AMS578_project_116125547

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#Library

```
required_packages <- c("tidyverse", "caret", "neuralnet", "ggplot2", "glmnet",
  "rpart", "rattle", "factoextra", "cluster","gridExtra","corrplot","lmtest","car","forecast","e1071")
for (pkg in required_packages) {
  if (!requireNamespace(pkg, quietly = TRUE)) {
    install.packages(pkg) }
  library(pkg, character.only = TRUE)}
```

```
## Warning: package 'tidyverse' was built under R version 4.3.3

## Warning: package 'ggplot2' was built under R version 4.3.3

## Warning: package 'tidyr' was built under R version 4.3.3

## Warning: package 'readr' was built under R version 4.3.3

## Warning: package 'purrr' was built under R version 4.3.3

## Warning: package 'dplyr' was built under R version 4.3.3

## Warning: package 'stringr' was built under R version 4.3.3

## Warning: package 'forcats' was built under R version 4.3.3

## Warning: package 'lubridate' was built under R version 4.3.3

## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.4     v tidyr     1.3.1
## v purrr     1.0.4
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

## Warning: package 'caret' was built under R version 4.3.3
```

```
## Loading required package: lattice
##
## Attaching package: 'caret'
##
## The following object is masked from 'package:purrr':
##
##     lift

## Warning: package 'neuralnet' was built under R version 4.3.3

##
## Attaching package: 'neuralnet'
##
## The following object is masked from 'package:dplyr':
##
##     compute

## Warning: package 'glmnet' was built under R version 4.3.3

## Loading required package: Matrix
##
## Attaching package: 'Matrix'
##
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
##
## Loaded glmnet 4.1-8

## Warning: package 'rpart' was built under R version 4.3.3

## Warning: package 'rattle' was built under R version 4.3.3

## Loading required package: bitops

## Warning: package 'bitops' was built under R version 4.3.3

##
## Attaching package: 'bitops'
##
## The following object is masked from 'package:Matrix':
##
##     %&%
##
## Rattle: A free graphical interface for data science with R.
## Version 5.5.1 Copyright (c) 2006-2021 Togaware Pty Ltd.
## Type 'rattle()' to shake, rattle, and roll your data.

## Warning: package 'factoextra' was built under R version 4.3.3

## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
## Warning: package 'gridExtra' was built under R version 4.3.3

##
## Attaching package: 'gridExtra'
##
## The following object is masked from 'package:dplyr':
##
##     combine

## Warning: package 'corrplot' was built under R version 4.3.3

## corrplot 0.95 loaded

## Warning: package 'lmtest' was built under R version 4.3.3

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

## Warning: package 'car' was built under R version 4.3.3

## Loading required package: carData

## Warning: package 'carData' was built under R version 4.3.3

##
## Attaching package: 'car'
##
## The following object is masked from 'package:dplyr':
##
##     recode
##
## The following object is masked from 'package:purrr':
##
##     some
##
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo

## Warning: package 'forecast' was built under R version 4.3.3

## Warning: package 'e1071' was built under R version 4.3.3
```

Data

```
df <- read.csv("C:/Users/Ajeet Rai/OneDrive/Desktop/SBU/Academics/Sem III/AMS 578 Regression Theory/Pro
head(df)
```

```
##     State  County TotalPop   Men Women Hispanic White Black Native Asian
## 1 Alabama Autauga    55221 26745 28476      2.6  75.8  18.5    0.4   1.0
## 2 Alabama Baldwin   195121 95314 99807      4.5  83.1   9.5    0.6   0.7
## 3 Alabama Barbour    26932 14497 12435      4.6  46.2  46.7    0.2   0.4
## 4 Alabama    Bibb    22604 12073 10531      2.2  74.5  21.4    0.4   0.1
## 5 Alabama  Blount    57710 28512 29198      8.6  87.9   1.5    0.3   0.1
## 6 Alabama Bullock    10678  5660  5018      4.4  22.2  70.7    1.2   0.2
##   Pacific Citizen Income IncomeErr IncomePerCap IncomePerCapErr Poverty
## 1       0   40725  51281      2391        24974            1080    12.9
## 2       0  147695  50254      1263        27317             711    13.4
## 3       0   20714  32964      2973        16824             798    26.7
## 4       0   17495  38678      3995        18431            1618    16.8
## 5       0   42345  45813      3141        20532             708    16.7
## 6       0    8057  31938      5884        17580            2055    24.6
##   ChildPoverty Professional Service Office Construction Production Drive
## 1         18.6         33.2    17.0   24.2          8.6       17.1  87.5
## 2         19.2         33.1    17.7   27.1         10.8       11.2  84.7
## 3         45.3         26.8    16.1   23.1         10.8       23.1  83.8
## 4         27.9         21.5    17.9   17.8         19.0       23.7  83.2
## 5         27.2         28.5    14.1   23.9         13.5       19.9  84.9
## 6         38.4         18.8    15.0   19.7         20.1       26.4  74.9
##   Carpool Transit Walk OtherTransp WorkAtHome MeanCommute Employed PrivateWork
## 1     8.8     0.1  0.5         1.3        1.8        26.5    23986        73.6
## 2     8.8     0.1  1.0         1.4        3.9        26.4    85953        81.5
## 3    10.9     0.4  1.8         1.5        1.6        24.1     8597        71.8
## 4    13.5     0.5  0.6         1.5        0.7        28.8     8294        76.8
## 5    11.2     0.4  0.9         0.4        2.3        34.9    22189        82.0
## 6    14.9     0.7  5.0         1.7        2.8        27.5     3865        79.5
##   PublicWork SelfEmployed FamilyWork Unemployment
## 1       20.9          5.5        0.0          7.6
## 2       12.3          5.8        0.4          7.5
## 3       20.8          7.3        0.1         17.6
## 4       16.1          6.7        0.4          8.3
## 5       13.5          4.2        0.4          7.7
## 6       15.1          5.4        0.0         18.0
```

Summary

Shape

```
dim(df)
```

```
## [1] 3220   36
```

Datatypes

```
str(df)
```

```
## 'data.frame':    3220 obs. of  36 variables:
##  $ State          : chr  "Alabama" "Alabama" "Alabama" "Alabama" ...
##  $ County         : chr  "Autauga" "Baldwin" "Barbour" "Bibb" ...
##  $ TotalPop       : int  55221 195121 26932 22604 57710 10678 20354 116648 34079 26008 ...
##  $ Men            : int  26745 95314 14497 12073 28512 5660 9502 56274 16258 12975 ...
##  $ Women          : int  28476 99807 12435 10531 29198 5018 10852 60374 17821 13033 ...
##  $ Hispanic       : num  2.6 4.5 4.6 2.2 8.6 4.4 1.2 3.5 0.4 1.5 ...
##  $ White          : num  75.8 83.1 46.2 74.5 87.9 22.2 53.3 73 57.3 91.7 ...
##  $ Black          : num  18.5 9.5 46.7 21.4 1.5 70.7 43.8 20.3 40.3 4.8 ...
##  $ Native         : num  0.4 0.6 0.2 0.4 0.3 1.2 0.1 0.2 0.2 0.6 ...
##  $ Asian          : num  1 0.7 0.4 0.1 0.1 0.2 0.4 0.9 0.8 0.3 ...
##  $ Pacific        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Citizen        : int  40725 147695 20714 17495 42345 8057 15581 88612 26462 20600 ...
##  $ Income         : int  51281 50254 32964 38678 45813 31938 32229 41703 34177 36296 ...
##  $ IncomeErr      : int  2391 1263 2973 3995 3141 5884 1793 925 2949 1710 ...
##  $ IncomePerCap   : int  24974 27317 16824 18431 20532 17580 18390 21374 21071 21811 ...
##  $ IncomePerCapErr: int  1080 711 798 1618 708 2055 714 489 1366 1556 ...
##  $ Poverty        : num  12.9 13.4 26.7 16.8 16.7 24.6 25.4 20.5 21.6 19.2 ...
##  $ ChildPoverty   : num  18.6 19.2 45.3 27.9 27.2 38.4 39.2 31.6 37.2 30.1 ...
##  $ Professional   : num  33.2 33.1 26.8 21.5 28.5 18.8 27.5 27.3 23.3 29.3 ...
##  $ Service        : num  17 17.7 16.1 17.9 14.1 15 16.6 17.7 14.5 16 ...
##  $ Office         : num  24.2 27.1 23.1 17.8 23.9 19.7 21.9 24.2 26.3 19.5 ...
##  $ Construction   : num  8.6 10.8 10.8 19 13.5 20.1 10.3 10.5 11.5 13.7 ...
##  $ Production     : num  17.1 11.2 23.1 23.7 19.9 26.4 23.7 20.4 24.4 21.5 ...
##  $ Drive          : num  87.5 84.7 83.8 83.2 84.9 74.9 84.5 85.3 85.1 83.9 ...
##  $ Carpool        : num  8.8 8.8 10.9 13.5 11.2 14.9 12.4 9.4 11.9 12.1 ...
##  $ Transit        : num  0.1 0.1 0.4 0.5 0.4 0.7 0 0.2 0.2 0.2 ...
##  $ Walk           : num  0.5 1 1.8 0.6 0.9 5 0.8 1.2 0.3 0.6 ...
##  $ OtherTransp    : num  1.3 1.4 1.5 1.5 0.4 1.7 0.6 1.2 0.4 0.7 ...
##  $ WorkAtHome     : num  1.8 3.9 1.6 0.7 2.3 2.8 1.7 2.7 2.1 2.5 ...
##  $ MeanCommute    : num  26.5 26.4 24.1 28.8 34.9 27.5 24.6 24.1 25.1 27.4 ...
##  $ Employed       : int  23986 85953 8597 8294 22189 3865 7813 47401 13689 10155 ...
##  $ PrivateWork    : num  73.6 81.5 71.8 76.8 82 79.5 77.4 74.1 85.1 73.1 ...
##  $ PublicWork     : num  20.9 12.3 20.8 16.1 13.5 15.1 16.2 20.8 12.1 18.5 ...
##  $ SelfEmployed   : num  5.5 5.8 7.3 6.7 4.2 5.4 6.2 5 2.8 7.9 ...
##  $ FamilyWork     : num  0 0.4 0.1 0.4 0.4 0 0.2 0.1 0 0.5 ...
##  $ Unemployment   : num  7.6 7.5 17.6 8.3 7.7 18 10.9 12.3 8.9 7.9 ...
```

Descriptions

```
summary(df)
```

```
##     State              County            TotalPop             Men          
##  Length:3220        Length:3220        Min.   :      85   Min.   :     42  
##  Class :character   Class :character   1st Qu.:   11218   1st Qu.:   5637  
##  Mode  :character   Mode  :character   Median :   26035   Median :  12932  
```

```
##                                        Mean   :   99409   Mean   :  48897
##                                        3rd Qu.:   66430   3rd Qu.:  32993
##                                        Max.   :10038388   Max.   :4945351
##
##      Women            Hispanic          White           Black
##  Min.   :     43   Min.   : 0.000   Min.   : 0.00   Min.   : 0.000
##  1st Qu.:   5572   1st Qu.: 1.900   1st Qu.:64.10   1st Qu.: 0.500
##  Median :  13057   Median : 3.900   Median :84.10   Median : 1.900
##  Mean   :  50512   Mean   :11.012   Mean   :75.43   Mean   : 8.665
##  3rd Qu.:  33488   3rd Qu.: 9.825   3rd Qu.:93.20   3rd Qu.: 9.600
##  Max.   :5093037   Max.   :99.900   Max.   :99.80   Max.   :85.900
##
##      Native           Asian           Pacific            Citizen
##  Min.   : 0.000   Min.   : 0.000   Min.   : 0.00000   Min.   :     80
##  1st Qu.: 0.100   1st Qu.: 0.200   1st Qu.: 0.00000   1st Qu.:   8450
##  Median : 0.300   Median : 0.500   Median : 0.00000   Median :  19643
##  Mean   : 1.724   Mean   : 1.229   Mean   : 0.08273   Mean   :  69935
##  3rd Qu.: 0.600   3rd Qu.: 1.200   3rd Qu.: 0.00000   3rd Qu.:  49920
##  Max.   :92.100   Max.   :41.600   Max.   :35.30000   Max.   :6046749
##
##      Income         IncomeErr      IncomePerCap   IncomePerCapErr
##  Min.   : 10499   Min.   :  270   Min.   : 5878   Min.   :  113
##  1st Qu.: 38192   1st Qu.: 1635   1st Qu.:20239   1st Qu.:  755
##  Median : 44749   Median : 2406   Median :23460   Median : 1096
##  Mean   : 46130   Mean   : 2850   Mean   :23982   Mean   : 1363
##  3rd Qu.: 52074   3rd Qu.: 3446   3rd Qu.:27053   3rd Qu.: 1631
##  Max.   :123453   Max.   :21355   Max.   :65600   Max.   :15266
##  NA's   :1        NA's   :1
##     Poverty       ChildPoverty    Professional      Service
##  Min.   : 1.40   Min.   : 0.00   Min.   :13.50   Min.   : 5.00
##  1st Qu.:12.10   1st Qu.:16.30   1st Qu.:26.70   1st Qu.:16.00
##  Median :16.15   Median :22.70   Median :29.90   Median :18.10
##  Mean   :17.49   Mean   :24.18   Mean   :30.99   Mean   :18.35
##  3rd Qu.:20.70   3rd Qu.:30.00   3rd Qu.:34.40   3rd Qu.:20.30
##  Max.   :64.20   Max.   :81.60   Max.   :74.00   Max.   :38.20
##                  NA's   :1
##      Office       Construction     Production        Drive
##  Min.   : 4.10   Min.   : 1.70   Min.   : 0.00   Min.   : 5.20
##  1st Qu.:20.20   1st Qu.: 9.80   1st Qu.:11.50   1st Qu.:76.60
##  Median :22.40   Median :12.10   Median :15.25   Median :80.70
##  Mean   :22.22   Mean   :12.71   Mean   :15.73   Mean   :79.18
##  3rd Qu.:24.40   3rd Qu.:14.90   3rd Qu.:19.32   3rd Qu.:83.70
##  Max.   :35.40   Max.   :40.30   Max.   :55.60   Max.   :94.60
##
##     Carpool         Transit             Walk         OtherTransp
##  Min.   : 0.00   Min.   : 0.0000   Min.   : 0.000   Min.   : 0.000
##  1st Qu.: 8.40   1st Qu.: 0.1000   1st Qu.: 1.400   1st Qu.: 0.900
##  Median : 9.90   Median : 0.4000   Median : 2.400   Median : 1.300
##  Mean   :10.28   Mean   : 0.9718   Mean   : 3.324   Mean   : 1.613
##  3rd Qu.:11.80   3rd Qu.: 0.8000   3rd Qu.: 4.000   3rd Qu.: 1.900
##  Max.   :29.90   Max.   :61.7000   Max.   :71.200   Max.   :39.100
##
##    WorkAtHome      MeanCommute       Employed        PrivateWork
##  Min.   : 0.000   Min.   : 4.90   Min.   :     62   Min.   :25.00
```

```
##  1st Qu.: 2.700   1st Qu.:19.50   1st Qu.:   4551   1st Qu.:70.50
##  Median : 3.900   Median :23.00   Median :  10508   Median :75.70
##  Mean   : 4.632   Mean   :23.28   Mean   :  45594   Mean   :74.22
##  3rd Qu.: 5.600   3rd Qu.:26.80   3rd Qu.:  28633   3rd Qu.:79.70
##  Max.   :37.200   Max.   :44.00   Max.   :4635465   Max.   :88.30
##
##    PublicWork     SelfEmployed      FamilyWork      Unemployment
##  Min.   : 5.80   Min.   : 0.000   Min.   :0.0000   Min.   : 0.000
##  1st Qu.:13.10   1st Qu.: 5.400   1st Qu.:0.1000   1st Qu.: 5.500
##  Median :16.20   Median : 6.900   Median :0.2000   Median : 7.600
##  Mean   :17.56   Mean   : 7.932   Mean   :0.2881   Mean   : 8.094
##  3rd Qu.:20.50   3rd Qu.: 9.400   3rd Qu.:0.3000   3rd Qu.: 9.900
##  Max.   :66.20   Max.   :36.600   Max.   :9.8000   Max.   :36.500
##
```

Imputing missing values

```
dim(df)
```

```
## [1] 3220   36
```

```
df = na.omit(df)
dim(df)
```

```
## [1] 3218   36
```

Independent vs dependent

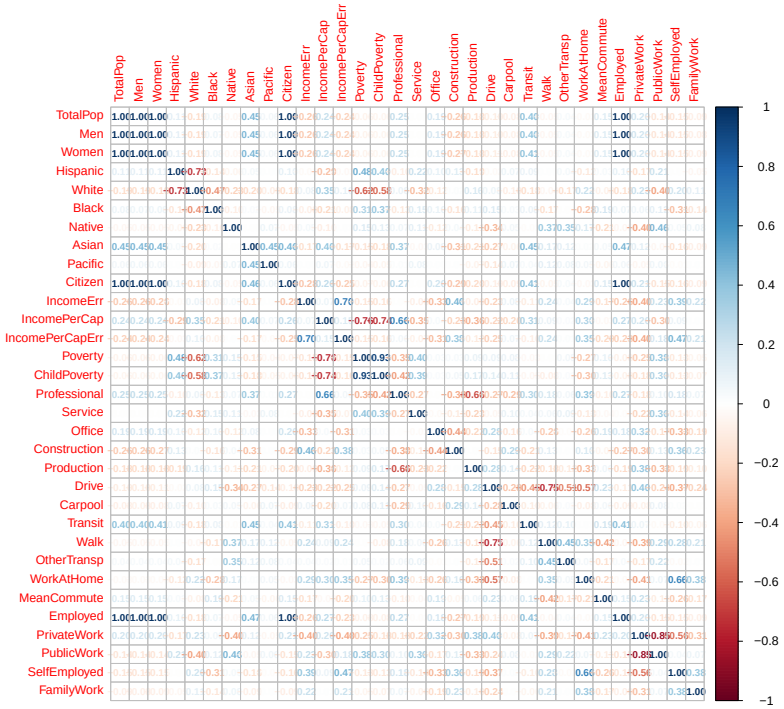
```
Y1 <- df$Income
Y2 <- df$Unemployment
Y=Y2   #Y=Y1
X <- df[, !(names(df) %in% c("Income", "Unemployment","State","County"))]
```

Exploratory data analysis

Correlation

As we can see collinearity between features, we'll need check VIF carefully.

```
correlation_matrix <- cor(X)
corrplot(correlation_matrix, method = "number", number.cex = 0.7, tl.cex = 0.8)
```



Distributin (Dependent)

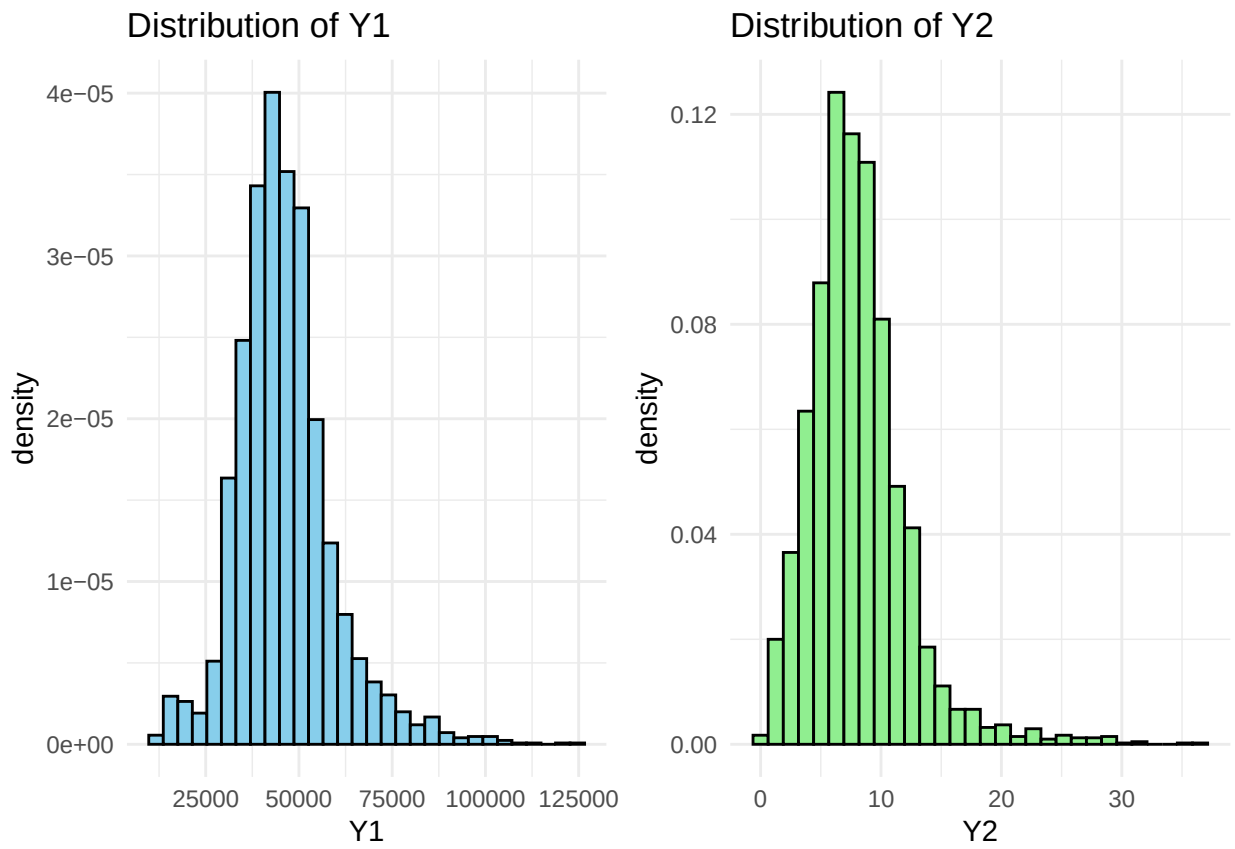
Y1 and Y2 are slightly skewed, and transformation is needed to prevent this.

```
p1 <- ggplot(data = data.frame(Y1), aes(x = Y1)) +
  geom_histogram(aes(y = ..density..), bins = 30, fill = 'skyblue', color = 'black') +
  ggtitle('Distribution of Y1') +
  theme_minimal()

p2 <- ggplot(data = data.frame(Y2), aes(x = Y2)) +
  geom_histogram(aes(y = ..density..), bins = 30, fill = 'lightgreen', color = 'black') +
  ggtitle('Distribution of Y2') +
  theme_minimal()

grid.arrange(p1, p2, ncol = 2)
```

```
## Warning: The dot-dot notation (`..density..`) was deprecated in ggplot2 3.4.0.
## i Please use `after_stat(density)` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```



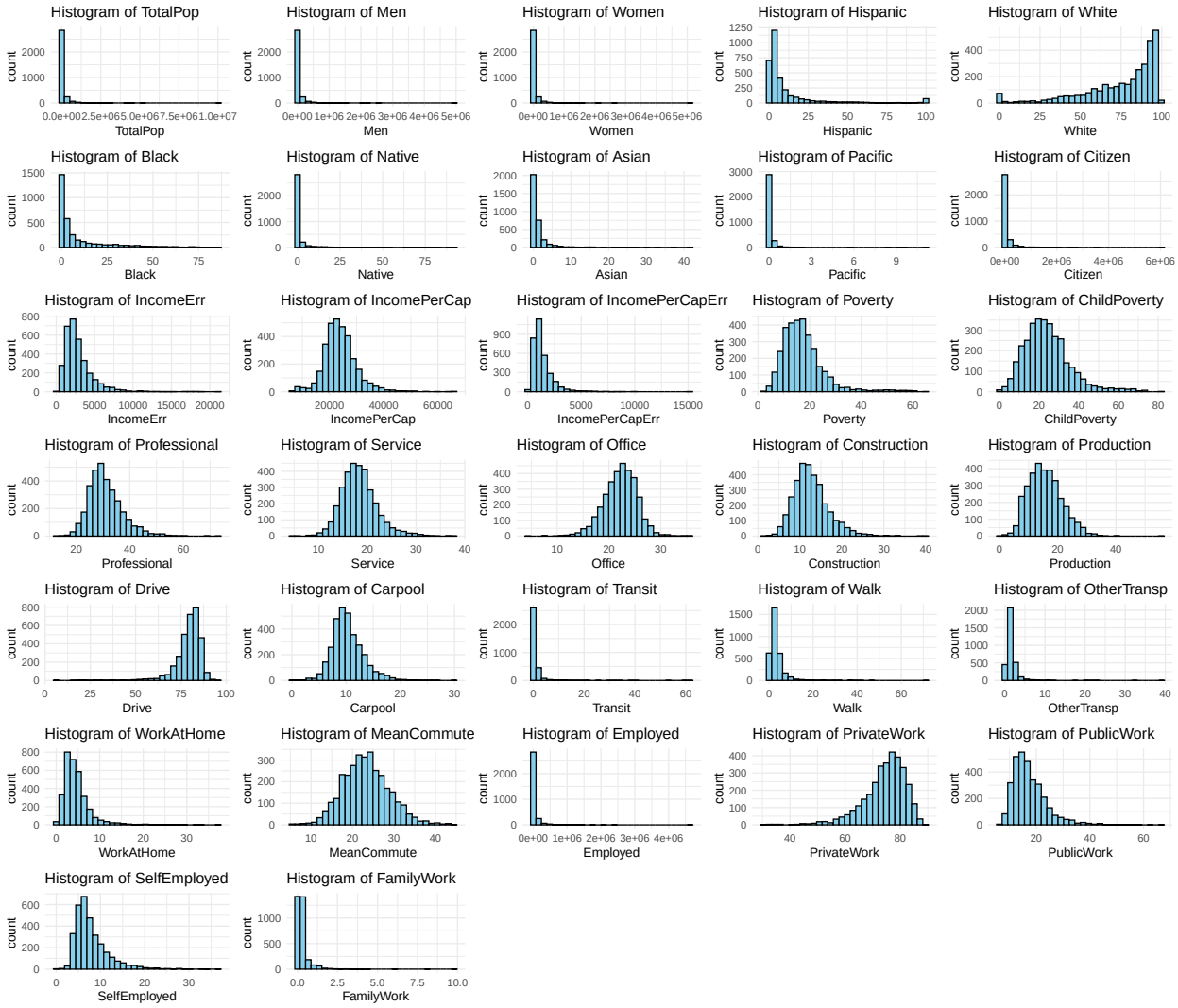
Distributin (Independent)

Independent features are skewed, and transformation is needed to prevent this.

```
plots <- lapply(names(X), function(colname) {
  if (is.numeric(X[[colname]])) {
    ggplot(X, aes_string(x = colname)) +
      geom_histogram(bins = 30, fill = "skyblue", color = "black") +
      ggtitle(paste("Histogram of", colname)) +
      theme_minimal()
  } else {
    ggplot(X, aes_string(x = colname)) +
      geom_bar(fill = "lightgreen", color = "black") +
      ggtitle(paste("Bar Plot of", colname)) +
      theme_minimal()
  }
})
```

```
## Warning: `aes_string()` was deprecated in ggplot2 3.0.0.
## i Please use tidy evaluation idioms with `aes()`.
## i See also `vignette("ggplot2-in-packages")` for more information.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```
grid.arrange(grobs = plots, ncol = 5)
```

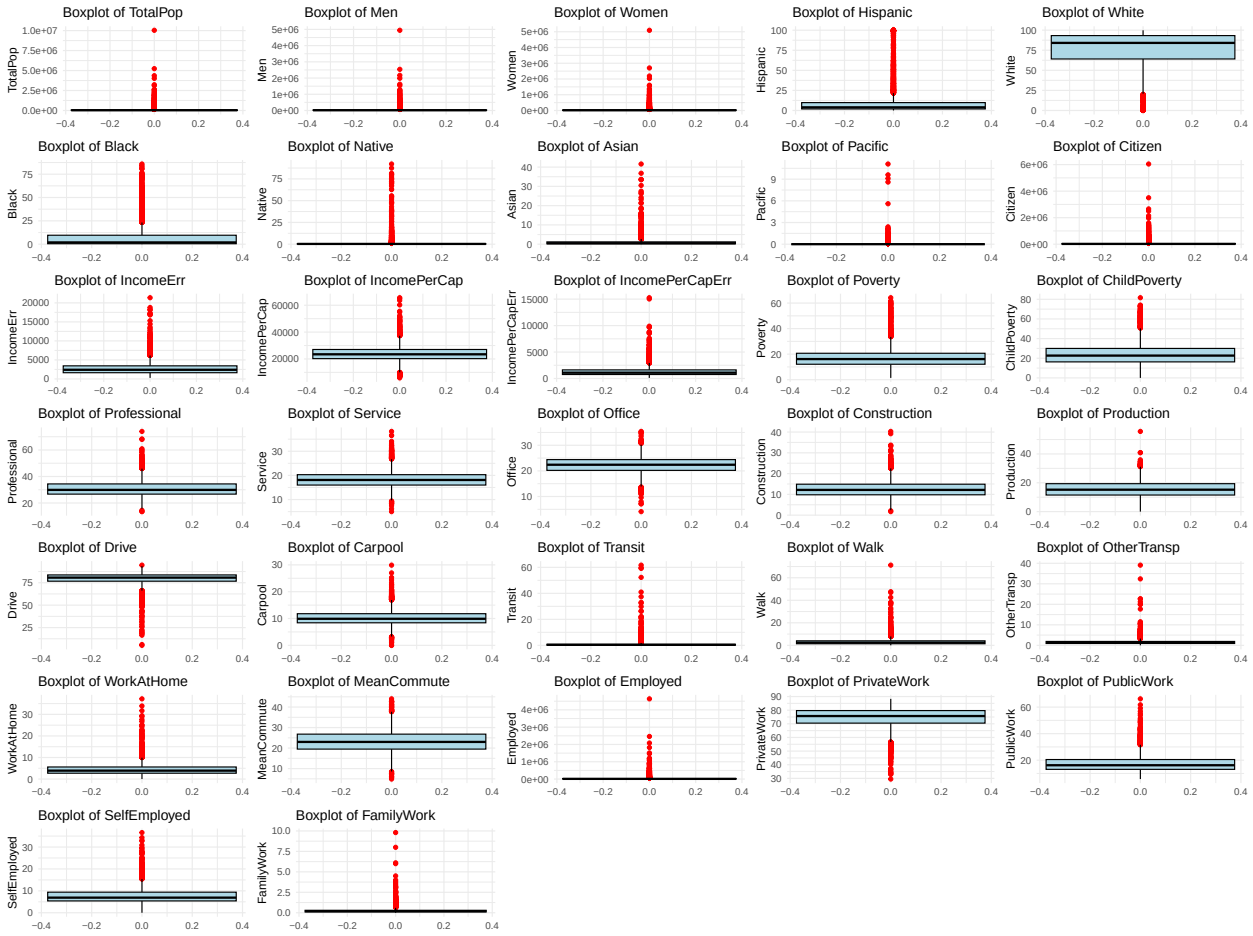


Outliers

Need careful treatment for outliers as it will effect cook's distance

```
plots <- lapply(names(X), function(colname) {
  if (is.numeric(X[[colname]])) {
    ggplot(X, aes_string(y = colname)) +
      geom_boxplot(fill = "lightblue", color = "black", outlier.color = "red") +
      ggtitle(paste("Boxplot of", colname)) +
      theme_minimal()
  } else {
    NULL
  }
})
plots <- Filter(Negate(is.null), plots)
```

```
grid.arrange(grobs = plots, ncol = 5)
```



Feature selection

As we have seen above so many features are correlated and among 34 features many of them are not contributing in Y1/Y2.

So, we will use STEP wise model in both direction to selected only meaningful features.

```
full_model <- lm(Y ~ ., data = X)
stepwise_model_both <- step(full_model, direction = "both")
```

```
## Start:  AIC=5881.99
## Y ~ TotalPop + Men + Women + Hispanic + White + Black + Native +
##     Asian + Pacific + Citizen + IncomeErr + IncomePerCap + IncomePerCapErr +
##     Poverty + ChildPoverty + Professional + Service + Office +
##     Construction + Production + Drive + Carpool + Transit + Walk +
```

```
##     OtherTransp + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     PublicWork + SelfEmployed + FamilyWork
##
##
## Step:  AIC=5881.99
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Pacific + Citizen + IncomeErr + IncomePerCap + IncomePerCapErr +
##     Poverty + ChildPoverty + Professional + Service + Office +
##     Construction + Production + Drive + Carpool + Transit + Walk +
##     OtherTransp + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     PublicWork + SelfEmployed + FamilyWork
##
##                   Df Sum of Sq   RSS    AIC
## - Professional     1      0.07 19623 5880.0
## - Construction     1      0.07 19623 5880.0
## - IncomePerCap     1      0.09 19623 5880.0
## - Production       1      0.28 19624 5880.0
## - OtherTransp      1      0.45 19624 5880.1
## - Service          1      0.46 19624 5880.1
## - Office           1      0.48 19624 5880.1
## - Pacific          1      0.52 19624 5880.1
## - FamilyWork       1      1.18 19624 5880.2
## - White            1      1.22 19624 5880.2
## - Carpool          1      1.50 19625 5880.2
## - WorkAtHome       1      1.54 19625 5880.2
## - Asian            1      1.57 19625 5880.2
## - Walk             1      1.65 19625 5880.3
## - Drive            1      1.68 19625 5880.3
## - Transit          1      1.71 19625 5880.3
## - PublicWork       1      1.87 19625 5880.3
## - PrivateWork      1      2.28 19626 5880.4
## - SelfEmployed     1      2.86 19626 5880.5
## - Hispanic         1      4.31 19628 5880.7
## <none>                         19623 5882.0
## - IncomeErr        1     12.21 19635 5882.0
## - TotalPop         1     12.97 19636 5882.1
## - Black            1     14.23 19637 5882.3
## - ChildPoverty     1     17.45 19641 5882.9
## - Men              1     18.15 19641 5883.0
## - IncomePerCapErr  1     31.10 19654 5885.1
## - Native           1     41.28 19665 5886.8
## - Citizen          1    133.62 19757 5901.8
## - Employed         1    136.90 19760 5902.4
## - Poverty          1   1304.86 20928 6087.2
## - MeanCommute      1   1808.70 21432 6163.7
##
## Step:  AIC=5880
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Pacific + Citizen + IncomeErr + IncomePerCap + IncomePerCapErr +
##     Poverty + ChildPoverty + Service + Office + Construction +
##     Production + Drive + Carpool + Transit + Walk + OtherTransp +
##     WorkAtHome + MeanCommute + Employed + PrivateWork + PublicWork +
##     SelfEmployed + FamilyWork
##
```

```
##                   Df Sum of Sq   RSS    AIC
## - Construction     1      0.00 19623 5878.0
## - IncomePerCap     1      0.09 19623 5878.0
## - OtherTransp      1      0.45 19624 5878.1
## - Pacific          1      0.53 19624 5878.1
## - FamilyWork       1      1.19 19625 5878.2
## - White            1      1.21 19625 5878.2
## - Carpool          1      1.49 19625 5878.2
## - WorkAtHome       1      1.53 19625 5878.3
## - Asian            1      1.56 19625 5878.3
## - Walk             1      1.64 19625 5878.3
## - Drive            1      1.68 19625 5878.3
## - Transit          1      1.71 19625 5878.3
## - PublicWork       1      1.88 19625 5878.3
## - PrivateWork      1      2.30 19626 5878.4
## - SelfEmployed     1      2.88 19626 5878.5
## - Hispanic         1      4.30 19628 5878.7
## <none>                         19623 5880.0
## - IncomeErr        1     12.28 19636 5880.0
## - TotalPop         1     13.01 19636 5880.1
## - Black            1     14.20 19638 5880.3
## - ChildPoverty     1     17.45 19641 5880.9
## - Men              1     18.20 19642 5881.0
## + Professional     1      0.07 19623 5882.0
## - IncomePerCapErr  1     31.11 19654 5883.1
## - Native           1     41.25 19665 5884.8
## - Citizen          1    133.56 19757 5899.8
## - Employed         1    136.87 19760 5900.4
## - Production       1    186.73 19810 5908.5
## - Office           1    226.95 19850 5915.0
## - Service          1    303.83 19927 5927.4
## - Poverty          1   1306.11 20929 6085.4
## - MeanCommute      1   1809.29 21433 6161.8
##
## Step:  AIC=5878
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Pacific + Citizen + IncomeErr + IncomePerCap + IncomePerCapErr +
##     Poverty + ChildPoverty + Service + Office + Production +
##     Drive + Carpool + Transit + Walk + OtherTransp + WorkAtHome +
##     MeanCommute + Employed + PrivateWork + PublicWork + SelfEmployed +
##     FamilyWork
##
##                   Df Sum of Sq   RSS    AIC
## - IncomePerCap     1      0.09 19623 5876.0
## - OtherTransp      1      0.45 19624 5876.1
## - Pacific          1      0.52 19624 5876.1
## - FamilyWork       1      1.19 19625 5876.2
## - White            1      1.21 19625 5876.2
## - Carpool          1      1.49 19625 5876.2
## - WorkAtHome       1      1.53 19625 5876.3
## - Asian            1      1.56 19625 5876.3
## - Walk             1      1.64 19625 5876.3
## - Drive            1      1.68 19625 5876.3
## - Transit          1      1.71 19625 5876.3
```

```
## - PublicWork       1      1.89 19625 5876.3
## - PrivateWork      1      2.30 19626 5876.4
## - SelfEmployed     1      2.88 19626 5876.5
## - Hispanic         1      4.30 19628 5876.7
## <none>                         19623 5878.0
## - IncomeErr        1     12.66 19636 5878.1
## - TotalPop         1     13.04 19636 5878.1
## - Black            1     14.20 19638 5878.3
## - ChildPoverty     1     17.98 19641 5878.9
## - Men              1     18.31 19642 5879.0
## + Construction     1      0.00 19623 5880.0
## + Professional     1      0.00 19623 5880.0
## - IncomePerCapErr  1     31.34 19655 5881.1
## - Native           1     41.25 19665 5882.8
## - Citizen          1    134.74 19758 5898.0
## - Employed         1    137.06 19760 5898.4
## - Production       1    225.90 19849 5912.8
## - Office           1    291.07 19914 5923.4
## - Service          1    353.57 19977 5933.5
## - Poverty          1   1401.59 21025 6098.0
## - MeanCommute      1   1858.90 21482 6167.3
##
## Step:  AIC=5876.02
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Pacific + Citizen + IncomeErr + IncomePerCapErr + Poverty +
##     ChildPoverty + Service + Office + Production + Drive + Carpool +
##     Transit + Walk + OtherTransp + WorkAtHome + MeanCommute +
##     Employed + PrivateWork + PublicWork + SelfEmployed + FamilyWork
##
##                    Df Sum of Sq   RSS    AIC
## - OtherTransp       1      0.46 19624 5874.1
## - Pacific           1      0.56 19624 5874.1
## - White             1      1.19 19625 5874.2
## - FamilyWork        1      1.22 19625 5874.2
## - Carpool           1      1.51 19625 5874.3
## - WorkAtHome        1      1.55 19625 5874.3
## - Walk              1      1.66 19625 5874.3
## - Asian             1      1.67 19625 5874.3
## - Drive             1      1.69 19625 5874.3
## - Transit           1      1.72 19625 5874.3
## - PublicWork        1      1.91 19625 5874.3
## - PrivateWork       1      2.33 19626 5874.4
## - SelfEmployed      1      2.92 19626 5874.5
## - Hispanic          1      4.27 19628 5874.7
## <none>                         19623 5876.0
## - IncomeErr         1     12.89 19636 5876.1
## - TotalPop          1     13.34 19637 5876.2
## - Black             1     14.15 19638 5876.3
## - ChildPoverty      1     17.90 19641 5877.0
## - Men               1     18.42 19642 5877.0
## + IncomePerCap      1      0.09 19623 5878.0
## + Professional      1      0.00 19623 5878.0
## + Construction      1      0.00 19623 5878.0
## - IncomePerCapErr   1     32.24 19656 5879.3
```

```
## - Native           1     41.20 19665 5880.8
## - Citizen          1    138.56 19762 5896.7
## - Employed         1    140.32 19764 5896.9
## - Production       1    267.23 19891 5917.5
## - Office           1    293.82 19917 5921.8
## - Service          1    371.26 19995 5934.3
## - Poverty          1   1650.51 21274 6133.9
## - MeanCommute      1   1860.60 21484 6165.5
##
## Step:  AIC=5874.09
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Pacific + Citizen + IncomeErr + IncomePerCapErr + Poverty +
##     ChildPoverty + Service + Office + Production + Drive + Carpool +
##     Transit + Walk + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     PublicWork + SelfEmployed + FamilyWork
##
##                   Df Sum of Sq   RSS    AIC
## - Pacific          1      0.55 19624 5872.2
## - White            1      1.18 19625 5872.3
## - FamilyWork       1      1.23 19625 5872.3
## - Asian            1      1.65 19626 5872.4
## - PublicWork       1      1.95 19626 5872.4
## - PrivateWork      1      2.36 19626 5872.5
## - SelfEmployed     1      2.95 19627 5872.6
## - Hispanic         1      4.25 19628 5872.8
## <none>                         19624 5874.1
## - IncomeErr        1     12.87 19637 5874.2
## - TotalPop         1     13.18 19637 5874.3
## - Black            1     14.12 19638 5874.4
## - ChildPoverty     1     17.89 19642 5875.0
## - Men              1     18.24 19642 5875.1
## + OtherTransp      1      0.46 19623 5876.0
## + IncomePerCap     1      0.10 19624 5876.1
## + Professional     1      0.00 19624 5876.1
## + Construction     1      0.00 19624 5876.1
## - IncomePerCapErr  1     32.41 19656 5877.4
## - Native           1     41.16 19665 5878.8
## - Walk             1     91.49 19715 5887.1
## - WorkAtHome       1     94.98 19719 5887.6
## - Carpool          1     96.20 19720 5887.8
## - Transit          1    111.45 19735 5890.3
## - Citizen          1    138.42 19762 5894.7
## - Employed         1    140.55 19764 5895.1
## - Drive            1    161.01 19785 5898.4
## - Production       1    266.77 19891 5915.5
## - Office           1    293.37 19917 5919.8
## - Service          1    371.02 19995 5932.4
## - Poverty          1   1650.57 21274 6132.0
## - MeanCommute      1   1862.17 21486 6163.8
##
## Step:  AIC=5872.18
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Citizen + IncomeErr + IncomePerCapErr + Poverty + ChildPoverty +
##     Service + Office + Production + Drive + Carpool + Transit +
```

```
##     Walk + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     PublicWork + SelfEmployed + FamilyWork
##
##                    Df Sum of Sq   RSS    AIC
## - FamilyWork        1      1.19 19626 5870.4
## - PublicWork        1      1.88 19626 5870.5
## - Asian             1      1.90 19626 5870.5
## - PrivateWork       1      2.29 19627 5870.6
## - White             1      2.63 19627 5870.6
## - SelfEmployed      1      2.88 19627 5870.7
## - Hispanic          1      7.44 19632 5871.4
## <none>                          19624 5872.2
## - TotalPop          1     13.29 19638 5872.4
## - IncomeErr         1     13.29 19638 5872.4
## - ChildPoverty      1     17.92 19642 5873.1
## - Men               1     18.27 19643 5873.2
## - Black             1     21.70 19646 5873.7
## + Pacific           1      0.55 19624 5874.1
## + OtherTransp       1      0.45 19624 5874.1
## + IncomePerCap      1      0.14 19624 5874.2
## + Professional      1      0.02 19624 5874.2
## + Construction      1      0.02 19624 5874.2
## - IncomePerCapErr   1     32.44 19657 5875.5
## - Native            1     57.20 19682 5879.5
## - Walk              1     91.40 19716 5885.1
## - WorkAtHome        1     95.45 19720 5885.8
## - Carpool           1     96.39 19721 5885.9
## - Transit           1    110.90 19735 5888.3
## - Citizen           1    138.40 19763 5892.8
## - Employed          1    140.06 19764 5893.1
## - Drive             1    160.94 19785 5896.5
## - Production        1    266.57 19891 5913.6
## - Office            1    292.83 19917 5917.8
## - Service           1    371.30 19996 5930.5
## - Poverty           1   1650.19 21275 6130.0
## - MeanCommute       1   1862.05 21486 6161.9
##
## Step:  AIC=5870.38
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Asian +
##     Citizen + IncomeErr + IncomePerCapErr + Poverty + ChildPoverty +
##     Service + Office + Production + Drive + Carpool + Transit +
##     Walk + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     PublicWork + SelfEmployed
##
##                    Df Sum of Sq   RSS    AIC
## - Asian             1      1.88 19627 5868.7
## - White             1      2.59 19628 5868.8
## - PublicWork        1      4.44 19630 5869.1
## - Hispanic          1      7.37 19633 5869.6
## - PrivateWork       1      9.84 19635 5870.0
## <none>                          19626 5870.4
## - IncomeErr         1     13.17 19639 5870.5
## - TotalPop          1     13.35 19639 5870.6
## - ChildPoverty      1     17.92 19644 5871.3
```

```
## - Men              1     18.33 19644 5871.4
## - SelfEmployed     1     18.76 19644 5871.5
## - Black            1     21.59 19647 5871.9
## + FamilyWork       1      1.19 19624 5872.2
## + Pacific          1      0.51 19625 5872.3
## + OtherTransp      1      0.47 19625 5872.3
## + IncomePerCap     1      0.17 19625 5872.3
## + Professional     1      0.03 19626 5872.4
## + Construction     1      0.03 19626 5872.4
## - IncomePerCapErr  1     32.52 19658 5873.7
## - Native           1     57.05 19683 5877.7
## - Walk             1     91.05 19717 5883.3
## - WorkAtHome       1     94.99 19721 5883.9
## - Carpool          1     96.17 19722 5884.1
## - Transit          1    110.47 19736 5886.4
## - Citizen          1    138.12 19764 5890.9
## - Employed         1    139.57 19765 5891.2
## - Drive            1    160.39 19786 5894.6
## - Production       1    266.31 19892 5911.8
## - Office           1    292.39 19918 5916.0
## - Service          1    372.25 19998 5928.8
## - Poverty          1   1651.10 21277 6128.3
## - MeanCommute      1   1861.65 21487 6160.0
##
## Step:  AIC=5868.69
## Y ~ TotalPop + Men + Hispanic + White + Black + Native + Citizen +
##     IncomeErr + IncomePerCapErr + Poverty + ChildPoverty + Service +
##     Office + Production + Drive + Carpool + Transit + Walk +
##     WorkAtHome + MeanCommute + Employed + PrivateWork + PublicWork +
##     SelfEmployed
##
##                    Df Sum of Sq   RSS    AIC
## - White             1      0.72 19628 5866.8
## - PublicWork        1      4.29 19632 5867.4
## - Hispanic          1      8.46 19636 5868.1
## - PrivateWork       1      9.57 19637 5868.3
## <none>                          19627 5868.7
## - IncomeErr         1     13.46 19641 5868.9
## - TotalPop          1     15.03 19643 5869.1
## - SelfEmployed      1     18.52 19646 5869.7
## - ChildPoverty      1     18.78 19646 5869.8
## - Men               1     20.06 19648 5870.0
## + Asian             1      1.88 19626 5870.4
## + FamilyWork        1      1.16 19626 5870.5
## + Pacific           1      0.74 19627 5870.6
## + OtherTransp       1      0.45 19627 5870.6
## + IncomePerCap      1      0.34 19627 5870.6
## + Professional      1      0.15 19627 5870.7
## + Construction      1      0.14 19627 5870.7
## - IncomePerCapErr   1     32.69 19660 5872.0
## - Black             1     41.23 19669 5873.4
## - Walk              1     89.48 19717 5881.3
## - WorkAtHome        1     93.80 19721 5882.0
## - Carpool           1     96.01 19723 5882.4
```

```
## - Transit          1    108.59 19736 5884.4
## - Native           1    130.55 19758 5888.0
## - Employed         1    137.81 19765 5889.2
## - Citizen          1    137.98 19765 5889.2
## - Drive            1    159.33 19787 5892.7
## - Production       1    266.28 19894 5910.0
## - Office           1    290.81 19918 5914.0
## - Service          1    370.38 19998 5926.8
## - Poverty          1   1658.34 21286 6127.7
## - MeanCommute      1   1867.38 21495 6159.1
##
## Step:  AIC=5866.8
## Y ~ TotalPop + Men + Hispanic + Black + Native + Citizen + IncomeErr +
##     IncomePerCapErr + Poverty + ChildPoverty + Service + Office +
##     Production + Drive + Carpool + Transit + Walk + WorkAtHome +
##     MeanCommute + Employed + PrivateWork + PublicWork + SelfEmployed
##
##                   Df Sum of Sq   RSS    AIC
## - PublicWork       1      4.41 19633 5865.5
## - PrivateWork      1      9.73 19638 5866.4
## <none>                         19628 5866.8
## - IncomeErr        1     13.23 19641 5867.0
## - TotalPop         1     14.34 19643 5867.2
## - ChildPoverty     1     18.64 19647 5867.9
## - SelfEmployed     1     18.66 19647 5867.9
## - Men              1     19.41 19648 5868.0
## + Pacific          1      1.45 19627 5868.6
## + FamilyWork       1      1.15 19627 5868.6
## + White            1      0.72 19627 5868.7
## + OtherTransp      1      0.44 19628 5868.7
## + IncomePerCap     1      0.17 19628 5868.8
## + Professional     1      0.07 19628 5868.8
## + Construction     1      0.07 19628 5868.8
## + Asian            1      0.00 19628 5868.8
## - IncomePerCapErr  1     32.21 19660 5870.1
## - Walk             1     91.18 19719 5879.7
## - WorkAtHome       1     93.99 19722 5880.2
## - Hispanic         1     94.18 19722 5880.2
## - Carpool          1     97.14 19725 5880.7
## - Transit          1    113.83 19742 5883.4
## - Citizen          1    137.63 19766 5887.3
## - Employed         1    140.27 19768 5887.7
## - Drive            1    159.72 19788 5890.9
## - Production       1    268.68 19897 5908.6
## - Office           1    290.40 19919 5912.1
## - Service          1    370.61 19999 5925.0
## - Black            1    444.38 20073 5936.8
## - Native           1    528.53 20157 5950.3
## - Poverty          1   1663.64 21292 6126.6
## - MeanCommute      1   1871.44 21500 6157.9
##
## Step:  AIC=5865.53
## Y ~ TotalPop + Men + Hispanic + Black + Native + Citizen + IncomeErr +
##     IncomePerCapErr + Poverty + ChildPoverty + Service + Office +
```

```
##     Production + Drive + Carpool + Transit + Walk + WorkAtHome +
##     MeanCommute + Employed + PrivateWork + SelfEmployed
##
##                    Df Sum of Sq   RSS    AIC
## <none>                          19633 5865.5
## - IncomeErr         1     12.47 19645 5865.6
## - TotalPop          1     13.95 19647 5865.8
## - ChildPoverty      1     18.59 19651 5866.6
## - Men               1     19.03 19652 5866.6
## + PublicWork        1      4.41 19628 5866.8
## + FamilyWork        1      3.73 19629 5866.9
## + Pacific           1      1.45 19631 5867.3
## + White             1      0.84 19632 5867.4
## + OtherTransp       1      0.52 19632 5867.4
## + IncomePerCap      1      0.07 19633 5867.5
## + Asian             1      0.01 19633 5867.5
## + Professional      1      0.00 19633 5867.5
## + Construction      1      0.00 19633 5867.5
## - IncomePerCapErr   1     33.27 19666 5869.0
## - Walk              1     89.39 19722 5878.1
## - WorkAtHome        1     90.40 19723 5878.3
## - Hispanic          1     92.16 19725 5878.6
## - Carpool           1     95.81 19728 5879.2
## - Transit           1    112.82 19745 5882.0
## - PrivateWork       1    117.71 19750 5882.8
## - Citizen           1    136.74 19769 5885.9
## - Employed          1    140.90 19774 5886.5
## - Drive             1    157.91 19791 5889.3
## - SelfEmployed      1    165.57 19798 5890.6
## - Production        1    269.31 19902 5907.4
## - Office            1    289.11 19922 5910.6
## - Service           1    367.91 20001 5923.3
## - Black             1    441.73 20074 5935.1
## - Native            1    524.98 20158 5948.4
## - Poverty           1   1667.40 21300 6125.8
## - MeanCommute       1   1867.03 21500 6155.9
```

```
summary(stepwise_model_both)
```

```
##
## Call:
## lm(formula = Y ~ TotalPop + Men + Hispanic + Black + Native +
##     Citizen + IncomeErr + IncomePerCapErr + Poverty + ChildPoverty +
##     Service + Office + Production + Drive + Carpool + Transit +
##     Walk + WorkAtHome + MeanCommute + Employed + PrivateWork +
##     SelfEmployed, data = X)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.3955  -1.3416  -0.0866   1.2015  15.5527
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.317e+01  3.309e+00   3.980 7.04e-05 ***
```

```
## TotalPop        -1.691e-05  1.123e-05  -1.507 0.131986
## Men              3.783e-05  2.150e-05   1.760 0.078569 .
## Hispanic         1.205e-02  3.111e-03   3.873 0.000110 ***
## Black            3.354e-02  3.955e-03   8.479  < 2e-16 ***
## Native           7.231e-02  7.823e-03   9.243  < 2e-16 ***
## Citizen          1.402e-05  2.972e-06   4.717 2.49e-06 ***
## IncomeErr       -4.828e-05  3.390e-05  -1.424 0.154429
## IncomePerCapErr -1.465e-04  6.296e-05  -2.327 0.020033 *
## Poverty          2.743e-01  1.665e-02  16.473  < 2e-16 ***
## ChildPoverty    -2.003e-02  1.152e-02  -1.739 0.082085 .
## Service          1.153e-01  1.490e-02   7.738 1.35e-14 ***
## Office           1.199e-01  1.749e-02   6.859 8.28e-12 ***
## Production       7.540e-02  1.139e-02   6.620 4.19e-11 ***
## Drive           -1.588e-01  3.133e-02  -5.069 4.22e-07 ***
## Carpool         -1.418e-01  3.590e-02  -3.949 8.03e-05 ***
## Transit         -1.605e-01  3.745e-02  -4.285 1.88e-05 ***
## Walk            -1.542e-01  4.042e-02  -3.814 0.000139 ***
## WorkAtHome      -1.411e-01  3.679e-02  -3.836 0.000128 ***
## MeanCommute      1.607e-01  9.222e-03  17.431  < 2e-16 ***
## Employed        -2.246e-05  4.690e-06  -4.789 1.76e-06 ***
## PrivateWork     -4.424e-02  1.011e-02  -4.377 1.24e-05 ***
## SelfEmployed    -1.000e-01  1.927e-02  -5.191 2.22e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.479 on 3195 degrees of freedom
## Multiple R-squared:  0.6357, Adjusted R-squared:  0.6332
## F-statistic: 253.4 on 22 and 3195 DF,  p-value: < 2.2e-16
```

```
selected_features_step <- names(coef(stepwise_model_both))[-1]
selected_features_step
```

```
##  [1] "TotalPop"        "Men"             "Hispanic"        "Black"
##  [5] "Native"          "Citizen"         "IncomeErr"       "IncomePerCapErr"
##  [9] "Poverty"         "ChildPoverty"    "Service"         "Office"
## [13] "Production"      "Drive"           "Carpool"         "Transit"
## [17] "Walk"            "WorkAtHome"      "MeanCommute"     "Employed"
## [21] "PrivateWork"     "SelfEmployed"
```

Filtering out these features

```
X=X[selected_features_step]
```

Base Model with main effect before diagnosis

```
fit1 <- lm(Y ~ ., data = X)
base_model_main_effect <- summary(fit1)
r2 <- base_model_main_effect$r.squared
adj_r2 <- base_model_main_effect$adj.r.squared
```

Base Model diagnosis with main effect

```
cat("R2:", r2, "\n")
```

```
## R2: 0.6357207
```

```
cat("Adjusted R2:", adj_r2, "\n")
```

```
## Adjusted R2: 0.6332124
```

```
cat("AIC:", AIC(fit1), "\n")
```

```
## AIC: 14999.82
```

```
cat("BIC:", BIC(fit1), "\n")
```

```
## BIC: 15145.65
```

```
print(dwtest(fit1))
```

```
##
##  Durbin-Watson test
##
## data:  fit1
## DW = 1.7425, p-value = 7.563e-14
## alternative hypothesis: true autocorrelation is greater than 0
```

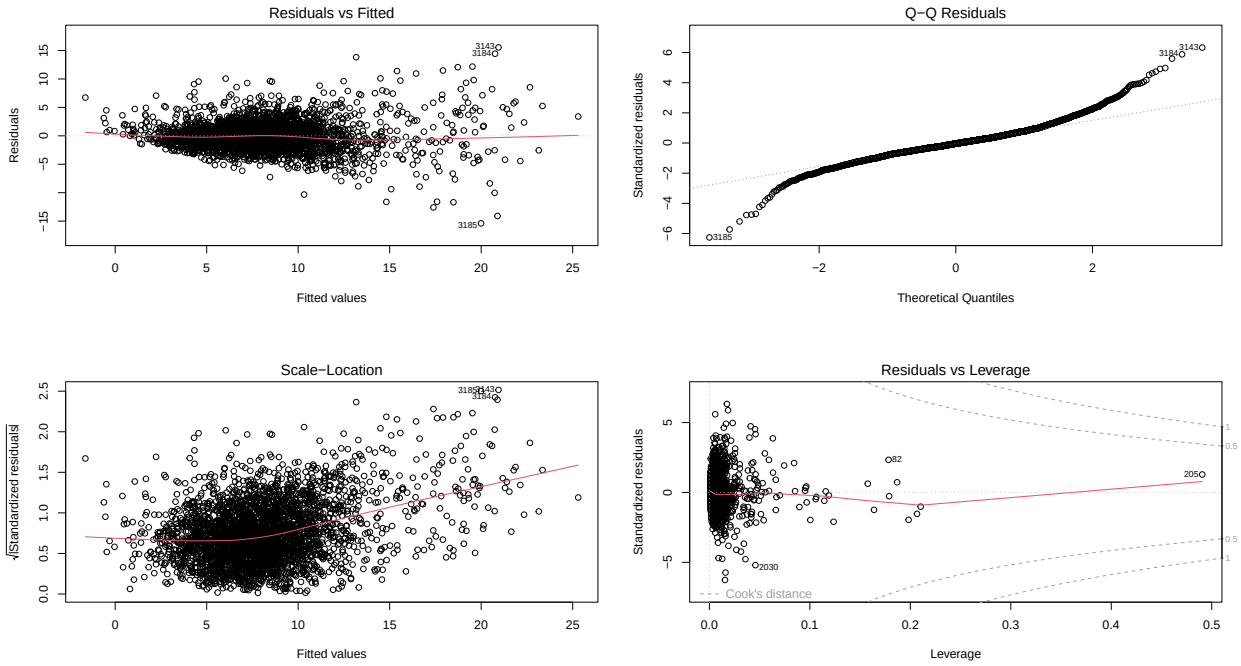
```
print(shapiro.test(residuals(fit1)))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(fit1)
## W = 0.94976, p-value < 2.2e-16
```

```
print(vif(fit1))
```

```
##        TotalPop             Men        Hispanic           Black          Native
##     6729.858380     5943.820288        1.876346        1.670589        1.685241
##         Citizen       IncomeErr IncomePerCapErr         Poverty    ChildPoverty
##      194.670501        2.206393        2.239038       10.044622        9.494422
##         Service          Office      Production           Drive         Carpool
##        1.536147        1.634983        2.235852       29.793033        5.707091
##         Transit            Walk      WorkAtHome     MeanCommute        Employed
##        6.876556       11.706473        7.134674        1.394586      258.166916
##     PrivateWork    SelfEmployed
##        3.269309        2.977632
```

```r
par(mfrow = c(2, 2))
plot(fit1)
```



As we can see we got good R2 but assumptions failed.

Treatment in main effect

Dropping features with VIF<5

```r
vif_values <- vif(fit1)
low_vif_features <- names(vif_values)[vif_values < 5]
print(low_vif_features)
```

```
##  [1] "Hispanic"        "Black"           "Native"          "IncomeErr"
##  [5] "IncomePerCapErr" "Service"         "Office"          "Production"
##  [9] "MeanCommute"     "PrivateWork"     "SelfEmployed"
```

```r
X <- X[low_vif_features]
dim(X)
```

```
## [1] 3218   11
```

Tranformation

```r
Y <- bestNormalize::yeojohnson(Y)$x.t
X[abs(apply(X, 2, e1071::skewness)) > 1] <- lapply(X[abs(apply(X, 2, e1071::skewness)) > 1], log1p)  # A
head(X)
```

```
##   Hispanic     Black    Native IncomeErr IncomePerCapErr Service Office
## 1 1.280934 2.9704145 0.3364722  7.779885        6.985642    17.0   24.2
## 2 1.704748 2.3513753 0.4700036  7.142037        6.568078    17.7   27.1
## 3 1.722767 3.8649314 0.1823216  7.997663        6.683361    16.1   23.1
## 4 1.163151 3.1090610 0.3364722  8.293049        7.389564    17.9   17.8
## 5 2.261763 0.9162907 0.2623643  8.052615        6.563856    14.1   23.9
## 6 1.686399 4.2724907 0.7884574  8.680162        7.628518    15.0   19.7
##   Production MeanCommute PrivateWork SelfEmployed
## 1       17.1        26.5    4.312141     1.871802
## 2       11.2        26.4    4.412798     1.916923
## 3       23.1        24.1    4.287716     2.116256
## 4       23.7        28.8    4.354141     2.041220
## 5       19.9        34.9    4.418841     1.648659
## 6       26.4        27.5    4.388257     1.856298
```

Base model after diagnosis(VIF filter+transformation) with main effect

```r
fit2 <- lm(Y ~ ., data = X)
base_model_main_effect <- summary(fit2)
r2 <- base_model_main_effect$r.squared
adj_r2 <- base_model_main_effect$adj.r.squared
```

```r
cat("R2:", r2, "\n")
```

```
## R2: 0.4901547
```

```r
cat("Adjusted R2:", adj_r2, "\n")
```

```
## Adjusted R2: 0.4884054
```

```r
cat("AIC:", AIC(fit2), "\n")
```

```
## AIC: 6989.489
```

```r
cat("BIC:", BIC(fit2), "\n")
```

```
## BIC: 7068.484
```

```r
print(dwtest(fit2))
```

```
##
##  Durbin-Watson test
##
## data:  fit2
## DW = 1.574, p-value < 2.2e-16
## alternative hypothesis: true autocorrelation is greater than 0
```

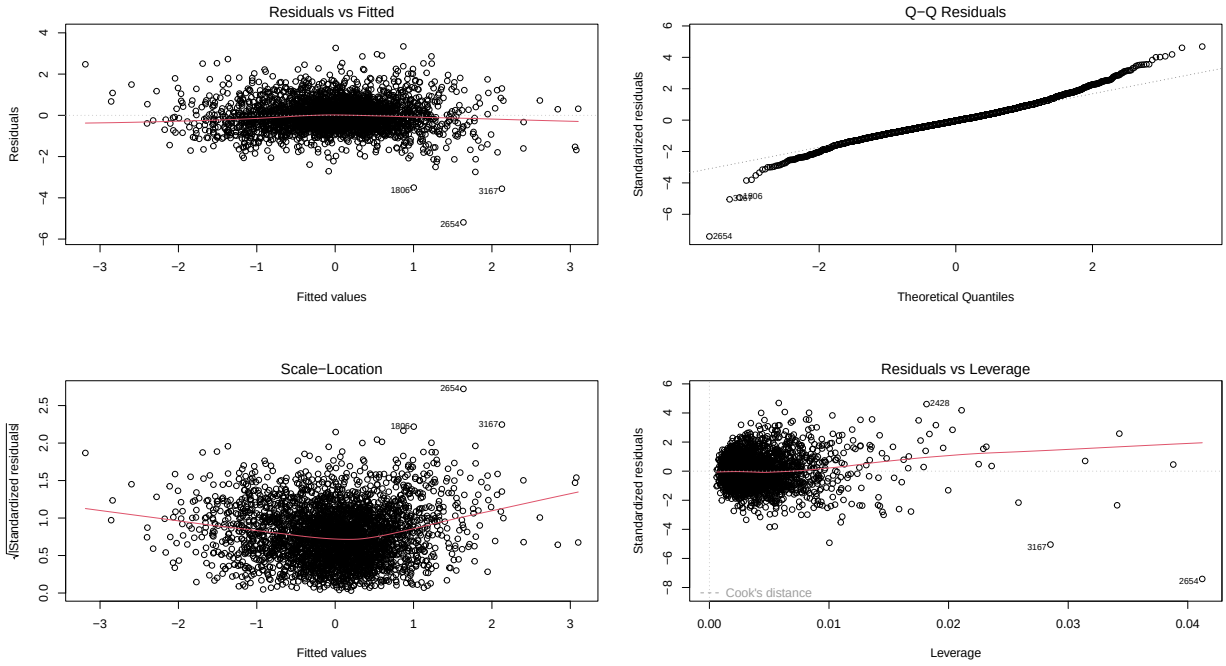
```
print(shapiro.test(residuals(fit2)))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(fit2)
## W = 0.97761, p-value < 2.2e-16
```

```
print(vif(fit2))
```

```
##        Hispanic           Black          Native       IncomeErr IncomePerCapErr
##        1.137995        1.366685        1.351824        3.453582        3.722128
##         Service          Office      Production      MeanCommute     PrivateWork
##        1.203293        1.460795        1.462111        1.190094        2.205046
##    SelfEmployed
##        1.884212
```

```
par(mfrow = c(2, 2))
plot(fit2)
```



Dropping outliers for cooks distance

```
dim(X)
```

```
## [1] 3218   11
```

```r
cooks_dist <- cooks.distance(fit2)
threshold <- 4 / length(cooks_dist)
influential_points <- which(cooks_dist > threshold)
X <- X[-influential_points, ]
Y <- Y[-influential_points]
```

Base model after diagnosis(Influential points) with main effect

```r
fit3 <- lm(Y ~ ., data = X)
base_model_main_effect <- summary(fit3)
r2 <- base_model_main_effect$r.squared
adj_r2 <- base_model_main_effect$adj.r.squared
```

```r
cat("R2:", r2, "\n")
```

```
## R2: 0.6018305
```

```r
cat("Adjusted R2:", adj_r2, "\n")
```

```
## Adjusted R2: 0.6003483
```

```r
cat("AIC:", AIC(fit3), "\n")
```

```
## AIC: 4812.527
```

```r
cat("BIC:", BIC(fit3), "\n")
```

```
## BIC: 4890.466
```

```r
print(dwtest(fit3))
```

```
##
##  Durbin-Watson test
##
## data:  fit3
## DW = 1.5639, p-value < 2.2e-16
## alternative hypothesis: true autocorrelation is greater than 0
```

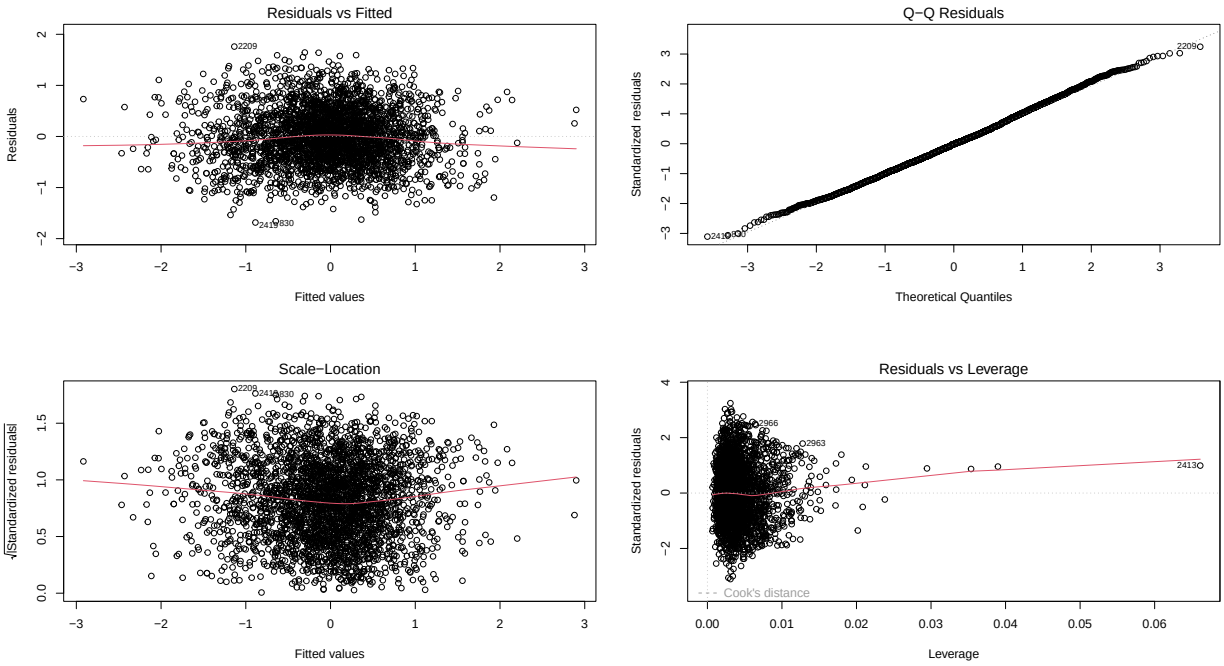
```r
print(shapiro.test(residuals(fit3)))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(fit3)
## W = 0.99816, p-value = 0.001644
```

```
print(vif(fit3))
```

```
##        Hispanic           Black          Native       IncomeErr IncomePerCapErr
##        1.120317        1.418119        1.233576        3.443550        3.723739
##         Service          Office      Production      MeanCommute     PrivateWork
##        1.194446        1.507933        1.512994        1.157602        2.264456
##    SelfEmployed
##        1.998758
```

```
par(mfrow = c(2, 2))
plot(fit3)
```



Only multicollineariy has been passed, but plot has been improved.

two main effect

All combination of two main effect has been implemented and the best features extracted using STEP.

```
full_model <- lm(Y ~ (.)^2, data = X)
step_model <- step(full_model, direction = "both", trace = FALSE)
final_formula <- formula(step_model)
final_fit <- lm(final_formula, data = X)
cooks_dist <- cooks.distance(final_fit)
threshold <- 4 / length(cooks_dist)
influential_points <- which(cooks_dist > threshold)
```

```r
X <- X[-influential_points, , drop = FALSE]
Y <- Y[-influential_points]
final_fit <- lm(final_formula, data = X)
model_summary <- summary(final_fit)
r2 <- model_summary$r.squared
adj_r2 <- model_summary$adj.r.squared
cat("R2:", r2, "\n")
```

```
## R2: 0.6880194
```

```r
cat("Adjusted R2:", adj_r2, "\n")
```

```
## Adjusted R2: 0.6835918
```

```r
cat("AIC:", AIC(final_fit), "\n")
```

```
## AIC: 3642.337
```

```r
cat("BIC:", BIC(final_fit), "\n")
```

```
## BIC: 3885.593
```

```r
print(final_formula)
```

```
## Y ~ Hispanic + Black + Native + IncomeErr + IncomePerCapErr +
##     Service + Office + Production + MeanCommute + PrivateWork +
##     SelfEmployed + Hispanic:Black + Hispanic:Native + Hispanic:Service +
##     Hispanic:Production + Black:Native + Black:IncomePerCapErr +
##     Black:Service + Black:Office + Black:MeanCommute + Native:Service +
##     Native:PrivateWork + IncomeErr:IncomePerCapErr + IncomeErr:Service +
##     IncomeErr:MeanCommute + IncomeErr:PrivateWork + IncomeErr:SelfEmployed +
##     IncomePerCapErr:Office + IncomePerCapErr:Production + IncomePerCapErr:PrivateWork +
##     Service:Office + Service:Production + Office:Production +
##     Office:SelfEmployed + Production:MeanCommute + Production:PrivateWork +
##     Production:SelfEmployed + MeanCommute:PrivateWork + MeanCommute:SelfEmployed
```

```r
print(dwtest(final_fit))
```

```
##
##  Durbin-Watson test
##
## data:  final_fit
## DW = 1.7045, p-value = 1.321e-15
## alternative hypothesis: true autocorrelation is greater than 0
```

```r
print(shapiro.test(residuals(final_fit)))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(final_fit)
## W = 0.9989, p-value = 0.0707
```

```r
par(mfrow = c(2, 2))
plot(final_fit)
```