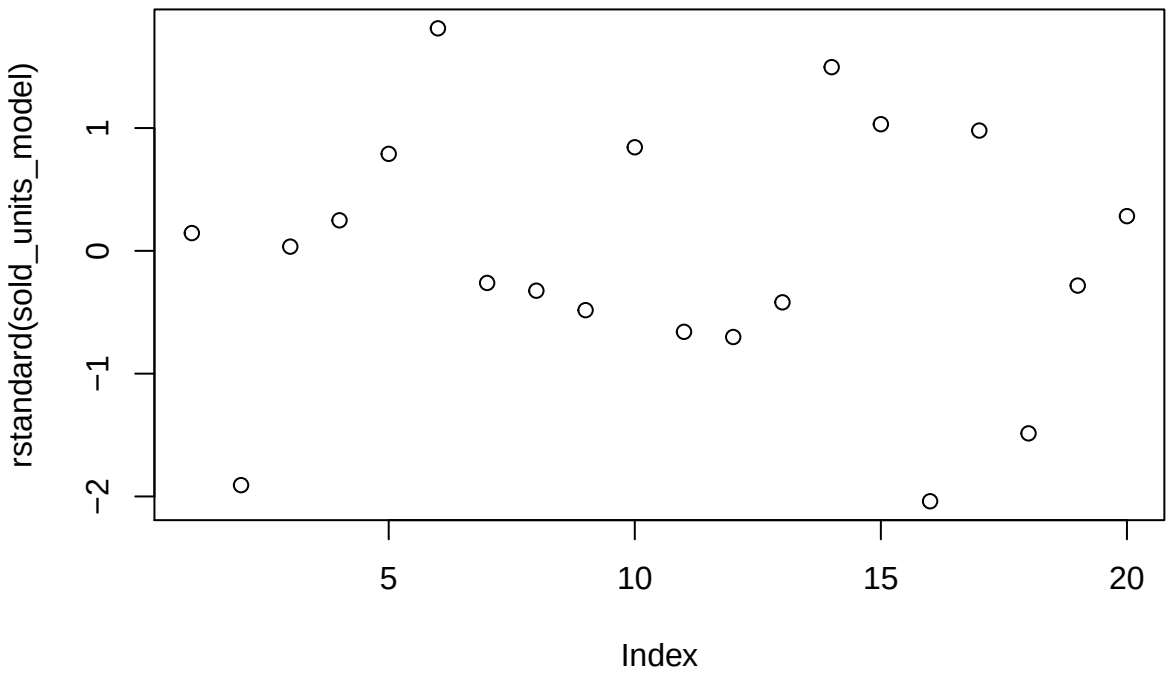
```
plot(fitted(sold_units_model),rstandard(sold_units_model))
```




```
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 semiconductor_crisis
## itcrb                          1.00000000   -0.84998083          0.031025294
## imported_cars                 -0.84998083    1.00000000         -0.275463784
## semiconductor_crisis           0.03102529   -0.27546378          1.000000000
## devaluacion_interanual         0.04051446   -0.02721305          0.005059507
## inflation                     -0.27166538    0.10875007          0.391827027
## import_restriction            -0.45615253    0.15017680          0.509175077
## PIB                           -0.97038025    0.84102366          0.011897026
## reserves                      -0.64341540    0.59313786          0.113498077
## PIB_over_reserves             -0.57391965    0.39056882         -0.123565165
## exchange_difference           -0.40454741    0.09171044          0.650902612
## industry_trade_balance_diference  0.62115112   -0.85146240          0.258351230
##                               devaluacion_interanual   inflation
## itcrb                                    0.040514456 -0.27166538
## imported_cars                           -0.027213050  0.10875007
## semiconductor_crisis                     0.005059507  0.39182703
## devaluacion_interanual                   1.000000000  0.65528084
## inflation                                0.655280837  1.00000000
## import_restriction                       0.060402026  0.31212355
## PIB                                      0.125177055  0.42376923
## reserves                                 0.081914320  0.41050289
## PIB_over_reserves                        0.092155529  0.14588345
```

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

Variance inflation factors

```
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_diference
##                         12.545070
```

Eigenvalues of the correlation matrix

```
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
```

Feature selection

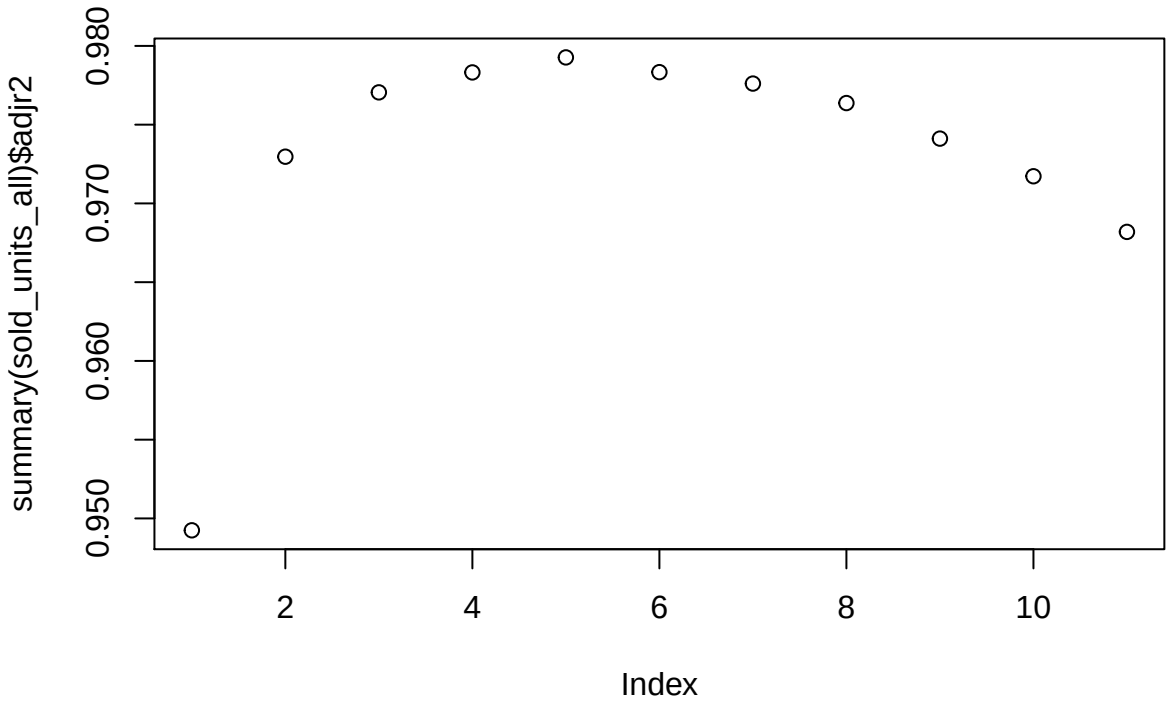
Applying best subset selection

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

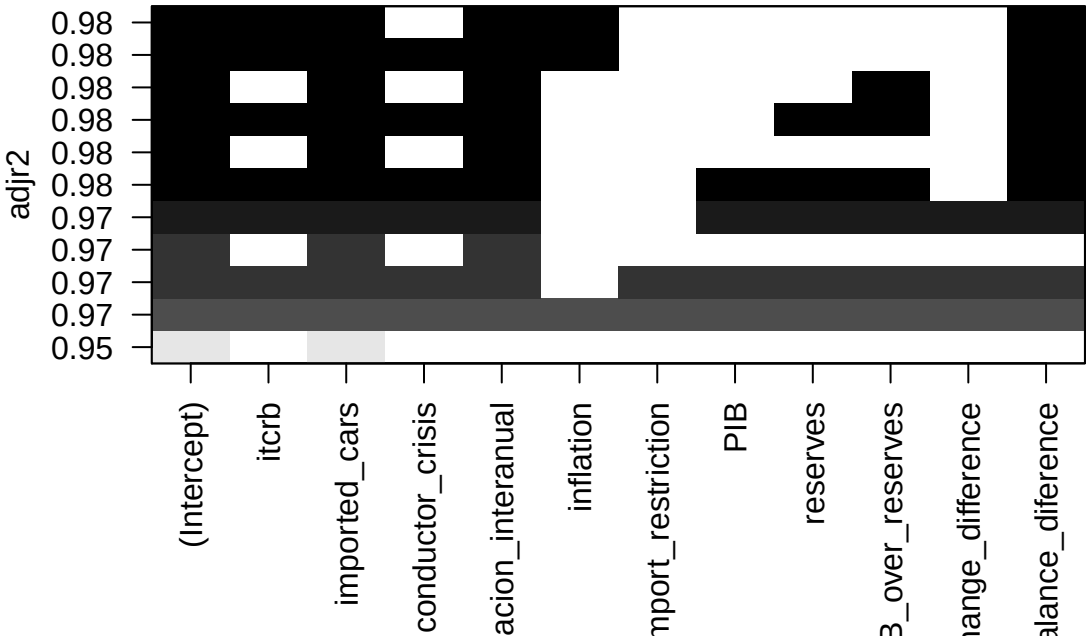
```
## Subset selection object
## Call: regsubsets.formula(sold_units$num_units ~ ., sold_units, nvmax = 12)
## 11 Variables  (and intercept)
##                                  Forced in Forced out
## itcrb                                FALSE      FALSE
## imported_cars                        FALSE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




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

Building the selected model

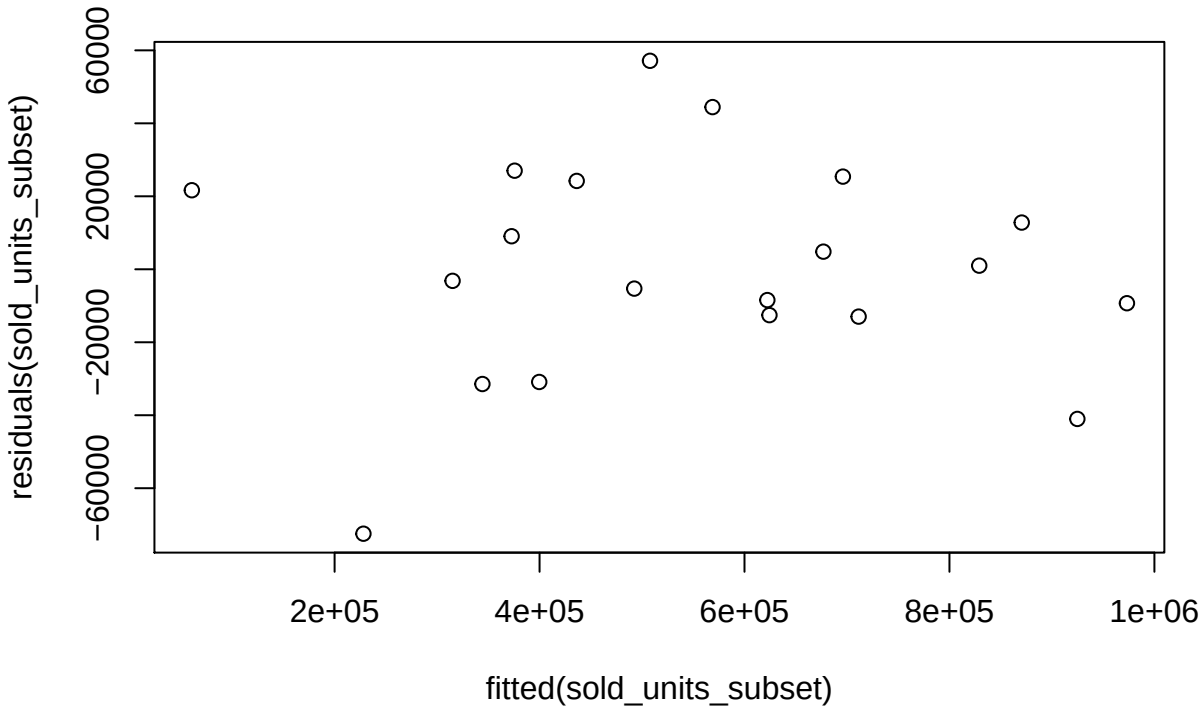
```
sold_units_subset<-
  lm(sold_units[,names(sold_units)%in%
    c("num_units",subset_coef)], y = TRUE, x = TRUE)
summary(sold_units_subset)
```

```
##
## 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 *
```

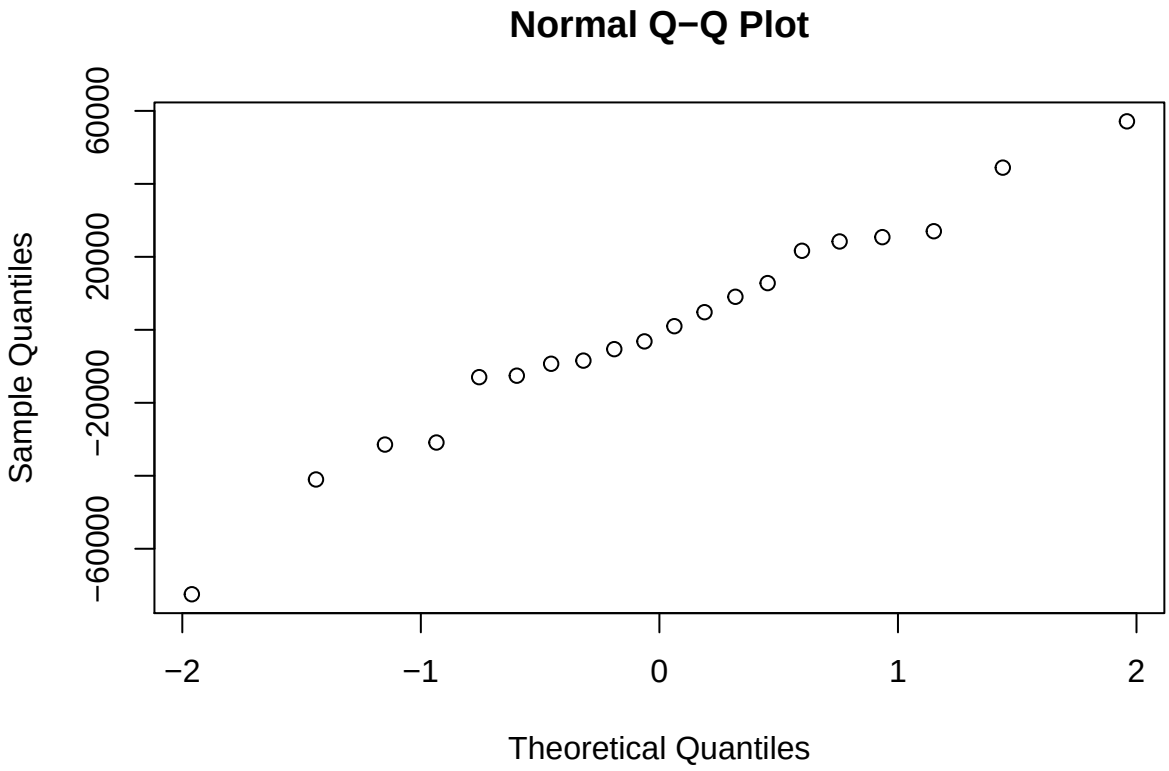
```
## inflation                        -1.214e+05  8.538e+04  -1.421  0.17709
## industry_trade_balance_diference  1.457e+01  8.434e+00   1.728  0.10602
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 35190 on 14 degrees of freedom
## Multiple 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))
```

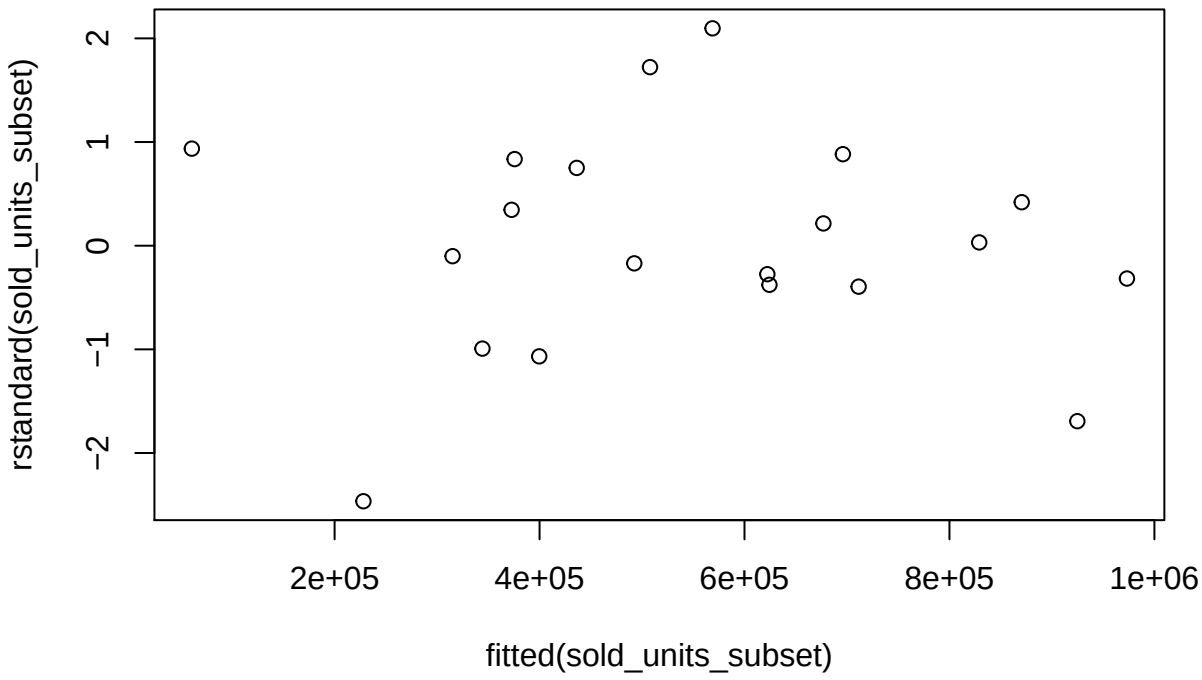



```
qqnorm(residuals(sold_units_subset))
```

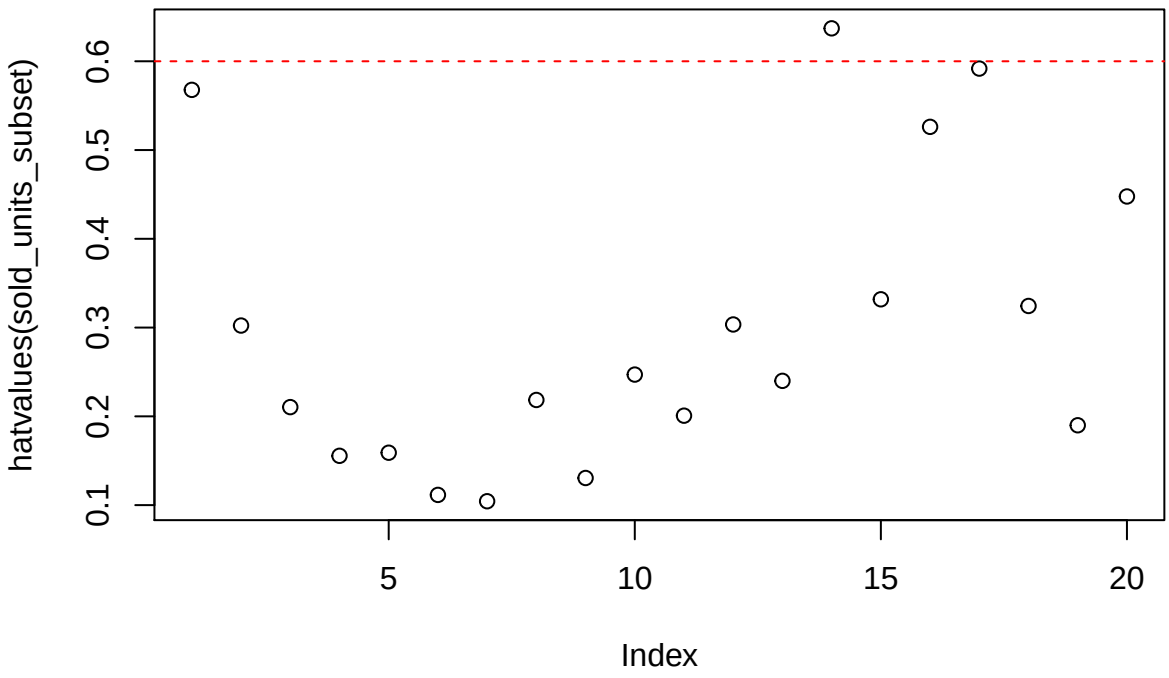


Looking for outliers and high leverage points

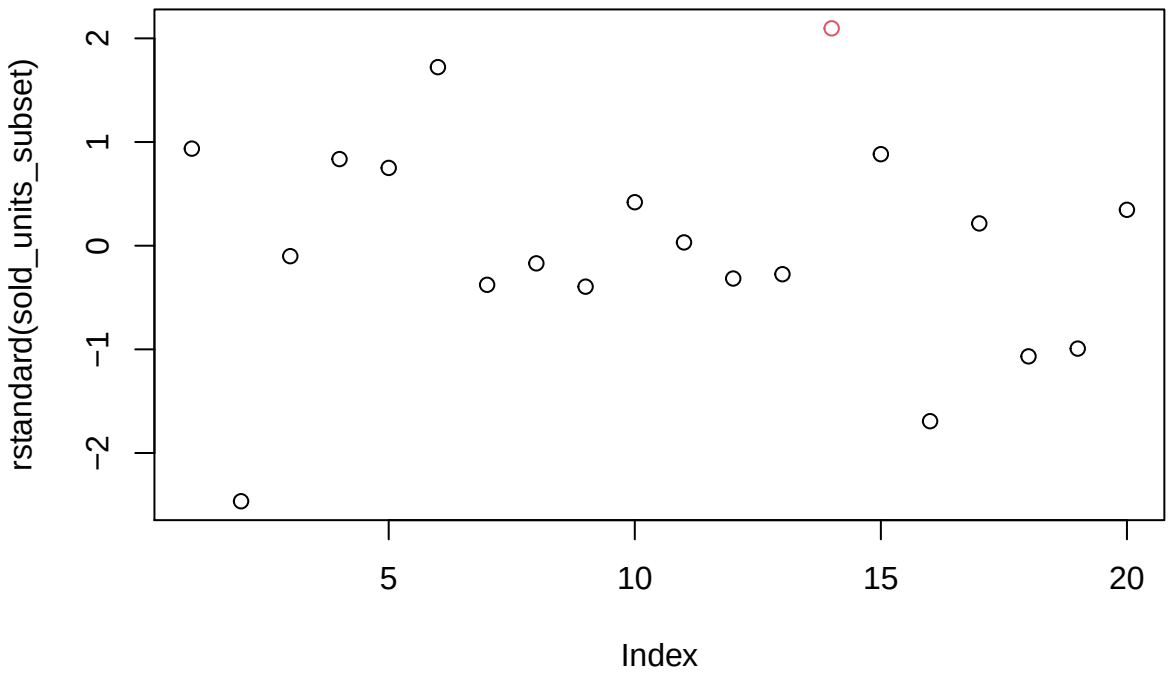
```
plot(fitted(sold_units_subset),rstandard(sold_units_subset))
```




```
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_diference  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_diference          0.07995415  0.08132427
##                                industry_trade_balance_diference
## itcrb                                                 0.62115112
## imported_cars                                        -0.85146240
## devaluacion_interanual                                0.07995415
## inflation                                             0.08132427
## industry_trade_balance_diference                      1.00000000
```

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

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

Variance inflation factors

```
vif(sold_units_subset)
```

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

Removing the high leverage outlier

```
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_diference 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
```

```
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_diference  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
```

```
vif(sold_units_subset_rm)
```

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

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

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

```
## Mean absolute error        :  32529.77
## Sample standard deviation  :  10727.72
##
## Mean squared error         :  1868219969
## Sample standard deviation  :  1155332488
##
## Root mean squared error    :  41557.71
## Sample standard deviation  :  13284.24
```

Applying LASSO

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

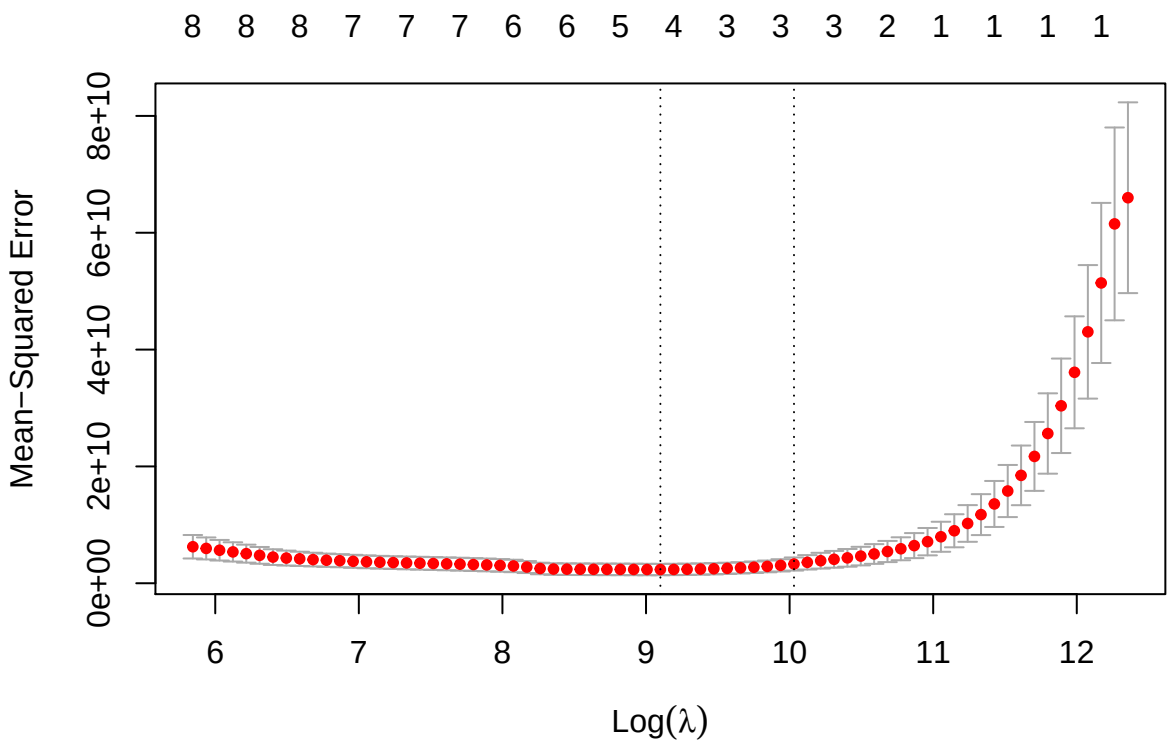
```
##
## Call:  glmnet(x = as.matrix(sold_units[, -1]), y = as.matrix(sold_units[,      1]), alpha = 1)
##
##    Df  %Dev Lambda
## 1   0  0.00 232400
## 2   1 16.16 211800
## 3   1 29.58 193000
## 4   1 40.72 175800
## 5   1 49.97 160200
## 6   1 57.65 146000
## 7   1 64.02 133000
## 8   1 69.31 121200
## 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
```

```
#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   8957    36 2.345e+09 9.732e+08       4
## 1se  22709    26 3.290e+09 1.122e+09       3
```

```
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 97.85   8957
```

```
coef(sold_units_lasso_best)
```

```
## 12 x 1 sparse Matrix of class "dgCMatrix"
##                                       s0
## (Intercept)                 327791.67080
## itcrb                         -810.86582
## imported_cars                   83.75542
## semiconductor_crisis         -12291.72615
## devaluacion_interanual       -89169.40936
## inflation                            .
## import_restriction                   .
## PIB                                  .
## reserves                             .
```

```
## PIB_over_reserves                    .
## exchange_difference                  .
## industry_trade_balance_diference     .
```

```
#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] 2345288951
```

```
mse_subset
```

```
## [1] 1868219969
```

```
sqrt(mse_lasso)
```

```
## [1] 48428.18
```

```
sqrt(mse_subset)
```

```
## [1] 43222.91
```