

Data 621 - HW5

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11/16/2020

Overview

In this homework assignment, you will explore, analyze and model a data set containing information on approximately 12,000 commercially available wines. The variables are mostly related to the chemical properties of the wine being sold. The response variable is the number of sample cases of wine that were purchased by wine distribution companies after sampling a wine. These cases would be used to provide tasting samples to restaurants and wine stores around the United States. The more sample cases purchased, the more likely is a wine to be sold at a high end restaurant. A large wine manufacturer is studying the data in order to predict the number of wine cases ordered based upon the wine characteristics. If the wine manufacturer can predict the number of cases, then that manufacturer will be able to adjust their wine offering to maximize sales.

Your objective is to build a count regression model to predict the number of cases of wine that will be sold given certain properties of the wine. HINT: Sometimes, the fact that a variable is missing is actually predictive of the target. You can only use the variables given to you (or variables that you derive from the variables provided).

Below is a short description of the variables of interest in the data set:

VARIABLE NAME	DEFINITION
INDEX	Identification Variable (do not use)
TARGET	Number of Cases Purchased
AcidIndex	Proprietary method of testing total acidity of wine by using a weighted average of the titration of individual acids.
Alcohol	Alcohol Content
Chlorides	Chloride content of wine
CitricAcid	Citric Acid Content
Density	Density of Wine
FixedAcidity	Fixed Acidity of Wine
FreeSulfurDioxide	Sulfur Dioxide content of wine
LabelAppeal	Marketing Score indicating the appeal of label design for consumers. Positive numbers suggest customers like the label design. Negative numbers suggest they don't like the design.
ResidualSugar	Residual Sugar of wine
STARS	Wine rating by a team of experts. 4 Stars = Excellent, 1 Star = Poor
Sulphates	Sulfate content of wine
TotalSulfurDioxide	Total Sulfur Dioxide of Wine
VolatileAcidity	Volatile Acid content of wine
pH	pH of wine

Loading Data

In this assignment there are 2 datasets wine training dataset and wine evaluation dataset

Wine Training Dataset : This dataset contains 12795 observation, 1 response variable and 14 predictors.

Wine Evaluation Dataset : This dataset contains 16129 observation, 1 response variable and 14 predictors.

Both of these datasets has missing values. Lets observe the data to get more insight into it.

Display the top 5 records of Training and Evaluation dataset

Training Dataset

```
## # A tibble: 6 x 16
##   TARGET INDEX FixedAcidity VolatileAcidity CitricAcid ResidualSugar Chlorides
##   <dbl> <dbl>      <dbl>        <dbl>     <dbl>       <dbl>      <dbl>
## 1     3     1         3.2        1.16    -0.98      54.2     -0.567
## 2     3     2         4.5        0.16    -0.81      26.1     -0.425
## 3     5     4         7.1        2.64    -0.88      14.8      0.037
## 4     3     5         5.7        0.385   0.04      18.8     -0.425
## 5     4     6         8          0.33    -1.26      9.4      NA
## 6     0     7        11.3        0.32     0.59      2.2      0.556
## # ... with 9 more variables: FreeSulfurDioxide <dbl>, TotalSulfurDioxide <dbl>,
## #   Density <dbl>, pH <dbl>, Sulphates <dbl>, Alcohol <dbl>, LabelAppeal <dbl>,
## #   AcidIndex <dbl>, STARS <dbl>
```

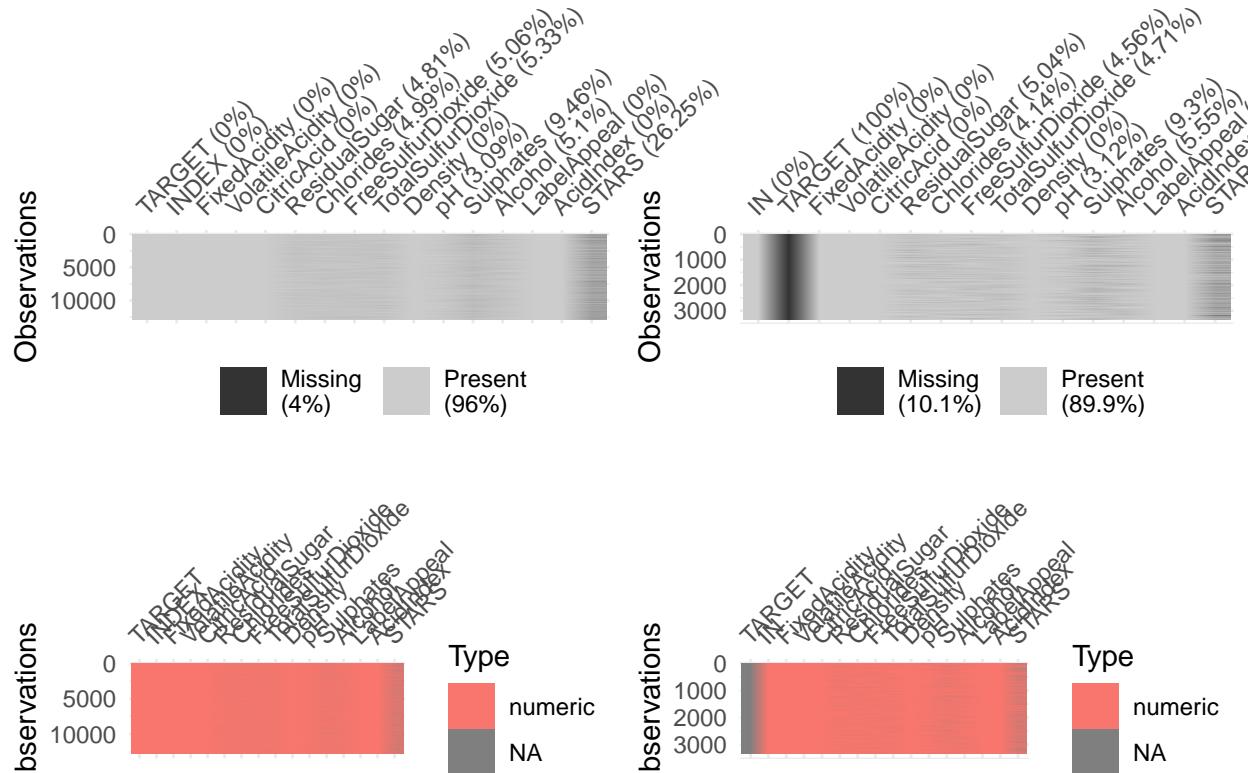
Evaluation Dataset

```
## # A tibble: 6 x 16
##   IN TARGET FixedAcidity VolatileAcidity CitricAcid ResidualSugar Chlorides
##   <dbl> <lgl>      <dbl>        <dbl>     <dbl>       <dbl>      <dbl>
## 1     3 NA         5.4        -0.86     0.27     -10.7     0.092
## 2     9 NA        12.4        0.385    -0.76     -19.7     1.17
## 3    10 NA         7.2        1.75     0.17     -33       0.065
## 4    18 NA         6.2        0.1       1.8      1       -0.179
## 5    21 NA        11.4        0.21     0.28      1.2      0.038
## 6    30 NA        17.6        0.04    -1.15      1.4      0.535
## # ... with 9 more variables: FreeSulfurDioxide <dbl>, TotalSulfurDioxide <dbl>,
## #   Density <dbl>, pH <dbl>, Sulphates <dbl>, Alcohol <dbl>, LabelAppeal <dbl>,
## #   AcidIndex <dbl>, STARS <dbl>
```

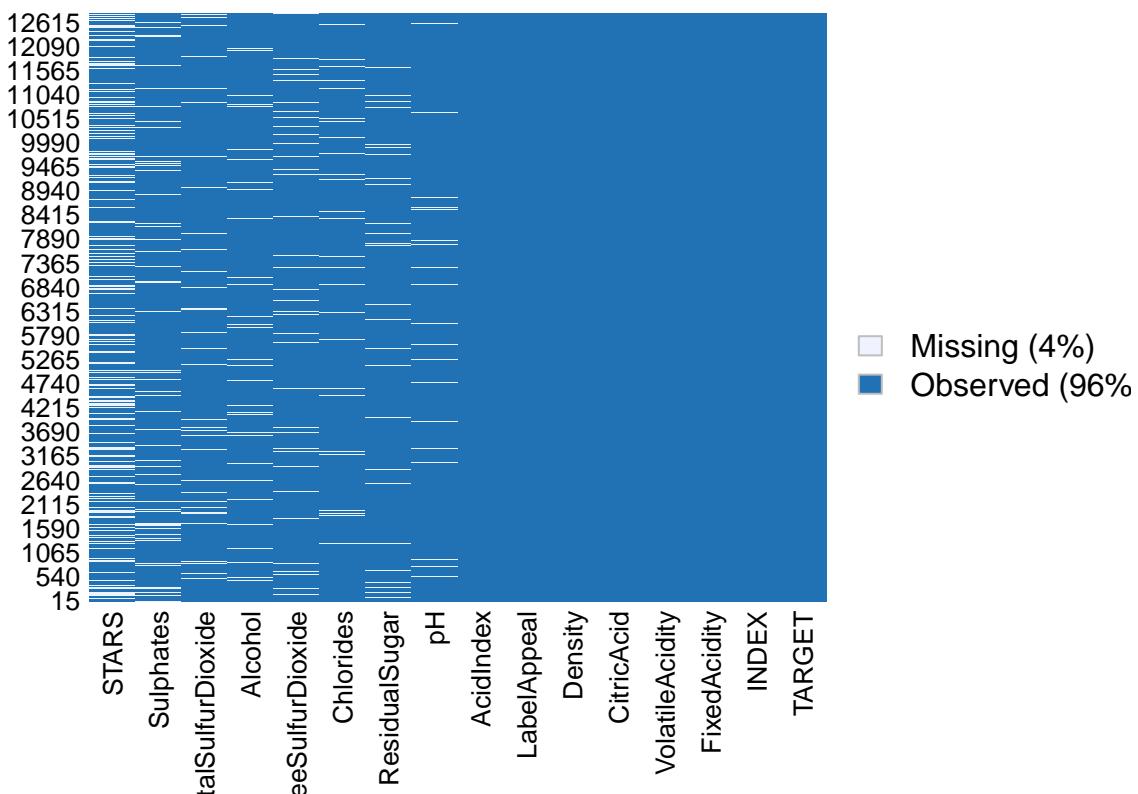
Check Data types and Missing values

Training and Evaluation datasets both have missing values. There are 3 categorical fields (LabelAppeal,AcidIndex,STARS), 11 continuous fields and field 'Target' is categorical.

Missing Values and Data Type Check



Missing vs Observed in Training Data



	Non_NAs	NAs	NA_Percent
TARGET	12795	0	0.0000000
INDEX	12795	0	0.0000000
FixedAcidity	12795	0	0.0000000
VolatileAcidity	12795	0	0.0000000
CitricAcid	12795	0	0.0000000
ResidualSugar	12179	616	0.0481438
Chlorides	12157	638	0.0498632
FreeSulfurDioxide	12148	647	0.0505666
TotalSulfurDioxide	12113	682	0.0533021
Density	12795	0	0.0000000
pH	12400	395	0.0308714
Sulphates	11585	1210	0.0945682
Alcohol	12142	653	0.0510356
LabelAppeal	12795	0	0.0000000
AcidIndex	12795	0	0.0000000
STARS	9436	3359	0.2625244

Data Statistics Summary

A binary logistic regression model is built using the `training set`, therefore the `training set` is used for the following data exploration.

The data types in the raw dataset are all ‘doubles’, however the counter `INDEX` and the response variable `target` are categorical.

The statistics of all variables are listed below:

```

##      TARGET      FixedAcidity      VolatileAcidity      CitricAcid
##  Min.   :0.000   Min.   :-18.100   Min.   :-2.7900   Min.   :-3.2400
##  1st Qu.:2.000   1st Qu.: 5.200   1st Qu.: 0.1300   1st Qu.: 0.0300
##  Median :3.000   Median : 6.900   Median : 0.2800   Median : 0.3100
##  Mean   :3.029   Mean   : 7.076   Mean   : 0.3241   Mean   : 0.3084
##  3rd Qu.:4.000   3rd Qu.: 9.500   3rd Qu.: 0.6400   3rd Qu.: 0.5800
##  Max.   :8.000   Max.   :34.400   Max.   : 3.6800   Max.   : 3.8600
##
##      ResidualSugar      Chlorides      FreeSulfurDioxide TotalSulfurDioxide
##  Min.   :-127.800   Min.   :-1.1710   Min.   :-555.00   Min.   :-823.0
##  1st Qu.: -2.000   1st Qu.: -0.0310   1st Qu.:  0.00   1st Qu.:  27.0
##  Median : 3.900   Median : 0.0460   Median : 30.00   Median : 123.0
##  Mean   : 5.419   Mean   : 0.0548   Mean   : 30.85   Mean   : 120.7
##  3rd Qu.: 15.900   3rd Qu.: 0.1530   3rd Qu.: 70.00   3rd Qu.: 208.0
##  Max.   :141.150   Max.   : 1.3510   Max.   : 623.00   Max.   :1057.0
##  NA's   :616       NA's   :638       NA's   :647       NA's   :682
##      Density          pH          Sulphates          Alcohol
##  Min.   :0.8881   Min.   :0.480   Min.   :-3.1300   Min.   :-4.70
##  1st Qu.:0.9877   1st Qu.:2.960   1st Qu.: 0.2800   1st Qu.: 9.00
##  Median :0.9945   Median :3.200   Median : 0.5000   Median :10.40
##  Mean   :0.9942   Mean   :3.208   Mean   : 0.5271   Mean   :10.49
##  3rd Qu.:1.0005   3rd Qu.:3.470   3rd Qu.: 0.8600   3rd Qu.:12.40
##  Max.   :1.0992   Max.   :6.130   Max.   : 4.2400   Max.   :26.50
##  NA's   :395       NA's   :1210    NA's   :653
##      LabelAppeal      AcidIndex      STARS
##  Min.   :-2.000000   Min.   : 4.000   Min.   :1.000
##  1st Qu.: -1.000000   1st Qu.: 7.000   1st Qu.:1.000
##  Median : 0.000000   Median : 8.000   Median :2.000
##  Mean   : -0.009066   Mean   : 7.773   Mean   :2.042
##  3rd Qu.: 1.000000   3rd Qu.: 8.000   3rd Qu.:3.000
##  Max.   : 2.000000   Max.   :17.000   Max.   :4.000
##  NA's   :3359

```

The statistics of TARGET Variable.

TARGET: Number of Cases Purchased as Actual

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	StdD	Skew	Kurt
	0.00	2.00	3.00	3.03	4.00	8.00	1.93	-0.33	-0.88

DATA EXPLORATION

Attributes

FixedAcidity: This variable tells us about the FixedAcidity of wine.

VolatileAcidity: This variable tells us about the VolatileAcidity content of Wine.

CitricAcid: This variable tells us about the Citric Acid Content of wine.

ResidualSugar: This variable tells us about the ResidualSugar of wine.

Chlorides: This variable tells us about the Chloride content of wine.

FreeSulfurDioxide : This variable tells us about the Sulfur Dioxide content of wine.

TotalSulfurDioxide : This variable tells us about the Total Sulfur Dioxide of Wine.

Density: This variable tells us about the Density of wine.

Sulphates: This variable tells us about the Sulphates content of wine.

Alcohol: This variable tells us about the Alcohol content.

LabelAppeal: Marketing Score indicating the appeal of label design for consumers. High numbers suggest customers like the label design.

AcidIndex: Proprietary method of testing total acidity of wine by using a weighted average.

STARS: Wine rating by a team of experts. 4 Stars = Excellent, 1 Star = Poor. A high number of stars suggests high sales.

Outliers

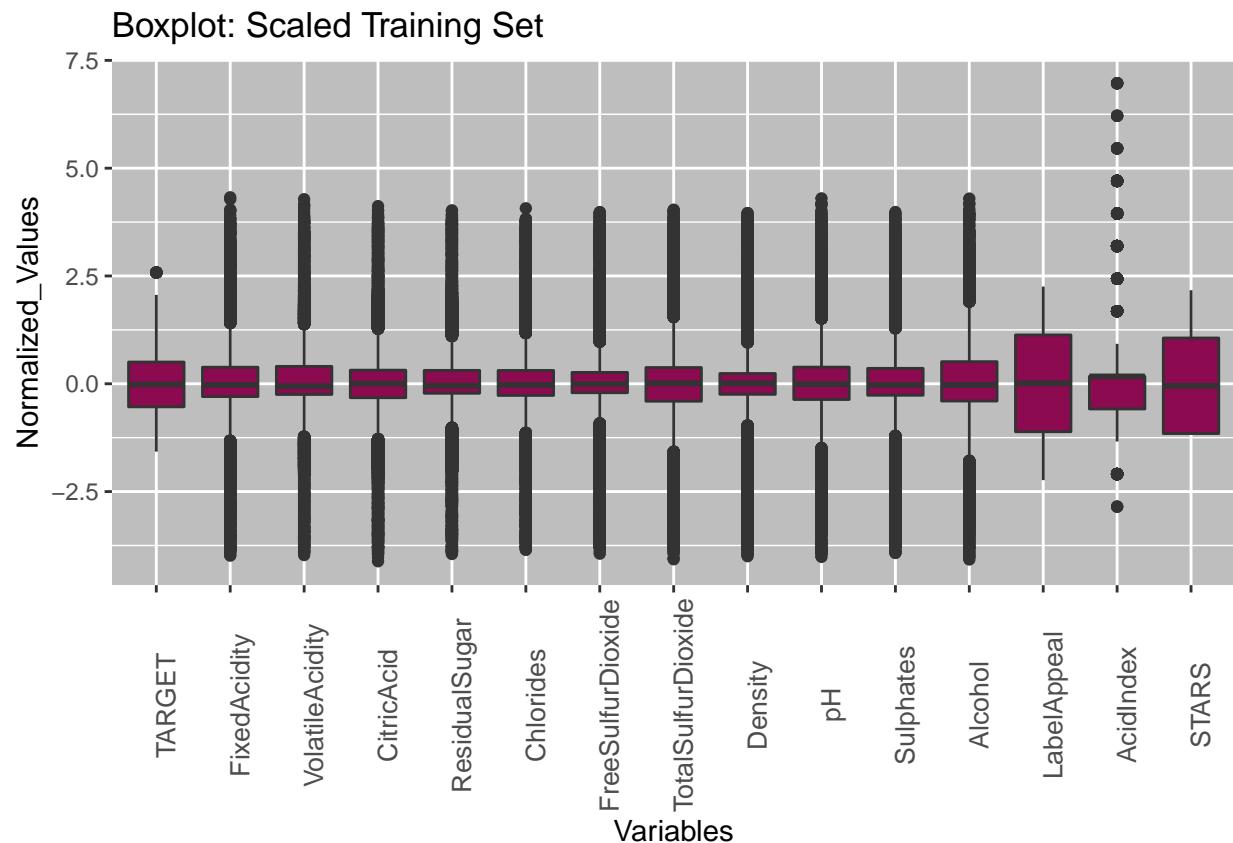
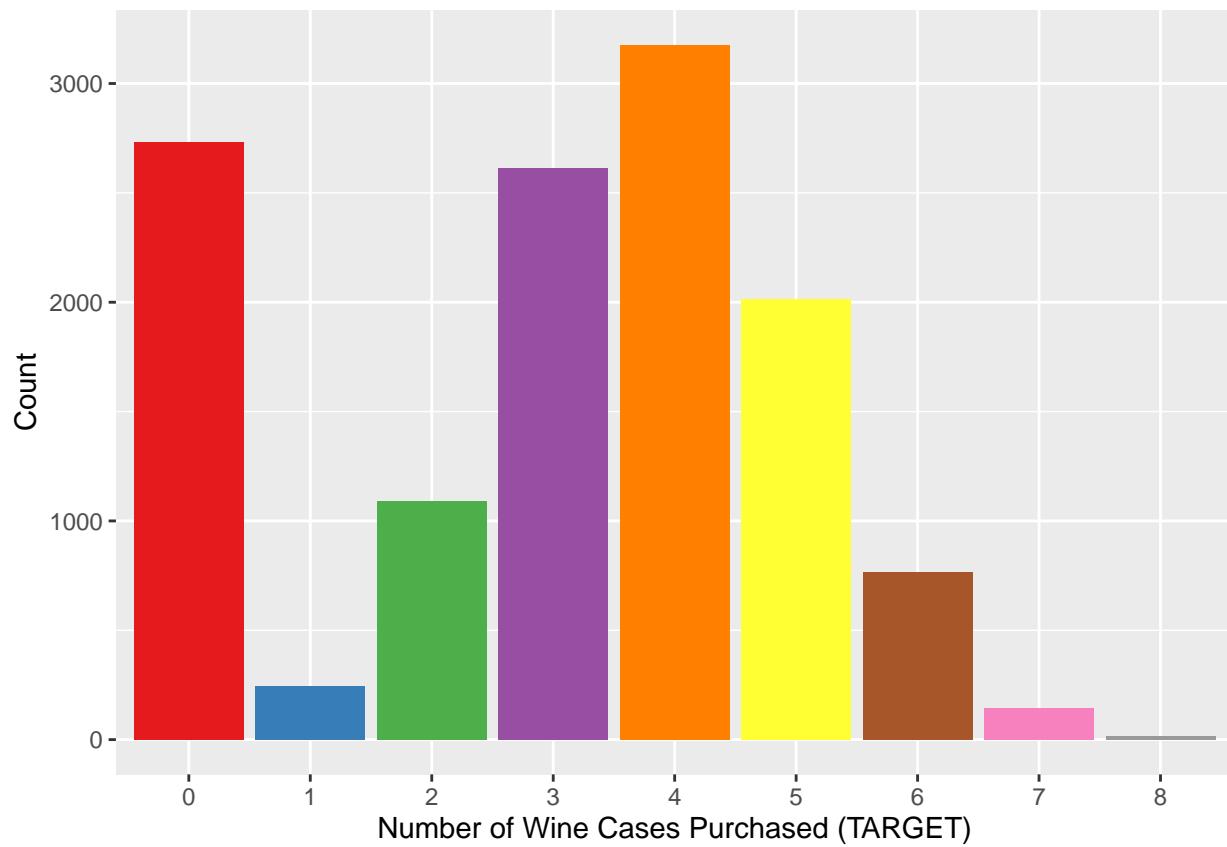


Figure 1: Boxplot: Scaled Training Set

The box plot shows that outliers exist in variables FixedAcidity, VolatileAcidity, CitricAcid, ResidualSugar, Chlorides, FreeSulfurDioxide, TotalSulfurDioxide, Density, pH, Sulphates, Alcohol, LabelAppeal and AcidIndex.

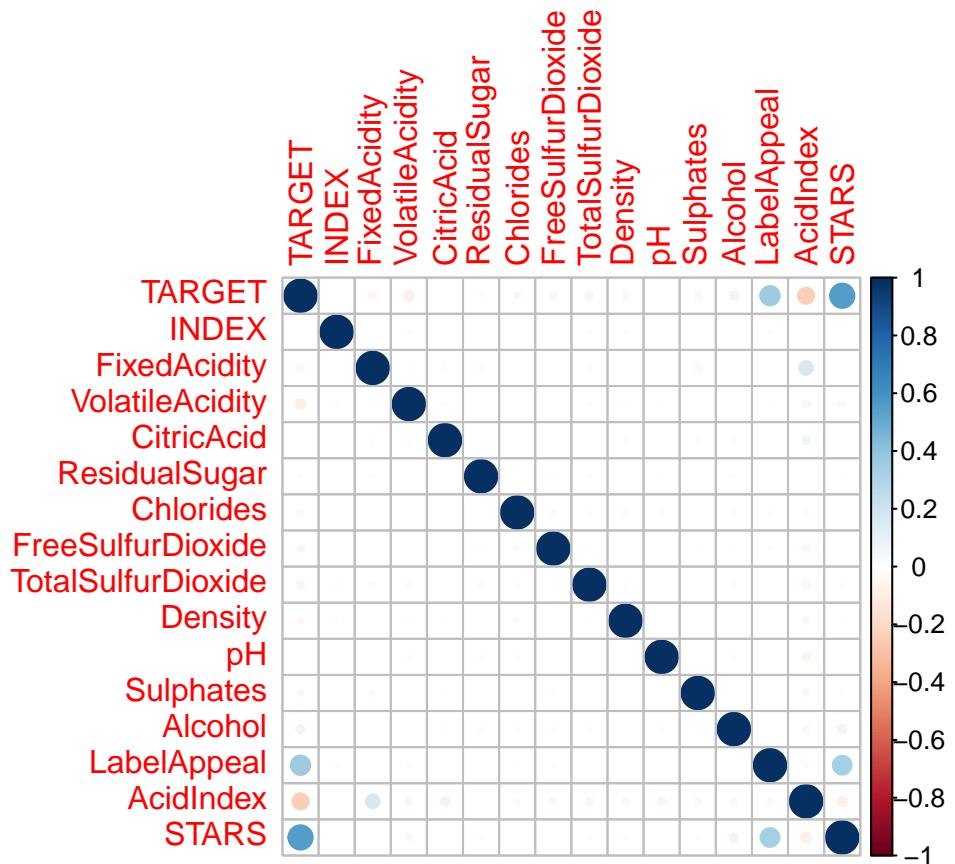
Univariate Analysis

Response Variable



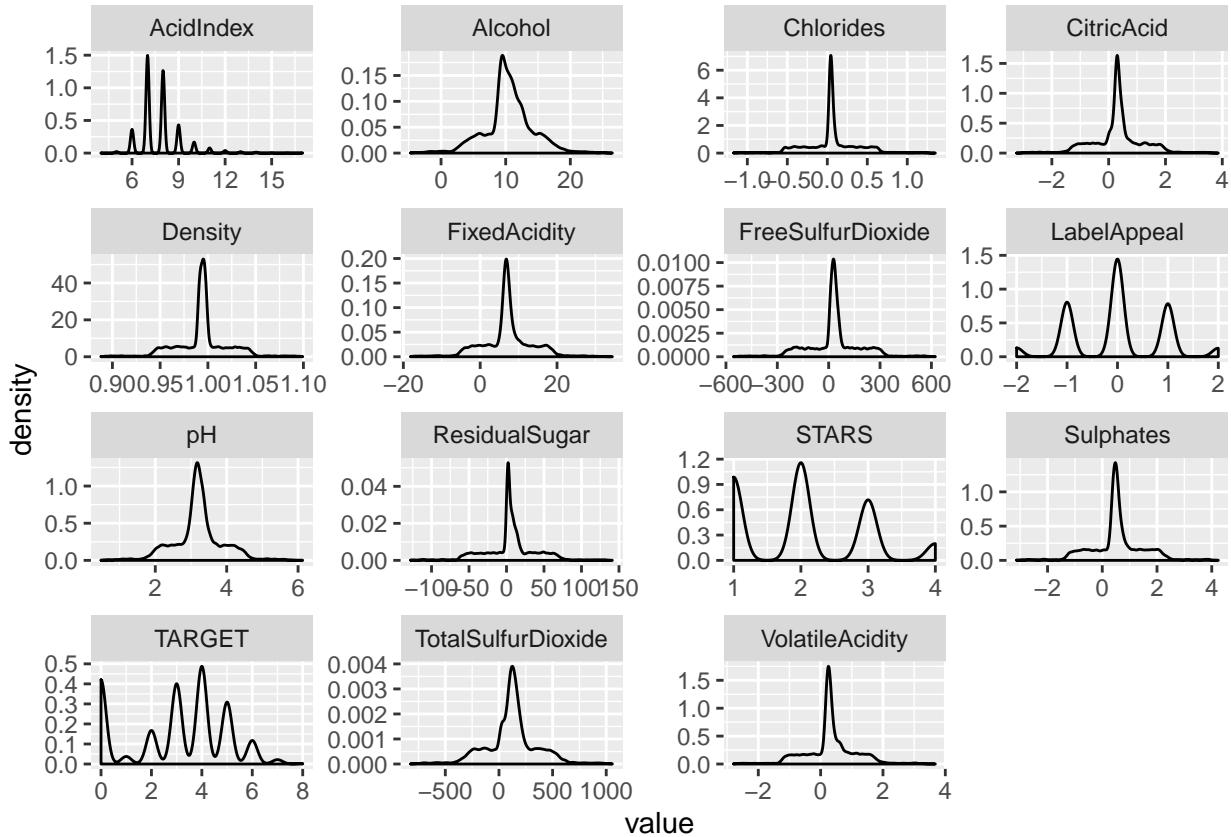
Correlation Plot

The correlation plot below shows how variables in the dataset are related to each other.



Density Plot

Based on the below plots we can observe that AcidIndex is right skewed; AcidIndex, STARS, LabelAppeal and TARGET have multimodal distribution; while most others seem to be normally distributed due to the bell curve they display.



Summarized Data Dictionary

As a summary of the data exploration process, a data dictionary is created below:

Variable	Missing_Value	Mean	Median	Max	Min	SD	Correlation_vs_Response
TARGET	No	NA	NA	NA	NA	NA	1.00
INDEX	No	NA	NA	NA	NA	NA	0.00
FixedAcidity	No	7.08	6.90	34.40	-18.10	6.32	-0.05
VolatileAcidity	No	0.32	0.28	3.68	-2.79	0.78	-0.09
CitricAcid	No	0.31	0.31	3.86	-3.24	0.86	0.01
ResidualSugar	No	NA	NA	NA	NA	NA	NA
Chlorides	No	NA	NA	NA	NA	NA	NA
FreeSulfurDioxide	No	NA	NA	NA	NA	NA	NA
TotalSulfurDioxide	No	NA	NA	NA	NA	NA	NA
Density	No	0.99	0.99	1.10	0.89	0.03	-0.04
pH	No	NA	NA	NA	NA	NA	NA
Sulphates	No	NA	NA	NA	NA	NA	NA
Alcohol	No	NA	NA	NA	NA	NA	NA
LabelAppeal	No	-0.01	0.00	2.00	-2.00	0.89	0.36
AcidIndex	No	7.77	8.00	17.00	4.00	1.32	-0.25
STARS	No	NA	NA	NA	NA	NA	NA

DATA PREPARATION

In the data preparation we will split data into training and test dataset.

MICE package (Multivariate Imputation by Chained Equations) implements a method to deal with missing data. The package creates multiple imputations (replacement values) for multivariate missing data. helps in inspecting, imputing, diagonise, analyze, pool the result, and generate simulated incomplete data

```
##  
## iter imp variable  
## 1 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 2 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 3 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 4 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 5 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
  
##  
## iter imp variable  
## 1 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 2 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 3 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 4 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA  
## 5 1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA
```

‘AcidIndex’ and ‘TARGET’ has low correlation between them. We will log transform it to test even if it doesn't make big difference.

BUILD MODELS

Model I: Poisson Model

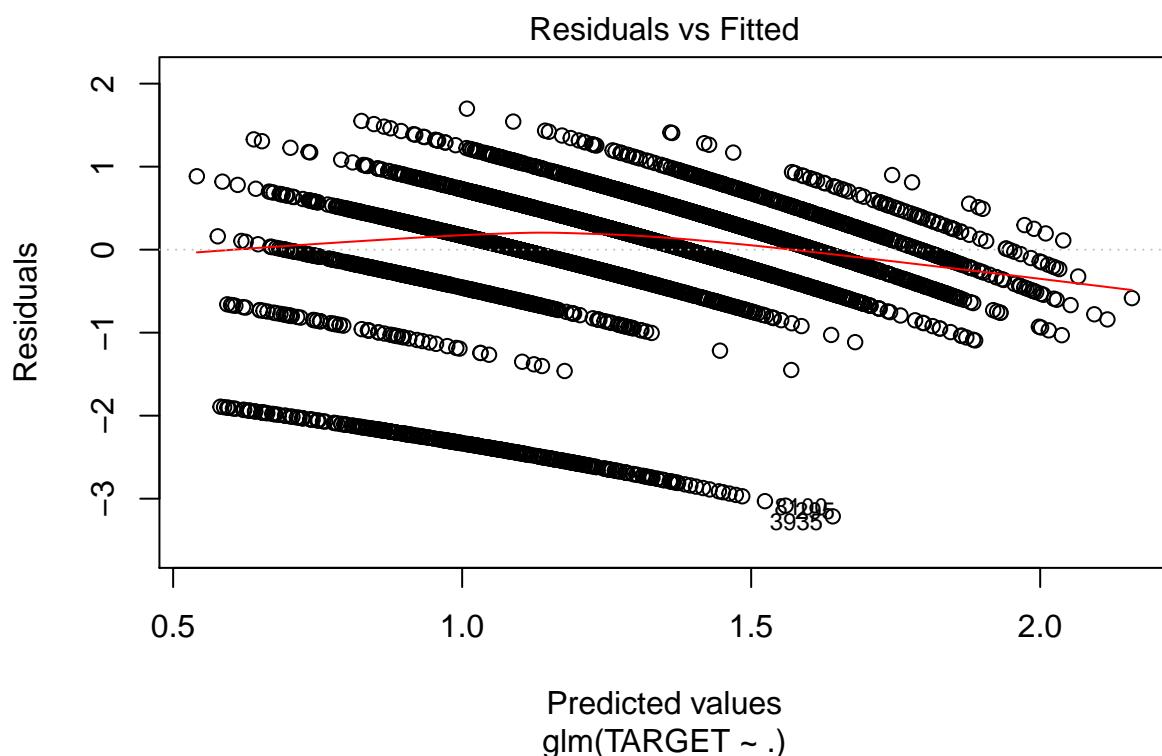
Model 1: Poisson Model without imputations

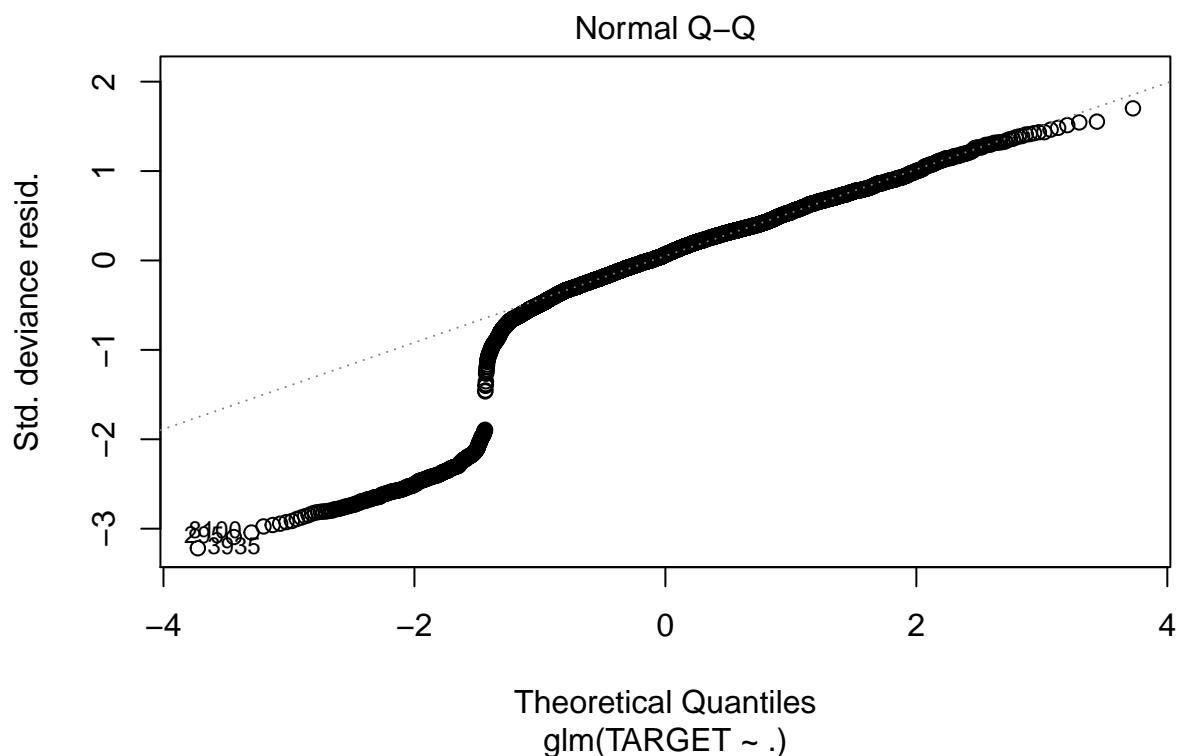
```
##  
## Call:  
## glm(formula = TARGET ~ ., family = poisson, data = wine_train1)  
##  
## Deviance Residuals:  
##      Min        1Q     Median        3Q       Max  
## -3.2128  -0.2757   0.0647   0.3766   1.6981  
##  
## Coefficients:  
##                               Estimate Std. Error z value Pr(>|z|)  
## (Intercept) 1.608e+00 2.796e-01  5.750 8.90e-09 ***  
## FixedAcidity 6.705e-04 1.177e-03  0.570  0.56901  
## VolatileAcidity -2.750e-02 9.283e-03 -2.963  0.00305 **  
## CitricAcid -3.835e-03 8.519e-03 -0.450  0.65259  
## ResidualSugar 1.828e-05 2.152e-04  0.085  0.93232  
## Chlorides -3.764e-02 2.314e-02 -1.627  0.10377  
## FreeSulfurDioxide 5.671e-05 4.892e-05  1.159  0.24630  
## TotalSulfurDioxide 2.230e-05 3.177e-05  0.702  0.48274  
## Density -4.025e-01 2.749e-01 -1.464  0.14326
```

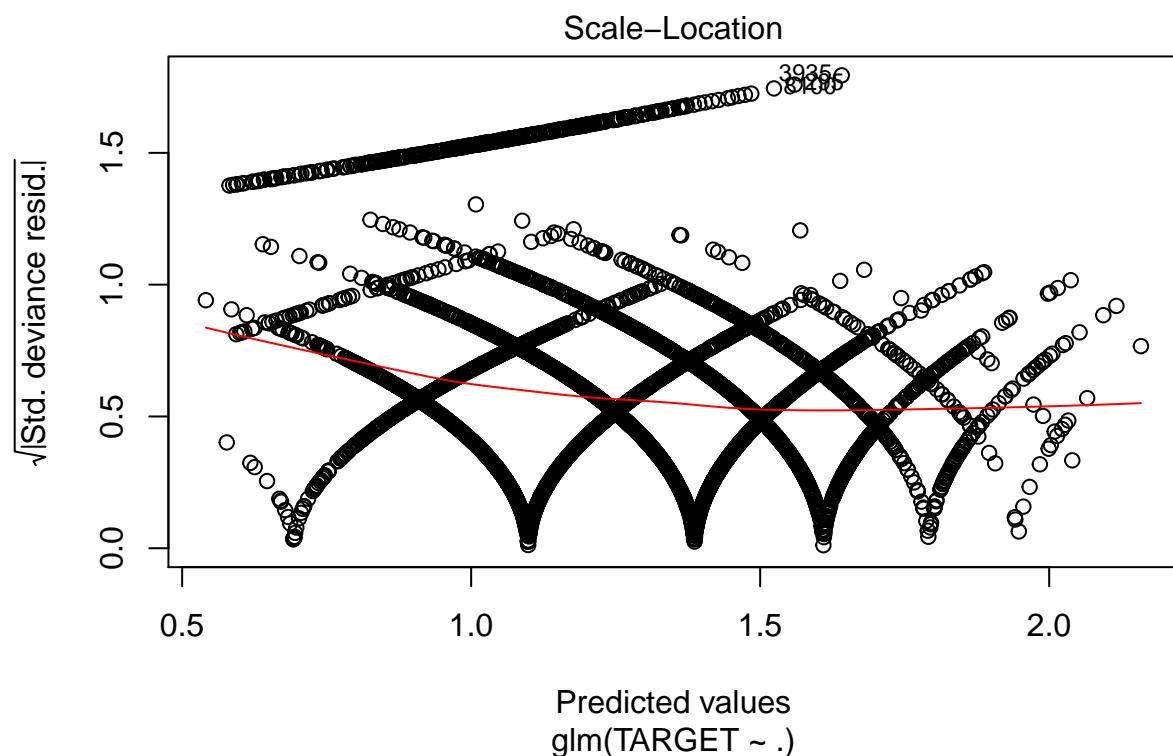
```

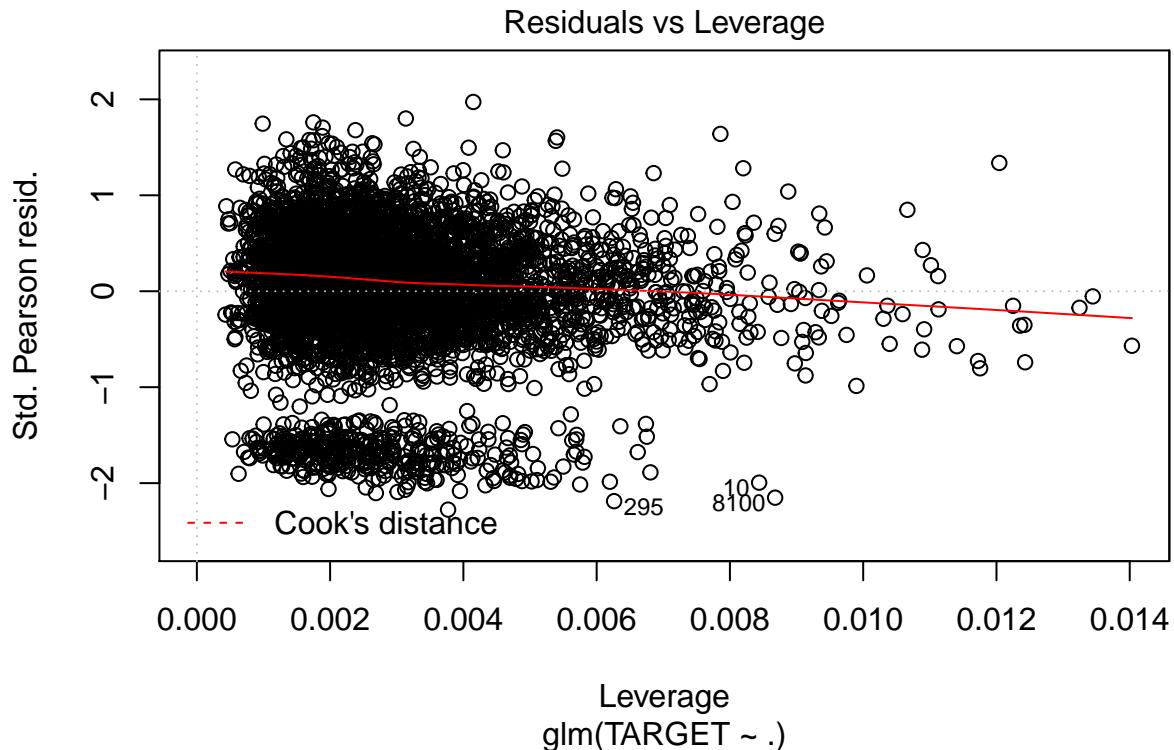
## pH           2.307e-04  1.085e-02   0.021  0.98303
## Sulphates    -5.984e-03 7.973e-03  -0.751  0.45293
## Alcohol       3.262e-03  2.004e-03   1.628  0.10360
## LabelAppeal   1.730e-01  8.858e-03  19.530 < 2e-16 ***
## AcidIndex     -4.967e-02 6.666e-03  -7.451 9.28e-14 ***
## STARS         1.929e-01  8.328e-03  23.160 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
## Null deviance: 4720.5 on 5143 degrees of freedom
## Residual deviance: 3242.8 on 5129 degrees of freedom
## (5093 observations deleted due to missingness)
## AIC: 18545
##
## Number of Fisher Scoring iterations: 5

```





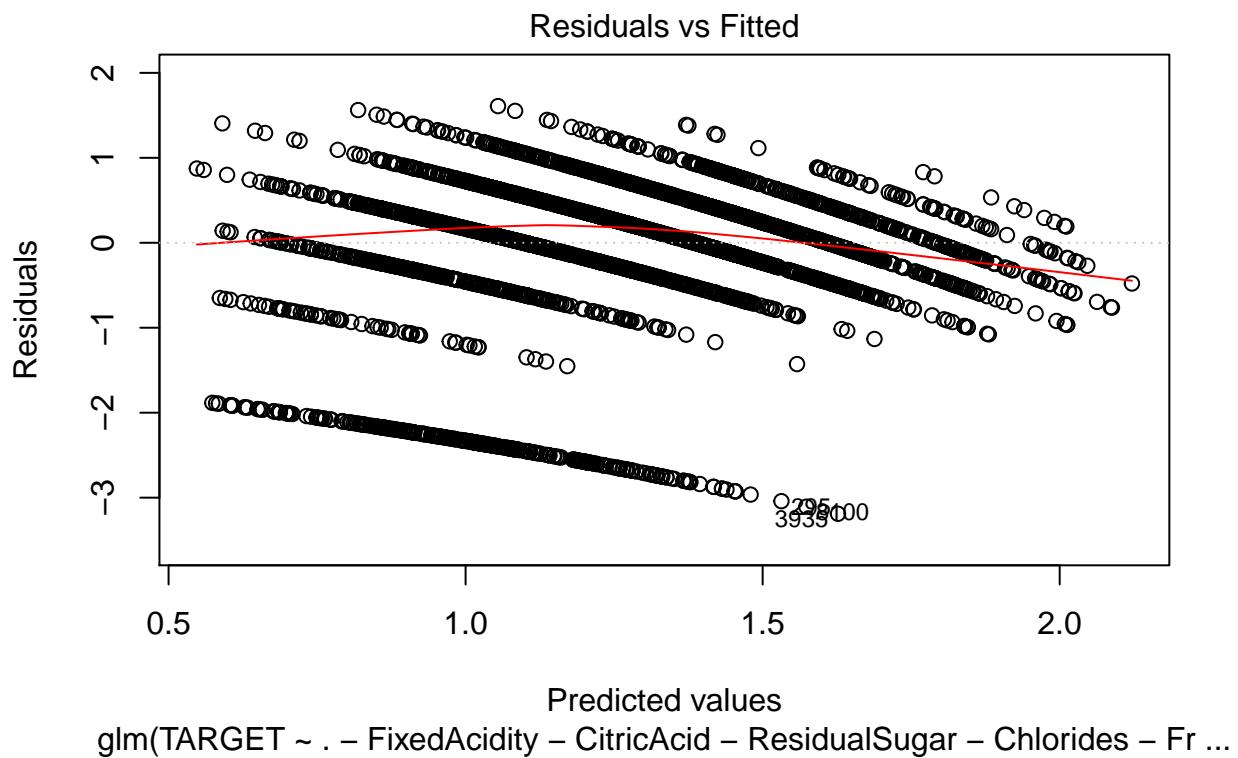


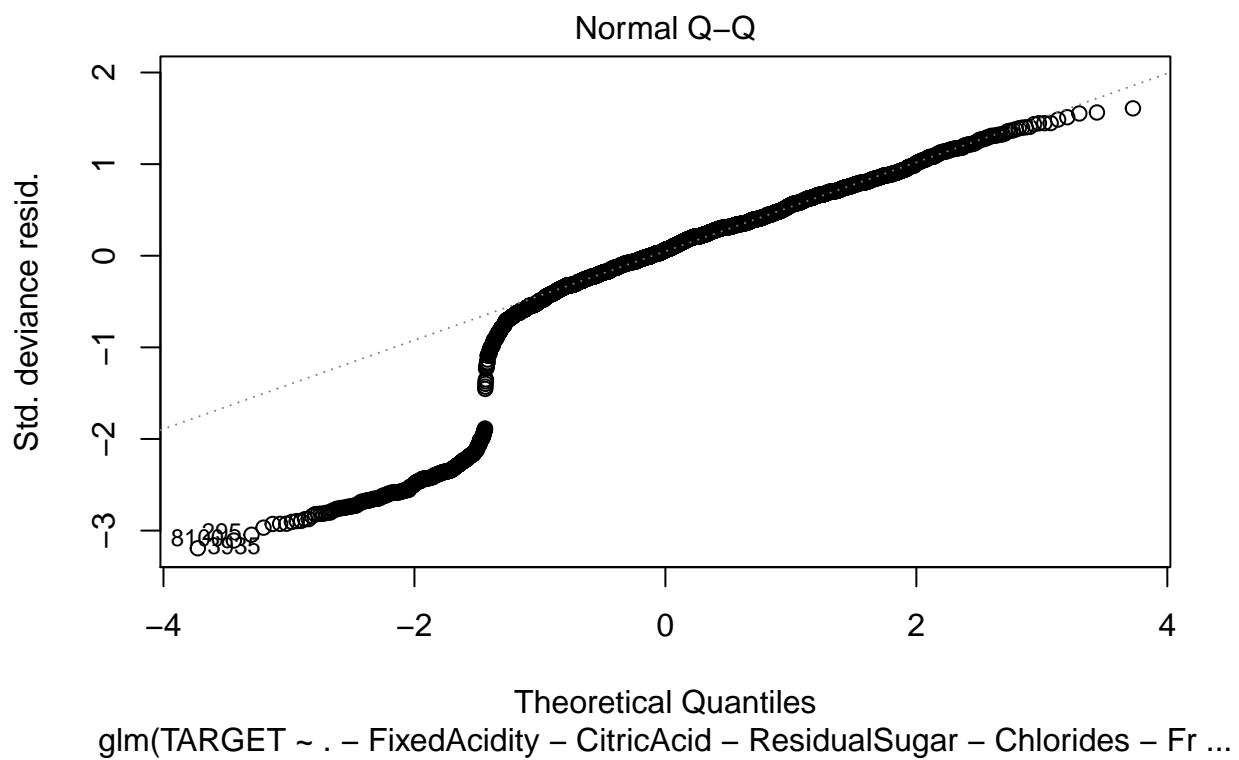


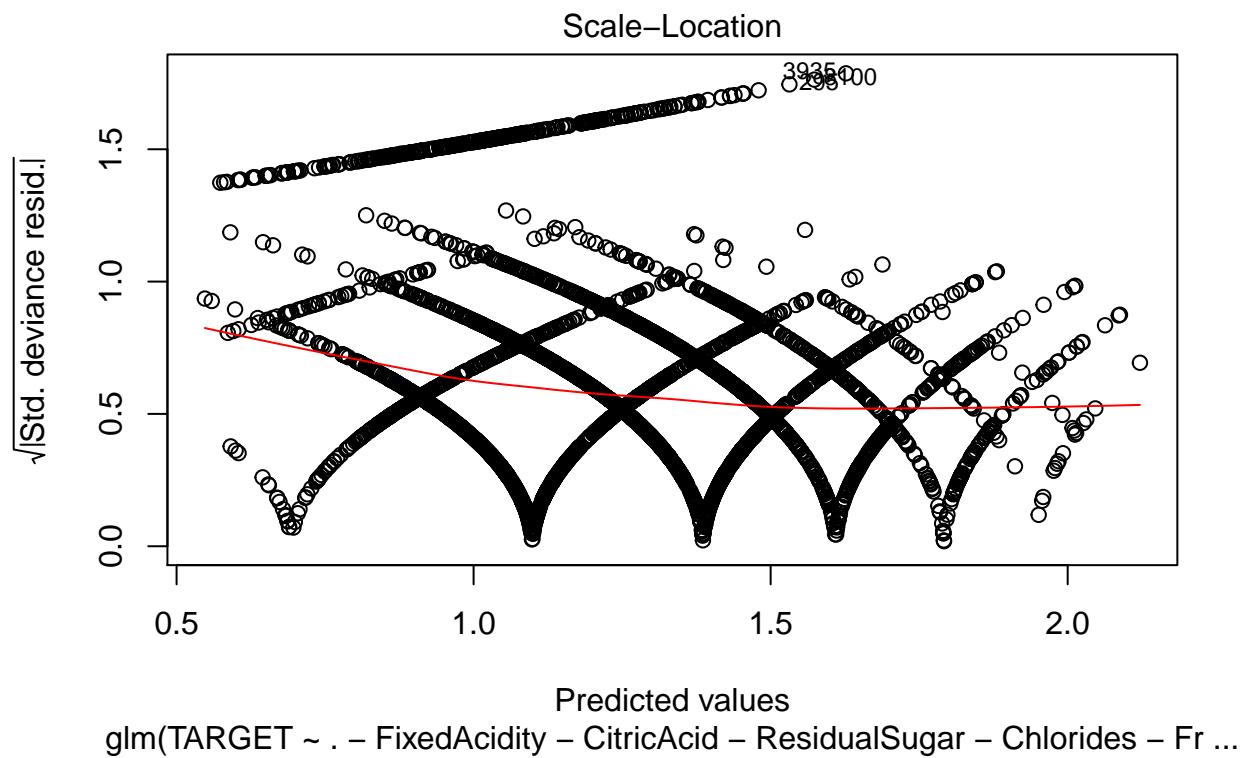
Model 2: Poisson Model without imputations and only significant variables

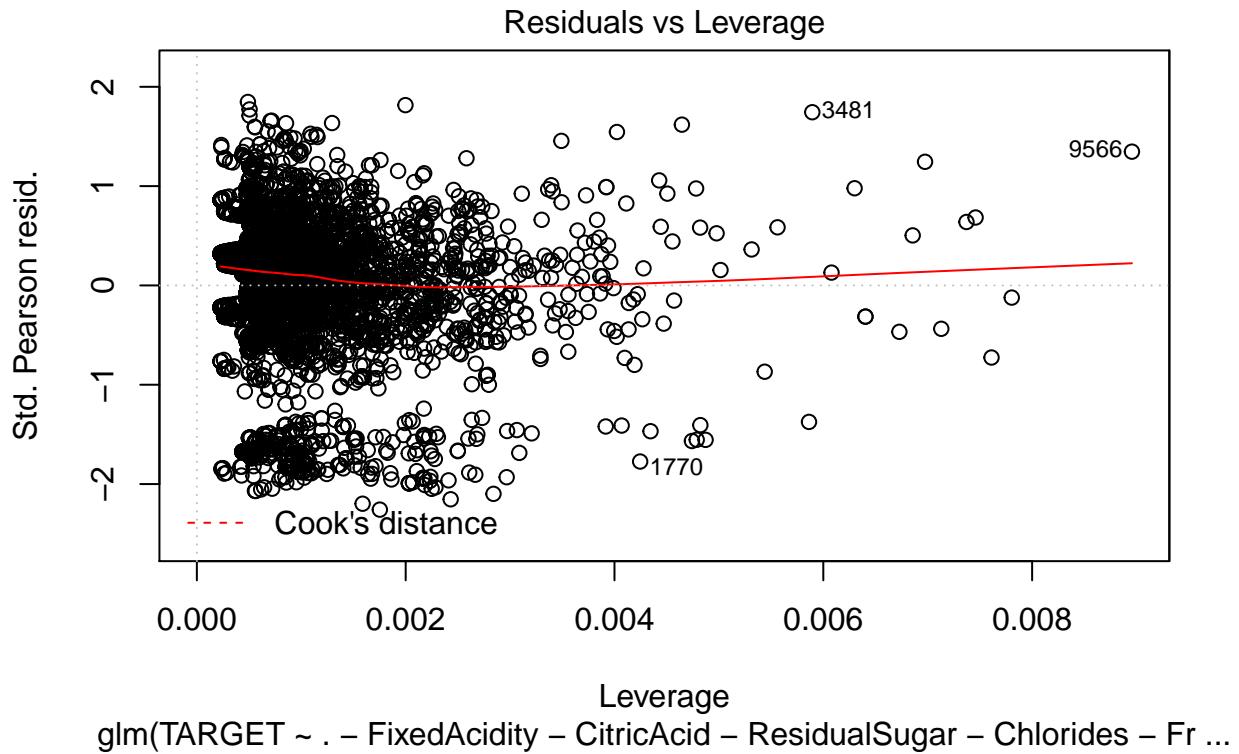
```
##
## Call:
## glm(formula = TARGET ~ . - FixedAcidity - CitricAcid - ResidualSugar -
##      Chlorides - FreeSulfurDioxide - TotalSulfurDioxide - Density -
##      pH - Sulphates - Alcohol, family = poisson, data = wine_train1)
##
## Deviance Residuals:
##    Min      1Q   Median      3Q     Max
## -3.1898 -0.2777  0.0622  0.3764  1.6086
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 1.251442  0.054724 22.868 < 2e-16 ***
## VolatileAcidity -0.027581  0.009278 -2.973  0.00295 **
## LabelAppeal  0.173177  0.008853 19.562 < 2e-16 ***
## AcidIndex   -0.050616  0.006553 -7.724 1.13e-14 ***
## STARS       0.194208  0.008292 23.421 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
## Null deviance: 4720.5 on 5143 degrees of freedom
```

```
## Residual deviance: 3253.1 on 5139 degrees of freedom
##   (5093 observations deleted due to missingness)
## AIC: 18535
##
## Number of Fisher Scoring iterations: 5
```









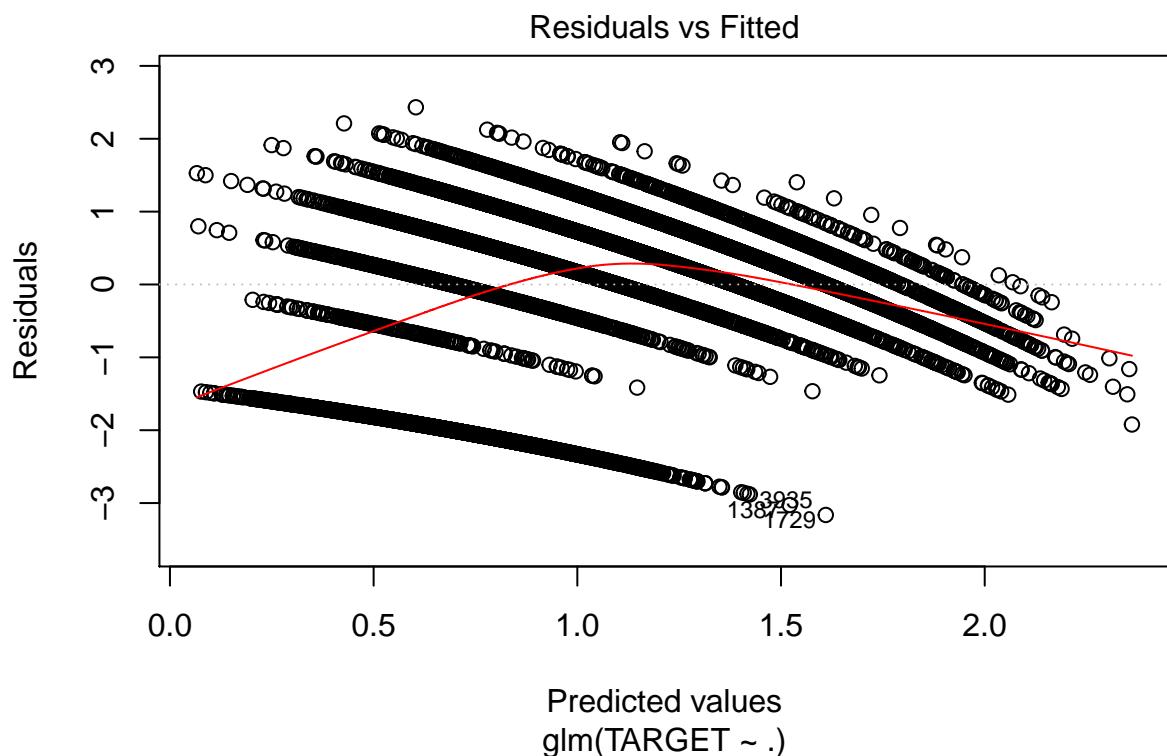
Model 3: Poisson Model with imputations

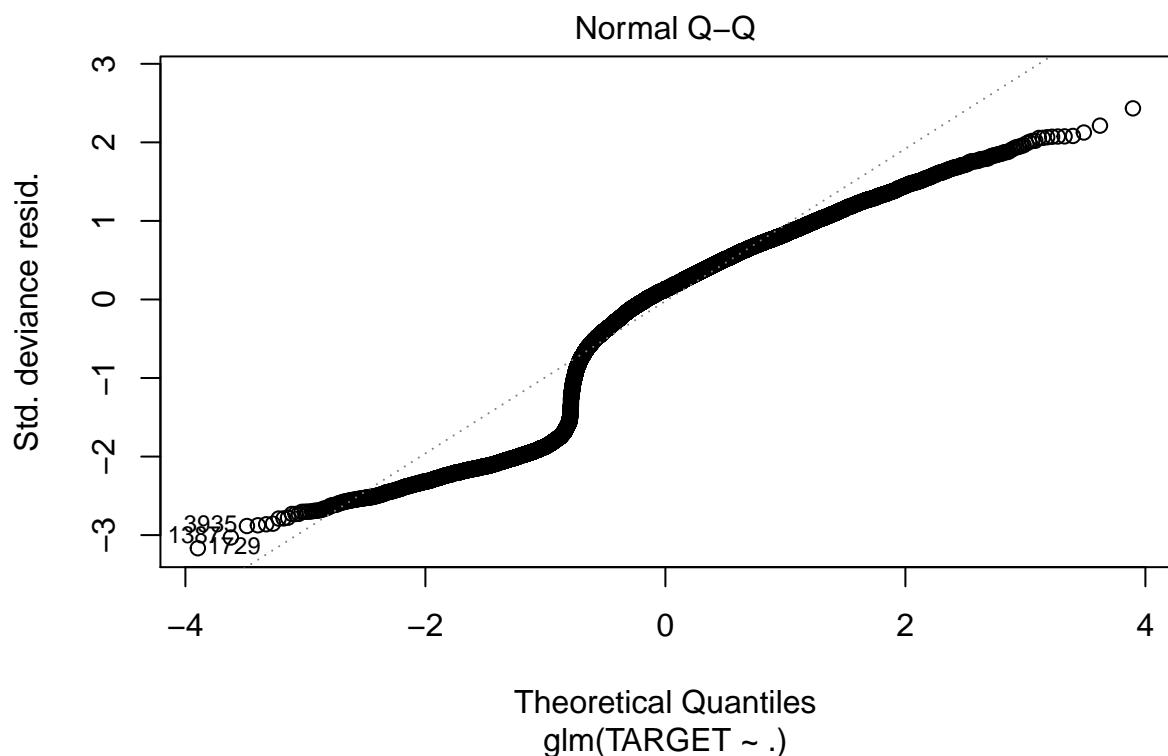
```
##
## Call:
## glm(formula = TARGET ~ ., family = poisson, data = wine_train2)
##
## Deviance Residuals:
##      Min        1Q     Median        3Q       Max
## -3.1630   -0.6739    0.1305    0.6337    2.4320
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                2.337e+00  2.281e-01 10.242 < 2e-16 ***
## FixedAcidity               2.250e-04  9.190e-04  0.245 0.806610
## VolatileAcidity            -4.313e-02  7.286e-03 -5.919 3.23e-09 ***
## CitricAcid                 8.534e-03  6.573e-03  1.298 0.194168
## ResidualSugar              1.271e-04  1.675e-04  0.759 0.448033
## Chlorides                  -6.572e-02  1.790e-02 -3.673 0.000240 ***
## FreeSulfurDioxide          1.336e-04  3.804e-05  3.512 0.000444 ***
## TotalSulfurDioxide         9.235e-05  2.460e-05  3.754 0.000174 ***
## Density                   -3.404e-01  2.144e-01 -1.588 0.112379
## pH                        -1.962e-02  8.417e-03 -2.331 0.019744 *
## Sulphates                 -1.569e-02  6.157e-03 -2.549 0.010805 *
## Alcohol                   2.951e-03  1.554e-03  1.898 0.057632 .
## LabelAppeal                1.409e-01  6.798e-03 20.724 < 2e-16 ***
##
```

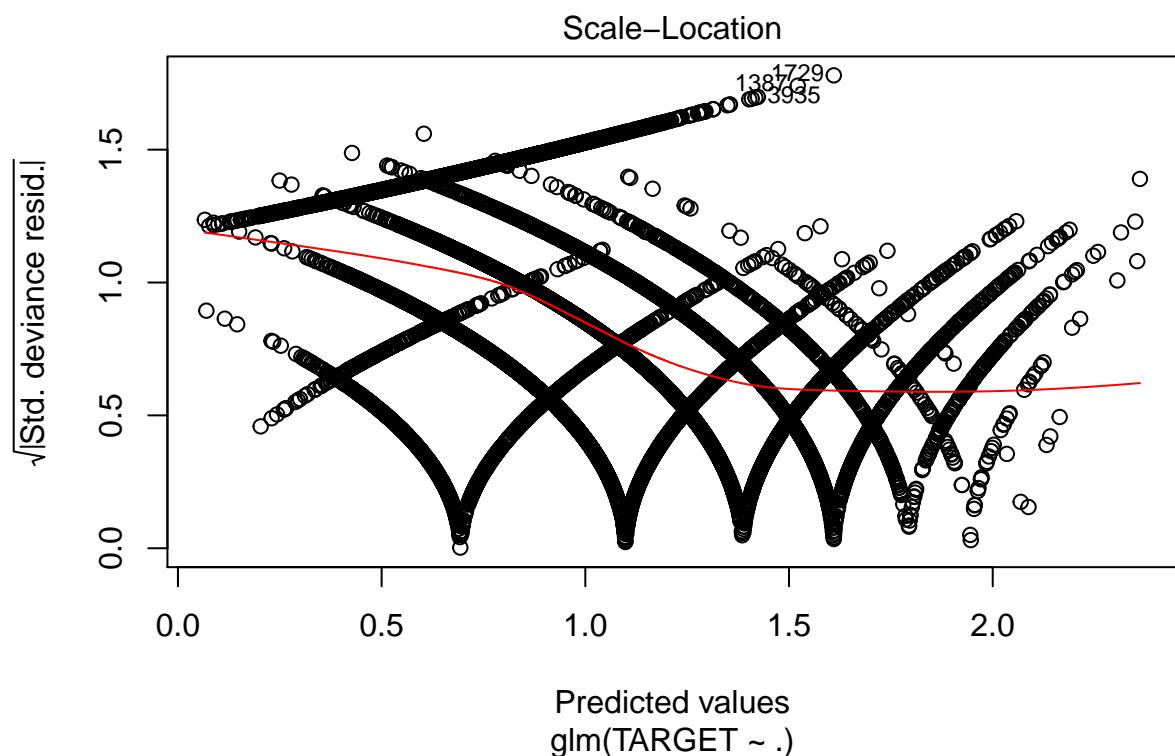
```

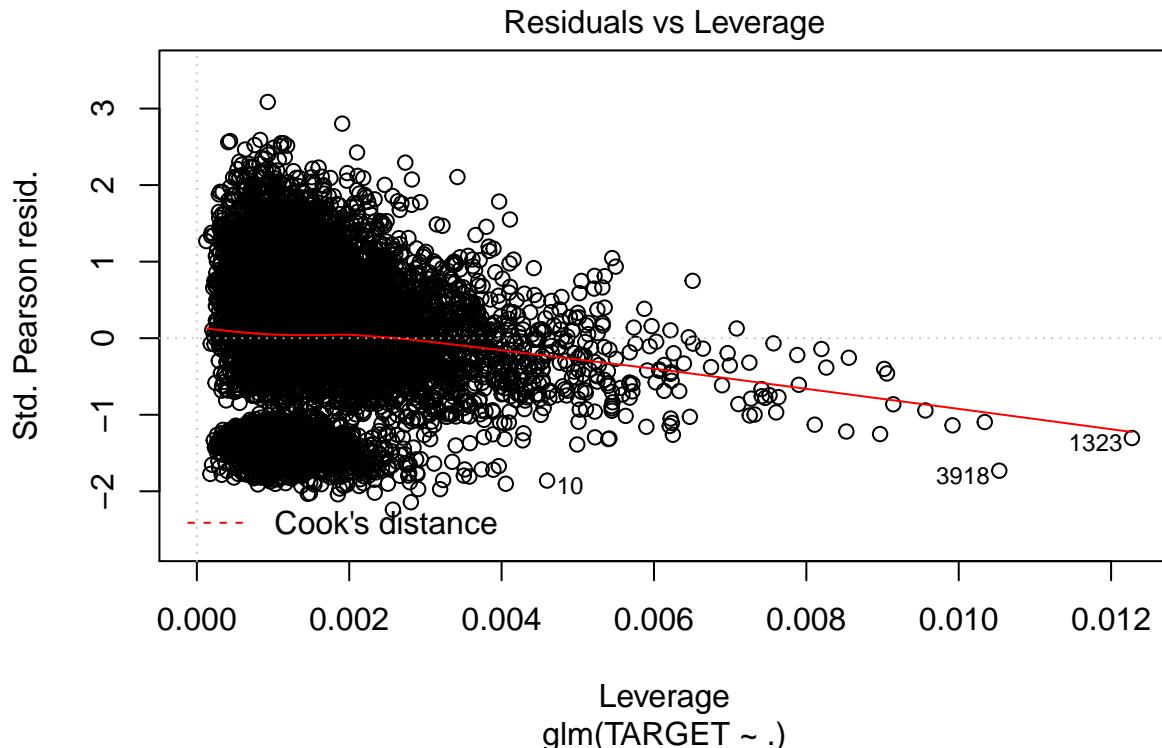
## AcidIndex      -7.709e-01  3.998e-02 -19.280 < 2e-16 ***
## STARS         3.407e-01  6.270e-03  54.337 < 2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
## Null deviance: 18291 on 10236 degrees of freedom
## Residual deviance: 12829 on 10222 degrees of freedom
## AIC: 38417
##
## Number of Fisher Scoring iterations: 5

```









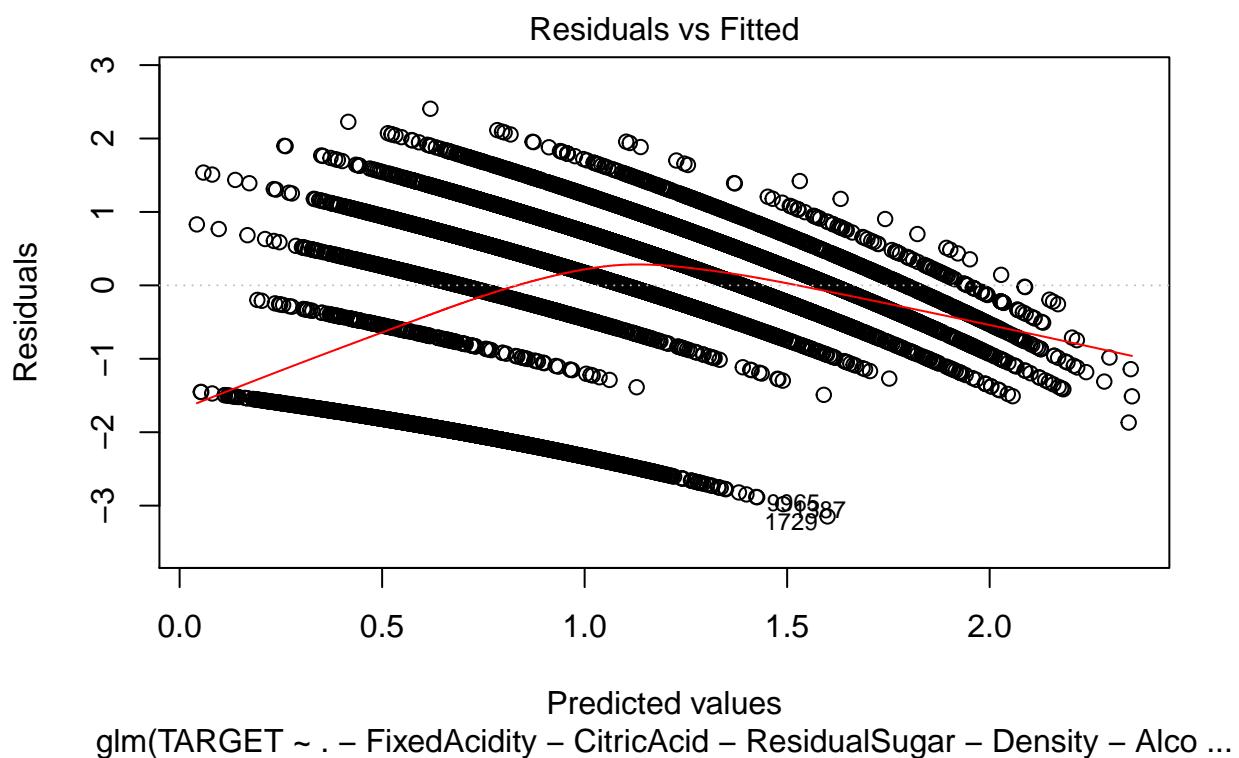
Model 4: Poisson Model with imputations and only significant variables

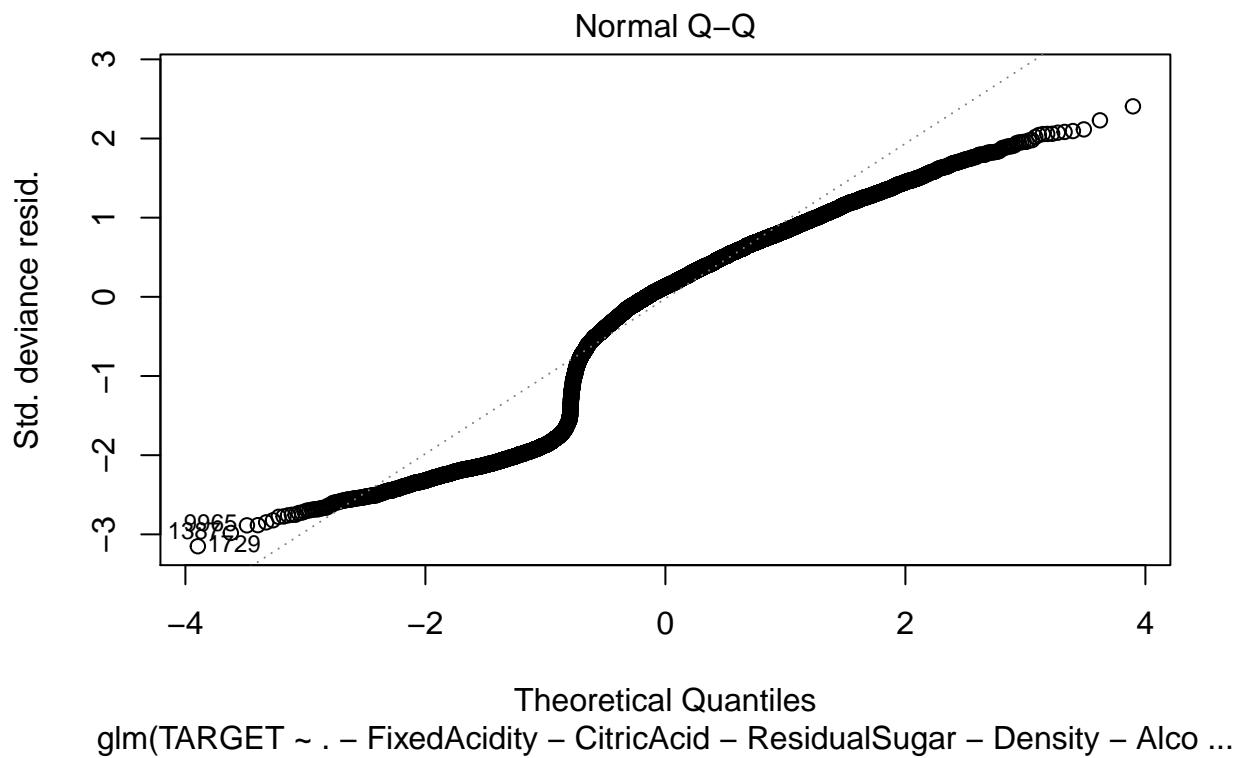
```
##
## Call:
## glm(formula = TARGET ~ . - FixedAcidity - CitricAcid - ResidualSugar -
##      Density - Alcohol, family = poisson, data = wine_train2)
##
## Deviance Residuals:
##    Min      1Q   Median      3Q     Max
## -3.1469 -0.6828  0.1295  0.6379  2.4054
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 2.038e+00 8.840e-02 23.052 < 2e-16 ***
## VolatileAcidity -4.348e-02 7.284e-03 -5.969 2.39e-09 ***
## Chlorides -6.725e-02 1.789e-02 -3.760 0.000170 ***
## FreeSulfurDioxide 1.316e-04 3.801e-05 3.461 0.000537 ***
## TotalSulfurDioxide 9.150e-05 2.458e-05 3.723 0.000197 ***
## pH -1.991e-02 8.415e-03 -2.366 0.018003 *
## Sulphates -1.563e-02 6.153e-03 -2.540 0.011086 *
## LabelAppeal 1.409e-01 6.798e-03 20.727 < 2e-16 ***
## AcidIndex -7.729e-01 3.936e-02 -19.636 < 2e-16 ***
## STARS 3.417e-01 6.255e-03 54.634 < 2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

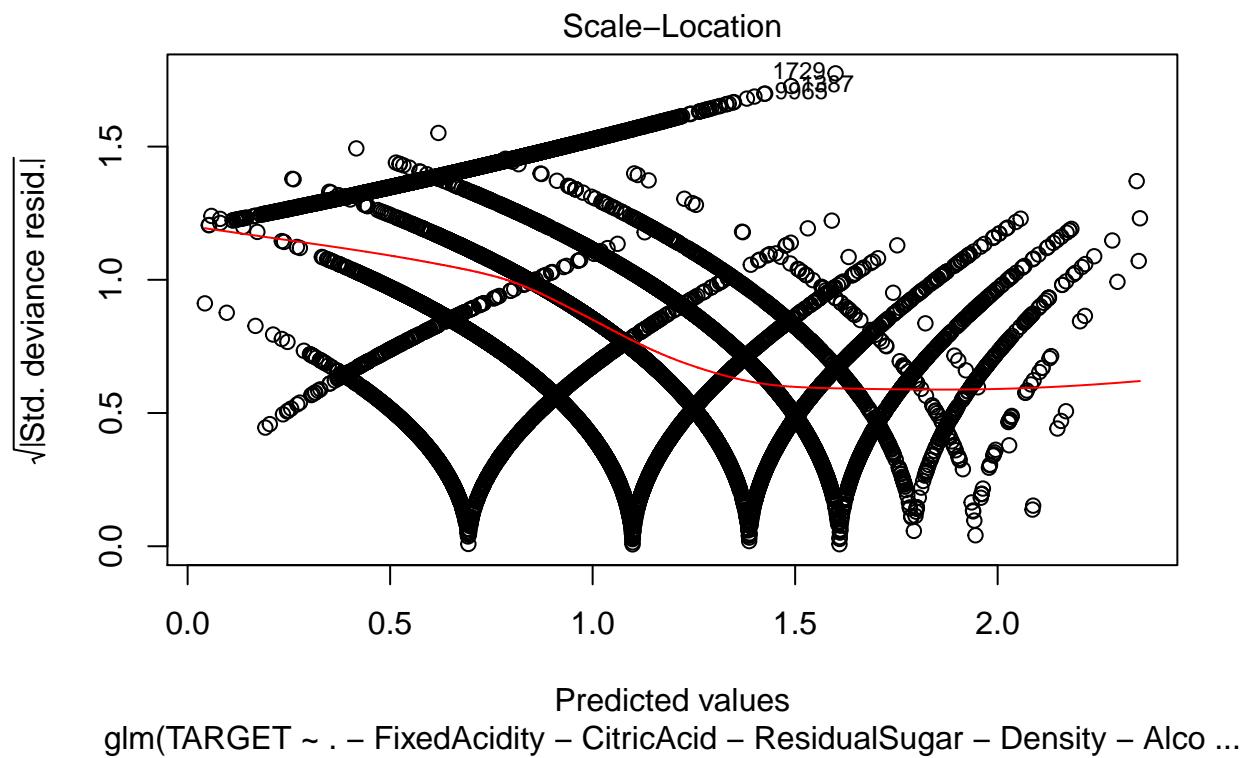
```

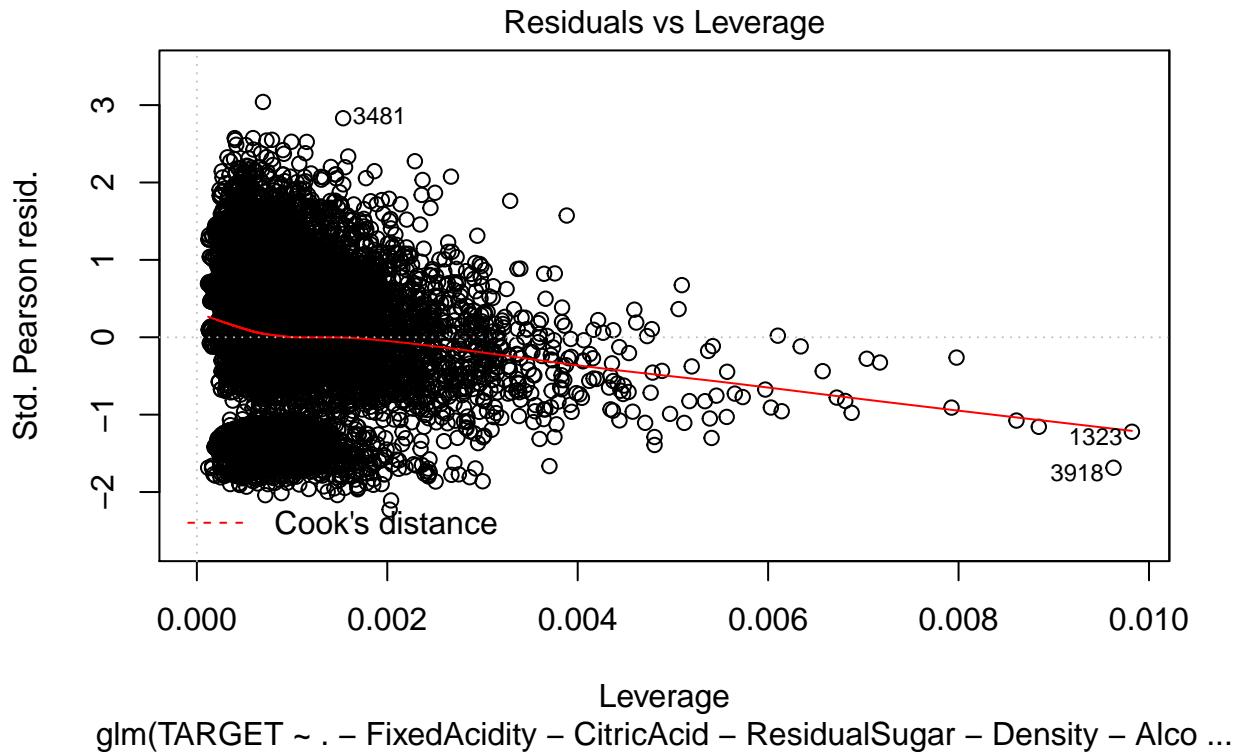
## 
## (Dispersion parameter for poisson family taken to be 1)
## 
## Null deviance: 18291 on 10236 degrees of freedom
## Residual deviance: 12837 on 10227 degrees of freedom
## AIC: 38415
## 
## Number of Fisher Scoring iterations: 5

```









Model II: Negative Binomial Model

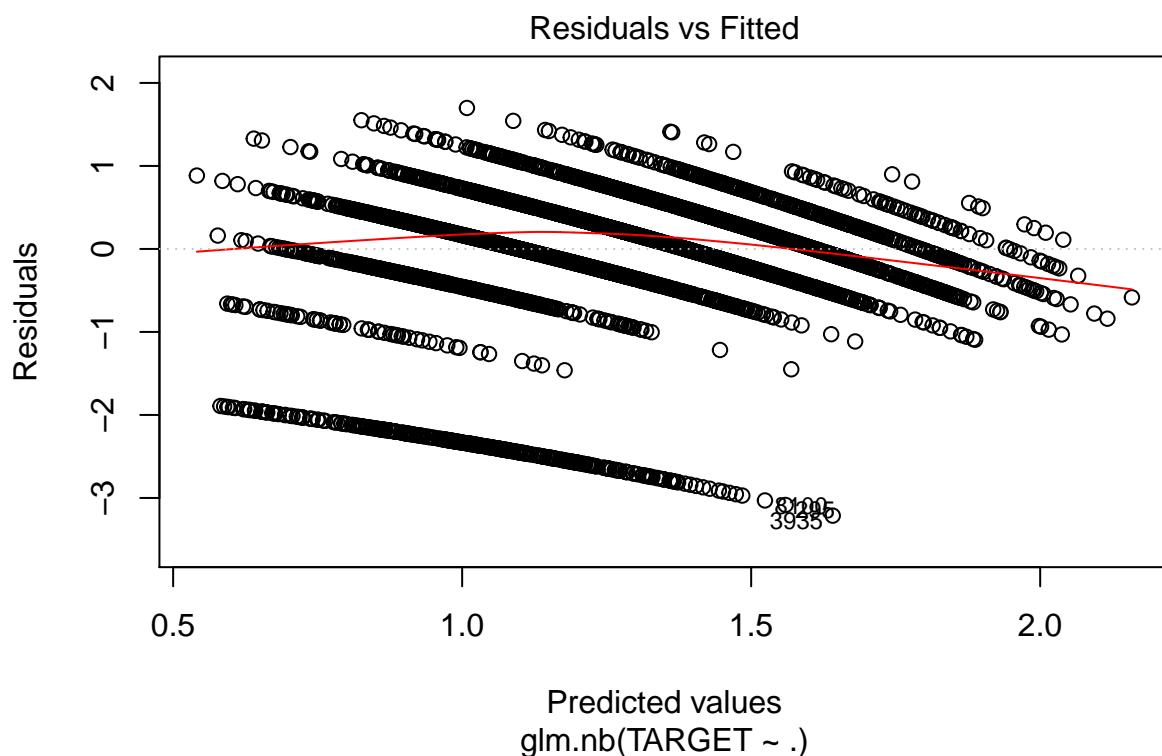
Model 5 : Negative Binomial Model without imputations

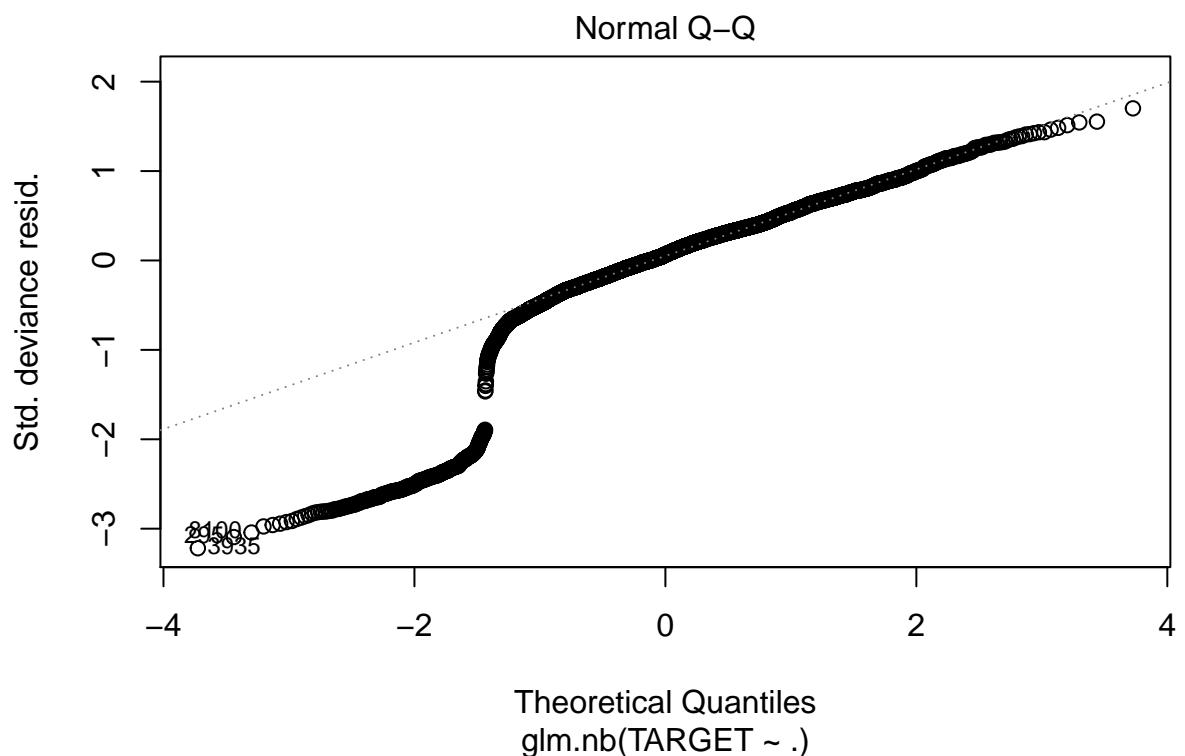
```
##
## Call:
## glm.nb(formula = TARGET ~ ., data = wine_train1, init.theta = 138898.9107,
##         link = log)
##
## Deviance Residuals:
##    Min      1Q      Median      3Q      Max
## -3.2127 -0.2757   0.0647   0.3766   1.6981
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 1.608e+00 2.796e-01  5.750 8.91e-09 ***
## FixedAcidity 6.705e-04 1.177e-03  0.570  0.56900
## VolatileAcidity -2.750e-02 9.283e-03 -2.963  0.00305 **
## CitricAcid -3.835e-03 8.519e-03 -0.450  0.65259
## ResidualSugar 1.828e-05 2.152e-04  0.085  0.93231
## Chlorides -3.764e-02 2.314e-02 -1.627  0.10378
## FreeSulfurDioxide 5.671e-05 4.892e-05  1.159  0.24630
## TotalSulfurDioxide 2.230e-05 3.177e-05  0.702  0.48275
## Density -4.025e-01 2.750e-01 -1.464  0.14326
## pH        2.307e-04 1.085e-02  0.021  0.98303
```

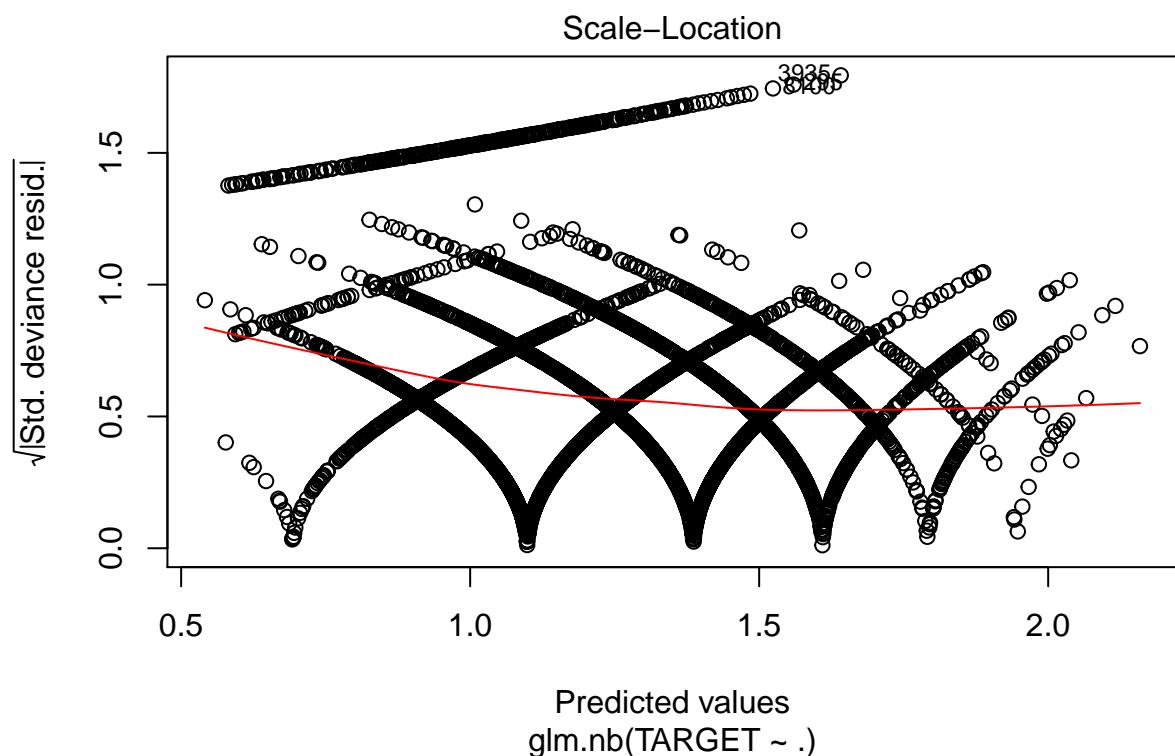
```

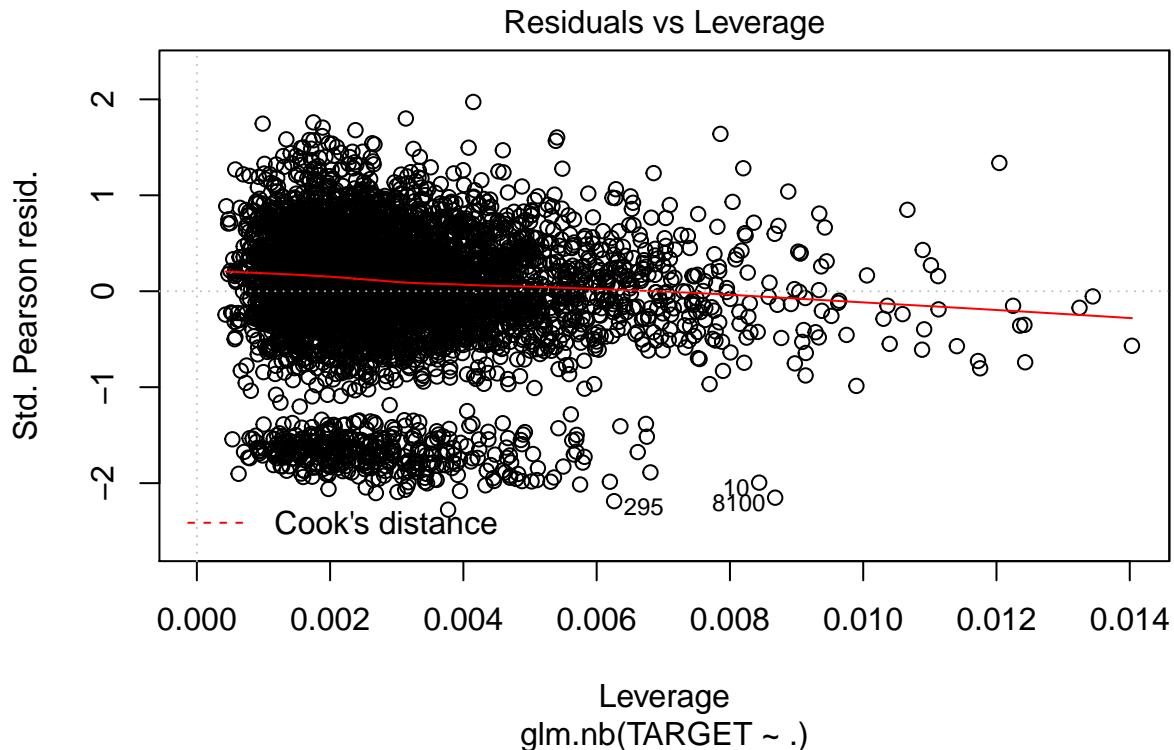
## Sulphates      -5.984e-03 7.973e-03 -0.751  0.45293
## Alcohol        3.262e-03 2.004e-03  1.628  0.10360
## LabelAppeal    1.730e-01 8.858e-03 19.529 < 2e-16 ***
## AcidIndex      -4.967e-02 6.666e-03 -7.451 9.28e-14 ***
## STARS          1.929e-01 8.328e-03 23.160 < 2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(138898.9) family taken to be 1)
##
## Null deviance: 4720.4 on 5143 degrees of freedom
## Residual deviance: 3242.7 on 5129 degrees of freedom
## (5093 observations deleted due to missingness)
## AIC: 18547
##
## Number of Fisher Scoring iterations: 1
##
##
## Theta: 138899
## Std. Err.: 259921
## Warning while fitting theta: iteration limit reached
##
## 2 x log-likelihood: -18515.07

```









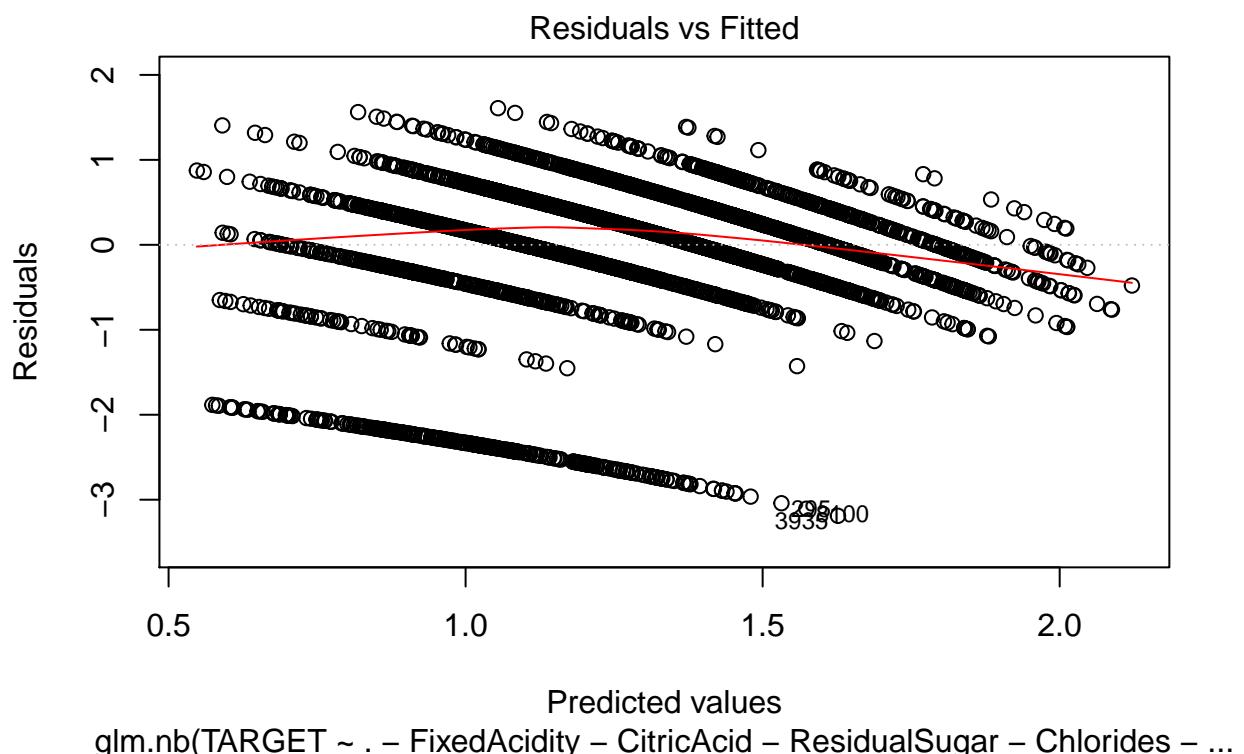
Model 6 : Negative Binomial Model without imputations and only significant variables

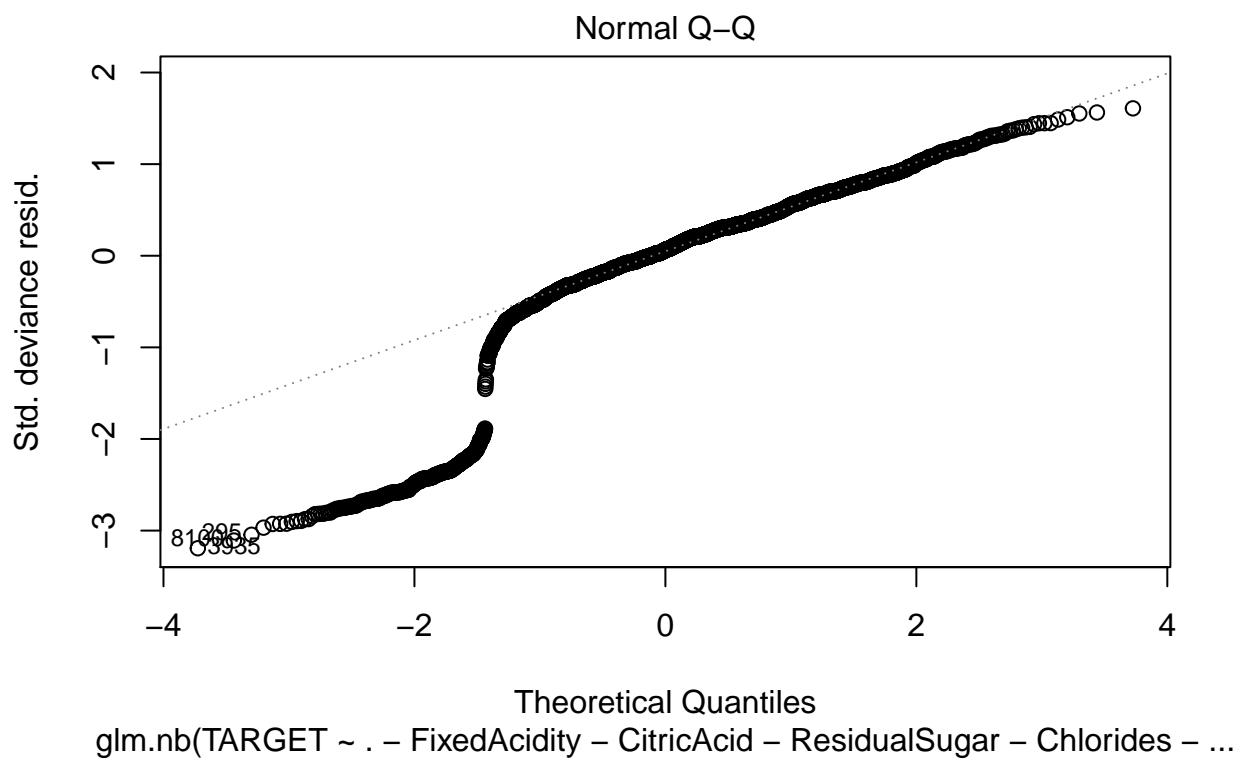
```
##
## Call:
## glm.nb(formula = TARGET ~ . - FixedAcidity - CitricAcid - ResidualSugar -
##         Chlorides - FreeSulfurDioxide - TotalSulfurDioxide - Density -
##         pH - Sulphates - Alcohol, data = wine_train1, init.theta = 138402.5261,
##         link = log)
##
## Deviance Residuals:
##      Min        1Q     Median        3Q       Max
## -3.1898   -0.2777    0.0622    0.3764    1.6086
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 1.251443  0.054725 22.868 < 2e-16 ***
## VolatileAcidity -0.027581  0.009279 -2.973  0.00295 **
## LabelAppeal  0.173177  0.008853 19.562 < 2e-16 ***
## AcidIndex    -0.050616  0.006553 -7.724 1.13e-14 ***
## STARS        0.194209  0.008292 23.421 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(138402.5) family taken to be 1)
##
```

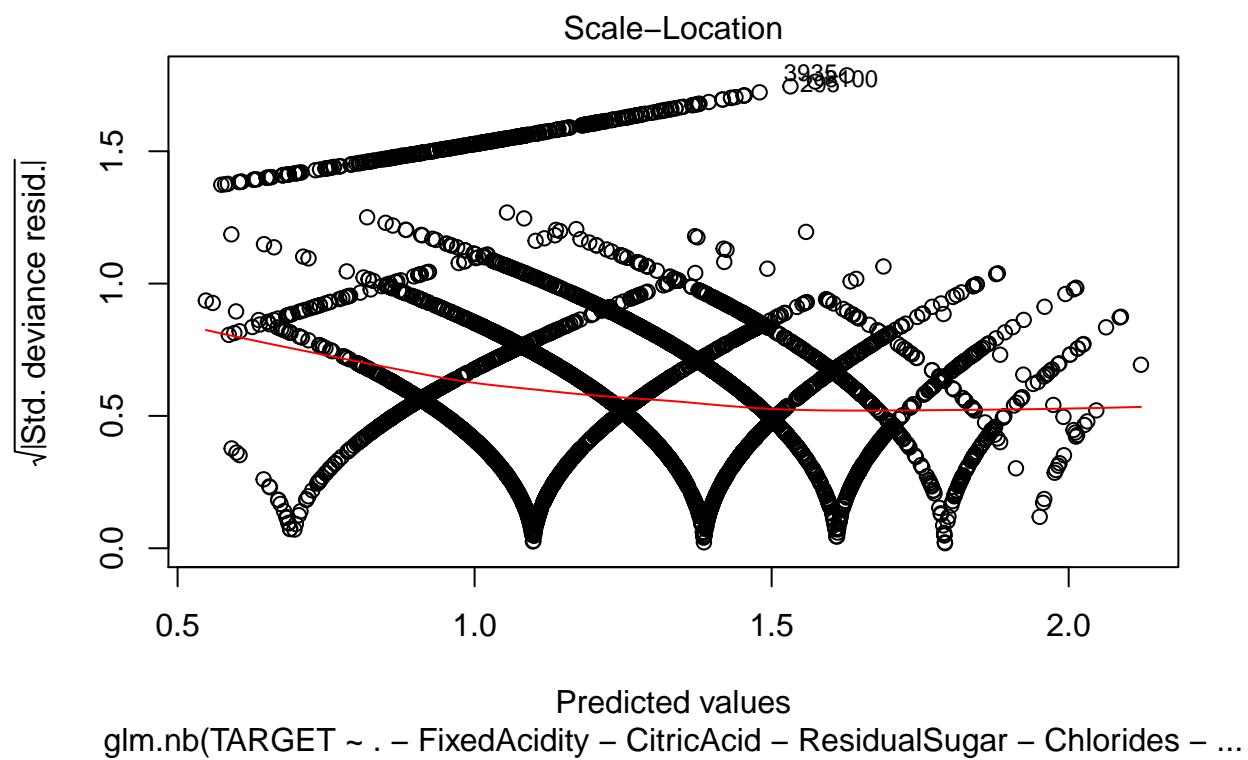
```

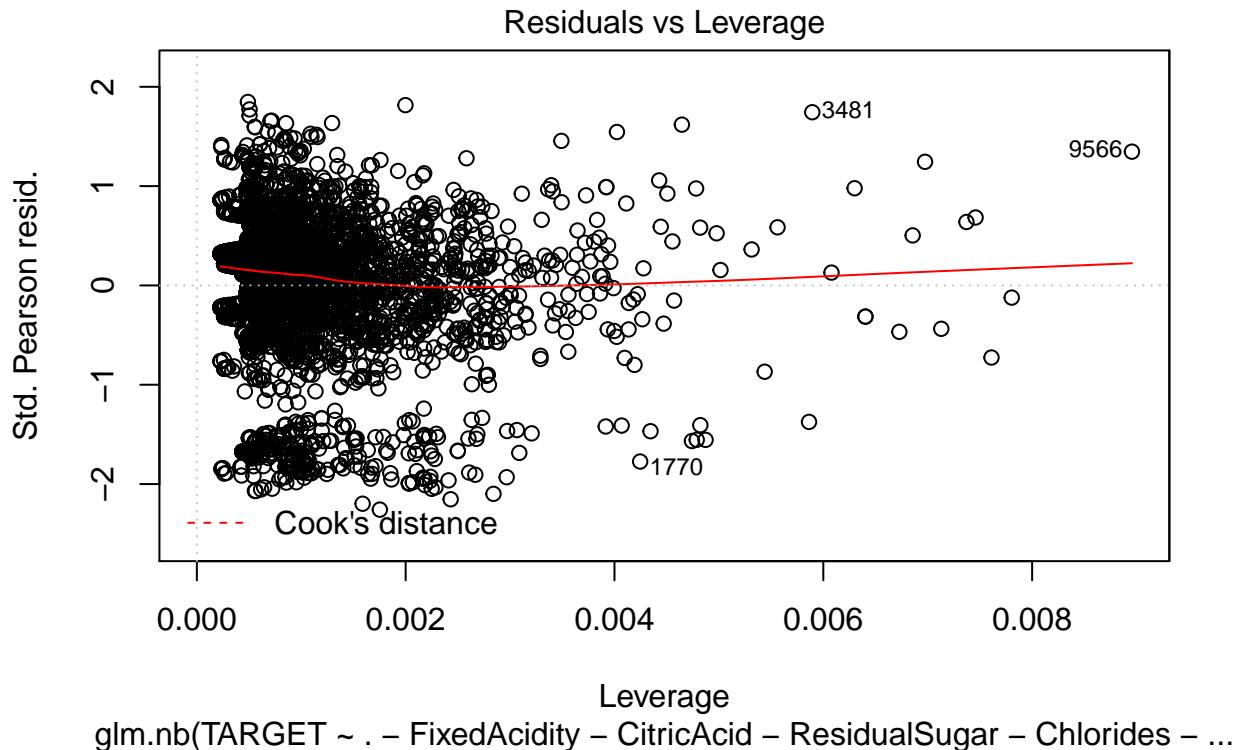
##      Null deviance: 4720.4  on 5143  degrees of freedom
## Residual deviance: 3253.0  on 5139  degrees of freedom
## (5093 observations deleted due to missingness)
## AIC: 18537
##
## Number of Fisher Scoring iterations: 1
##
##
##          Theta:  138403
##          Std. Err.: 258834
## Warning while fitting theta: iteration limit reached
##
## 2 x log-likelihood: -18525.37

```









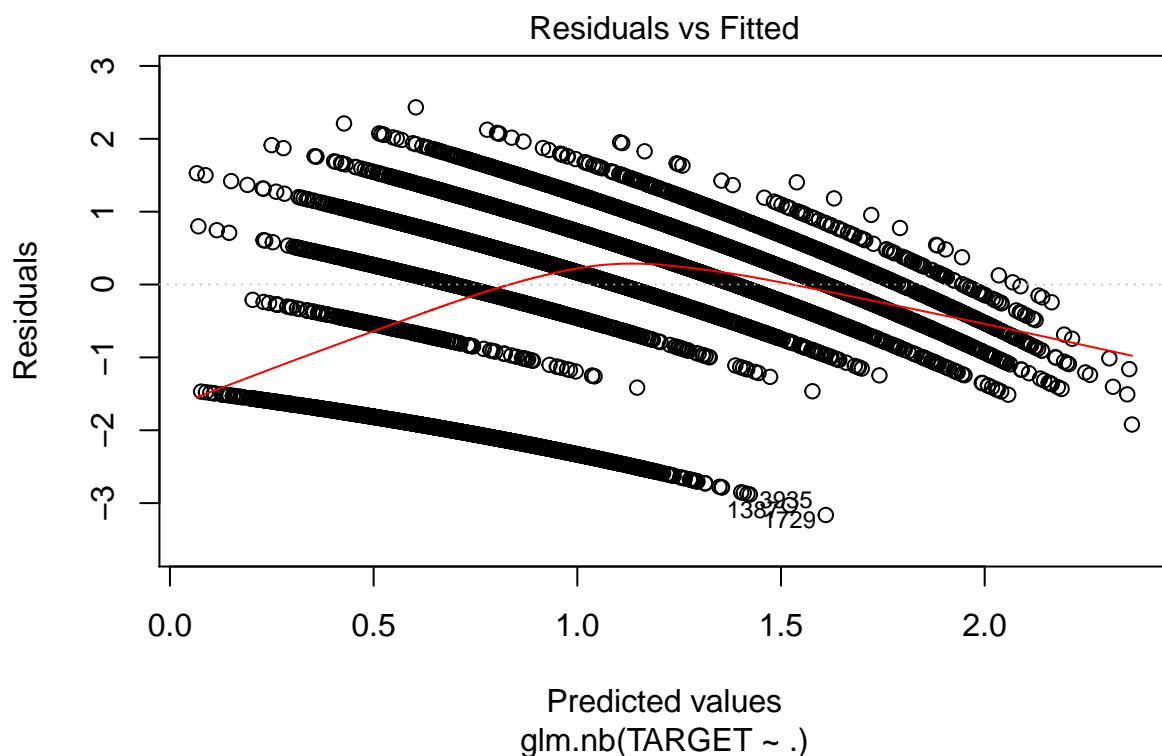
Model 7 : Negative Binomial Model with imputations

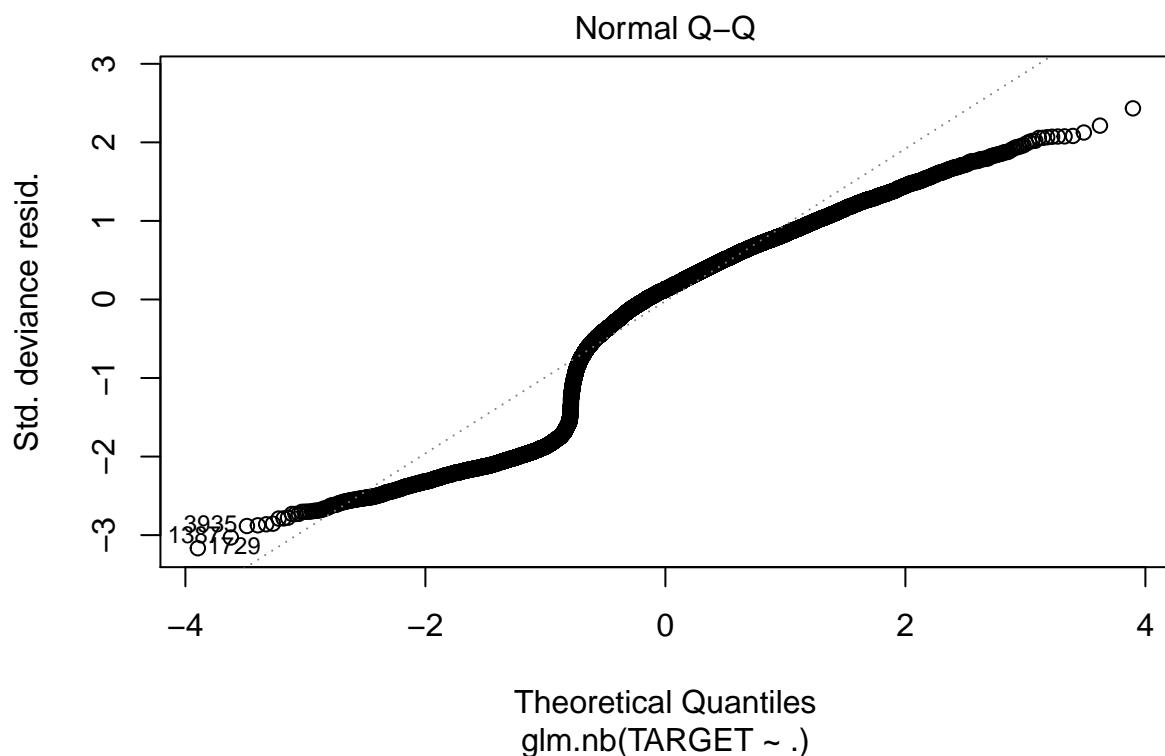
```
##
## Call:
## glm.nb(formula = TARGET ~ ., data = wine_train2, init.theta = 49078.50992,
##         link = log)
##
## Deviance Residuals:
##    Min      1Q   Median      3Q     Max
## -3.1629 -0.6739  0.1305  0.6337  2.4320
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)             2.337e+00  2.281e-01 10.242 < 2e-16 ***
## FixedAcidity            2.250e-04  9.190e-04  0.245  0.806608
## VolatileAcidity        -4.313e-02  7.286e-03 -5.919 3.23e-09 ***
## CitricAcid              8.534e-03  6.573e-03  1.298  0.194177
## ResidualSugar           1.271e-04  1.675e-04  0.759  0.448021
## Chlorides               -6.573e-02  1.790e-02 -3.673  0.000240 ***
## FreeSulfurDioxide       1.336e-04  3.804e-05  3.512  0.000444 ***
## TotalSulfurDioxide      9.235e-05  2.460e-05  3.754  0.000174 ***
## Density                 -3.404e-01  2.144e-01 -1.588  0.112389
## pH                      -1.962e-02  8.418e-03 -2.331  0.019745 *
## Sulphates               -1.569e-02  6.157e-03 -2.549  0.010806 *
## Alcohol                 2.951e-03  1.554e-03  1.898  0.057642 .
##
```

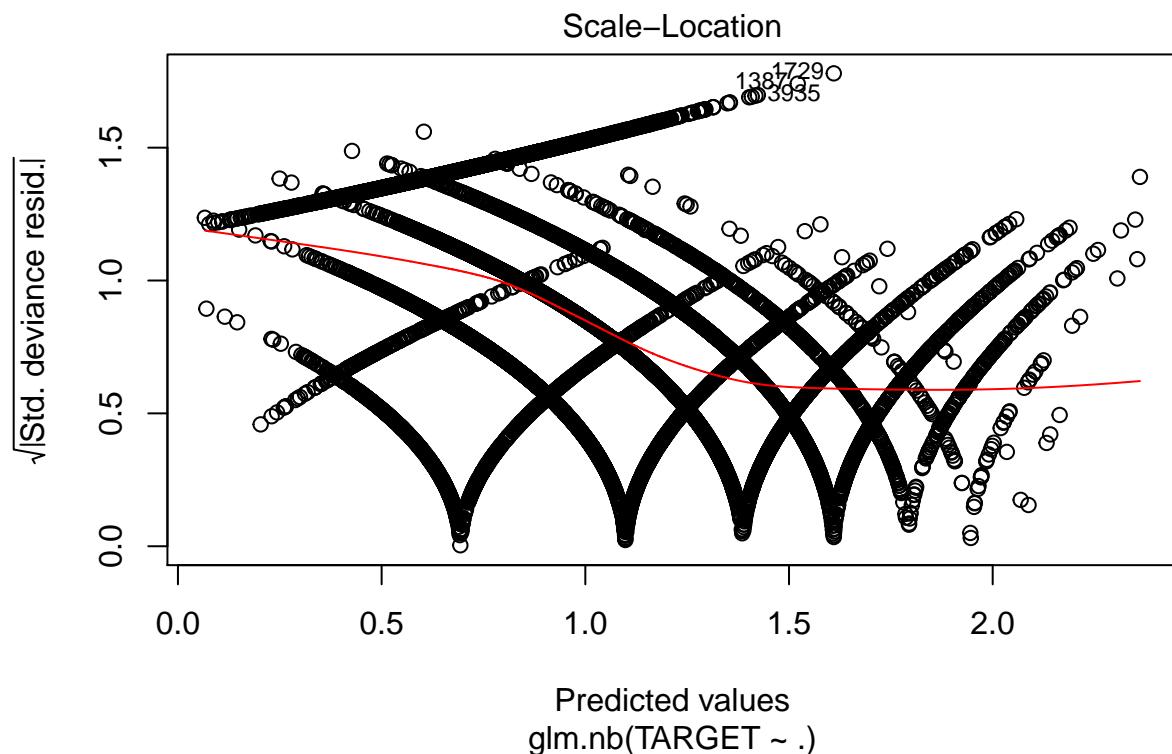
```

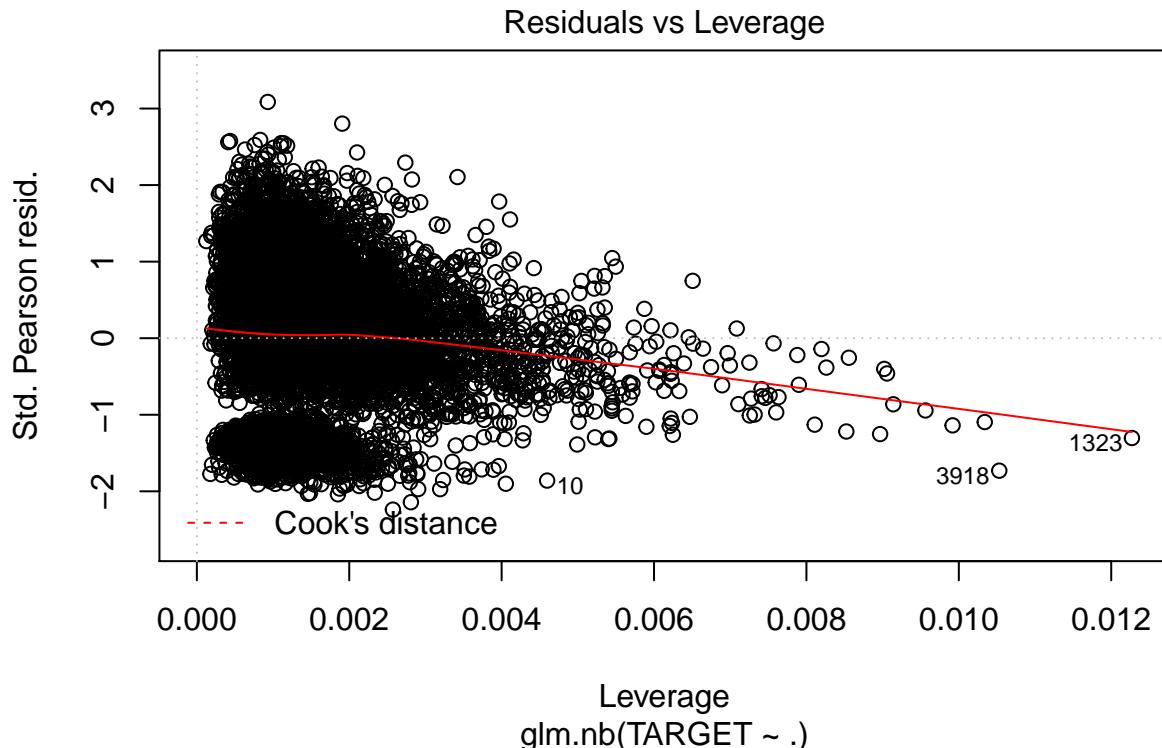
## LabelAppeal      1.409e-01  6.798e-03  20.723 < 2e-16 ***
## AcidIndex       -7.709e-01  3.999e-02 -19.279 < 2e-16 ***
## STARS          3.407e-01  6.270e-03  54.335 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(49078.51) family taken to be 1)
##
## Null deviance: 18290  on 10236  degrees of freedom
## Residual deviance: 12828  on 10222  degrees of freedom
## AIC: 38419
##
## Number of Fisher Scoring iterations: 1
##
##
## Theta: 49079
## Std. Err.: 63619
## Warning while fitting theta: iteration limit reached
##
## 2 x log-likelihood: -38387.04

```









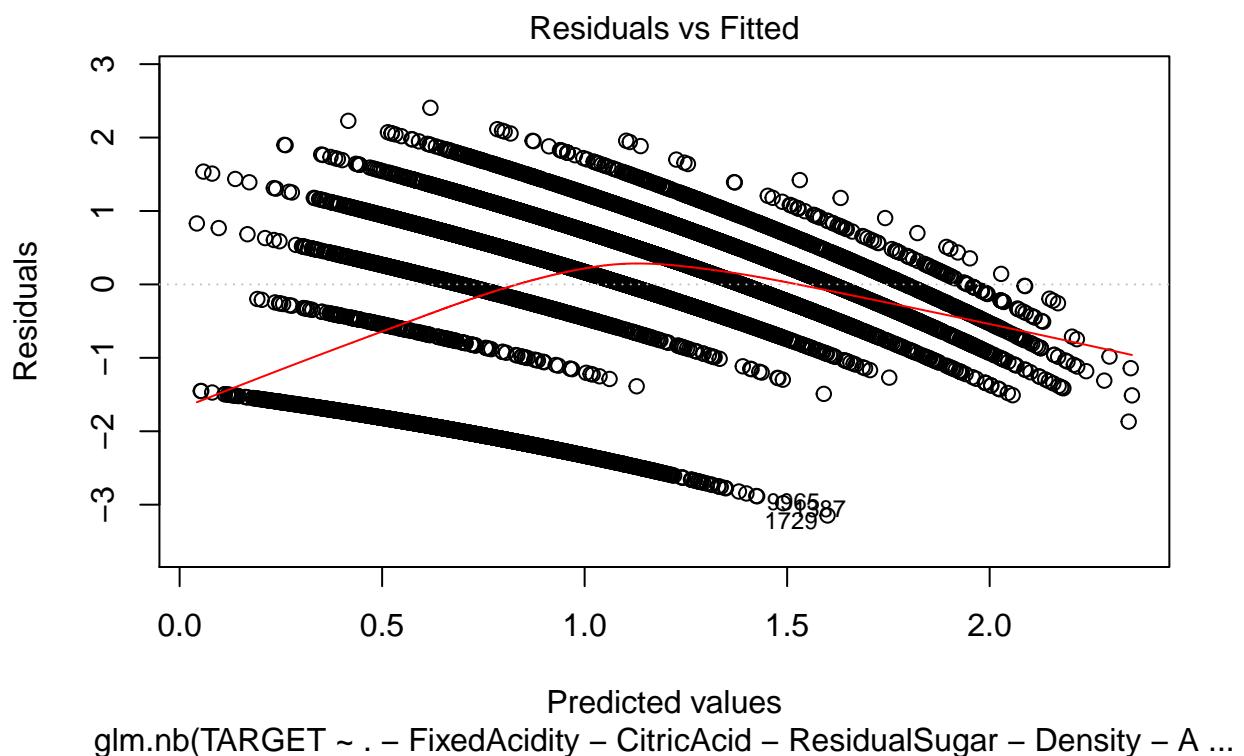
Model 8 : Negative Binomial Model with imputations and only significant variables

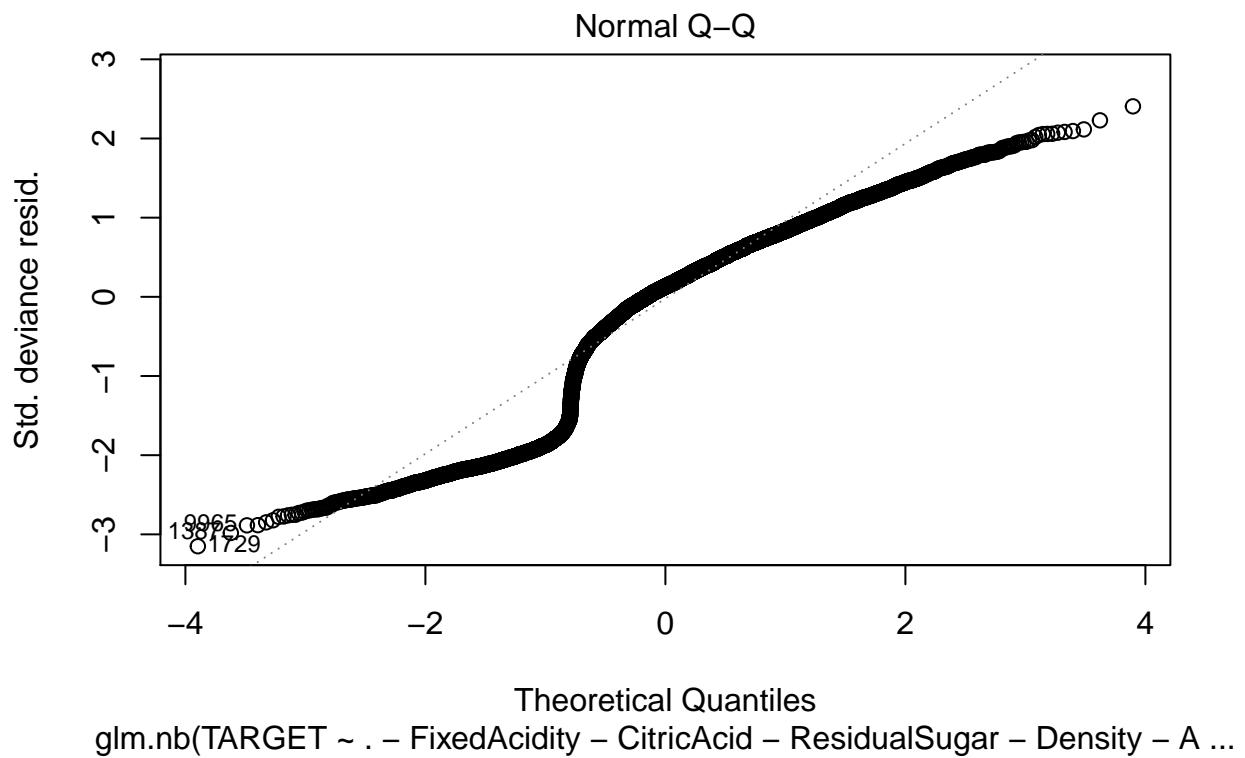
```
##
## Call:
## glm.nb(formula = TARGET ~ . - FixedAcidity - CitricAcid - ResidualSugar -
##         Density - Alcohol, data = wine_train2, init.theta = 48992.35936,
##         link = log)
##
## Deviance Residuals:
##    Min      1Q  Median      3Q     Max
## -3.1469 -0.6828  0.1295  0.6379  2.4053
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) 2.038e+00 8.840e-02 23.052 < 2e-16 ***
## VolatileAcidity -4.348e-02 7.284e-03 -5.969 2.39e-09 ***
## Chlorides     -6.726e-02 1.789e-02 -3.760 0.000170 ***
## FreeSulfurDioxide 1.316e-04 3.801e-05 3.461 0.000537 ***
## TotalSulfurDioxide 9.150e-05 2.458e-05 3.723 0.000197 ***
## pH          -1.991e-02 8.415e-03 -2.366 0.018004 *
## Sulphates    -1.563e-02 6.153e-03 -2.540 0.011087 *
## LabelAppeal   1.409e-01 6.798e-03 20.726 < 2e-16 ***
## AcidIndex    -7.730e-01 3.936e-02 -19.636 < 2e-16 ***
## STARS        3.417e-01 6.255e-03 54.632 < 2e-16 ***
## ---
```

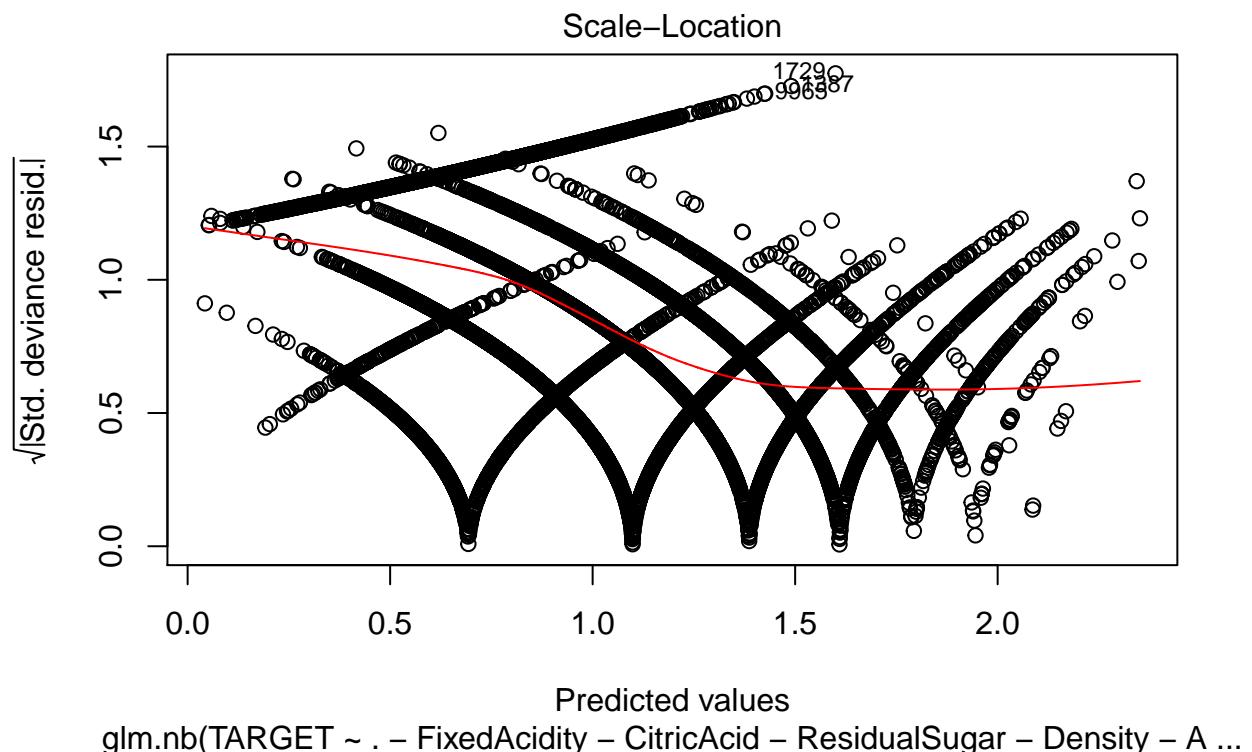
```

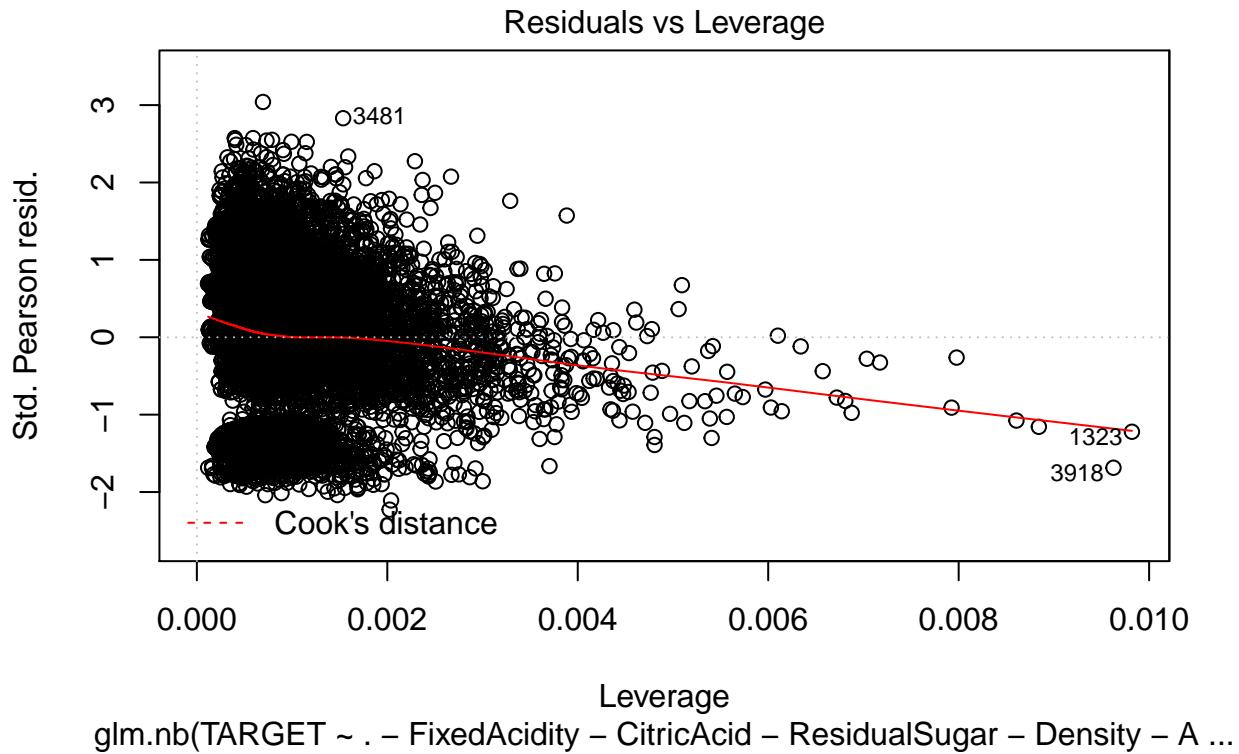
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(48992.36) family taken to be 1)
##
##      Null deviance: 18290  on 10236  degrees of freedom
## Residual deviance: 12837  on 10227  degrees of freedom
## AIC: 38418
##
## Number of Fisher Scoring iterations: 1
##
##
##          Theta:  48992
##          Std. Err.: 63531
## Warning while fitting theta: iteration limit reached
##
## 2 x log-likelihood: -38395.56

```









Model III: Linear Model

Model 9 : Linear Model with imputations

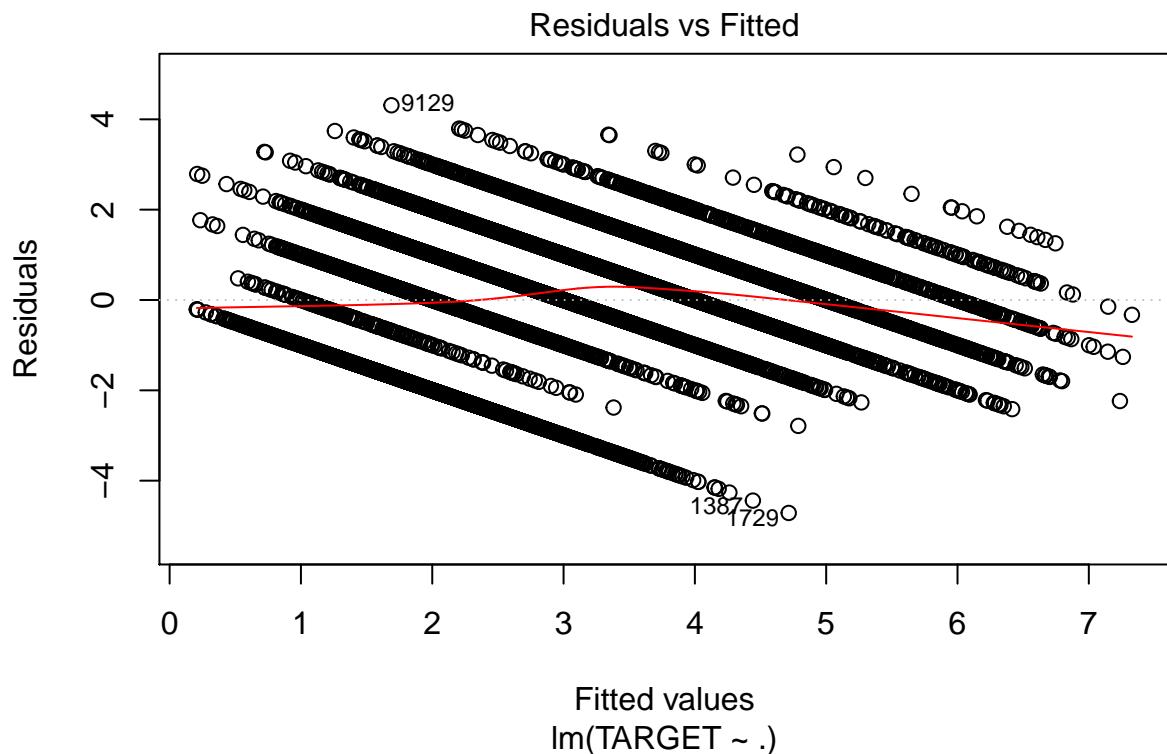
Use imputed training data on Linear regression model

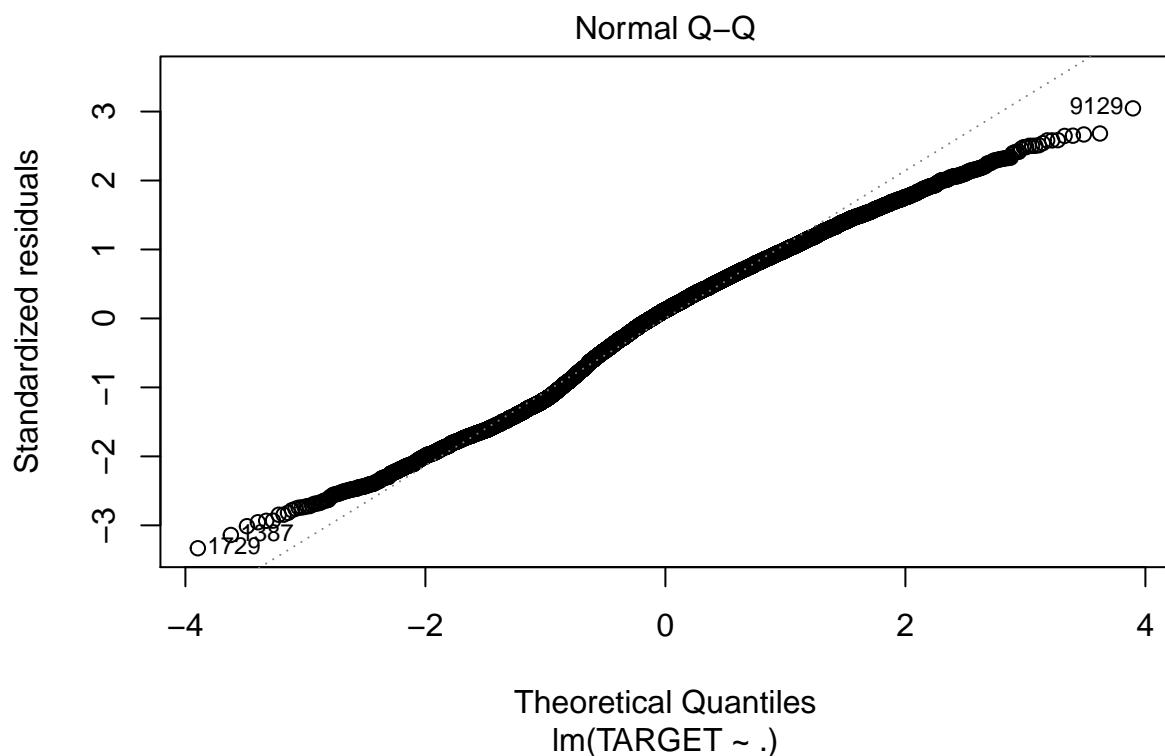
```
##
## Call:
## lm(formula = TARGET ~ ., data = wine_train2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.7147 -1.0144  0.1737  1.0276  4.3109
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)               5.968e+00  5.567e-01 10.719 < 2e-16 ***
## FixedAcidity            1.297e-03  2.253e-03  0.576 0.564897
## VolatileAcidity        -1.269e-01  1.791e-02 -7.085 1.48e-12 ***
## CitricAcid              2.625e-02  1.629e-02  1.611 0.107133
## ResidualSugar           4.231e-04  4.132e-04  1.024 0.305939
## Chlorides                -2.023e-01  4.391e-02 -4.606 4.15e-06 ***
## FreeSulfurDioxide      3.635e-04  9.387e-05  3.873 0.000108 ***
## TotalSulfurDioxide     2.432e-04  6.023e-05  4.038 5.42e-05 ***
## Density                 -8.659e-01  5.260e-01 -1.646 0.099740 .
##
```

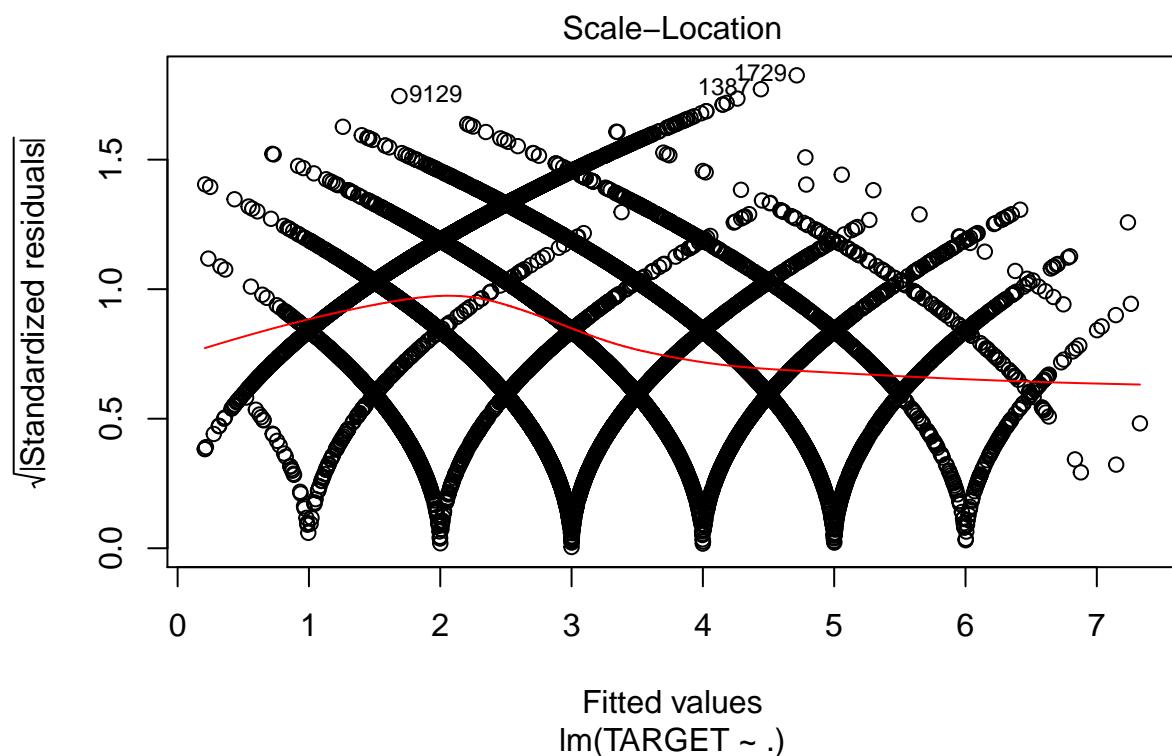
```

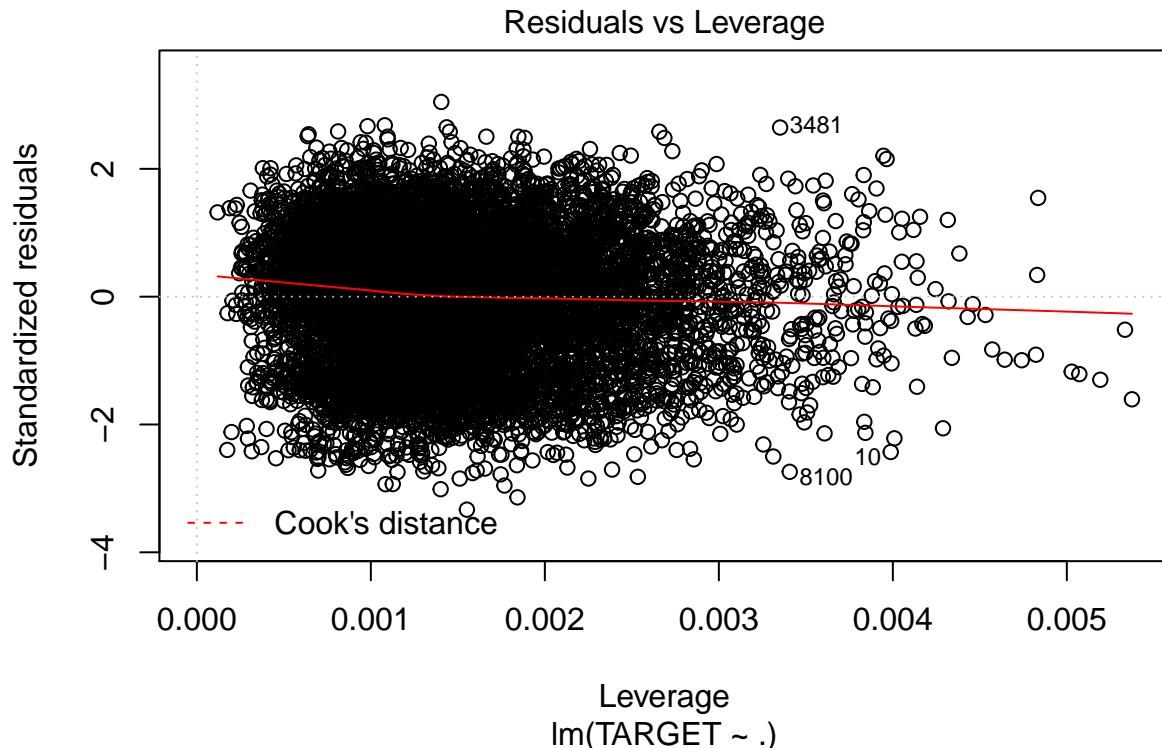
## pH           -4.730e-02  2.072e-02  -2.283  0.022424 *
## Sulphates   -4.212e-02  1.512e-02  -2.786  0.005346 **
## Alcohol      1.251e-02  3.807e-03   3.285  0.001025 **
## LabelAppeal  4.311e-01  1.646e-02  26.191 < 2e-16 ***
## AcidIndex    -2.068e+00  9.237e-02 -22.392 < 2e-16 ***
## STARS        1.167e+00  1.671e-02  69.805 < 2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.416 on 10222 degrees of freedom
## Multiple R-squared:  0.4605, Adjusted R-squared:  0.4598
## F-statistic: 623.3 on 14 and 10222 DF,  p-value: < 2.2e-16

```









Model 10 : Linear Model with imputations and only significant variables.

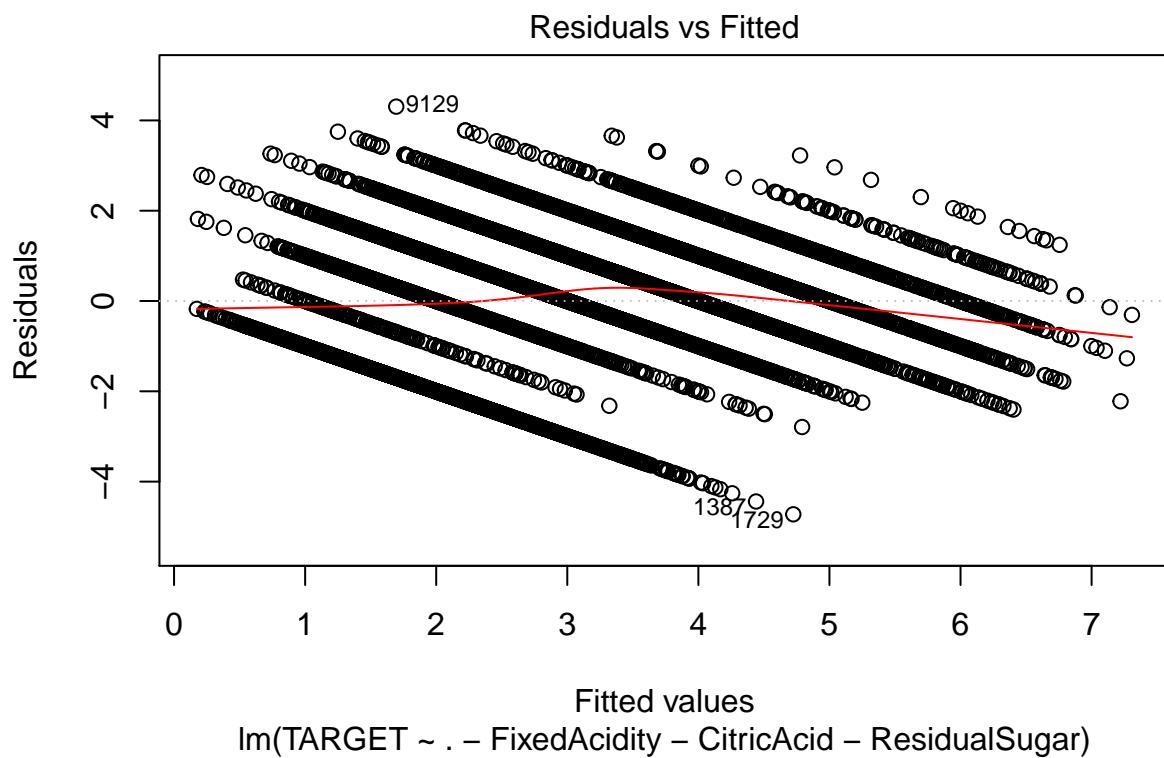
We got FixedAcidity, CitricAcid and ResidualSugar as significant variables and use same variables on Linear regression model with imputed training data.

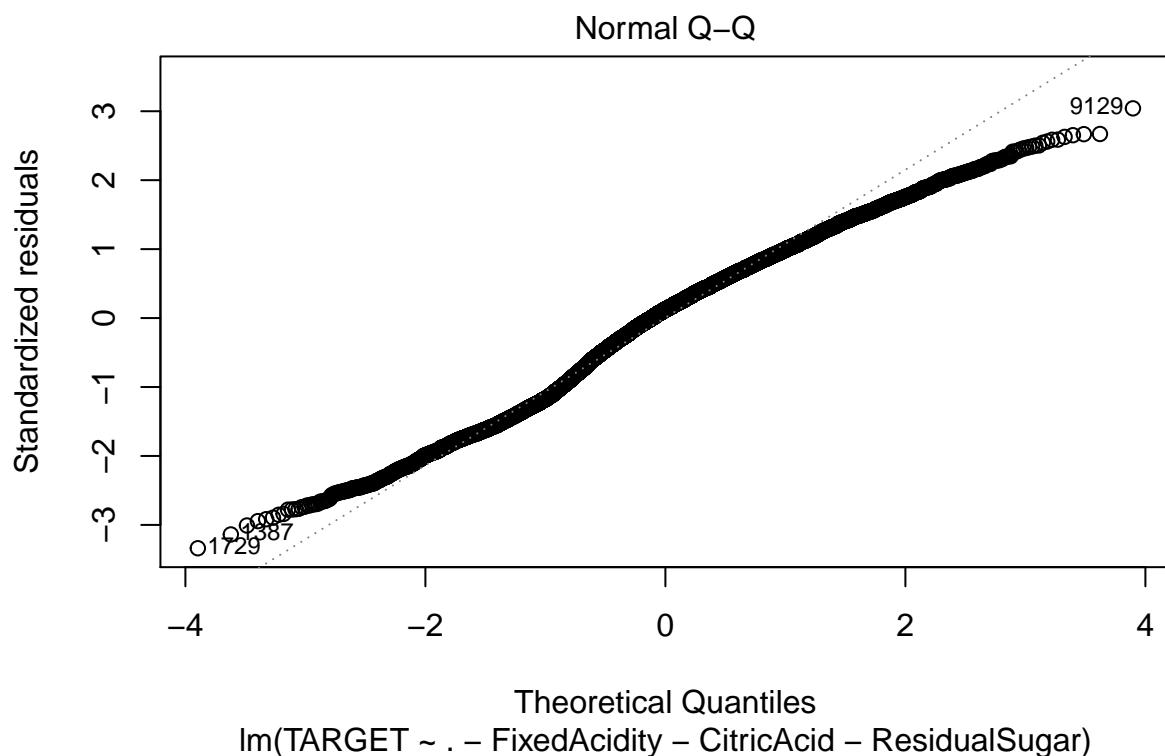
```
##
## Call:
## lm(formula = TARGET ~ . - FixedAcidity - CitricAcid - ResidualSugar,
##      data = wine_train2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.7242 -1.0131  0.1728  1.0331  4.3050
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)             5.951e+00  5.566e-01 10.691 < 2e-16 ***
## VolatileAcidity        -1.278e-01  1.791e-02 -7.138 1.01e-12 ***
## Chlorides               -2.032e-01  4.391e-02 -4.627 3.75e-06 ***
## FreeSulfurDioxide       3.660e-04  9.386e-05  3.899 9.71e-05 ***
## TotalSulfurDioxide     2.454e-04  6.021e-05  4.075 4.63e-05 ***
## Density                -8.712e-01  5.260e-01 -1.656  0.09768 .
## pH                     -4.728e-02  2.071e-02 -2.282  0.02249 *
## Sulphates              -4.236e-02  1.511e-02 -2.803  0.00507 **
## Alcohol                1.249e-02  3.807e-03  3.281  0.00104 **
##
```

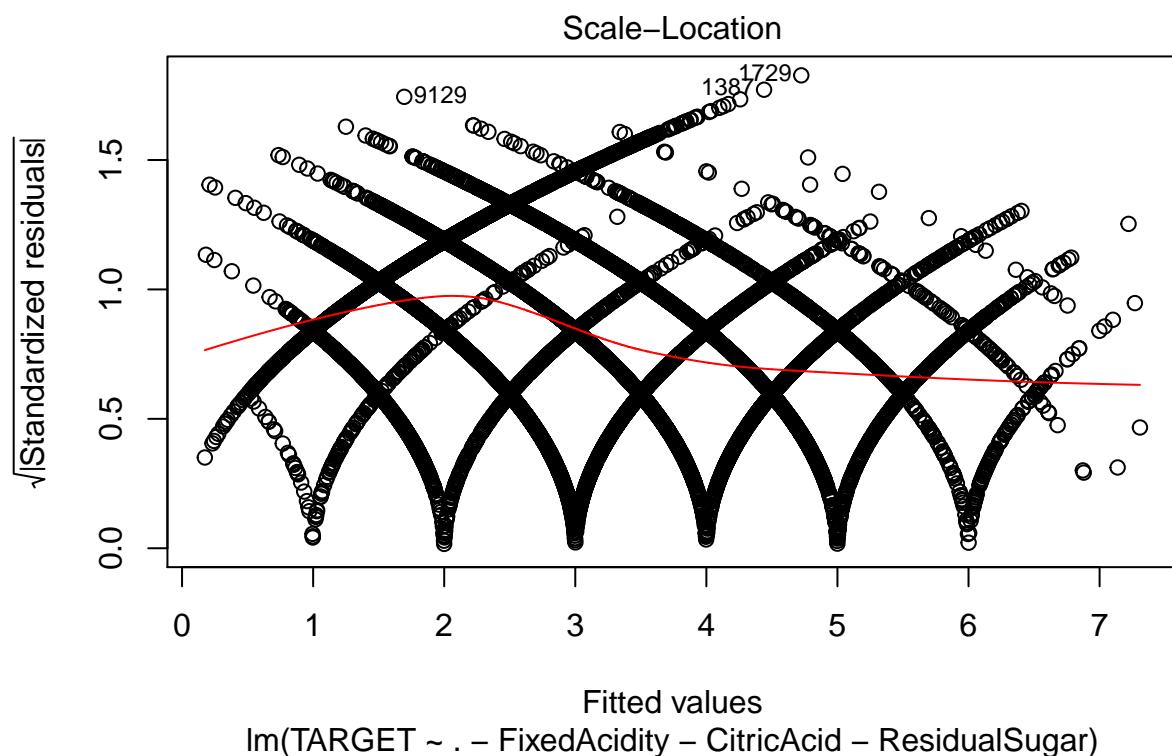
```

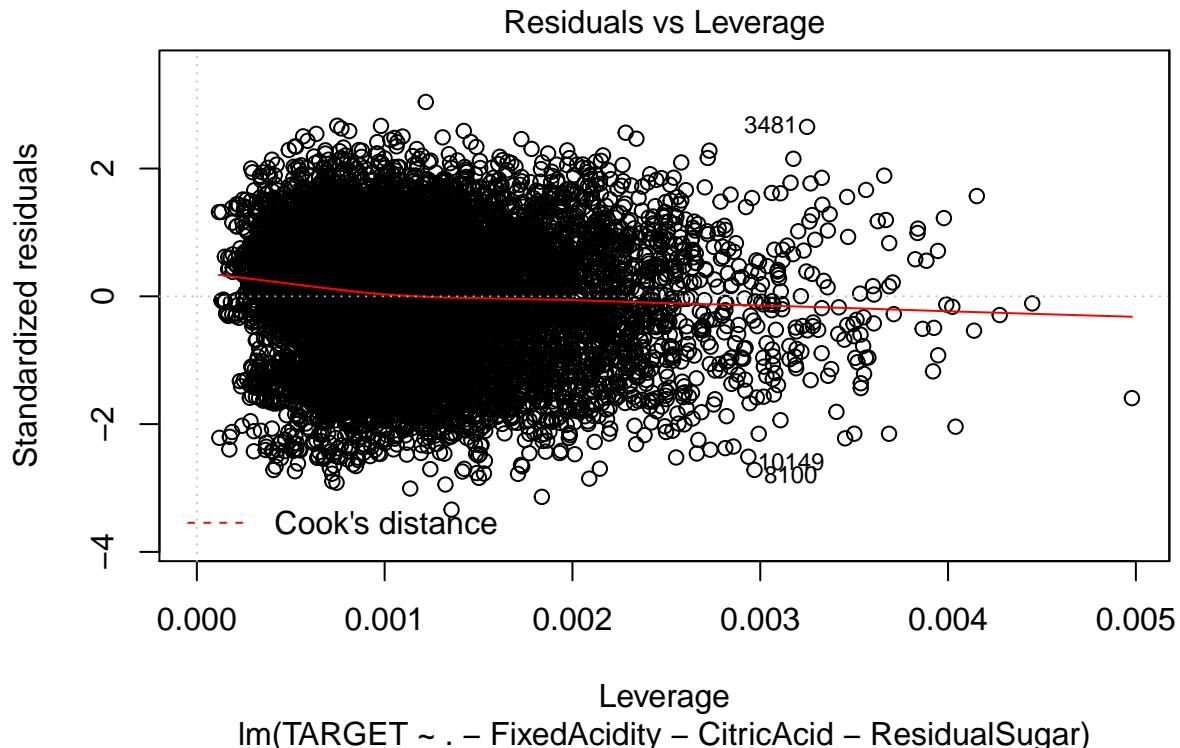
## LabelAppeal      4.310e-01  1.646e-02  26.186 < 2e-16 ***
## AcidIndex       -2.048e+00  9.074e-02 -22.572 < 2e-16 ***
## STARS          1.167e+00  1.671e-02  69.833 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.416 on 10225 degrees of freedom
## Multiple R-squared:  0.4603, Adjusted R-squared:  0.4598
## F-statistic: 792.9 on 11 and 10225 DF,  p-value: < 2.2e-16

```









Model 11 : Ordinal Logistic Regression

Since Ordinal logistic regression uses ordered factors we might find this as one of the top model based on our use cases.

```
## Call:
## polr(formula = TARGET ~ ., data = polrDF, Hess = TRUE)
##
## Coefficients:
##                               Value Std. Error t value
## FixedAcidity      0.0021819  0.0029055  0.7510
## VolatileAcidity -0.1555960  0.0232760 -6.6848
## CitricAcid        0.0289713  0.0211212  1.3717
## ResidualSugar    0.0003196  0.0005320  0.6008
## Chlorides         -0.2627487  0.0566657 -4.6368
## FreeSulfurDioxide 0.0004607  0.0001216  3.7875
## TotalSulfurDioxide 0.0002716  0.0000783  3.4686
## Density          -1.2981402  0.1490930 -8.7069
## pH                -0.0314095  0.0268078 -1.1717
## Sulphates        -0.0339150  0.0196712 -1.7241
## Alcohol           0.0269097  0.0048969  5.4953
## LabelAppeal       0.8256163  0.0237699 34.7337
## AcidIndex        -2.6646249  0.1250905 -21.3016
## STARS            1.4684471  0.0256683  57.2086
##
```

```

## Intercepts:
##      Value    Std. Error t value
## 0|1 -5.9211    0.1357 -43.6446
## 1|2 -5.7842    0.1355 -42.6743
## 2|3 -5.1811    0.1351 -38.3486
## 3|4 -3.8133    0.1350 -28.2556
## 4|5 -1.9656    0.1372 -14.3273
## 5|6  0.0034    0.1437   0.0237
## 6|7  2.2069    0.1675  13.1788
## 7|8  4.5480    0.3034  14.9895
##
## Residual Deviance: 30016.23
## AIC: 30060.23

```

Model 12 : Zero inflation

Zero-inflated poisson regression is used to model count data that has an excess of zero counts. Further, theory suggests that the excess zeros are generated by a separate process from the count values and that the excess zeros can be modeled independently. In Data exploration we saw many zero values, considering this we might get this as one of our best model.

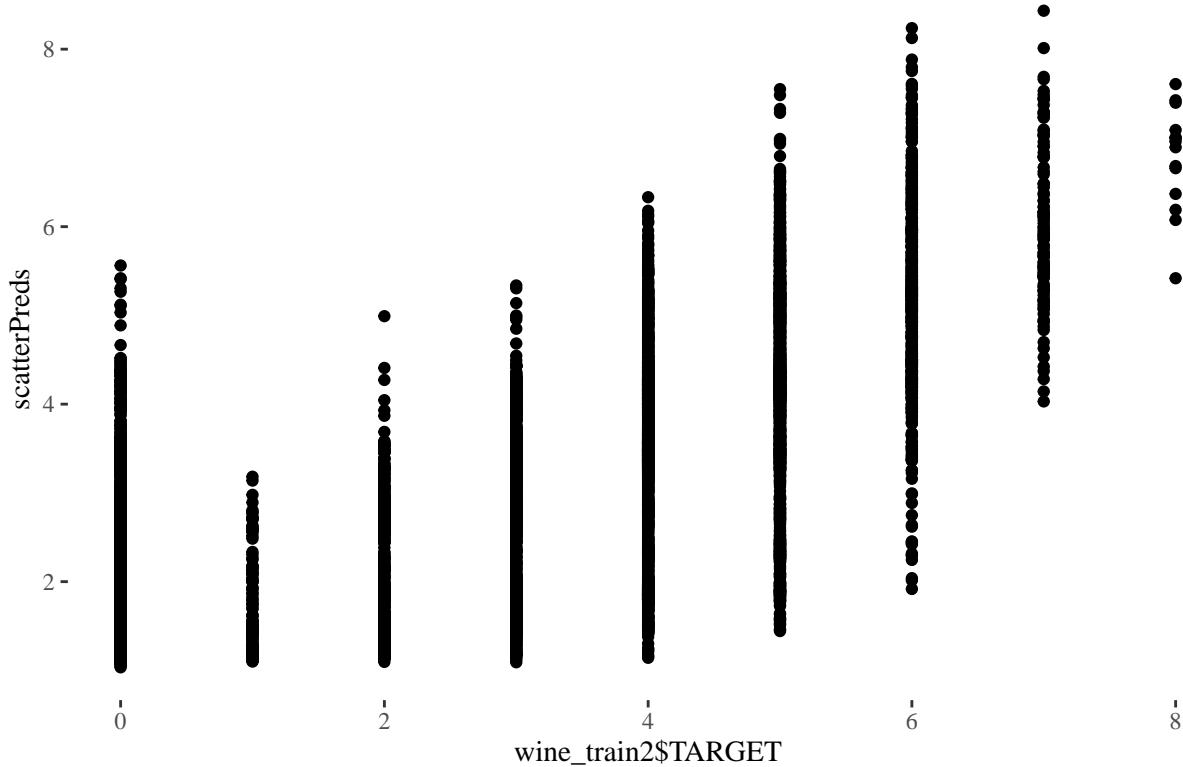
```

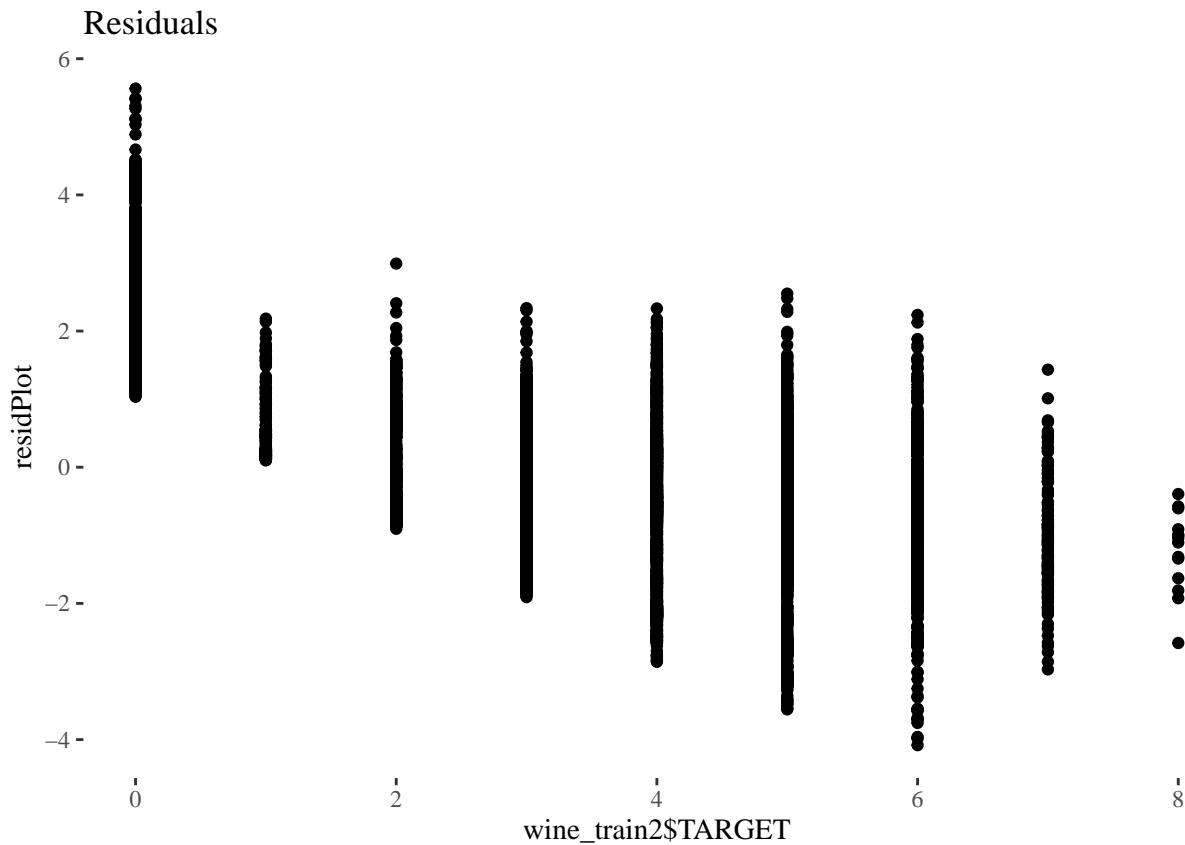
##
## Call:
## zeroinfl(formula = TARGET ~ . | STARS, data = wine_train2, dist = "negbin")
##
## Pearson residuals:
##      Min     1Q   Median     3Q    Max
## -2.09180 -0.49650  0.07134  0.48208  2.08565
##
## Count model coefficients (negbin with log link):
##                                         Estimate Std. Error z value Pr(>|z|)
## (Intercept)                  1.824e+00 2.385e-01  7.648 2.04e-14 ***
## FixedAcidity                 4.523e-04 9.473e-04  0.477 0.633017
## VolatileAcidity              -1.936e-02 7.560e-03 -2.561 0.010429 *
## CitricAcid                   2.116e-03 6.718e-03  0.315 0.752830
## ResidualSugar                -6.323e-05 1.722e-04 -0.367 0.713427
## Chlorides                     -3.245e-02 1.851e-02 -1.754 0.079503 .
## FreeSulfurDioxide            4.932e-05 3.854e-05  1.280 0.200613
## TotalSulfurDioxide           4.760e-06 2.460e-05  0.194 0.846535
## Density                      -2.990e-01 2.224e-01 -1.344 0.178840
## pH                            -1.910e-03 8.749e-03 -0.218 0.827223
## Sulphates                    -4.586e-03 6.391e-03 -0.718 0.473029
## Alcohol                      5.950e-03 1.591e-03  3.741 0.000184 ***
## LabelAppeal                  2.240e-01 7.112e-03 31.491 < 2e-16 ***
## AcidIndex                     -2.682e-01 4.492e-02 -5.971 2.36e-09 ***
## STARS                        1.227e-01 6.997e-03 17.531 < 2e-16 ***
## Log(theta)                   1.860e+01 2.758e+00  6.742 1.56e-11 ***
##
## Zero-inflation model coefficients (binomial with logit link):
##                                         Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.31678    0.11092   20.89 <2e-16 ***
## STARS       -2.66899    0.09689  -27.55 <2e-16 ***
## ---

```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Theta = 119421399.3444
## Number of iterations in BFGS optimization: 22
## Log-likelihood: -1.725e+04 on 18 Df
```

Predicted vs Actual





SELECT MODELS

Compare Models based on MSE/AIC

	MSE	AIC
Model1	6.929787	6.926722
Model2	6.849005	6.849920
Model3	6.929788	6.926723
Model4	6.849001	6.849916
Model5	2.002207	2.002977
Model6	NA	1.988813
Model7	18544.983192	18535.285631
Model8	38416.867732	38415.386508
Model9	18547.067808	18537.370350
Model10	38419.044066	38417.562708
Model11	6.929787	6.926722
Model12	6.849005	6.849920

Compare Models by Loss

Use test data and check the output

In order to validate we will use squared loss and squared difference to select model (MSE) from predicting on selected training datasets. If we get lower numbers for the models which means that model is good.

```

##          Loss:
## Model1  5.471932
## Model2  5.456474
## Model3  6.827070
## Model4  6.828240
## Model5  5.471926
## Model6  5.456468
## Model7  6.827066
## Model8  6.828236
## Model9  2.034647
## Model10 2.034185
## Model11 3.679046
## Model12 2.001981

```

Based on above results these are our observation

-> Linear model performed well. -> Poisson regression model and Negative binomial model did not performed as expected. -> We expected Ordinal logistic regression to be a better model but it did not performed well.

At this point we are concentrated more on square loss which tells us the accuracy of our model

Zero Poission Inflation seems to be the most accurate model with least loss score.

If we consider all the factors like least loss, good MSE and AIC score we found ‘Zero Poission Inflation’ as our best one.

Prediction on Evaluation Data

Here we use MICE just like how we used earlier for imputing and log transformation for AcidIndex.

```

## 
##   iter imp variable
##   1   1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA
##   2   1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA
##   3   1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA
##   4   1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA
##   5   1 ResidualSugar Chlorides FreeSulfurDioxide TotalSulfurDioxide pH Sulphates Alcohol STA

```

Display the Predicted values

```

## # A tibble: 3,335 x 15
##   TARGET FixedAcidity VolatileAcidity CitricAcid ResidualSugar Chlorides FreeSulfurDioxide
##   <dbl>      <dbl>        <dbl>     <dbl>       <dbl>      <dbl>           <dbl>
## 1 3.01        5.4       -0.86      0.27     -10.7     0.092          23
## 2 3.62       12.4        0.385     -0.76     -19.7     1.17          -37
## 3 1.74        7.2        1.75      0.17      -33       0.065            9
## 4 1.51        6.2        0.1       1.8      -0.179    -0.179         104
## 5 1.68       11.4        0.21      0.28       1.2      0.038          70
## 6 5.66        17.6       0.04      -1.15      1.4      0.535         -250
## 7 3.38       15.5        0.53      -0.53      4.6       1.26            10
## 8 5.17       15.9        1.19      1.14      31.9     -0.299         115
## 9 1.54       11.6        0.32      0.55     -50.9     0.076            35
## 10 4.28       3.8        0.22      0.31      -7.7      0.039           40
## # ... with 3,325 more rows, and 8 more variables: TotalSulfurDioxide <dbl>, Density <dbl>,
## #   pH <dbl>, Sulphates <dbl>, Alcohol <dbl>, LabelAppeal <dbl>, AcidIndex <dbl>, STARS <dbl>

```

For TARGET: Number of Cases Purchased as Predicted

```
##   Min. 1st Qu. Median   Mean 3rd Qu.   Max. StdD Skew Kurt
## 1.03    1.91   3.30   3.24   4.17   8.27   1.38  0.51 -0.32
```

Predicted Evaluation data

https://github.com/vijay564/Data621/blob/main/Evaluation_Full_Data.csv

Appendix

https://github.com/vijay564/Data621/blob/main/Data621_Hw5.Rmd