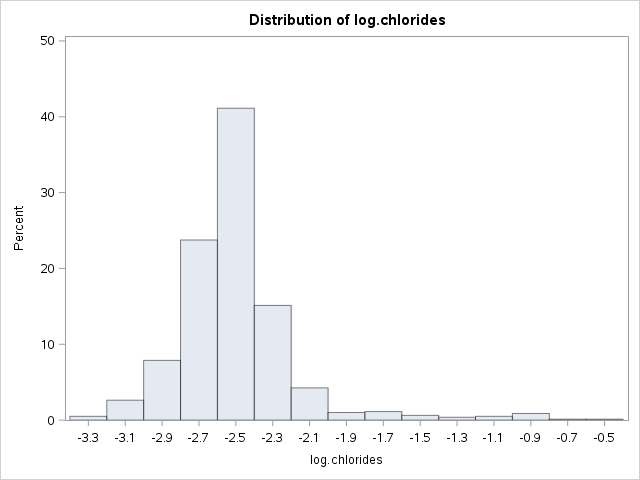
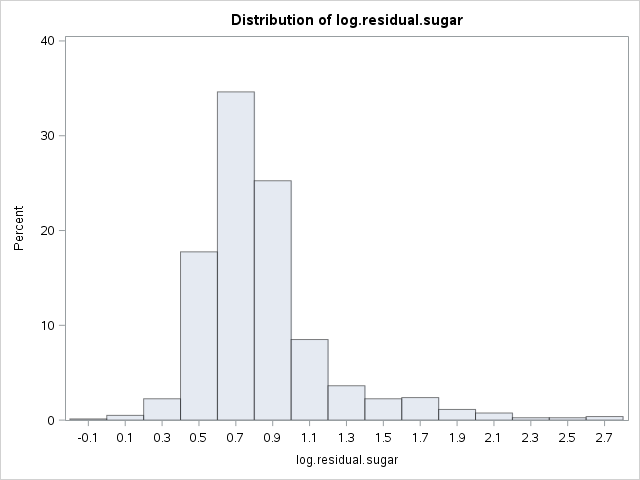
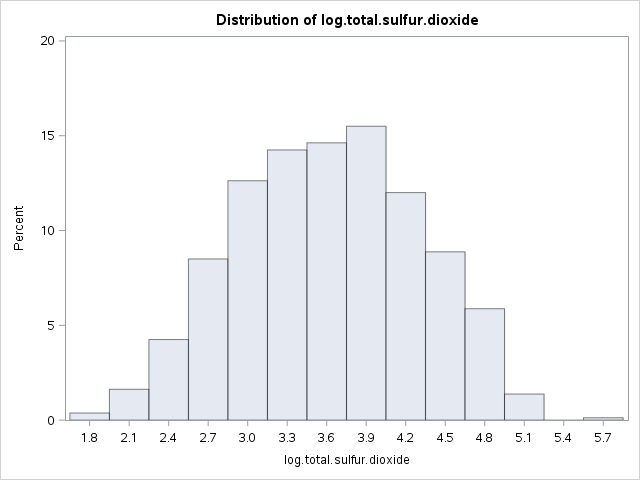
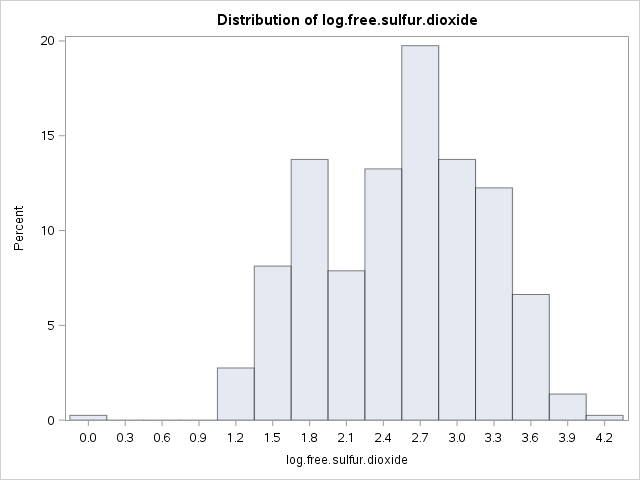
# Appendix

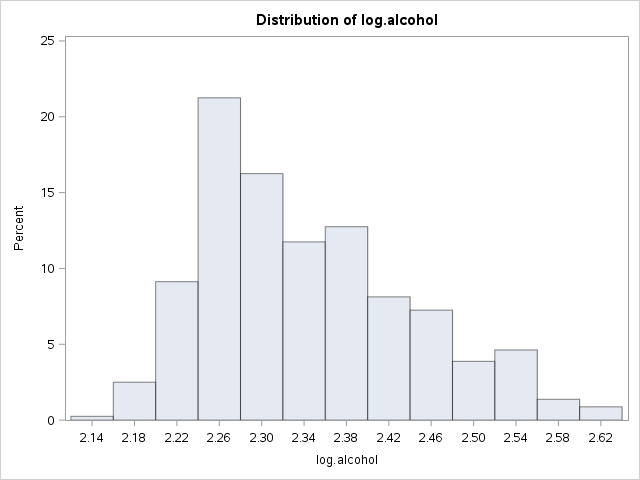
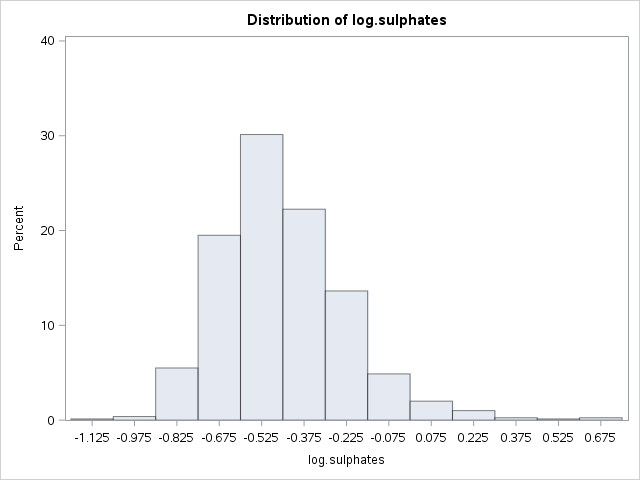
## EDA A (Histograms)







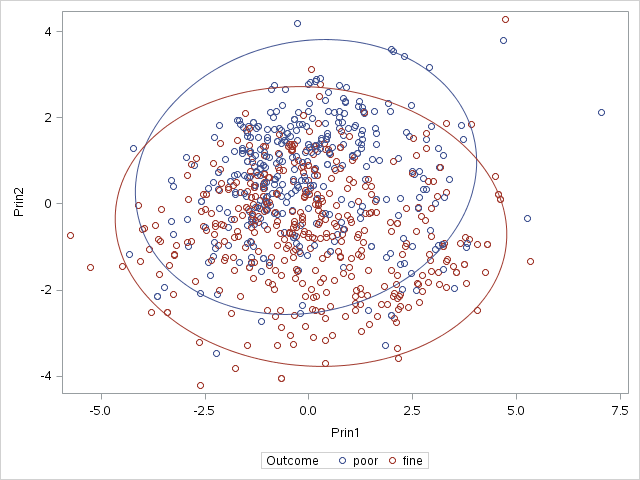


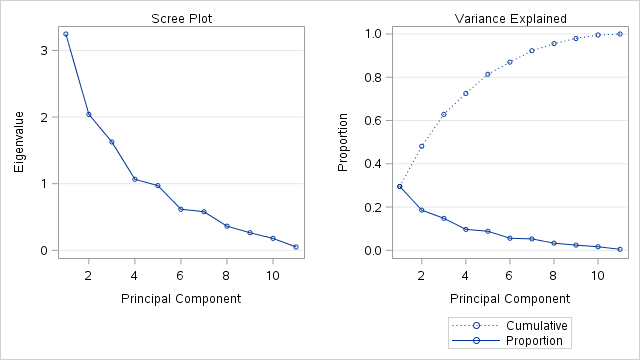


## EDA B (Correlation Coefficients)

| **Pearson Correlation Coefficients, N = 1599 Prob > |r| under H0: Rho=0** | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **fixed\_acidity** | **volatile\_acidity** | | **citric\_acid** | | | **residual\_sugar** | | **chlorides** | | **free\_sulfur\_dioxide** | | |
| **fixed\_acidity** | 1.00000 | -0.25613 <.0001 | | 0.67170 <.0001 | | | 0.11478 <.0001 | | 0.09371 0.0002 | | -0.15379 <.0001 | | |
| **volatile\_acidity** | -0.25613 <.0001 | 1.00000 | | -0.55250 <.0001 | | | 0.00192 0.9389 | | 0.06130 0.0142 | | -0.01050 0.6747 | | |
| **citric\_acid** | 0.67170 <.0001 | -0.55250 <.0001 | | 1.00000 | | | 0.14358 <.0001 | | 0.20382 <.0001 | | -0.06098 0.0147 | | |
| **residual\_sugar** | 0.11478 <.0001 | 0.00192 0.9389 | | 0.14358 <.0001 | | | 1.00000 | | 0.05561 0.0262 | | 0.18705 <.0001 | | |
| **chlorides** | 0.09371 0.0002 | 0.06130 0.0142 | | 0.20382 <.0001 | | | 0.05561 0.0262 | | 1.00000 | | 0.00556 0.8241 | | |
| **free\_sulfur\_dioxide** | -0.15379 <.0001 | -0.01050 0.6747 | | -0.06098 0.0147 | | | 0.18705 <.0001 | | 0.00556 0.8241 | | 1.00000 | | |
| **total\_sulfur\_dioxide** | -0.11318 <.0001 | 0.07647 0.0022 | | 0.03553 0.1555 | | | 0.20303 <.0001 | | 0.04740 0.0581 | | 0.66767 <.0001 | | |
| **density** | 0.66805 <.0001 | 0.02203 0.3788 | | 0.36495 <.0001 | | | 0.35528 <.0001 | | 0.20063 <.0001 | | -0.02195 0.3805 | | |
| **pH** | -0.68298 <.0001 | 0.23494 <.0001 | | -0.54190 <.0001 | | | -0.08565 0.0006 | | -0.26503 <.0001 | | 0.07038 0.0049 | | |
| **sulphates** | 0.18301 <.0001 | -0.26099 <.0001 | | 0.31277 <.0001 | | | 0.00553 0.8252 | | 0.37126 <.0001 | | 0.05166 0.0389 | | |
| **alcohol** | -0.06167 0.0136 | -0.20229 <.0001 | | 0.10990 <.0001 | | | 0.04208 0.0926 | | -0.22114 <.0001 | | -0.06941 0.0055 | | |
| **quality** | 0.12405 <.0001 | -0.39056 <.0001 | | 0.22637 <.0001 | | | 0.01373 0.5832 | | -0.12891 <.0001 | | -0.05066 0.0428 | | |
| **outcome** | 0.09509 0.0001 | -0.32144 <.0001 | | 0.15913 <.0001 | | | -0.00216 0.9312 | | -0.10949 <.0001 | | -0.06176 0.0135 | | |
| **Pearson Correlation Coefficients, N = 1599 Prob > |r| under H0: Rho=0** | | | | | | | | | | | | |
|  | **total\_sulfur\_dioxide** | | **density** | | **pH** | **sulphates** | | **alcohol** | | **quality** | | **outcome** |
| **fixed\_acidity** | -0.11318 <.0001 | | 0.66805 <.0001 | | -0.68298 <.0001 | 0.18301 <.0001 | | -0.06167 0.0136 | | 0.12405 <.0001 | | 0.09509 0.0001 |
| **volatile\_acidity** | 0.07647 0.0022 | | 0.02203 0.3788 | | 0.23494 <.0001 | -0.26099 <.0001 | | -0.20229 <.0001 | | -0.39056 <.0001 | | -0.32144 <.0001 |
| **citric\_acid** | 0.03553 0.1555 | | 0.36495 <.0001 | | -0.54190 <.0001 | 0.31277 <.0001 | | 0.10990 <.0001 | | 0.22637 <.0001 | | 0.15913 <.0001 |
| **residual\_sugar** | 0.20303 <.0001 | | 0.35528 <.0001 | | -0.08565 0.0006 | 0.00553 0.8252 | | 0.04208 0.0926 | | 0.01373 0.5832 | | -0.00216 0.9312 |
| **chlorides** | 0.04740 0.0581 | | 0.20063 <.0001 | | -0.26503 <.0001 | 0.37126 <.0001 | | -0.22114 <.0001 | | -0.12891 <.0001 | | -0.10949 <.0001 |
| **free\_sulfur\_dioxide** | 0.66767 <.0001 | | -0.02195 0.3805 | | 0.07038 0.0049 | 0.05166 0.0389 | | -0.06941 0.0055 | | -0.05066 0.0428 | | -0.06176 0.0135 |
| **total\_sulfur\_dioxide** | 1.00000 | | 0.07127 0.0044 | | -0.06649 0.0078 | 0.04295 0.0860 | | -0.20565 <.0001 | | -0.18510 <.0001 | | -0.23196 <.0001 |
| **density** | 0.07127 0.0044 | | 1.00000 | | -0.34170 <.0001 | 0.14851 <.0001 | | -0.49618 <.0001 | | -0.17492 <.0001 | | -0.15911 <.0001 |
| **pH** | -0.06649 0.0078 | | -0.34170 <.0001 | | 1.00000 | -0.19665 <.0001 | | 0.20563 <.0001 | | -0.05773 0.0210 | | -0.00326 0.8962 |
| **sulphates** | 0.04295 0.0860 | | 0.14851 <.0001 | | -0.19665 <.0001 | 1.00000 | | 0.09359 0.0002 | | 0.25140 <.0001 | | 0.21807 <.0001 |
| **alcohol** | -0.20565 <.0001 | | -0.49618 <.0001 | | 0.20563 <.0001 | 0.09359 0.0002 | | 1.00000 | | 0.47617 <.0001 | | 0.43475 <.0001 |
| **quality** | -0.18510 <.0001 | | -0.17492 <.0001 | | -0.05773 0.0210 | 0.25140 <.0001 | | 0.47617 <.0001 | | 1.00000 | |  |
| **outcome** | -0.23196 <.0001 | | -0.15911 <.0001 | | -0.00326 0.8962 | 0.21807 <.0001 | | 0.43475 <.0001 | |  | | 1.00000 |

## EDA C





| **Eigenvectors** | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Prin1** | **Prin2** | **Prin3** | **Prin4** | **Prin5** | **Prin6** | **Prin7** | **Prin8** | **Prin9** | **Prin10** | **Prin11** |
| **log.residual.sugar** | 0.202627 | 0.123392 | 0.020261 | 0.814467 | 0.210575 | 0.184599 | -.185556 | -.332122 | 0.038421 | 0.080907 | 0.220846 |
| **log.chlorides** | 0.254726 | 0.228768 | -.166801 | -.287023 | 0.588489 | 0.415282 | -.326898 | 0.283642 | -.227462 | -.115389 | 0.037793 |
| **log.free.sulfur.dioxide** | -.040139 | 0.479036 | 0.492869 | -.015304 | -.113395 | 0.032362 | 0.117605 | 0.059004 | -.495062 | 0.497236 | -.047019 |
| **log.total.sulfur.dioxide** | 0.015459 | 0.543050 | 0.401430 | -.008259 | -.150343 | 0.100546 | 0.057426 | 0.084612 | 0.400590 | -.580604 | 0.053849 |
| **log.sulphates** | 0.226229 | -.097617 | 0.357058 | -.218208 | 0.607700 | -.372766 | 0.326973 | -.348847 | 0.149155 | 0.033051 | 0.063148 |
| **log.alcohol** | -.145799 | -.446224 | 0.357382 | 0.283185 | 0.170404 | 0.365564 | 0.338502 | 0.271741 | -.198421 | -.254471 | -.341298 |
| **fixed.acidity** | 0.481550 | -.111009 | -.085173 | 0.028741 | -.224990 | -.064665 | 0.387777 | 0.231735 | -.317343 | -.195199 | 0.591627 |
| **volatile.acidity** | -.212523 | 0.310098 | -.432358 | 0.071343 | 0.182745 | 0.228762 | 0.651639 | 0.119531 | 0.278847 | 0.252755 | 0.018989 |
| **citric.acid** | 0.441340 | -.190797 | 0.233259 | -.003318 | -.106781 | 0.130904 | -.109003 | 0.417350 | 0.535007 | 0.460326 | -.040758 |
| **density** | 0.416156 | 0.232595 | -.242697 | 0.246959 | 0.012233 | -.448244 | 0.072067 | 0.196148 | -.117666 | -.125996 | -.615112 |
| **pH** | -.418028 | 0.020689 | 0.070637 | 0.243385 | 0.282795 | -.484916 | -.167342 | 0.567820 | 0.032667 | 0.013536 | 0.306281 |

## SAS Code – EDA

proc import datafile="/folders/myfolders/winequality-red.csv"

dbms=dlm out=wine replace;

delimiter=',';

getnames=yes;

run;

proc univariate data = wine;

histogram;

run;

/\*quality close to normal distribution, slight right skew. Enough levels to consider like a cont var\*/

/\*Included in write up\*/

proc corr data = wine plots(maxpoints=none)=scatter;

var fixed.acidity volatile.acidity citric.acid residual.sugar chlorides free.sulfur.dioxide total.sulfur.dioxide density pH sulphates alcohol quality outcome;

run;

/\*A closer look at high correlations\*/

proc sgscatter data = wine;

matrix fixed.acidity citric.acid free.sulfur.dioxide total.sulfur.dioxide density pH;

run;

proc princomp plots=all data=wine out=pca;  
var "log.residual.sugar"N

"log.chlorides"N  
 "log.free.sulfur.dioxide"N  
 "log.total.sulfur.dioxide"N  
 "log.sulphates"N  
 "log.alcohol"N  
 "fixed.acidity"N  
 "volatile.acidity"N  
 "citric.acid"N  
 density  
 pH;  
id Outcome;  
run;  
  
proc sgplot data=pca;  
scatter x=PRIN1 y=PRIN2 / group=Outcome;  
ellipse x=PRIN1 y=PRIN2 / group=Outcome;  
run;

## Objective 1 – SAS Output

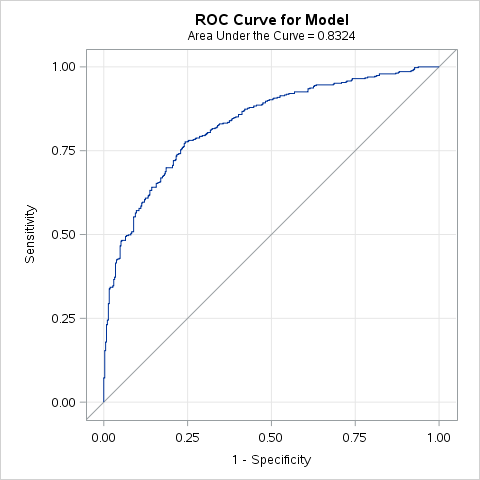
**All Variables**

| **Hosmer and Lemeshow Goodness-of-Fit Test** | | |
| --- | --- | --- |
| **Chi-Square** | **DF** | **Pr > ChiSq** |
| 1.4678 | 8 | 0.9932 |

| **Model Fit Statistics** | | |
| --- | --- | --- |
| **Criterion** | **Intercept Only** | **Intercept and Covariates** |
| **AIC** | 1106.827 | 825.998 |
| **SC** | 1111.511 | 882.214 |
| **-2 Log L** | 1104.827 | 801.998 |

| **Analysis of Maximum Likelihood Estimates** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Intercept** | 1 | 118.8 | 114.5 | 1.0764 | 0.2995 |
| **fixed.acidity** | 1 | 0.1105 | 0.1418 | 0.6068 | 0.4360 |
| **volatile.acidity** | 1 | -3.0677 | 0.6917 | 19.6697 | <.0001 |
| **citric.acid** | 1 | -1.9429 | 0.8011 | 5.8827 | 0.0153 |
| **residual.sugar** | 1 | 0.1703 | 0.0779 | 4.7795 | 0.0288 |
| **free.sulfur.dioxide** | 1 | 0.00832 | 0.0124 | 0.4515 | 0.5016 |
| **total.sulfur.dioxide** | 1 | -0.0144 | 0.00408 | 12.4031 | 0.0004 |
| **density** | 1 | -123.4 | 116.9 | 1.1147 | 0.2911 |
| **pH** | 1 | -1.3418 | 1.0140 | 1.7509 | 0.1858 |
| **sulphates** | 1 | 4.9100 | 0.7653 | 41.1645 | <.0001 |
| **alcohol** | 1 | 0.7442 | 0.1513 | 24.1863 | <.0001 |
| **chlorides** | 1 | -8.6028 | 2.3832 | 13.0305 | 0.0003 |

| **Classification Table** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Prob Level** | **Correct** | | **Incorrect** | | **Percentages** | | | | |
| **Event** | **Non- Event** | **Event** | **Non- Event** | **Correct** | **Sensi- tivity** | **Speci- ficity** | **False POS** | **False NEG** |
| **0.000** | 429 | 0 | 371 | 0 | 53.6 | 100.0 | 0.0 | 46.4 | . |
| **0.020** | 429 | 1 | 370 | 0 | 53.8 | 100.0 | 0.3 | 46.3 | 0.0 |
| **0.040** | 429 | 6 | 365 | 0 | 54.4 | 100.0 | 1.6 | 46.0 | 0.0 |
| **0.060** | 429 | 9 | 362 | 0 | 54.8 | 100.0 | 2.4 | 45.8 | 0.0 |
| **0.080** | 428 | 14 | 357 | 1 | 55.3 | 99.8 | 3.8 | 45.5 | 6.7 |
| **0.100** | 422 | 27 | 344 | 7 | 56.1 | 98.4 | 7.3 | 44.9 | 20.6 |
| **0.120** | 421 | 40 | 331 | 8 | 57.6 | 98.1 | 10.8 | 44.0 | 16.7 |
| **0.140** | 417 | 54 | 317 | 12 | 58.9 | 97.2 | 14.6 | 43.2 | 18.2 |
| **0.160** | 414 | 76 | 295 | 15 | 61.3 | 96.5 | 20.5 | 41.6 | 16.5 |
| **0.180** | 409 | 94 | 277 | 20 | 62.9 | 95.3 | 25.3 | 40.4 | 17.5 |
| **0.200** | 407 | 113 | 258 | 22 | 65.0 | 94.9 | 30.5 | 38.8 | 16.3 |
| **0.220** | 403 | 128 | 243 | 26 | 66.4 | 93.9 | 34.5 | 37.6 | 16.9 |
| **0.240** | 399 | 145 | 226 | 30 | 68.0 | 93.0 | 39.1 | 36.2 | 17.1 |
| **0.260** | 394 | 156 | 215 | 35 | 68.8 | 91.8 | 42.0 | 35.3 | 18.3 |
| **0.280** | 390 | 174 | 197 | 39 | 70.5 | 90.9 | 46.9 | 33.6 | 18.3 |
| **0.300** | 386 | 180 | 191 | 43 | 70.8 | 90.0 | 48.5 | 33.1 | 19.3 |
| **0.320** | 381 | 190 | 181 | 48 | 71.4 | 88.8 | 51.2 | 32.2 | 20.2 |
| **0.340** | 371 | 201 | 170 | 58 | 71.5 | 86.5 | 54.2 | 31.4 | 22.4 |
| **0.360** | 365 | 215 | 156 | 64 | 72.5 | 85.1 | 58.0 | 29.9 | 22.9 |
| **0.380** | 358 | 220 | 151 | 71 | 72.3 | 83.4 | 59.3 | 29.7 | 24.4 |
| **0.400** | 355 | 227 | 144 | 74 | 72.8 | 82.8 | 61.2 | 28.9 | 24.6 |
| **0.420** | 353 | 235 | 136 | 76 | 73.5 | 82.3 | 63.3 | 27.8 | 24.4 |
| **0.440** | 344 | 244 | 127 | 85 | 73.5 | 80.2 | 65.8 | 27.0 | 25.8 |
| **0.460** | 339 | 257 | 114 | 90 | 74.5 | 79.0 | 69.3 | 25.2 | 25.9 |
| **0.480** | 333 | 265 | 106 | 96 | 74.8 | 77.6 | 71.4 | 24.1 | 26.6 |
| **0.500** | 322 | 278 | 93 | 107 | 75.0 | 75.1 | 74.9 | 22.4 | 27.8 |
| **0.520** | 312 | 285 | 86 | 117 | 74.6 | 72.7 | 76.8 | 21.6 | 29.1 |
| **0.540** | 307 | 290 | 81 | 122 | 74.6 | 71.6 | 78.2 | 20.9 | 29.6 |
| **0.560** | 299 | 294 | 77 | 130 | 74.1 | 69.7 | 79.2 | 20.5 | 30.7 |
| **0.580** | 290 | 301 | 70 | 139 | 73.9 | 67.6 | 81.1 | 19.4 | 31.6 |
| **0.600** | 286 | 304 | 67 | 143 | 73.8 | 66.7 | 81.9 | 19.0 | 32.0 |
| **0.620** | 279 | 309 | 62 | 150 | 73.5 | 65.0 | 83.3 | 18.2 | 32.7 |
| **0.640** | 272 | 313 | 58 | 157 | 73.1 | 63.4 | 84.4 | 17.6 | 33.4 |
| **0.660** | 265 | 318 | 53 | 164 | 72.9 | 61.8 | 85.7 | 16.7 | 34.0 |
| **0.680** | 254 | 322 | 49 | 175 | 72.0 | 59.2 | 86.8 | 16.2 | 35.2 |
| **0.700** | 247 | 328 | 43 | 182 | 71.9 | 57.6 | 88.4 | 14.8 | 35.7 |
| **0.720** | 240 | 332 | 39 | 189 | 71.5 | 55.9 | 89.5 | 14.0 | 36.3 |
| **0.740** | 219 | 336 | 35 | 210 | 69.4 | 51.0 | 90.6 | 13.8 | 38.5 |
| **0.760** | 207 | 340 | 31 | 222 | 68.4 | 48.3 | 91.6 | 13.0 | 39.5 |
| **0.780** | 202 | 347 | 24 | 227 | 68.6 | 47.1 | 93.5 | 10.6 | 39.5 |
| **0.800** | 185 | 352 | 19 | 244 | 67.1 | 43.1 | 94.9 | 9.3 | 40.9 |
| **0.820** | 174 | 352 | 19 | 255 | 65.8 | 40.6 | 94.9 | 9.8 | 42.0 |
| **0.840** | 161 | 357 | 14 | 268 | 64.8 | 37.5 | 96.2 | 8.0 | 42.9 |
| **0.860** | 147 | 358 | 13 | 282 | 63.1 | 34.3 | 96.5 | 8.1 | 44.1 |
| **0.880** | 128 | 365 | 6 | 301 | 61.6 | 29.8 | 98.4 | 4.5 | 45.2 |
| **0.900** | 106 | 365 | 6 | 323 | 58.9 | 24.7 | 98.4 | 5.4 | 46.9 |
| **0.920** | 82 | 367 | 4 | 347 | 56.1 | 19.1 | 98.9 | 4.7 | 48.6 |
| **0.940** | 62 | 370 | 1 | 367 | 54.0 | 14.5 | 99.7 | 1.6 | 49.8 |
| **0.960** | 34 | 370 | 1 | 395 | 50.5 | 7.9 | 99.7 | 2.9 | 51.6 |
| **0.980** | 9 | 371 | 0 | 420 | 47.5 | 2.1 | 100.0 | 0.0 | 53.1 |
| **1.000** | 0 | 371 | 0 | 429 | 46.4 | 0.0 | 100.0 | . | 53.6 |



**Backward Selection**

| **Analysis of Maximum Likelihood Estimates** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Intercept** | 1 | -2.2781 | 2.3563 | 0.9347 | 0.3336 |
| **volatile\_acidity** | 1 | -3.2885 | 0.6575 | 25.0122 | <.0001 |
| **citric\_acid** | 1 | -2.0836 | 0.6644 | 9.8346 | 0.0017 |
| **residual\_sugar** | 1 | 0.1270 | 0.0612 | 4.3012 | 0.0381 |
| **chlorides** | 1 | -8.7840 | 2.2923 | 14.6835 | 0.0001 |
| **total\_sulfur\_dioxide** | 1 | -0.0125 | 0.00289 | 18.5886 | <.0001 |
| **pH** | 1 | -1.8922 | 0.6974 | 7.3621 | 0.0067 |
| **sulphates** | 1 | 4.8440 | 0.7320 | 43.7964 | <.0001 |
| **alcohol** | 1 | 0.8600 | 0.1063 | 65.4906 | <.0001 |

| **Parameter Estimates and Profile-Likelihood Confidence Intervals** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | | | | | **Estimate** | **95% Confidence Limits** | | | |
| **Intercept** | | | | | -2.2781 | -6.9303 | | | 2.3230 |
| **volatile\_acidity** | | | | | -3.2885 | -4.6023 | | | -2.0218 |
| **citric\_acid** | | | | | -2.0836 | -3.4002 | | | -0.7925 |
| **residual\_sugar** | | | | | 0.1270 | 0.00614 | | | 0.2488 |
| **chlorides** | | | | | -8.7840 | -13.4330 | | | -4.4004 |
| **total\_sulfur\_dioxide** | | | | | -0.0125 | -0.0183 | | | -0.00687 |
| **pH** | | | | | -1.8922 | -3.2672 | | | -0.5295 |
| **sulphates** | | | | | 4.8440 | 3.4468 | | | 6.3203 |
| **alcohol** | | | | | 0.8600 | 0.6567 | | | 1.0738 |
| **Hosmer and Lemeshow Goodness-of-Fit Test** | | | | | | |
| **Chi-Square** | | **DF** | **Pr > ChiSq** | | | |
| 1.7628 | | 8 | 0.9874 | | | |
| **Model Fit Statistics** | | | | | | | |
| **Criterion** | **Intercept Only** | | | **Intercept and Covariates** | | | |
| **AIC** | 1106.827 | | | 821.685 | | | |
| **SC** | 1111.511 | | | 863.847 | | | |
| **-2 Log L** | 1104.827 | | | 803.685 | | | |

| **Classification Table** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Prob Level** | **Correct** | | **Incorrect** | | **Percentages** | | | | |
| **Event** | **Non- Event** | **Event** | **Non- Event** | **Correct** | **Sensi- tivity** | **Speci- ficity** | **False POS** | **False NEG** |
| **0.000** | 429 | 0 | 371 | 0 | 53.6 | 100.0 | 0.0 | 46.4 | . |
| **0.020** | 429 | 1 | 370 | 0 | 53.8 | 100.0 | 0.3 | 46.3 | 0.0 |
| **0.040** | 429 | 7 | 364 | 0 | 54.5 | 100.0 | 1.9 | 45.9 | 0.0 |
| **0.060** | 429 | 11 | 360 | 0 | 55.0 | 100.0 | 3.0 | 45.6 | 0.0 |
| **0.080** | 426 | 17 | 354 | 3 | 55.4 | 99.3 | 4.6 | 45.4 | 15.0 |
| **0.100** | 422 | 28 | 343 | 7 | 56.3 | 98.4 | 7.5 | 44.8 | 20.0 |
| **0.120** | 421 | 39 | 332 | 8 | 57.5 | 98.1 | 10.5 | 44.1 | 17.0 |
| **0.140** | 420 | 56 | 315 | 9 | 59.5 | 97.9 | 15.1 | 42.9 | 13.8 |
| **0.160** | 416 | 78 | 293 | 13 | 61.8 | 97.0 | 21.0 | 41.3 | 14.3 |
| **0.180** | 411 | 95 | 276 | 18 | 63.3 | 95.8 | 25.6 | 40.2 | 15.9 |
| **0.200** | 407 | 109 | 262 | 22 | 64.5 | 94.9 | 29.4 | 39.2 | 16.8 |
| **0.220** | 404 | 130 | 241 | 25 | 66.8 | 94.2 | 35.0 | 37.4 | 16.1 |
| **0.240** | 400 | 143 | 228 | 29 | 67.9 | 93.2 | 38.5 | 36.3 | 16.9 |
| **0.260** | 396 | 156 | 215 | 33 | 69.0 | 92.3 | 42.0 | 35.2 | 17.5 |
| **0.280** | 389 | 170 | 201 | 40 | 69.9 | 90.7 | 45.8 | 34.1 | 19.0 |
| **0.300** | 384 | 180 | 191 | 45 | 70.5 | 89.5 | 48.5 | 33.2 | 20.0 |
| **0.320** | 380 | 190 | 181 | 49 | 71.3 | 88.6 | 51.2 | 32.3 | 20.5 |
| **0.340** | 376 | 204 | 167 | 53 | 72.5 | 87.6 | 55.0 | 30.8 | 20.6 |
| **0.360** | 370 | 214 | 157 | 59 | 73.0 | 86.2 | 57.7 | 29.8 | 21.6 |
| **0.380** | 364 | 225 | 146 | 65 | 73.6 | 84.8 | 60.6 | 28.6 | 22.4 |
| **0.400** | 358 | 233 | 138 | 71 | 73.9 | 83.4 | 62.8 | 27.8 | 23.4 |
| **0.420** | 352 | 237 | 134 | 77 | 73.6 | 82.1 | 63.9 | 27.6 | 24.5 |
| **0.440** | 346 | 250 | 121 | 83 | 74.5 | 80.7 | 67.4 | 25.9 | 24.9 |
| **0.460** | 343 | 259 | 112 | 86 | 75.3 | 80.0 | 69.8 | 24.6 | 24.9 |
| **0.480** | 334 | 263 | 108 | 95 | 74.6 | 77.9 | 70.9 | 24.4 | 26.5 |
| **0.500** | 327 | 279 | 92 | 102 | 75.8 | 76.2 | 75.2 | 22.0 | 26.8 |
| **0.520** | 316 | 286 | 85 | 113 | 75.3 | 73.7 | 77.1 | 21.2 | 28.3 |
| **0.540** | 307 | 291 | 80 | 122 | 74.8 | 71.6 | 78.4 | 20.7 | 29.5 |
| **0.560** | 300 | 293 | 78 | 129 | 74.1 | 69.9 | 79.0 | 20.6 | 30.6 |
| **0.580** | 294 | 298 | 73 | 135 | 74.0 | 68.5 | 80.3 | 19.9 | 31.2 |
| **0.600** | 286 | 305 | 66 | 143 | 73.9 | 66.7 | 82.2 | 18.8 | 31.9 |
| **0.620** | 273 | 308 | 63 | 156 | 72.6 | 63.6 | 83.0 | 18.8 | 33.6 |
| **0.640** | 268 | 312 | 59 | 161 | 72.5 | 62.5 | 84.1 | 18.0 | 34.0 |
| **0.660** | 263 | 316 | 55 | 166 | 72.4 | 61.3 | 85.2 | 17.3 | 34.4 |
| **0.680** | 254 | 321 | 50 | 175 | 71.9 | 59.2 | 86.5 | 16.4 | 35.3 |
| **0.700** | 248 | 327 | 44 | 181 | 71.9 | 57.8 | 88.1 | 15.1 | 35.6 |
| **0.720** | 234 | 333 | 38 | 195 | 70.9 | 54.5 | 89.8 | 14.0 | 36.9 |
| **0.740** | 223 | 338 | 33 | 206 | 70.1 | 52.0 | 91.1 | 12.9 | 37.9 |
| **0.760** | 210 | 343 | 28 | 219 | 69.1 | 49.0 | 92.5 | 11.8 | 39.0 |
| **0.780** | 201 | 347 | 24 | 228 | 68.5 | 46.9 | 93.5 | 10.7 | 39.7 |
| **0.800** | 185 | 351 | 20 | 244 | 67.0 | 43.1 | 94.6 | 9.8 | 41.0 |
| **0.820** | 173 | 352 | 19 | 256 | 65.6 | 40.3 | 94.9 | 9.9 | 42.1 |
| **0.840** | 158 | 357 | 14 | 271 | 64.4 | 36.8 | 96.2 | 8.1 | 43.2 |
| **0.860** | 146 | 361 | 10 | 283 | 63.4 | 34.0 | 97.3 | 6.4 | 43.9 |
| **0.880** | 131 | 363 | 8 | 298 | 61.8 | 30.5 | 97.8 | 5.8 | 45.1 |
| **0.900** | 104 | 365 | 6 | 325 | 58.6 | 24.2 | 98.4 | 5.5 | 47.1 |
| **0.920** | 79 | 366 | 5 | 350 | 55.6 | 18.4 | 98.7 | 6.0 | 48.9 |
| **0.940** | 54 | 370 | 1 | 375 | 53.0 | 12.6 | 99.7 | 1.8 | 50.3 |
| **0.960** | 36 | 370 | 1 | 393 | 50.8 | 8.4 | 99.7 | 2.7 | 51.5 |
| **0.980** | 11 | 371 | 0 | 418 | 47.8 | 2.6 | 100.0 | 0.0 | 53.0 |
| **1.000** | 0 | 371 | 0 | 429 | 46.4 | 0.0 | 100.0 | . | 53.6 |





## SAS Code for Regressions

proc import datafile="/home/anhainguyen820/sasuser.v94/wine\_train.csv"

dbms=dlm out=wine replace;

delimiter=',';

getnames=yes;

run;

/\*Simple Logistic regression\*/

proc logistic data=wine plots=roc;

class Outcome / param=ref;

model Outcome(event='fine') = "fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

"residual.sugar"N

"free.sulfur.dioxide"N

"total.sulfur.dioxide"N

density

pH

sulphates

alcohol

chlorides/ scale=none lackfit ctable clparm;

run;

/\* stepwise \*/

proc logistic data=wine plots=roc;

class Outcome / param=ref;

model Outcome(event='fine') = "fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

"residual.sugar"N

"free.sulfur.dioxide"N

"total.sulfur.dioxide"N

density

pH

sulphates

alcohol

chlorides/ selection = stepwise scale=none lackfit ctable clparm;

run;

/\* forward \*/

proc logistic data=wine plots=roc;

class Outcome / param=ref;

model Outcome(event='fine') = "fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

"residual.sugar"N

"free.sulfur.dioxide"N

"total.sulfur.dioxide"N

density

pH

sulphates

alcohol

chlorides/ selection = forward scale=none lackfit ctable clparm;

run;

/\*backward \*/

proc logistic data=wine plots=roc;

class Outcome / param=ref;

model Outcome(event='fine') = "fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

"residual.sugar"N

"free.sulfur.dioxide"N

"total.sulfur.dioxide"N

density

pH

sulphates

alcohol

chlorides/ selection = backward scale=none lackfit ctable clparm;

run;

/\*Simple Logistic regression\*/

proc logistic data=wine plots=roc;

class Outcome / param=ref;

model Outcome(event='fine') = "volatile.acidity"N

"citric.acid"N

"residual.sugar"N

"total.sulfur.dioxide"N

pH

sulphates

alcohol

chlorides/ scale=none lackfit ctable clparm;

run;

## Objective 2

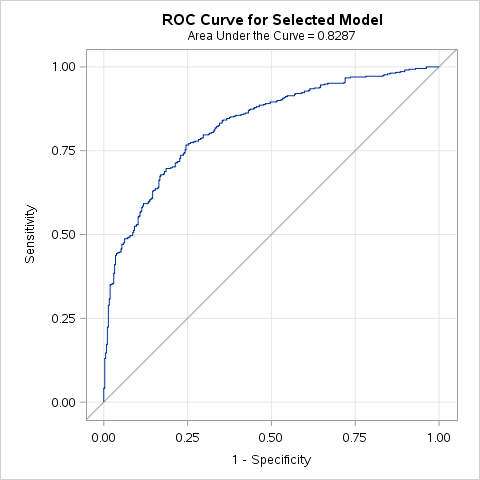
## Logistic Regression 2

| **Hosmer and Lemeshow Goodness-of-Fit Test** | | |
| --- | --- | --- |
| **Chi-Square** | **DF** | **Pr > ChiSq** |
| 4.8489 | 8 | 0.7736 |
| **Model Fit Statistics** | | |
| **Criterion** | **Intercept Only** | **Intercept and Covariates** |
| **AIC** | 1106.827 | 825.142 |
| **SC** | 1111.511 | 862.619 |
| **-2 Log L** | 1104.827 | 809.142 |

| **Analysis of Maximum Likelihood Estimates** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Intercept** | 1 | -11.6910 | 3.0092 | 15.0941 | 0.0001 |
| **log.chlorides** | 1 | -1.0685 | 0.3215 | 11.0442 | 0.0009 |
| **log.total.sulfur.dio** | 1 | -0.3460 | 0.1332 | 6.7514 | 0.0094 |
| **log.sulphates** | 1 | 3.5737 | 0.4936 | 52.4218 | <.0001 |
| **log.alcohol** | 1 | 9.0324 | 1.1476 | 61.9431 | <.0001 |
| **volatile.acidity** | 1 | -3.2189 | 0.6516 | 24.4033 | <.0001 |
| **citric.acid** | 1 | -2.1847 | 0.6547 | 11.1336 | 0.0008 |
| **pH** | 1 | -2.0224 | 0.7030 | 8.2758 | 0.0040 |

| **Parameter Estimates and Wald Confidence Intervals** | | | |
| --- | --- | --- | --- |
| **Parameter** | **Estimate** | **95% Confidence Limits** | |
| **Intercept** | -11.6910 | -17.5889 | -5.7931 |
| **volatile\_acidity** | -3.2189 | -4.4960 | -1.9418 |
| **citric\_acid** | -2.1847 | -3.4679 | -0.9014 |
| **logchlorides** | -1.0685 | -1.6987 | -0.4383 |
| **logtsd** | -0.3460 | -0.6071 | -0.0850 |
| **pH** | -2.0224 | -3.4003 | -0.6445 |
| **logsulphates** | 3.5737 | 2.6063 | 4.5412 |
| **logalcohol** | 9.0324 | 6.7831 | 11.2818 |

| **Classification Table** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Prob Level** | **Correct** | | **Incorrect** | | **Percentages** | | | | |
| **Event** | **Non- Event** | **Event** | **Non- Event** | **Correct** | **Sensi- tivity** | **Speci- ficity** | **False POS** | **False NEG** |
| **0.020** | 429 | 0 | 371 | 0 | 53.6 | 100.0 | 0.0 | 46.4 | . |
| **0.040** | 429 | 3 | 368 | 0 | 54.0 | 100.0 | 0.8 | 46.2 | 0.0 |
| **0.060** | 429 | 9 | 362 | 0 | 54.8 | 100.0 | 2.4 | 45.8 | 0.0 |
| **0.080** | 427 | 14 | 357 | 2 | 55.1 | 99.5 | 3.8 | 45.5 | 12.5 |
| **0.100** | 426 | 21 | 350 | 3 | 55.9 | 99.3 | 5.7 | 45.1 | 12.5 |
| **0.120** | 422 | 39 | 332 | 7 | 57.6 | 98.4 | 10.5 | 44.0 | 15.2 |
| **0.140** | 420 | 50 | 321 | 9 | 58.8 | 97.9 | 13.5 | 43.3 | 15.3 |
| **0.160** | 417 | 63 | 308 | 12 | 60.0 | 97.2 | 17.0 | 42.5 | 16.0 |
| **0.180** | 415 | 85 | 286 | 14 | 62.5 | 96.7 | 22.9 | 40.8 | 14.1 |
| **0.200** | 408 | 104 | 267 | 21 | 64.0 | 95.1 | 28.0 | 39.6 | 16.8 |
| **0.220** | 406 | 125 | 246 | 23 | 66.4 | 94.6 | 33.7 | 37.7 | 15.5 |
| **0.240** | 399 | 132 | 239 | 30 | 66.4 | 93.0 | 35.6 | 37.5 | 18.5 |
| **0.260** | 392 | 154 | 217 | 37 | 68.3 | 91.4 | 41.5 | 35.6 | 19.4 |
| **0.280** | 386 | 170 | 201 | 43 | 69.5 | 90.0 | 45.8 | 34.2 | 20.2 |
| **0.300** | 381 | 187 | 184 | 48 | 71.0 | 88.8 | 50.4 | 32.6 | 20.4 |
| **0.320** | 378 | 197 | 174 | 51 | 71.9 | 88.1 | 53.1 | 31.5 | 20.6 |
| **0.340** | 370 | 208 | 163 | 59 | 72.3 | 86.2 | 56.1 | 30.6 | 22.1 |
| **0.360** | 367 | 219 | 152 | 62 | 73.3 | 85.5 | 59.0 | 29.3 | 22.1 |
| **0.380** | 363 | 230 | 141 | 66 | 74.1 | 84.6 | 62.0 | 28.0 | 22.3 |
| **0.400** | 358 | 239 | 132 | 71 | 74.6 | 83.4 | 64.4 | 26.9 | 22.9 |
| **0.420** | 352 | 241 | 130 | 77 | 74.1 | 82.1 | 65.0 | 27.0 | 24.2 |
| **0.440** | 342 | 247 | 124 | 87 | 73.6 | 79.7 | 66.6 | 26.6 | 26.0 |
| **0.460** | 338 | 259 | 112 | 91 | 74.6 | 78.8 | 69.8 | 24.9 | 26.0 |
| **0.480** | 333 | 266 | 105 | 96 | 74.9 | 77.6 | 71.7 | 24.0 | 26.5 |
| **0.500** | 329 | 275 | 96 | 100 | 75.5 | 76.7 | 74.1 | 22.6 | 26.7 |
| **0.520** | 317 | 280 | 91 | 112 | 74.6 | 73.9 | 75.5 | 22.3 | 28.6 |
| **0.540** | 308 | 285 | 86 | 121 | 74.1 | 71.8 | 76.8 | 21.8 | 29.8 |
| **0.560** | 301 | 291 | 80 | 128 | 74.0 | 70.2 | 78.4 | 21.0 | 30.5 |
| **0.580** | 294 | 297 | 74 | 135 | 73.9 | 68.5 | 80.1 | 20.1 | 31.3 |
| **0.600** | 287 | 305 | 66 | 142 | 74.0 | 66.9 | 82.2 | 18.7 | 31.8 |
| **0.620** | 276 | 309 | 62 | 153 | 73.1 | 64.3 | 83.3 | 18.3 | 33.1 |
| **0.640** | 270 | 312 | 59 | 159 | 72.8 | 62.9 | 84.1 | 17.9 | 33.8 |
| **0.660** | 260 | 317 | 54 | 169 | 72.1 | 60.6 | 85.4 | 17.2 | 34.8 |
| **0.680** | 254 | 320 | 51 | 175 | 71.8 | 59.2 | 86.3 | 16.7 | 35.4 |
| **0.700** | 243 | 326 | 45 | 186 | 71.1 | 56.6 | 87.9 | 15.6 | 36.3 |
| **0.720** | 230 | 329 | 42 | 199 | 69.9 | 53.6 | 88.7 | 15.4 | 37.7 |
| **0.740** | 216 | 334 | 37 | 213 | 68.8 | 50.3 | 90.0 | 14.6 | 38.9 |
| **0.760** | 209 | 343 | 28 | 220 | 69.0 | 48.7 | 92.5 | 11.8 | 39.1 |
| **0.780** | 200 | 349 | 22 | 229 | 68.6 | 46.6 | 94.1 | 9.9 | 39.6 |
| **0.800** | 187 | 351 | 20 | 242 | 67.3 | 43.6 | 94.6 | 9.7 | 40.8 |
| **0.820** | 176 | 358 | 13 | 253 | 66.8 | 41.0 | 96.5 | 6.9 | 41.4 |
| **0.840** | 158 | 359 | 12 | 271 | 64.6 | 36.8 | 96.8 | 7.1 | 43.0 |
| **0.860** | 144 | 362 | 9 | 285 | 63.3 | 33.6 | 97.6 | 5.9 | 44.0 |
| **0.880** | 126 | 365 | 6 | 303 | 61.4 | 29.4 | 98.4 | 4.5 | 45.4 |
| **0.900** | 108 | 366 | 5 | 321 | 59.3 | 25.2 | 98.7 | 4.4 | 46.7 |
| **0.920** | 74 | 367 | 4 | 355 | 55.1 | 17.2 | 98.9 | 5.1 | 49.2 |
| **0.940** | 55 | 369 | 2 | 374 | 53.0 | 12.8 | 99.5 | 3.5 | 50.3 |
| **0.960** | 33 | 370 | 1 | 396 | 50.4 | 7.7 | 99.7 | 2.9 | 51.7 |
| **0.980** | 11 | 371 | 0 | 418 | 47.8 | 2.6 | 100.0 | 0.0 | 53.0 |
| **1.000** | 0 | 371 | 0 | 429 | 46.4 | 0.0 | 100.0 | . | 53.6 |







## SAS Code for Regressions

proc import datafile="/home/anhainguyen820/sasuser.v94/wine\_train.csv"

dbms=dlm out=wine replace;

delimiter=',';

getnames=yes;

run;

data wine;

set wine;

"log.residual.sugar"N = log("residual.sugar"N);

"log.chlorides"N = log(chlorides);

"log.free.sulfur.dioxide"N = log("free.sulfur.dioxide"N);

"log.total.sulfur.dioxide"N = log("total.sulfur.dioxide"N);

"log.sulphates"N = log(sulphates);

"log.alcohol"N = log(alcohol);

run;

/\*Logistic regression\*/

proc logistic data=wine plots=ROC;

class Outcome / param=ref;

model Outcome(event='fine') = "log.residual.sugar"N

"log.chlorides"N

"log.free.sulfur.dioxide"N

"log.total.sulfur.dioxide"N

"log.sulphates"N

"log.alcohol"N

"fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

density

pH/ selection=forward scale=none lackfit ctable clparm=both;

run;

## QDA

**Test of Homogeneity of Within Covariance Matrices**

| **Chi-Square** | **DF** | **Pr > ChiSq** |
| --- | --- | --- |
| 264.243869 | 66 | <.0001 |

| **Number of Observations and Percent Classified into Outcome** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **From Outcome** | | | **fine** | | **poor** | **Total** |
| **fine** | | | 312  72.73 | | 117  27.27 | 429  100.00 |
| **poor** | | | 76  20.49 | | 295  79.51 | 371  100.00 |
| **Total** | | | 388  48.50 | | 412  51.50 | 800  100.00 |
| **Priors** | | | 0.5 | | 0.5 |  |
| **Error Count Estimates for Outcome** | | | | |
|  | **fine** | **poor** | | **Total** |
| **Rate** | 0.2727 | 0.2049 | | 0.2388 |
| **Priors** | 0.5000 | 0.5000 | |  |

| **Number of Observations and Percent Classified into Outcome** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **From Outcome** | | | **fine** | | **poor** | **Total** |
| **fine** | | | 313  73.47 | | 113  26.53 | 426  100.00 |
| **poor** | | | 106  28.42 | | 267  71.58 | 373  100.00 |
| **Total** | | | 419  52.44 | | 380  47.56 | 799  100.00 |
| **Priors** | | | 0.5 | | 0.5 |  |
| **Error Count Estimates for Outcome** | | | | |
|  | **fine** | **poor** | | **Total** |
| **Rate** | 0.2653 | 0.2842 | | 0.2747 |
| **Priors** | 0.5000 | 0.5000 | |  |

## SAS Code for QDA

proc import datafile="/home/anhainguyen820/sasuser.v94/wine\_train.csv"

dbms=dlm out=wine replace;

delimiter=',';

getnames=yes;

run;

proc import datafile="/home/anhainguyen820/sasuser.v94/wine\_test.csv"

dbms=dlm out=test replace;

delimiter=',';

getnames=yes;

run;

data wine; set wine;

"log.residual.sugar"N = log("residual.sugar"N);

"log.chlorides"N = log(chlorides);

"log.free.sulfur.dioxide"N = log("free.sulfur.dioxide"N);

"log.total.sulfur.dioxide"N = log("total.sulfur.dioxide"N);

"log.sulphates"N = log(sulphates);

"log.alcohol"N = log(alcohol);

run;

data test; set test;

"log.residual.sugar"N = log("residual.sugar"N);

"log.chlorides"N = log(chlorides);

"log.free.sulfur.dioxide"N = log("free.sulfur.dioxide"N);

"log.total.sulfur.dioxide"N = log("total.sulfur.dioxide"N);

"log.sulphates"N = log(sulphates);

"log.alcohol"N = log(alcohol);

run;

proc discrim data=wine pool=test testdata=test;

class Outcome;

var "log.residual.sugar"N

"log.chlorides"N

"log.free.sulfur.dioxide"N

"log.total.sulfur.dioxide"N

"log.sulphates"N

"log.alcohol"N

"fixed.acidity"N

"volatile.acidity"N

"citric.acid"N

density

pH;

run;

# Objective 2 – Nonparametric approach

library(ggplot2)

library(tree)

library(ISLR)

library(randomForest)

library(FNN)

library(reprtree)

setwd("D:/My\_Docs/univer/Stat2/Project2/MSDS6372\_Project\_2-master")

wine<-read.csv("winequality-red.csv",header=T)

attach(wine)

names(wine) <- gsub(x = names(wine),

pattern = "\\.",

replacement = "\_")

QualityCat=ifelse(quality<=5,"Poor","Fine")

wine=data.frame(wine,QualityCat)

set.seed(2)

train=sample(1:nrow(wine), nrow(wine)\*2/3) #split 2/3 train 1/3 tes

wine.test=wine[-train,]

wine.train=wine[train,] #test data set

Quality.test=QualityCat[-train] #test

set.seed(5)

rf.wine<-randomForest(factor(QualityCat)~.-quality,wine,mtry=5,subset=train,importance=F,ntree=100)

rf.wine

rf.wine$err.rate[,1]

plot(rf.wine$err.rate[,1],xlab="Number of Trees",ylab="Error Rate")

fit.pred<-predict(rf.wine,newdata=wine.test,type="response")

table(fit.pred,wine.test$QualityCat)

confusionMatrix(fit.pred, wine.test$QualityCat)

# Get importance

importance <- importance(rf.wine)

varImportance <- data.frame(Variables = row.names(importance),

Importance = round(importance[ ,'MeanDecreaseGini'],2))

# Create a rank variable based on importance

rankImportance <- varImportance %>%

mutate(Rank = paste0('#',dense\_rank(desc(Importance))))

# Use ggplot2 to visualize the relative importance of variables

ggplot(rankImportance, aes(x = reorder(Variables, Importance),

y = Importance, fill = Importance)) +

geom\_bar(stat='identity') +

geom\_text(aes(x = Variables, y = 0.5, label = Rank),

hjust=0, vjust=0.55, size = 4, colour = 'red') +

labs(x = 'Variables') +

coord\_flip() +

theme\_classic()