Homework 5

Group 1

Contents

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1 Introduction

The wine industry was valued at $257.5 billion in 2012 and is predicted to be valued at $303.6 billion by 2016.[1] As wine is a consumer product, accommodating consumer preference is critical to maintaining a competitive advantage. By understanding the factors involved in wine sales we can better understand consumer behavior and adjust our strategies accordingly.

2 Statement of the Problem

The purpose of this report is to develop statistical models to make inference into the factors associated with the number of cases of wine sold.

3 Data Exploration

3.1 Variables Explained

The variables provided in the `Wine Training Data Set` are explained below:

Variable Code	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 averag**
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. High numbers suggest customers like the label design. Negative numbers suggest customes 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

[1] "Research and Markets: Wine: 2012 Global Industry Almanac - The Global Wine Market Grew by 3.1% in 2011 to Reach a Value of $257.5 Billion." Research and Markets: Wine: 2012 Global Industry Almanac - The Global Wine Market Grew by 3.1% in 2011 to Reach a Value of $257.5 Billion | Business Wire. N.p., 21 May 2012. Web. 20 Nov. 2016.

3.2 Variables Summary Statistics

3.2.1 Discrete Variables

Interestingly, we can see some general sense of the make up of our data set. In this set, most wines sell between 3 and 5 cases, have no label appeal, and very few received 4 stars with most wines receiving 2 or 1 stars. Additionally, we should note that `21.4%` of our wines had no case sales.

Table 2: Wine Training Data Table of Discrete Variables

Variable	Levels	n	%	$\sum$ %
TARGET	0	2734	21.4	21.4
	1	244	1.9	23.3
	2	1091	8.5	31.8
	3	2611	20.4	52.2
	4	3177	24.8	77.0
	5	2014	15.7	92.8
	6	765	6.0	98.8
	7	142	1.1	99.9
	8	17	0.1	100.0
	all	12795	100.0	
LabelAppeal	-2	504	3.9	3.9
	-1	3136	24.5	28.5
	0	5617	43.9	72.3
	1	3048	23.8	96.2
	2	490	3.8	100.0
	all	12795	100.0	
STARS	1	3042	32.2	32.2
	2	3570	37.8	70.1
	3	2212	23.4	93.5
	4	612	6.5	100.0
	all	9436	100.0	

3.2.2 Continous Variables

We see that Density is a very narrow measurement, the minimum value is 0.9 and the maximum is 1.1. The remaining continuous variables appear to have a larger range of variability, with the largest being `TotalSulfurDioxide` which has a range from -823 to 1057. In our models, this variability will provide some insights to our coefficients and the impact to the dependent variable.

Table 3: Wine Training Data Table of Continuous Variables

Variable	n	Min	q_1	$\widetilde{x}$	$\bar{x}$	q_3	Max	s	IQR	#NA
FixedAcidity	12795	-18.1	5.2	6.9	7.1	9.5	34.4	6.3	4.3	0
VolatileAcidity	12795	-2.8	0.1	0.3	0.3	0.6	3.7	0.8	0.5	0
CitricAcid	12795	-3.2	0.0	0.3	0.3	0.6	3.9	0.9	0.5	0
ResidualSugar	12179	-127.8	-2.0	3.9	5.4	15.9	141.2	33.7	17.9	616
Chlorides	12157	-1.2	0.0	0.0	0.1	0.2	1.4	0.3	0.2	638
FreeSulfurDioxide	12148	-555.0	0.0	30.0	30.8	70.0	623.0	148.7	70.0	647
TotalSulfurDioxide	12113	-823.0	27.0	123.0	120.7	208.0	1057.0	231.9	181.0	682
Density	12795	0.9	1.0	1.0	1.0	1.0	1.1	0.0	0.0	0
pH	12400	0.5	3.0	3.2	3.2	3.5	6.1	0.7	0.5	395
Sulphates	11585	-3.1	0.3	0.5	0.5	0.9	4.2	0.9	0.6	1210
Alcohol	12142	-4.7	9.0	10.4	10.5	12.4	26.5	3.7	3.4	653

3.3 Imputting Missing Values

In order to address the missing values in our variables we used a non-parametric imputation method (Random Forest) using the `missForest` package. The function is particularly useful in that it can handle any type of input data and it will make as few assumptions about the structure of the data as possible.[2]

Table 4 : Imputed Descriptive Statistics
13 Variables 12795 Observations

FixedAcidity

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	470	1	7	7	-4	-1	5	7	10	16	18

```
lowest : -18.1 -18.0 -17.7 -17.5 -17.4, highest:  32.4  32.5  32.6  34.1  34.4
```

VolatileAcidity

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	815	1	0.3	0.8	-1.0	-0.7	0.1	0.3	0.6	1.4	1.6

```
lowest : -2.790 -2.750 -2.745 -2.730 -2.720, highest:  3.500  3.550  3.565  3.590  3.680
```

CitricAcid

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	602	1	0.3	0.9	-1.16	-0.84	0.03	0.31	0.58	1.43	1.79

```
lowest : -3.24 -3.16 -3.10 -3.08 -3.06, highest:  3.63  3.68  3.70  3.77  3.86
```

ResidualSugar

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	2685	1	5	34	-52.0	-38.4	-0.5	4.1	15.0	48.9	62.1

```
lowest : -127.80 -127.10 -126.20 -126.10 -125.70
highest:  136.50  137.60  138.00  140.65  141.15
```

Chlorides

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	2285	1	0.05	0.3	-0.48	-0.36	-0.01	0.05	0.13	0.47	0.59

```
lowest : -1.171 -1.170 -1.158 -1.156 -1.155, highest:  1.260  1.261  1.270  1.275  1.351
```

FreeSulfurDioxide

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	1626	1	31	150	-220	-165	3	30	66	223	281

```
lowest : -555 -546 -536 -535 -532, highest:  613  617  618  622  623
```

TotalSulfurDioxide

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	2039	1	121	238	-266	-175	33	123	200	412	507

```
lowest : -823 -816 -793 -781 -779, highest: 1032 1041 1048 1054 1057
```

Density

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	5933	1	1	0.03	0.9	1.0	1.0	1.0	1.0	1.0	1.0

```
lowest : 0.88809 0.88949 0.88978 0.88983 0.89167
highest: 1.09658 1.09679 1.09695 1.09791 1.09924
```

pH

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	863	1	3	0.7	2	2	3	3	3	4	4

```
lowest : 0.48 0.53 0.54 0.58 0.59, highest: 5.91 5.94 6.02 6.05 6.13
```

[2] Stekhoven, Daniel J., and Peter B?hlmann. "MissForest-non-parametric missing value imputation for mixed-type data." Bioinformatics 28.1 (2012): 112-118.

Sulphates

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	1695	1	0.5	0.9	-1.0	-0.6	0.3	0.5	0.8	1.7	2.1

```
lowest : -3.13 -3.12 -3.10 -3.07 -3.03, highest:  4.11  4.16  4.19  4.21  4.24
```

Alcohol

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
12795	0	1036	1	10	4	4	6	9	10	12	15	17

```
lowest : -4.7 -4.5 -4.4 -4.3 -4.1, highest: 25.4 25.6 26.0 26.1 26.5
```

LabelAppeal

n	missing	distinct	Info	Mean	Gmd
12795	0	5	0.887	-0.009	1

```
lowest : -2 -1  0  1  2, highest: -2 -1  0  1  2
```

```
-2 (504, 0.039), -1 (3136, 0.245), 0 (5617, 0.439), 1 (3048, 0.238), 2 (490, 0.038)
```

STARS

n	missing	distinct
12795	0	4

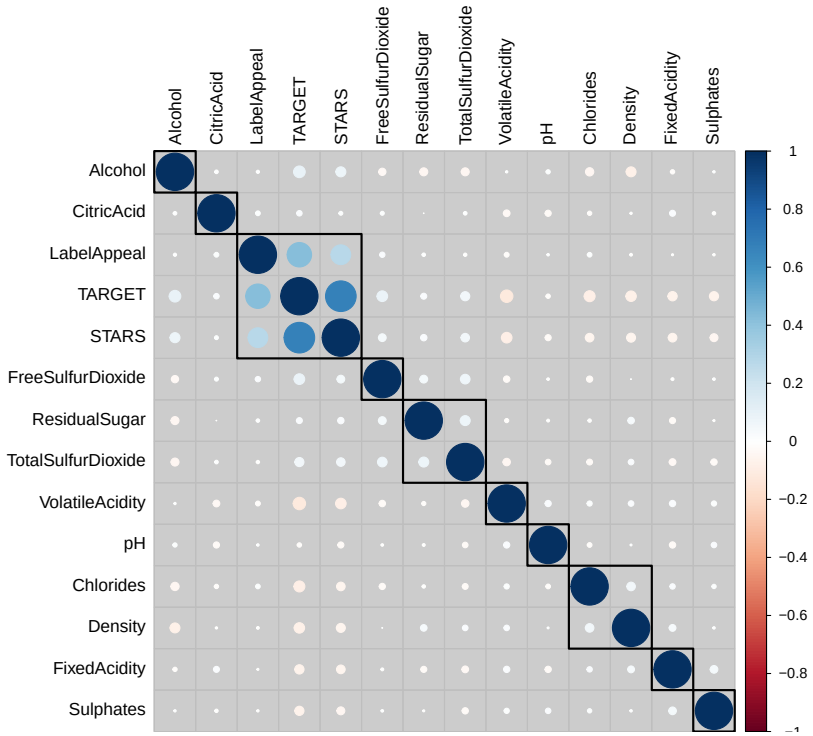
```
1 (5305, 0.415), 2 (4569, 0.357), 3 (2309, 0.180), 4 (612, 0.048)
```

3.4 Correlation of Variables

3.4.1 Correlation Matrix

If we modify our data frame to a matrix in our evaluation data set we can further plot a correlation matrix. There are surprisingly few interesting correlations in the data, but the lack of correlation in the data set is in itself interesting.

- `STARS` has the most positive correlation and strongest correlation with our dependent variable `TARGET`. It is intuitive that the greater the `STARS` value the more cases our wine would sell.
- `LabelAppeal` is the second most correlated with our dependent variable to our dependent variable. It is interesting that the two most correlated variables have less to do with wine quality and more to do with the appearance of a sophisticated wine.
- The lack of strong correlations is interesting in itself. It is concerning that most variables have nearly no correlation with our dependent variable but represent the actual quality of the wine. We see that public perception of wine is more important than the actual quality of the wine as measured by these variables.

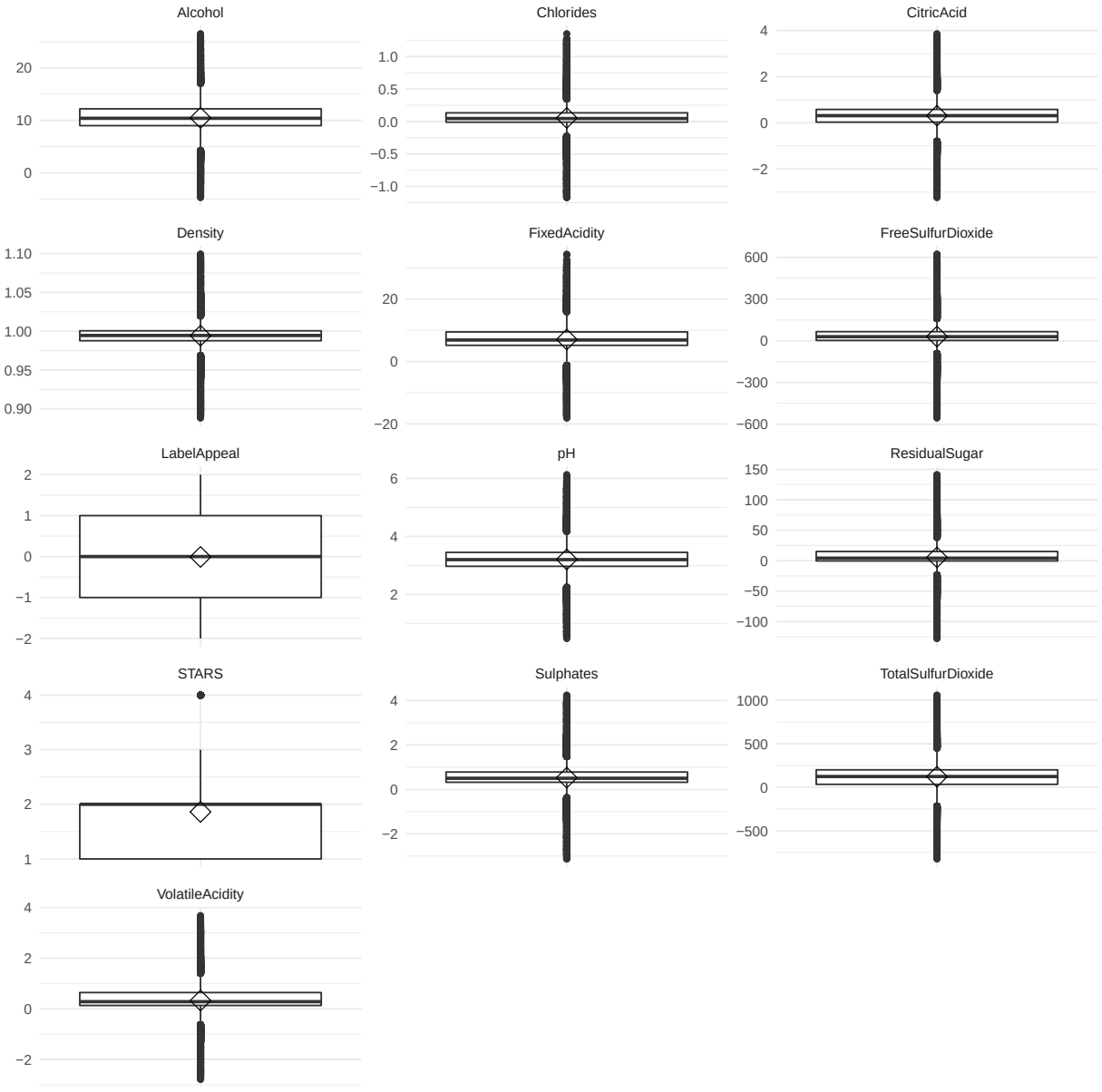


4 Data Transformation

4.1 Outliers Treatment

4.1.1 Box Plots of Variables for Winsorizing

Box Plots provide a visualization of the quartiles and outliers of our data set.[3] Using the box plots, we are can conclude that the variables to be winsorized are Free Sulfur Dioxide, Residual Sugar, and Total Sulfur Dioxide.



[3] "Box Plot." Wikipedia. Wikimedia Foundation, n.d. Web. 24 Nov. 2016.

4.1.2 Winsorizing

We chose winsorizing as the method to address outliers. Instead of trimming values, winsorizing uses the interquantile range to replace values that are above or below the interquantile range multiplied by a factor. Those values above or below the range multiplied by the factor are then replaced with max and min value of the interquantile range. Using the factor 2.2 for winsorizing outliers is a method developed my Hoaglin and Iglewicz and published Journal of American Statistical Association in 1987[4].

The below table is the summary results of the winsorizing of the data.

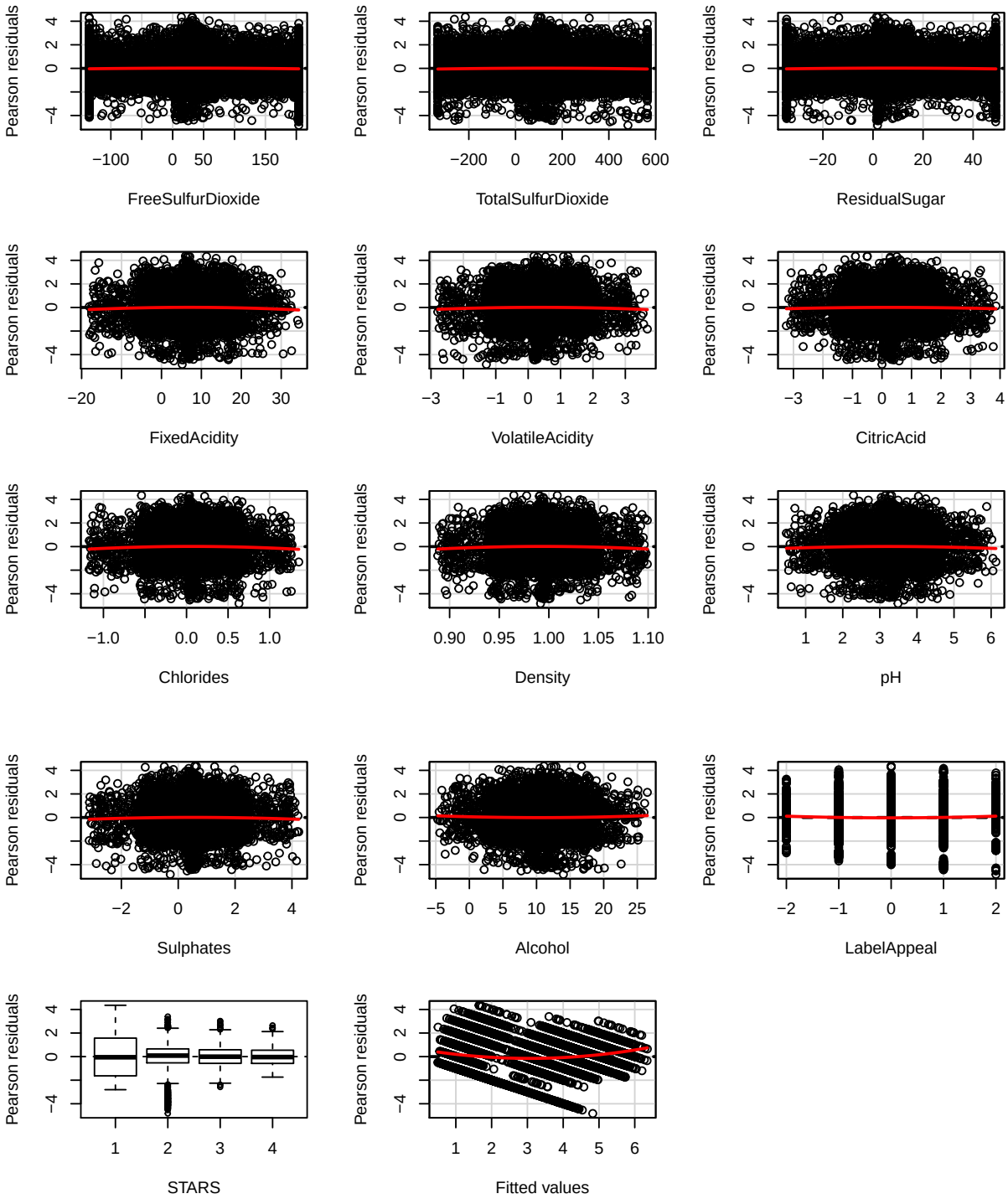
Table 4:

Statistic	N	Mean	St. Dev.	Min	Max
FreeSulfurDioxide	12,796	31.978	99.033	−135.000	204.000
TotalSulfurDioxide	12,796	120.521	203.181	−333.000	565.000
ResidualSugar	12,796	5.927	23.816	−34.600	49.100
TARGET	12,796	3.029	1.926	0	8
FixedAcidity	12,796	7.075	6.317	−18.100	34.400
VolatileAcidity	12,796	0.324	0.784	−2.790	3.680
CitricAcid	12,796	0.308	0.862	−3.240	3.860
Chlorides	12,796	0.055	0.313	−1.171	4.000
Density	12,796	0.994	0.032	0.888	3.000
pH	12,796	3.208	0.670	0.480	6.130
Sulphates	12,796	0.527	0.888	−3.130	4.240
Alcohol	12,796	10.489	3.636	−4.700	26.500
LabelAppeal	12,796	−0.009	0.891	−2	3

[4]Hoaglin, D. C., and Iglewicz, B. (1987), Fine tuning some resistant rules for outlier labeling, Journal of American Statistical Association, 82, 1147-1149.

4.2 BoxCox Transformations

Even after Winsorization we see non-constant variance in the Pearson Residuals for `FreeSulferDioxide`, `TotalSulfurDioxide`, and `ResidualSugar`. The Box-Cox evaluation was completed on these variables, based on the residual plots. In the residual plots, these three variables showed a great deal of non-constant variance because the plots were hyperbolic-shaped.


Pearson residuals
FreeSulfurDioxide
TotalSulfurDioxide
ResidualSugar
FixedAcidity
VolatileAcidity
CitricAcid
Chlorides
Density
pH
Sulphates
Alcohol
LabelAppeal
STARS
Fitted values

```
##                     Test stat Pr(>|t|)
## FreeSulfurDioxide      -1.892    0.058
## TotalSulfurDioxide     -1.751    0.080
## ResidualSugar          -2.101    0.036
## FixedAcidity           -1.881    0.060
## VolatileAcidity        -1.694    0.090
## CitricAcid             -1.092    0.275
## Chlorides              -2.370    0.018
## Density                -2.286    0.022
## pH                     -1.500    0.134
## Sulphates              -1.616    0.106
## Alcohol                 1.408    0.159
## LabelAppeal             3.071    0.002
## STARS                      NA       NA
## Tukey test             17.998    0.000
```

4.2.1 Determing BoxCox Transformations

Using the `BoxCox.lambda` function from the `forecast` package we are able to determine our necessary transformations to our independent variables.

λ	Variables
1.22449234379866	Free Sulfur Dioxide
1.0182875042235	Total Sulfur Dioxide
1.18389893233879	Residual Sugar

Utilizing transformations based on the lambda value of the BoxCox and rounding to the nearest tenth we further transform our independent variables for our regression models. We see that the `TotalSulfurDioxide` variable does not require further transformation

Box-Cox Transformations [5]

λ	Y'
0	$\log(Y)$
.25	$\sqrt[4]{Y}$
0.5	$Y^{0.5} = \sqrt{(Y)}$
1	$Y^1 = Y$
1.25	$Y^{1.25}$

variable	variable transformation
ResidualSugar	$ResidualSugar^{1.25}$
FreeSulfurDioxide	$FreeSulfurDioxide^{1.25}$

[5] Osborne, Jason W. "Improving your data transformations: Applying the Box-Cox transformation." Practical Assessment, Research & Evaluation 15.12 (2010): 1-9.

5 Models Built

5.1 Poisson Regression Models

First, we investigate the unconditional variance is slightly > unconditional mean. Which we do see in the below table so there may be some over-dispersion.

mean	var
3.029074	3.710895

5.1.1 Poisson Regression Model 1

We build out first Poisson Regression model but we need to verify the confidence levels are appropriate. After producing the Confidence level for ResidualSugar we see it runs through 1 and and its P(z) value is clearly not significant. Based on both items we can remove ResidualSugar from the model.

Table 7: Poisson Regression Model 1

	Dependent variable:
	TARGET
Constant	0.406*** (0.018)
STARS2	0.825*** (0.013)
STARS3	1.064*** (0.015)
STARS4	1.229*** (0.021)
Alcohol	0.005*** (0.001)
ResidualSugar	0.00005 (0.0002)
Observations	12,795
Log Likelihood	−23,658.340
Akaike Inf. Crit.	47,328.690
Residual Deviance	15,374.670 (df = 12789)
Null Deviance	22,860.890 (df = 12794)
Note:	*p<0.1; **p<0.05; ***p<0.01

2.5 % 97.5 % (Intercept) 1.500241 1.4473853 1.554840 STARS2 2.282690 2.2235058 2.343626 STARS3 2.898045 2.8161091 2.982460 STARS4 3.418939 3.2835775 3.559054 Alcohol 1.004914 1.0021539 1.007683 ResidualSugar 1.000048 0.9997468 1.000349

We removed ResidualSugar and Model with the independent variables STARS and Alcohol. We can see how great the STARS variable has on our modele, 2 STARS is 2.28 times wine case sales when compared to one STAR. Furthermore, 3 Stars will have wiine case sales of 2.90 times more than one STAR, and four STARS will be 3.42 times more than one STAR. Alcohol = For one unit increase in Alcohol, Wine sales will be 1.004 times more

2.5% 97.5	%		
(Intercept)	1.500699	1.447902	1.555234
STARS2	2.282846	2.223665	2.343778
STARS3	2.898279	2.816349	2.982688
STARS4	3.419275	3.283915	3.559386
Alcohol	1.004906	1.002146	1.007674

Table 8: Poisson Regression Model 1 without ResidualSugar

	Dependent variable:
	TARGET
Constant	0.406*** (0.018)
STARS2	0.825*** (0.013)
STARS3	1.064*** (0.015)
STARS4	1.229*** (0.021)
Alcohol	0.005*** (0.001)
Observations	12,795
Log Likelihood	−23,658.390
Akaike Inf. Crit.	47,326.790
Residual Deviance	15,374.760 (df = 12790)
Null Deviance	22,860.890 (df = 12794)
Note:	*p<0.1; **p<0.05; ***p<0.01

5.1.1.1 Poisson Regression Model 1 Metrics

5.1.1.1.1 Dispersion

dispersion 0.9730167

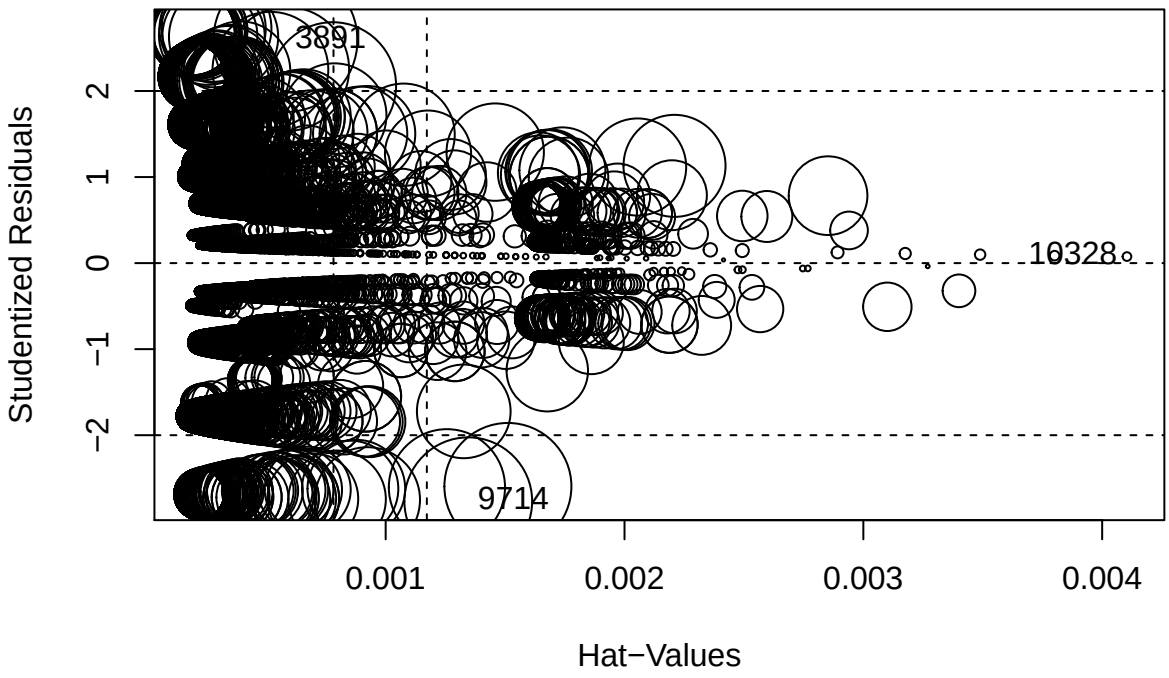
Our dispersion results are very close to 1. So, we can say it is not over or under dispersed. However, we can further test for overdispersion by dividing the deviance of our model by the residuals. The result of this test is 1.2020925 and since this result is not greater than 1.5, we can claim that the data is not over-dispersed.[6]

[7] : "Multiple Logistic Regression." R Companion: Multiple Logistic Regression. N.p., n.d. Web. 04 Dec. 2016.

5.1.1.1.2 Influential Points

We further test for influential points in the data set. This test indicates that rows 10328, 9714, and 3891, have great influence on our model. It would be important to discuss these rows with the appropriate data steward to understand if these are accurate measurements and should be included in the analysis. Due to time limitations, we are not able to verify these rows and they have been included in this analysis.

[6] "Which Variance Inflation Factor Should I Be Using: $GVIF$ or $textGVIF^{1/(2cdottextdf)}$?" R. N.p., n.d. Web. 13 Nov. 2016.
[7] "Which Variance Inflation Factor Should I Be Using: $GVIF$ or $textGVIF^{1/(2cdottextdf)}$?" R. N.p., n.d. Web. 13 Nov. 2016.



StudRes Hat CookD 3891 2.59248567 0.0005804453 1.31210e-03 9714 -2.76735034 0.0013458546 1.03277e-03 10328 0.07597296 0.0041037245 4.80641e-06

5.1.1.1.3 Verifying Predictions

We also verify predicted values for the training dataset, in order to verify the output of our model against the training data set.

TARGET STARS Alcohol Fitted 1 3 2 9.90000 3.595939 2 3 3 10.07133 4.569199 3 5 3 22.00000 4.843888 4 3 1 6.20000 1.546933 5 4 2 13.70000 3.663440 6 0 1 15.40000 1.618176

The predictions are close in value, we can further see the prediction quality of the model by reviewing the frequency table for observed vs predicted values.

Target Obs Predicted 1 0 2734 0 2 1 244 51 3 2 1091 5254 4 3 2611 262 5 4 3177 4574 6 5 2014 2553 7 6 765 101 8 7 142 0 9 8 17 0

Goodness of fit test

[1] 0

Goodness of test using Pearson Chi square test shows that our model is good

5.1.2 Poisson Regression Model 2

Again, we build out second Poisson Regression model and we need to verify the confidence levels are appropriate. After producing the Confidence level for Confidence level for CitricAcid and pH, we see that

they run through 1 and and their P(z) values are clearly not significant. Based on both info we can remove CitricAcid and pH from the model.

Table 10: Poisson Regression Model 2

	Dependent variable:
	TARGET
Constant	0.461*** (0.044)
LabelAppeal-1	0.383*** (0.038)
LabelAppeal0	0.685*** (0.037)
LabelAppeal1	0.909*** (0.037)
LabelAppeal2	1.092*** (0.042)
CitricAcid	0.004 (0.006)
pH	−0.011 (0.008)
Observations	12,795
Log Likelihood	−26,380.660
Akaike Inf. Crit.	52,775.320
Residual Deviance	20,819.300 (df = 12788)
Null Deviance	22,860.890 (df = 12794)
Note:	*p<0.1; **p<0.05; ***p<0.01

2.5 % 97.5 %			
(Intercept)	1.5854504	1.4548070	1.725820
LabelAppeal-1	1.4668746	1.3628879	1.581130
LabelAppeal0	1.9828886	1.8464493	2.132786
LabelAppeal1	2.4812965	2.3088261	2.670784
LabelAppeal2	2.9798450	2.7473514	3.235527
CitricAcid	1.0040643	0.9925526	1.015711
pH	0.9893755	0.9747114	1.004259

We removed CitricAcid and pH then created a new Model with only LabelAppeal. The impact of LabelAppeal is very significant since this variable is explaining a great deal of variation in our dependent variable. A neutral LabelAppeal of 0 will have wine sales 1.98 times greater than a very negative LabelAppeal of -2. Also, a great LabelAppeal of 2 will have 2.98 times greater wine sales than a than a very negative LabelAppeal of -2.

2.5% 97.5%			
(Intercept)	1.533730	1.428134	1.644404
LabelAppeal-1	1.467220	1.363210	1.581500
LabelAppeal0	1.983178	1.846719	2.133096
LabelAppeal1	2.482026	2.309507	2.671567
LabelAppeal2	2.979265	2.746820	3.234891

5.1.2.1 Poisson Regression Model 2 Metrics

dispersion 1.035287

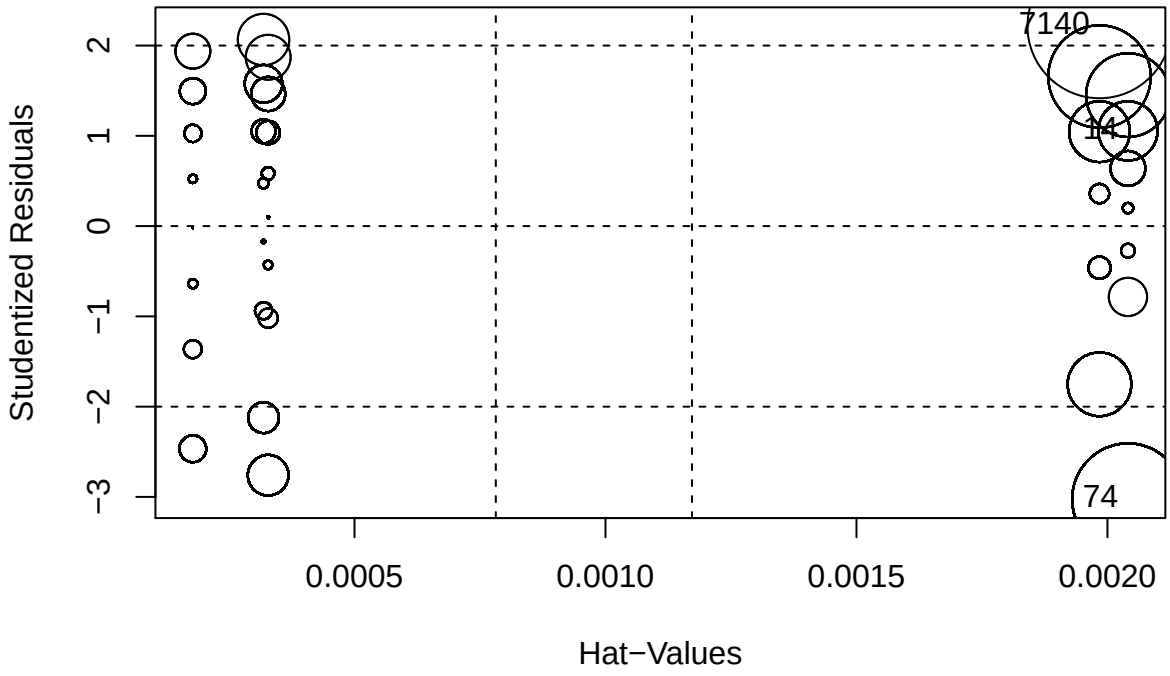
Our dispersion results are very close to 1. So, we can say it is not over or under dispersed. However, we can further test for overdispersion by dividing the deviance of our model by the residuals. The result of this test is 1.6279715 and since this result is not greater than 1.5, we can claim that the data is not over-dispersed.

Table 12: Poisson Regression Model 2 with LabelAppeal

	Dependent variable:
	TARGET
Constant	0.428*** (0.036)
LabelAppeal-1	0.383*** (0.038)
LabelAppeal0	0.685*** (0.037)
LabelAppeal1	0.909*** (0.037)
LabelAppeal2	1.092*** (0.042)
Observations	12,795
Log Likelihood	−26,381.890
Akaike Inf. Crit.	52,773.780
Residual Deviance	20,821.760 (df = 12790)
Null Deviance	22,860.890 (df = 12794)
Note:	*p<0.1; **p<0.05; ***p<0.01

5.1.2.1.1 Influential points

We further test for influential points in the data set. This test indicates that rows 7140, 14, and 74, have great influence on our model. It would be important to discuss these rows with the appropriate data steward to understand if these are accurate measurements and should be included in the analysis. Due to time limitations, we are not able to verify these rows and they have been included in this analysis.



StudRes Hat CookD 14 1.054918 0.002040816 0.0005298851 74 -3.024586 0.002040816 0.0018726921 7140 2.213682 0.001984127 0.0031210472

5.1.2.1.2 Verifying Predictions

We also verify predicted values for the training dataset, in order to verify the output of our model against the training data set.

TARGET LabelAppeal Alcohol Fitted 1 3 0 9.90000 3.041659 2 3 -1 10.07133 2.250319 3 5 -1 22.00000 2.250319 4 3 -1 6.20000 2.250319 5 4 0 13.70000 3.041659 6 0 0 15.40000 3.041659

The predictions are close in value, we can further see the prediction quality of the model by reviewing the frequency table for observed vs predicted values.

[1] 0 1 2 3 4 5 6 7 8

Goodness of fit test

```
round(pchisq(model2$deviance, df=model2$df.residual, lower.tail=FALSE),3)
```

```
## [1] 0
```

The goodness of fit test using pearson Chisquare test shows that our model is good and statistically significant.

5.2 Binomial Regression Models

5.2.1 Binomial Regression Model 1

In the first negative binomial regression model, all of the coefficients are positive. The variable that had to be removed was residual sugar, due to the fact that it was the least significant variable. The categorical variable used (wine rating) guarantees high significance and also higher coefficients (0.4 for STARS = 2, 0.6 for STARS = 3, and 0.7 for STARS = 4). The alcohol content is also an equally significant variable but does not have a coefficient as high as those of the wine rating. The standard error in this model was very high thus guaranteeing high variance. The theta value is also very high. This means that there is a high level of dispersion.

Table 14: Binomial Regression Model 1

	Dependent variable:	
	TARGET	
	(1)	(2)
Constant	0.405*** (0.018)	0.406*** (0.018)
ResidualSugar	0.0002 (0.0002)	
Alcohol	0.005*** (0.001)	0.005*** (0.001)
STARS2	0.825*** (0.013)	0.825*** (0.013)
STARS3	1.064*** (0.015)	1.064*** (0.015)
STARS4	1.229*** (0.021)	1.229*** (0.021)
Observations	12,795	12,795
Log Likelihood	−23,659.120	−23,659.560
θ	39,834.340 (37,787.630) (p = 0.292)	39,835.040 (37,788.470) (p = 0.292)
Akaike Inf. Crit.	47,330.240	47,329.110
Residual Deviance	15,373.240 (df = 12789)	15,374.120 (df = 12790)
Null Deviance (df = 12794)	22,859.700	22,859.700
Note:		*p<0.1; **p<0.05; ***p<0.01

5.2.1.1 Binomial Regression Model 1 Evaluation

In the model-fitting criterion, the chi-squared p-value is 1. This implies a failure to reject the null hypothesis.

$residual.deviance [1] 15374.12

$residual.degrees.of.freedom [1] 12790

$chisq.p.value [1] 2.201289e-52

5.2.2 Binomial Regression Model 2

In the second negative binomial regression model, all of the coefficients are positive except for that of pH. The only significant variable is the label appeal. Except for the score of 3, all of the other scores for label appeal, yield significant results. Most of the coefficients for label appeal are close to 1 or slightly greater than 1 (0.7 for Label Appeal = 0, 0.9 for Label Appeal = 1, 1.09 for Label Appeal = 2, and 0.7 for Label Appeal = 3). The only score that yeilds a coefficient that is less than 1 is -1. The coefficient for this is 0.4. The standard error is 3.5. The theta value is 23.46, guaranteeing a lower level of overdispersion.

Table 15: Binomial Regression Model 2

	Dependent variable:	
	TARGET	
	(1)	(2)
Constant	0.462*** (0.045)	0.428*** (0.037)
CitricAcid	0.004 (0.006)	
pH	−0.011 (0.008)	
LabelAppeal-1	0.383*** (0.039)	0.383*** (0.039)
LabelAppeal0	0.685*** (0.038)	0.685*** (0.038)
LabelAppeal1	0.909*** (0.038)	0.909*** (0.038)
LabelAppeal2	1.092*** (0.044)	1.092*** (0.044)
LabelAppeal3	0.703 (0.615)	0.671 (0.614)
Observations	12,796	12,796
Log Likelihood	−26,356.870	−26,358.000
θ	23.465*** (3.501) (p = 0.000)	23.422*** (3.489) (p = 0.000)
Akaike Inf. Crit.	52,729.730	52,728.000
Residual Deviance	19,237.720 (df = 12788)	19,237.400 (df = 12790)
Null Deviance (df = 12795)	21,051.280	21,048.310
Note:		*p<0.1; **p<0.05; ***p<0.01

5.2.2.1 Binomial Regression Model 2 Evaluation

Unlike the previous model, the chi-squared p-value for this model is close to 0. This means that the null hypothesis can be rejected.

$residual.deviance [1] 19237.4

$residual.degrees.of.freedom [1] 12790

$chisq.p.value [1] 4.355531e-269

5.3 Multiple Linear Regression

5.3.1 Linear Regression with All Variables

The first linear regression we generate includes all variables from our data set. The intercept is at `3.139` cases and `Density` shows a large negative impact on cases sold but with its narrow range its difficult to tell how meaningful this variable is in cases sold. The `STARS` variable shows an expected impact on cases sold, the difference between 1 Star and 4 Stars is an added `3.36` cases in sales.

Table 16: Linear Model with all variables

	Dependent variable:
	TARGET
Constant	3.139*** (0.606)
FixedAcidity	−0.008*** (0.003)
VolatileAcidity	−0.125*** (0.020)
CitricAcid	0.013 (0.019)
I(ResidualSugar^1.25)	−0.001** (0.0002)
Chlorides	−0.234*** (0.052)
I(FreeSulfurDioxide^1.25)	0.0001*** (0.00003)
TotalSulfurDioxide	0.0002** (0.0001)
Density	−1.480** (0.602)
pH	−0.003 (0.024)
Sulphates	−0.046** (0.018)
Alcohol	0.016*** (0.004)
LabelAppeal	0.427*** (0.019)
STARS2	1.905*** (0.037)
STARS3	2.697*** (0.046)
STARS4	3.355*** (0.080)
Observations	7,256
R^2	0.501
Adjusted R^2	0.500
Residual Std. Error	1.356 (df = 7240)
F Statistic	485.267*** (df = 15; 7240) (p = 0.000)
Note:	*p<0.1; **p<0.05; ***p<0.01

5.3.1.1 Linear Model Metrics with all Variables

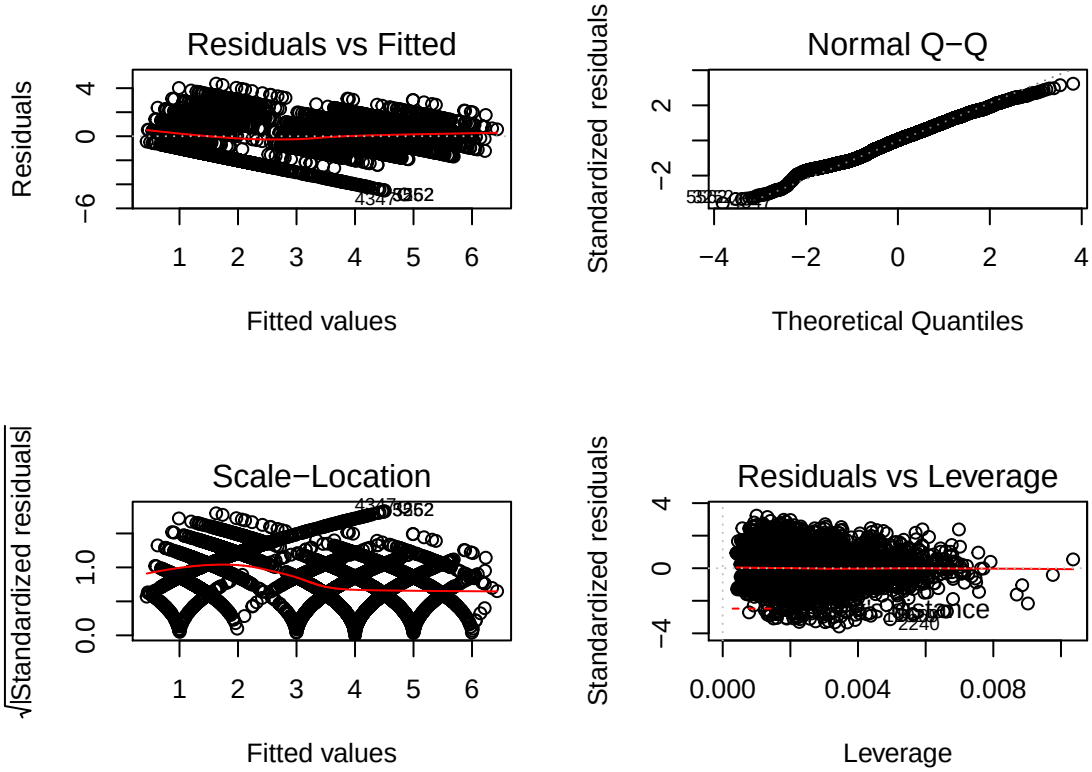
5.3.1.1.1 Multicollinearity

We square `GVIF^(1/(2*Df))` [8] in order to use the VIF threshold of 5 for multicollinearity. Fortunately, we find that no variable exceeds our pre-established threshold of 5 for multicollinearity.

rn	GVIF	Df	GVIF^(1/(2*Df))	Adjusted_GVIF
FixedAcidity	1.003005	1	1.001501	1.003005
VolatileAcidity	1.004193	1	1.002095	1.004193
CitricAcid	1.003311	1	1.001654	1.003311
I(ResidualSugar^1.25)	1.001823	1	1.000911	1.001823
Chlorides	1.002043	1	1.001021	1.002043
I(FreeSulfurDioxide^1.25)	1.003812	1	1.001904	1.003812
TotalSulfurDioxide	1.005073	1	1.002533	1.005073
Density	1.002075	1	1.001037	1.002075
pH	1.002538	1	1.001268	1.002538
Sulphates	1.003861	1	1.001929	1.003861
Alcohol	1.006806	1	1.003397	1.006806
LabelAppeal	1.106042	1	1.051685	1.106042
STARS	1.121941	3	1.019362	1.039098

5.3.1.1.2 Diagnositic Plots

[8] "Which Variance Inflation Factor Should I Be Using: $GVIF$ or $textGVIF^{1/(2cdottextdf)}$?" R. N.p., n.d. Web. 13 Nov. 2016.


Residuals vs Fitted
Residuals
Fitted values
Normal Q−Q
Standardized residuals
Theoretical Quantiles
Scale−Location
√|Standardized residuals|
Fitted values
Residuals vs Leverage
Standardized residuals
Cook's distance
Leverage

5.3.2 Linear Regression Selection using AIC

5.3.2.1 Variable Selection

Using the R package `MASS` we can utilize the `stepAIC` function with the parameter of `direction` set to `both` to select our best subset of variables for a new model.

The method effectively removed `pH` and `CitricAcid` which were both shown to be not significiant in the previous linear model using all variables.

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## TARGET ~ FixedAcidity + VolatileAcidity + CitricAcid + I(ResidualSugar^1.25) +
##     Chlorides + I(FreeSulfurDioxide^1.25) + TotalSulfurDioxide +
##     Density + pH + Sulphates + Alcohol + LabelAppeal + STARS
##
## Final Model:
## TARGET ~ FixedAcidity + VolatileAcidity + I(ResidualSugar^1.25) +
##     Chlorides + I(FreeSulfurDioxide^1.25) + TotalSulfurDioxide +
##     Density + Sulphates + Alcohol + LabelAppeal + STARS
##
##
##           Step Df   Deviance Resid. Df Resid. Dev      AIC
## 1                                 7240   13311.93 4435.174
## 2         - pH  1 0.03552113      7241   13311.97 4433.193
## 3 - CitricAcid  1 0.94340380      7242   13312.91 4431.707
```

5.3.2.2 Model using Variable Selection

We see slight variation in our intercept and some variable coefficients which is expected with the reduced number of variables. However, we don't see any large changes, one benefit with the reduced variables is our model interpretability is improved and our F Statistic has increased with the reduced degrees of freedom.

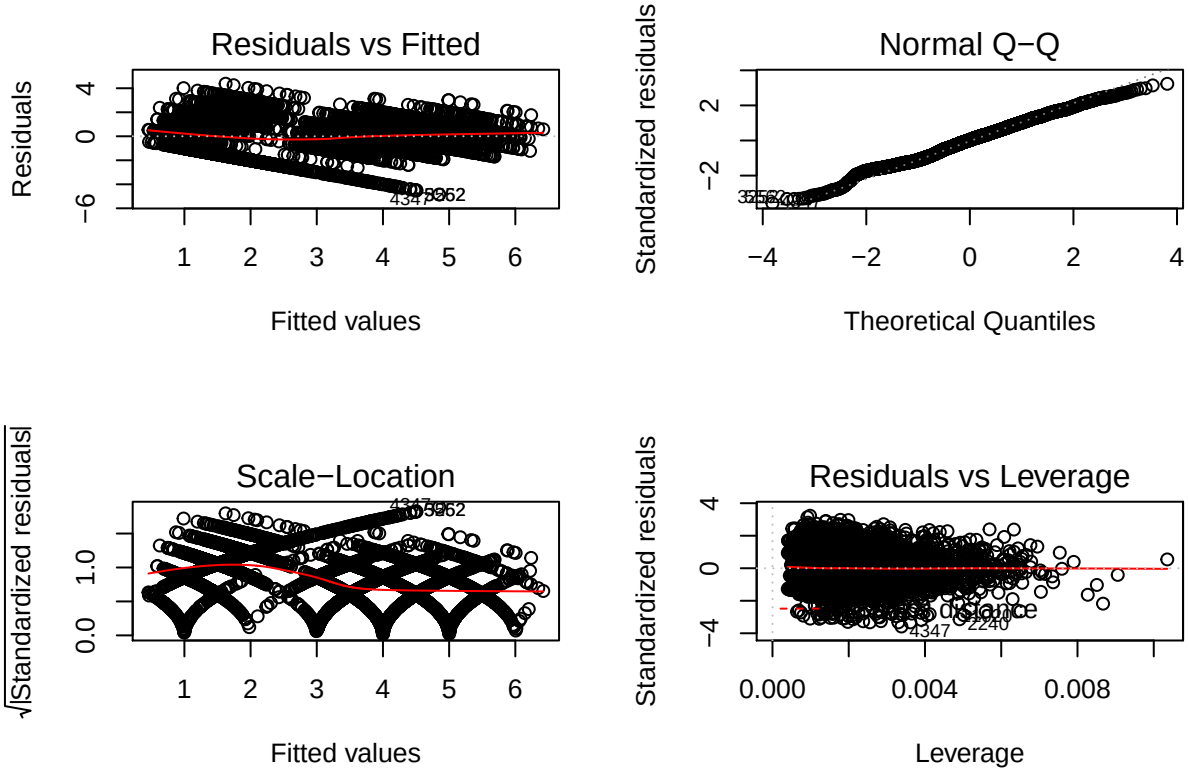
Additionally, we see that the adjusted R^2 has not changed which is expected since we removed variables that were not considered significant.

Table 18: Linear Model with select variables

	Dependent variable:
	TARGET
Constant	3.134*** (0.601)
FixedAcidity	−0.008*** (0.003)
VolatileAcidity	−0.126*** (0.020)
I(ResidualSugar^1.25)	−0.001** (0.0002)
Chlorides	−0.235*** (0.052)
I(FreeSulfurDioxide^1.25)	0.0001*** (0.00003)
TotalSulfurDioxide	0.0002** (0.0001)
Density	−1.482** (0.602)
Sulphates	−0.046** (0.018)
Alcohol	0.016*** (0.004)
LabelAppeal	0.427*** (0.019)
STARS2	1.906*** (0.037)
STARS3	2.697*** (0.046)
STARS4	3.355*** (0.080)
Observations	7,256
R^2	0.501
Adjusted R^2	0.500
Residual Std. Error	1.356 (df = 7242)
F Statistic	559.996*** (df = 13; 7242) (p = 0.000)
Note:	*p<0.1; **p<0.05; ***p<0.01

5.3.2.3 Linear Model Metrics with select Variables

5.3.2.3.1 Diagnositic Plots



5.3.2.3.2 Multicollinearity

We square `GVIF^(1/(2*Df))` in order to use the VIF threshold of 5 for multicollinearity. Fortunately, we find that no variable exceeds our pre-established threshold of 5 for multicollinearity.

rn	GVIF	Df	GVIF^(1/(2*Df))	Adjusted_GVIF
FixedAcidity	1.002826	1	1.001412	1.002826
VolatileAcidity	1.004095	1	1.002045	1.004095
I(ResidualSugar^1.25)	1.001601	1	1.000800	1.001601
Chlorides	1.001750	1	1.000875	1.001750
I(FreeSulfurDioxide^1.25)	1.003762	1	1.001879	1.003762
TotalSulfurDioxide	1.004725	1	1.002360	1.004725
Density	1.002057	1	1.001028	1.002057
Sulphates	1.003403	1	1.001700	1.003403
Alcohol	1.006586	1	1.003288	1.006586
LabelAppeal	1.105763	1	1.051553	1.105763
STARS	1.118645	3	1.018862	1.038080

6 Selected Model

We reference AIC as per this paper blah blah blah

7 Appendix A

7.1 Session Info

- R version 3.3.2 (2016-10-31), `x86_64-w64-mingw32`
- Locale: `LC_COLLATE=English_United States.1252`, `LC_CTYPE=English_United States.1252`, `LC_MONETARY=English_United States.1252`, `LC_NUMERIC=C`, `LC_TIME=English_United States.1252`
- Base packages: base, datasets, graphics, grDevices, methods, parallel, stats, utils
- Other packages: abc 2.1, abc.data 1.0, AER 1.2-4, bibtex 0.4.0, boot 1.3-18, car 2.1-4, corrplot 0.77, data.table 1.10.0, doParallel 1.0.10, dplyr 0.5.0, e1071 1.6-7, foreach 1.4.3, forecast 7.3, Formula 1.2-1, ggplot2 2.2.0, glmulti 1.0.7, highlight 0.4.7, Hmisc 4.0-0, iterators 1.0.8, itertools 0.1-3, knitcitations 1.0.7, knitr 1.15.1, lars 1.2, lattice 0.20-34, leaps 2.9, lmtest 0.9-34, locfit 1.5-9.1, magrittr 1.5, MASS 7.3-45, matrixStats 0.51.0, missForest 1.4, nnet 7.3-12, pacman 0.4.1, pander 0.6.0, pracma 1.9.5, purrr 0.2.2, quantreg 5.29, randomForest 4.6-12, readr 1.0.0, rJava 0.9-8, sandwich 2.3-4, scales 0.4.1, SparseM 1.74, stargazer 5.2, stringr 1.1.0, survival 2.40-1, tibble 1.2, tidyr 0.6.0, tidyverse 1.0.0, timeDate 3012.100, xlsx 0.5.7, xlsxjars 0.6.1, xtable 1.8-2, zoo 1.7-13
- Loaded via a namespace (and not attached): acepack 1.4.1, assertthat 0.1, backports 1.0.4, bitops 1.0-6, class 7.3-14, cluster 2.0.5, codetools 0.2-15, colorspace 1.3-1, DBI 0.5-1, digest 0.6.10, evaluate 0.10, foreign 0.8-67, fracdiff 1.4-2, grid 3.3.2, gridExtra 2.2.1, gtable 0.2.0, highr 0.6, htmlTable 1.7, htmltools 0.3.5, httr 1.2.1, latticeExtra 0.6-28, lazyeval 0.2.0, lme4 1.1-12, lubridate 1.6.0, Matrix 1.2-7.1, MatrixModels 0.4-1, mgcv 1.8-16, minqa 1.2.4, munsell 0.4.3, nlme 3.1-128, nloptr 1.0.4, pbkrtest 0.4-6, plyr 1.8.4, quadprog 1.5-5, R6 2.2.0, RColorBrewer 1.1-2, Rcpp 0.12.8, RCurl 1.95-4.8, RefManageR 0.13.1, RJSONIO 1.3-0, rmarkdown 1.2, rpart 4.1-10, rprojroot 1.1, splines 3.3.2, stringi 1.1.2, tools 3.3.2, tseries 0.10-35, XML 3.98-1.5, yaml 2.1.14

7.2 Data Dictionary

Variable Code	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 averag**
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. High numbers suggest customers like the label design. Negative numbers suggest customes 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

7.3 R source code

Please see Homework 5.rmd on GitHub for source code.

https://github.com/ChristopheHunt/DATA-621-Group-1/blob/master/Homework%205/Homework%205.Rmd