

Model Evaluation

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Overview

This section evaluates the fit of the model's using the car package. Multiple linear regression (MLR) requires the model residuals to be $\sim \text{IID } N(0, \sigma^2)$. The model residuals will be standardized for the assessment.

1. Normality Assumptions will be accessed using:
 - Normality tests from the nortest package
 - Visualizations such as histograms, QQ-plots, Residual Plots and Add Variable Plots
2. Constant Variance will be accessed using:
 - non-constant variance test
3. Multi-collinearity will be accessed using:
 - variance inflation factors
4. Outliers will be accessed using:
 - Cooks Distance

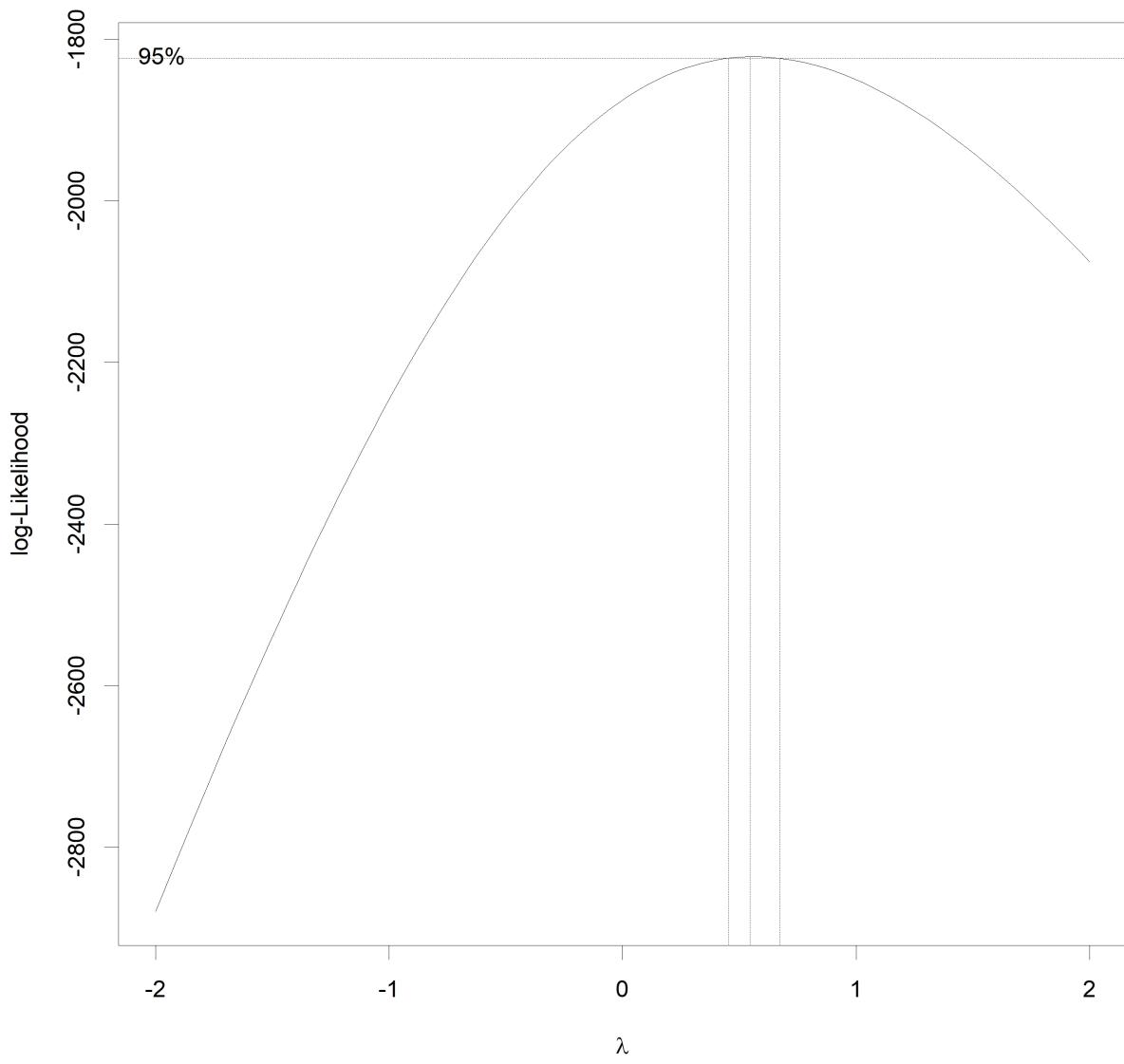
Overall Model

```
##  
## Call:  
## lm(formula = overall_final_model_form, data = processed_data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -9.5505 -2.3301 -0.2858  2.1846  7.8517  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 3.7244    0.6169   6.037 2.64e-09 ***  
## Average_Points 0.4798    0.1253   3.830 0.000141 ***  
## acousticness 0.6959    0.1302   5.344 1.26e-07 ***  
## speechiness 0.6973    0.1362   5.119 4.05e-07 ***  
## METRIC_Citizens 0.3251    0.1399   2.324 0.020438 *  
## TC_PerfType_Solo 1.4412    0.5613   2.568 0.010457 *  
## key_0 1.2923    0.4516   2.861 0.004353 **  
## CAP_DIST_km 0.2956    0.1280   2.309 0.021260 *  
## OOA 1.2837    0.4512   2.845 0.004579 **  
## FC_NonCOB 0.3604    0.1391   2.592 0.009766 **  
## ComSONGLAN 0.2760    0.1287   2.145 0.032338 *  
## ---  
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 3.074 on 647 degrees of freedom  
## Multiple R-squared: 0.1762, Adjusted R-squared: 0.1635  
## F-statistic: 13.84 on 10 and 647 DF, p-value: < 2.2e-16
```

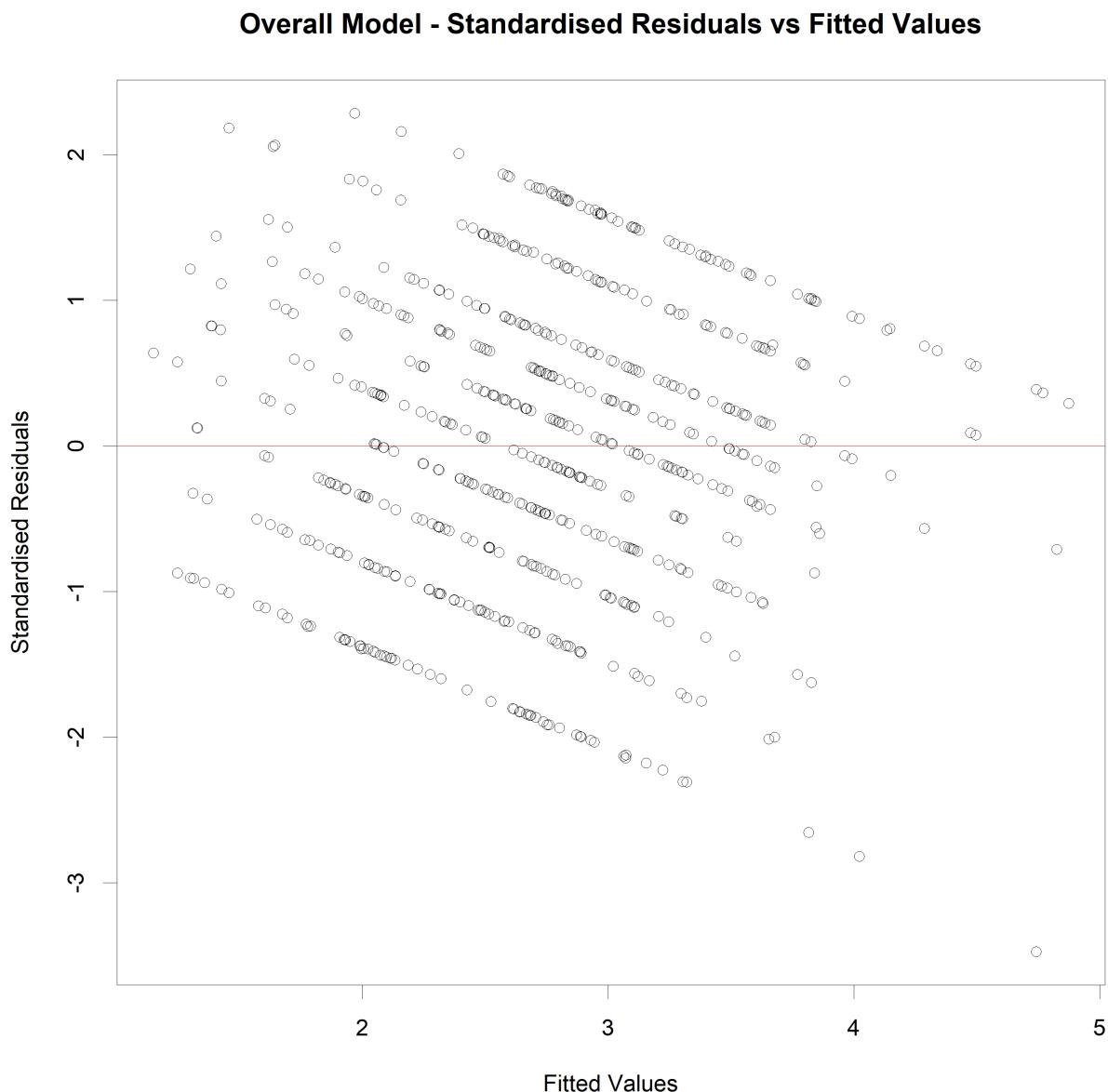
Response Variable Transformation

Box-Cox Power Transformation

```
##  
## Call:  
## lm(formula = overall_final_model_bct_form, data = processed_data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -4.7417 -1.0276  0.0449  1.1112  3.3083  
##  
## Coefficients:  
##                               Estimate Std. Error t value Pr(>|t|)  
## (Intercept)           1.71220   0.29239  5.856 7.55e-09 ***  
## Average_Points        0.20209   0.05938  3.403 0.000706 ***  
## acousticness         0.34061   0.06173  5.518 4.96e-08 ***  
## speechiness          0.33666   0.06456  5.215 2.48e-07 ***  
## METRIC_Citizens     0.12269   0.06630  1.851 0.064672 .  
## TC_PerfType_Solo    0.69660   0.26601  2.619 0.009035 **  
## key_0                0.65422   0.21405  3.056 0.002332 **  
## CAP_DIST_km          0.12426   0.06069  2.048 0.041007 *  
## OOA                  0.62781   0.21385  2.936 0.003446 **  
## FC_NonCOB            0.18387   0.06591  2.790 0.005428 **  
## ComSONGLAN           0.14046   0.06099  2.303 0.021585 *  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 1.457 on 647 degrees of freedom  
## Multiple R-squared:  0.169,  Adjusted R-squared:  0.1562  
## F-statistic: 13.16 on 10 and 647 DF,  p-value: < 2.2e-16
```



Residuals vs Fitted Values



Model Outliers

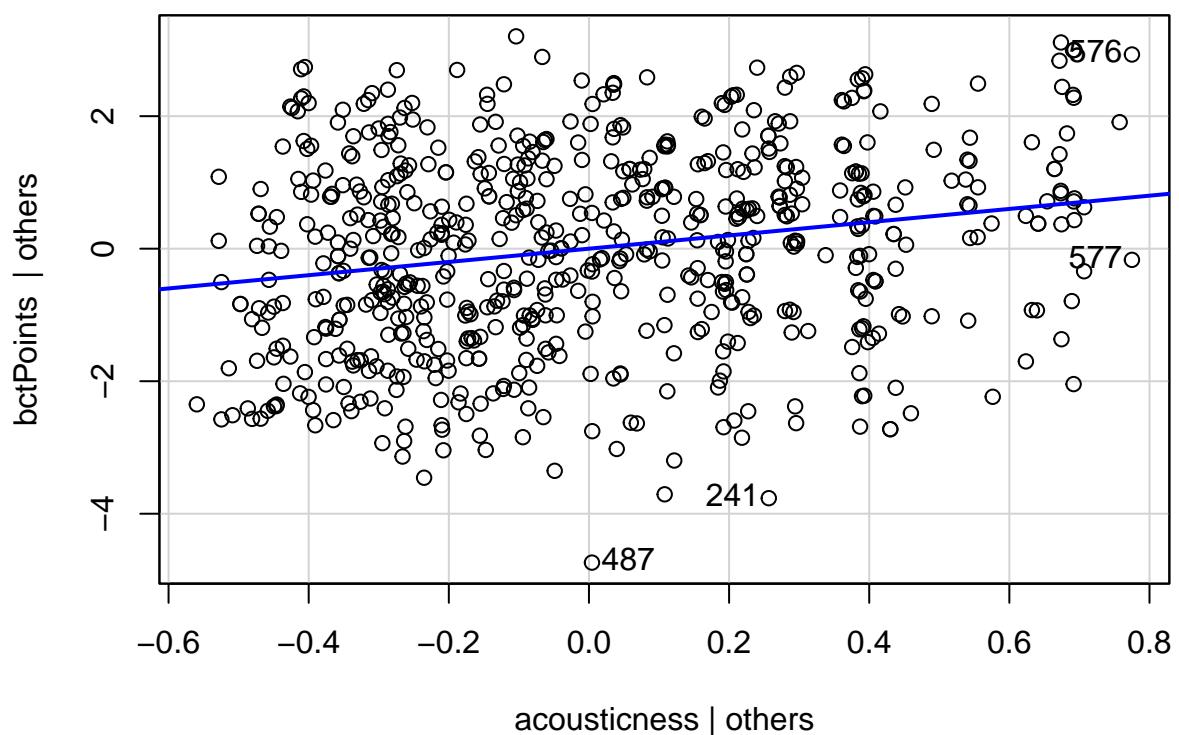
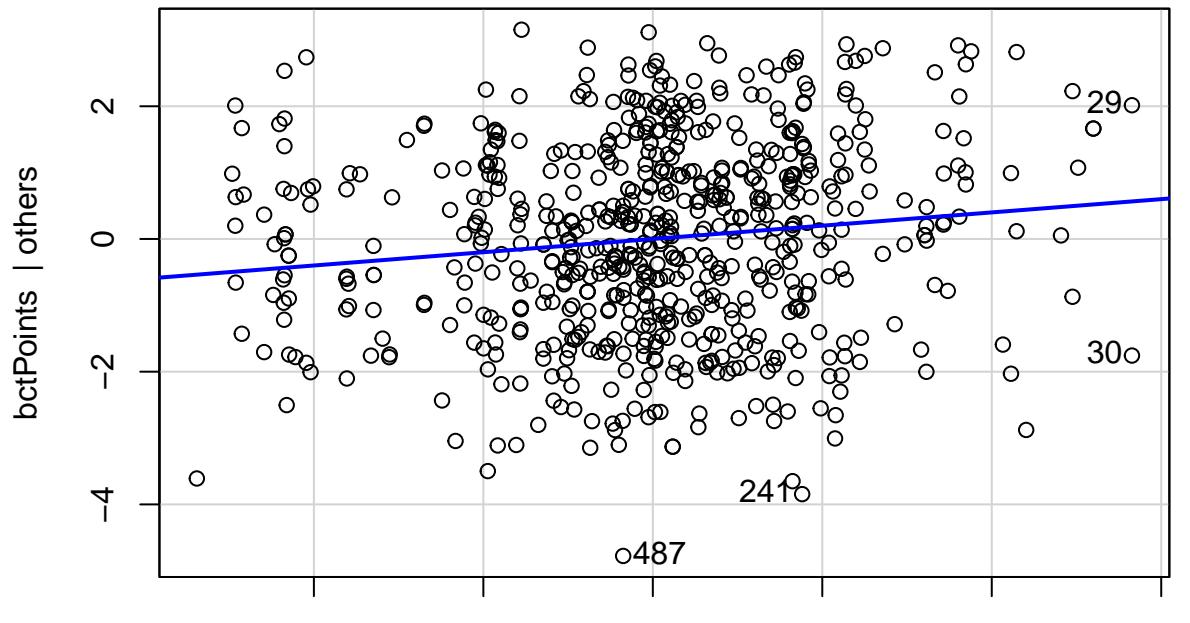
Bonferroni Outlier Test

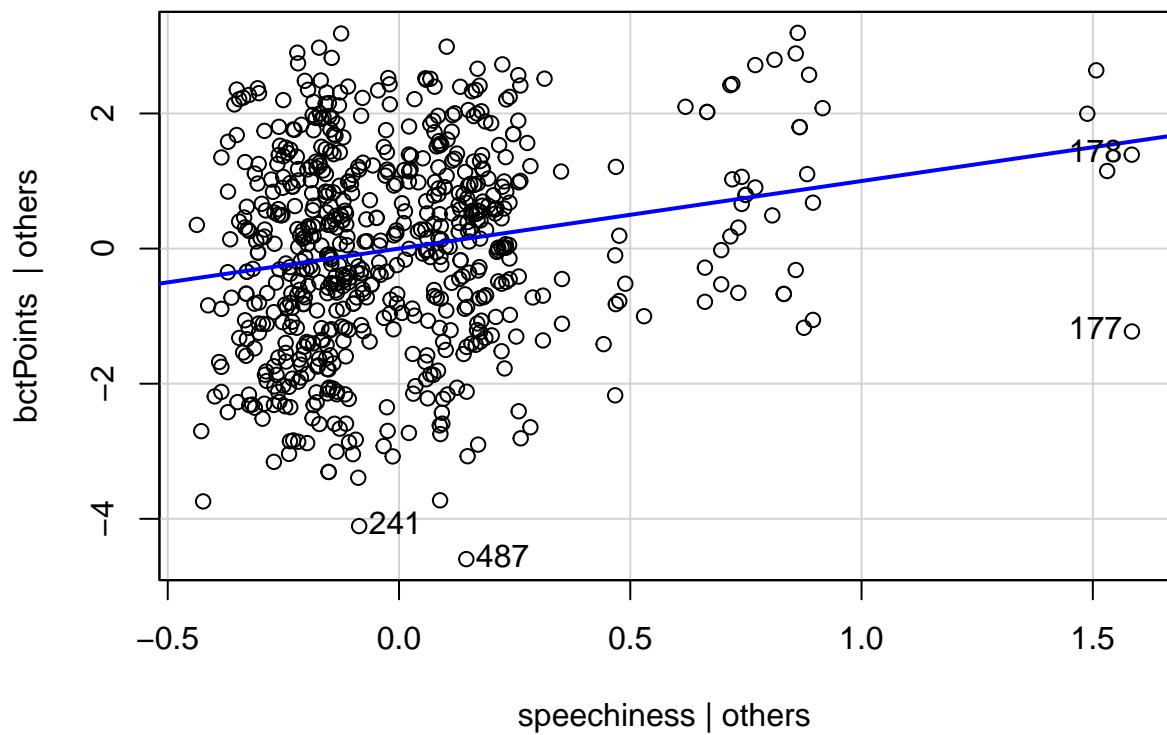
| | rstudent | p | bonf.p | signif | cutoff |
|-----|-----------|-----------|-----------|--------|--------|
| 487 | -3.473914 | 0.0005472 | 0.3600624 | 0 | 0.05 |

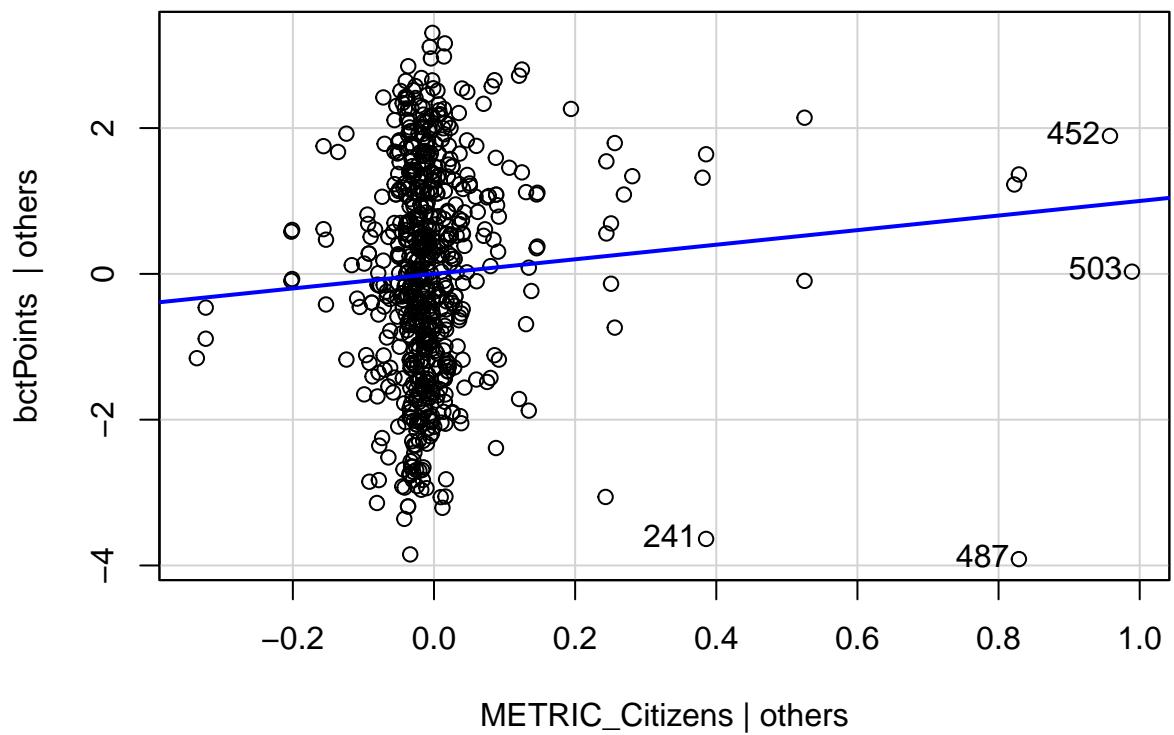
Outlier Residuals

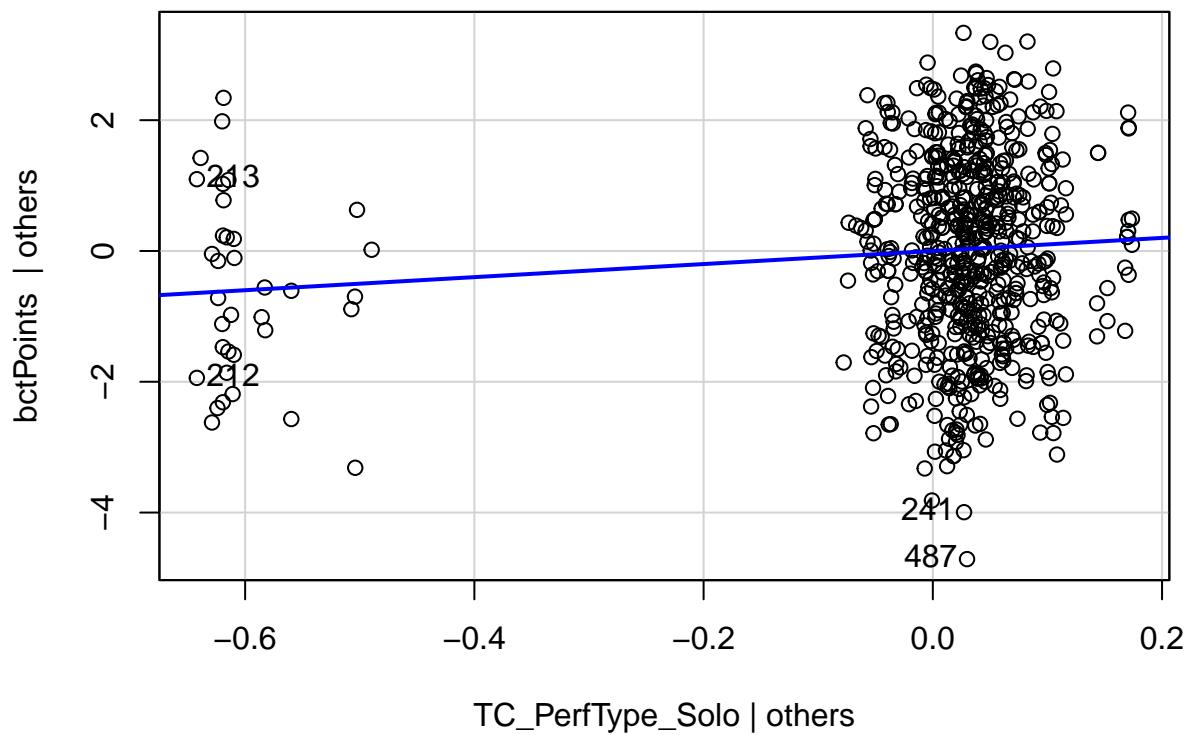
| outlier_residuals |
|-------------------|
| 39 |
| 77 |
| 103 |
| 177 |
| 241 |
| 360 |

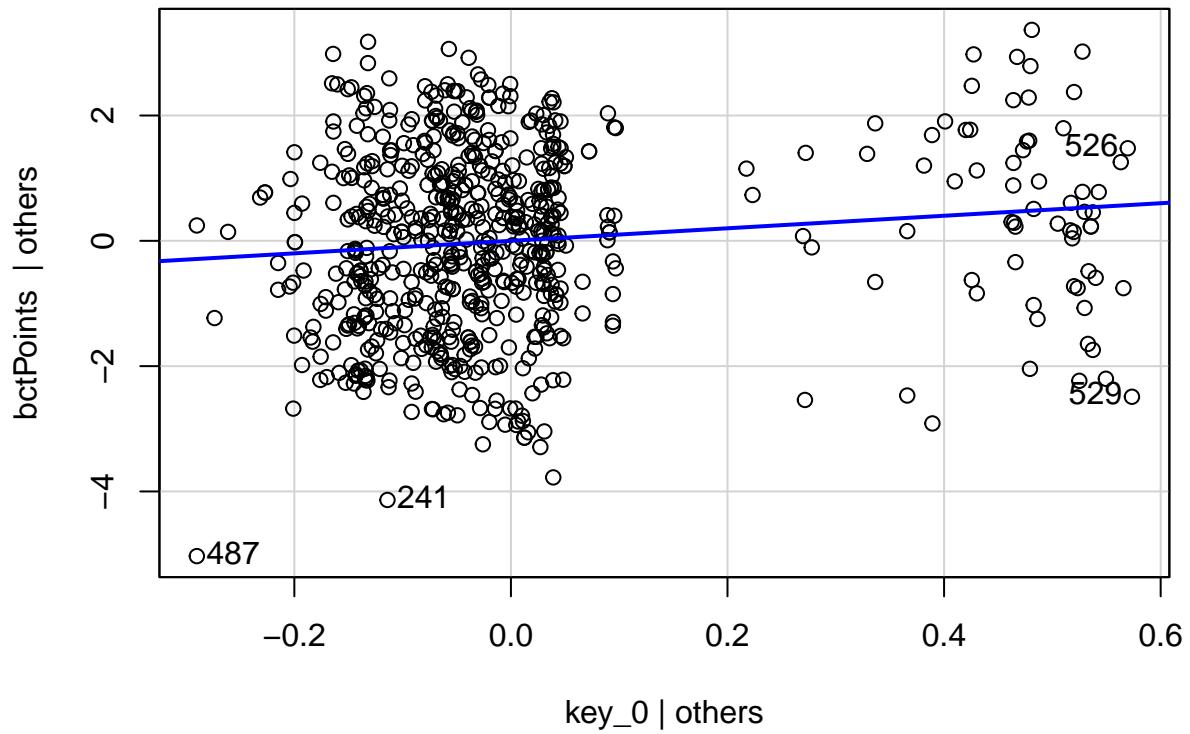
Leverage Plots

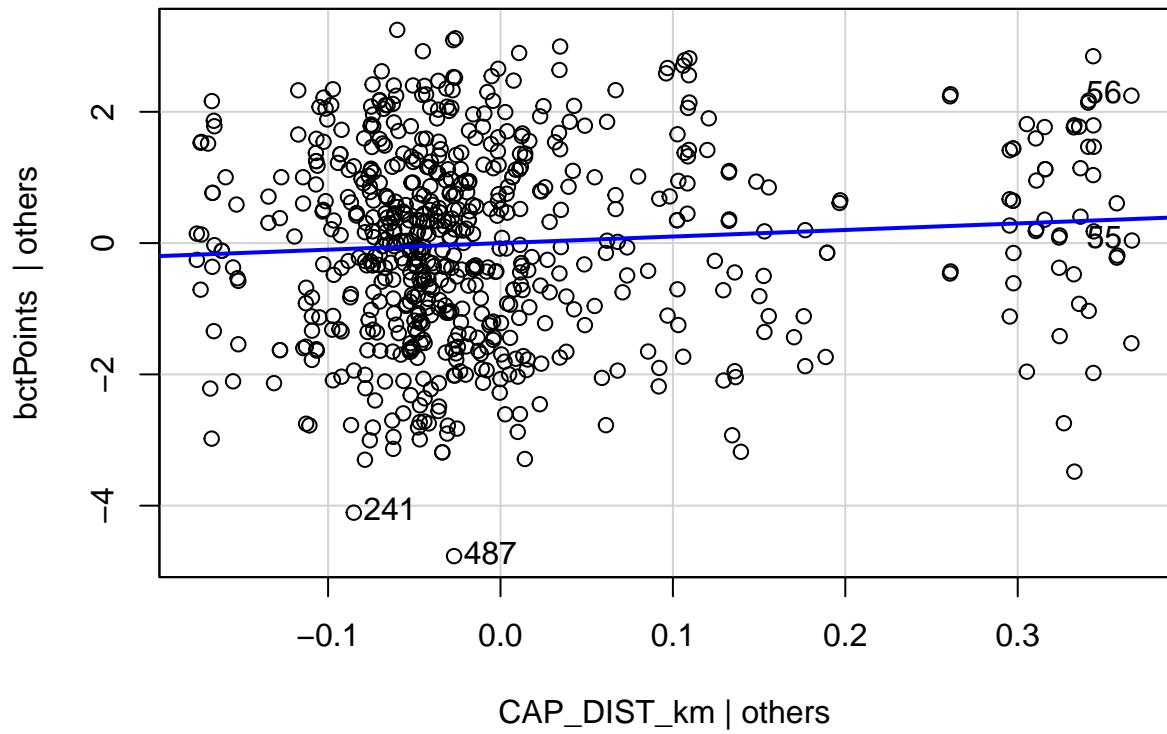


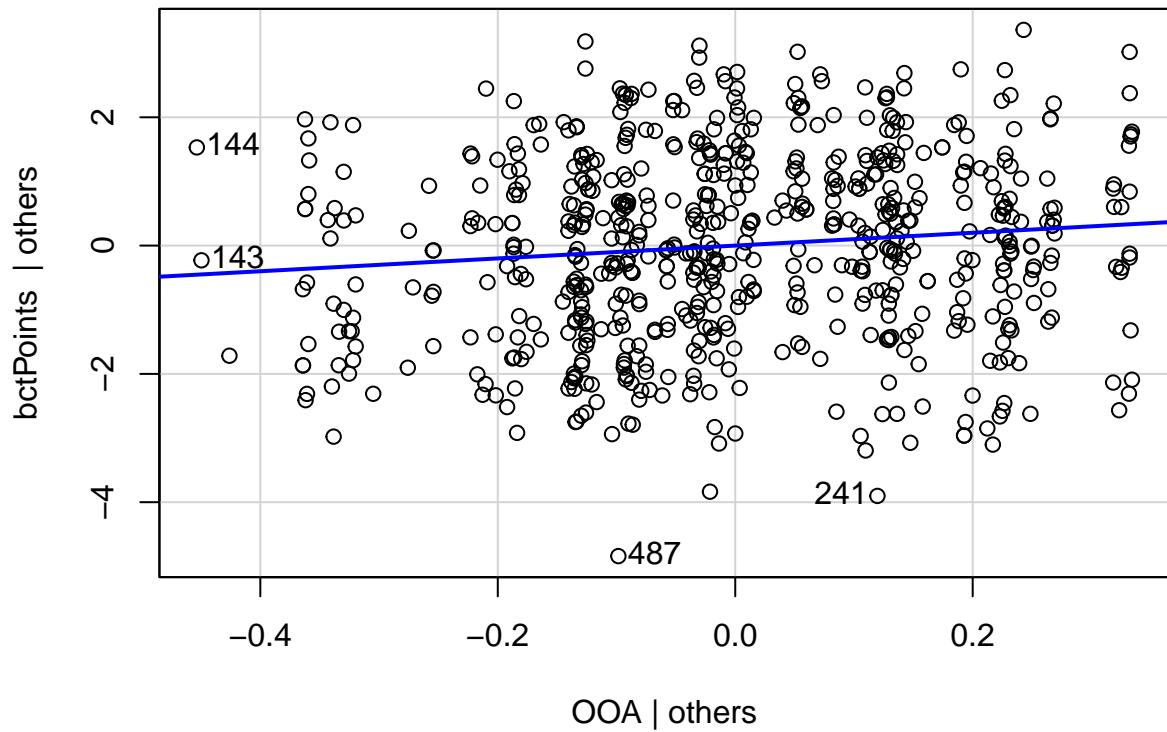


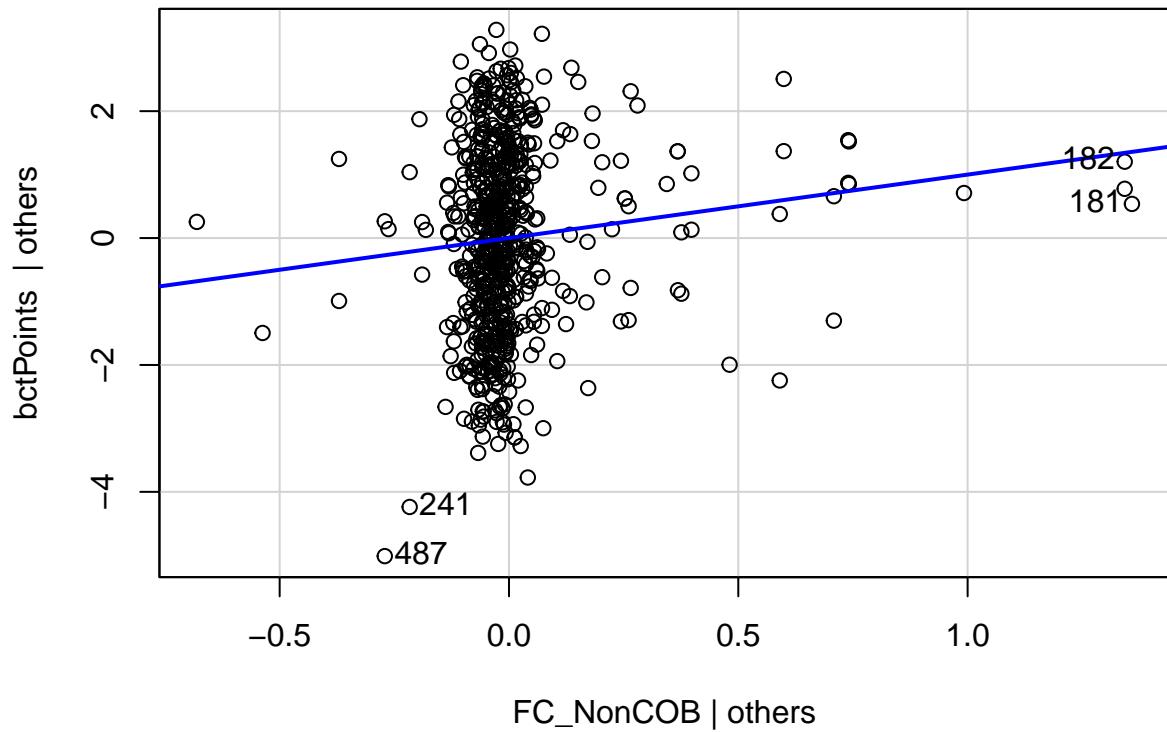




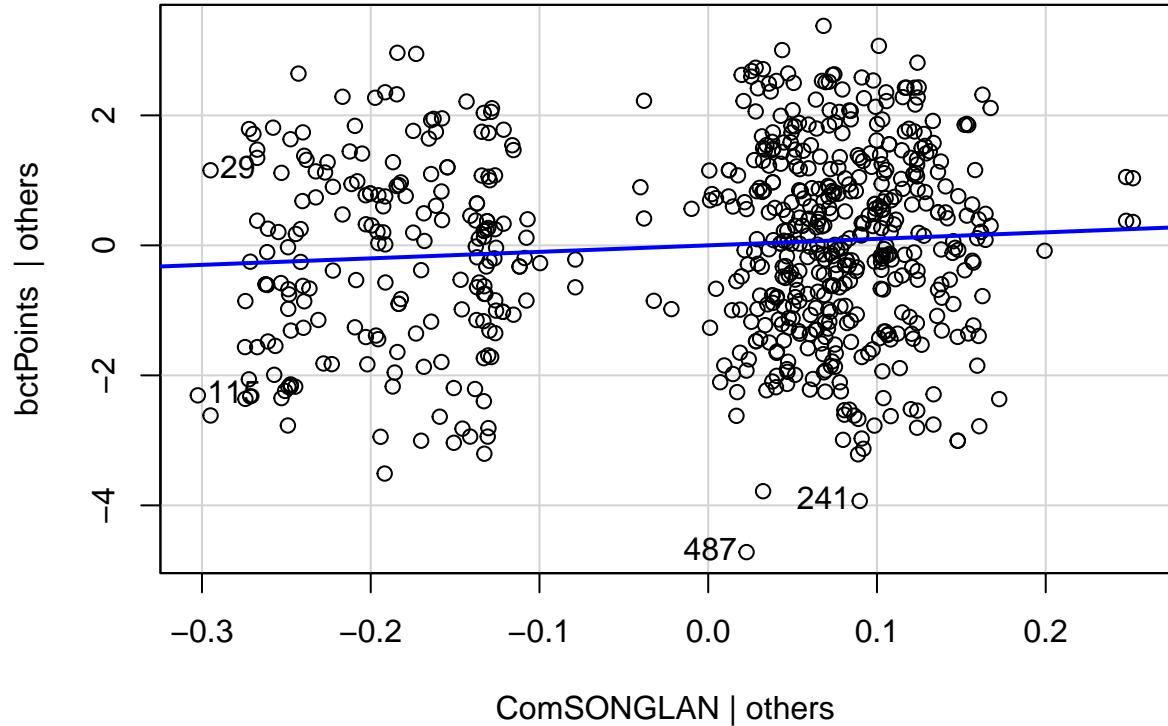




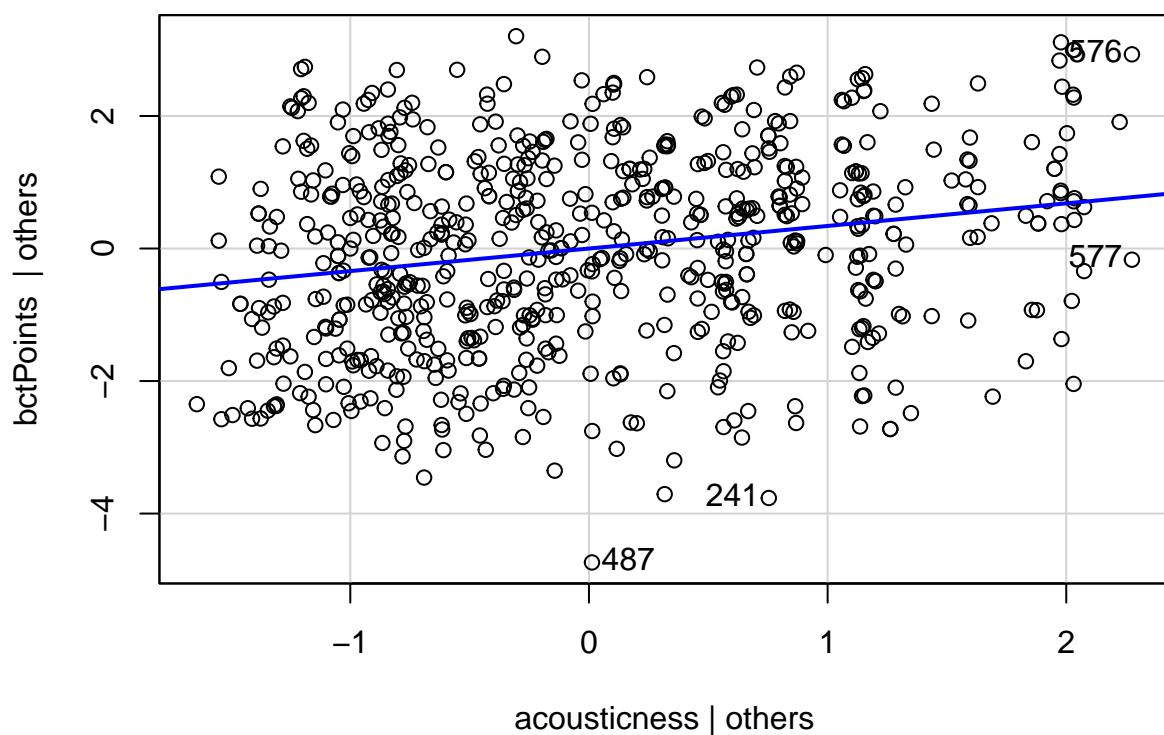
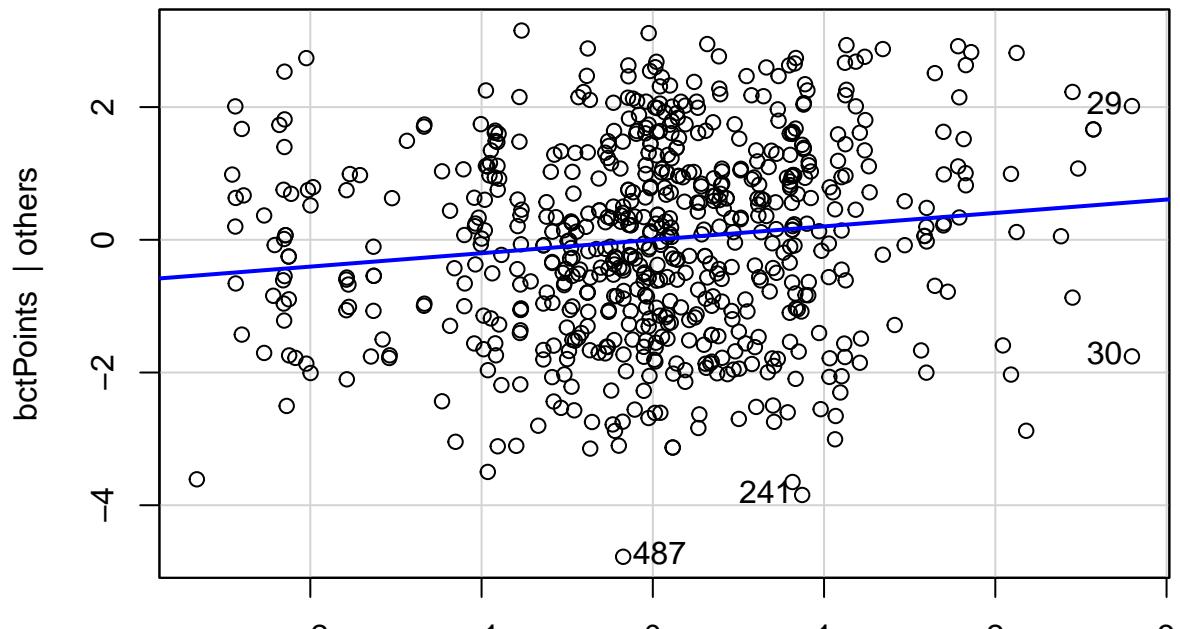


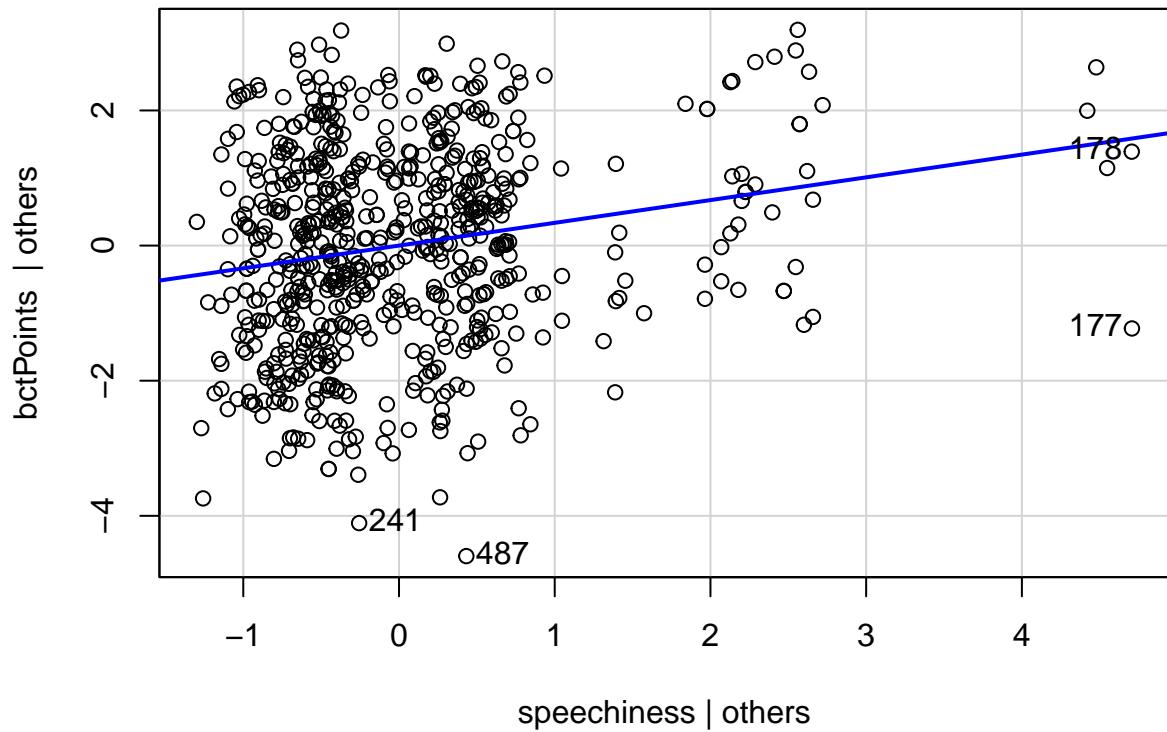


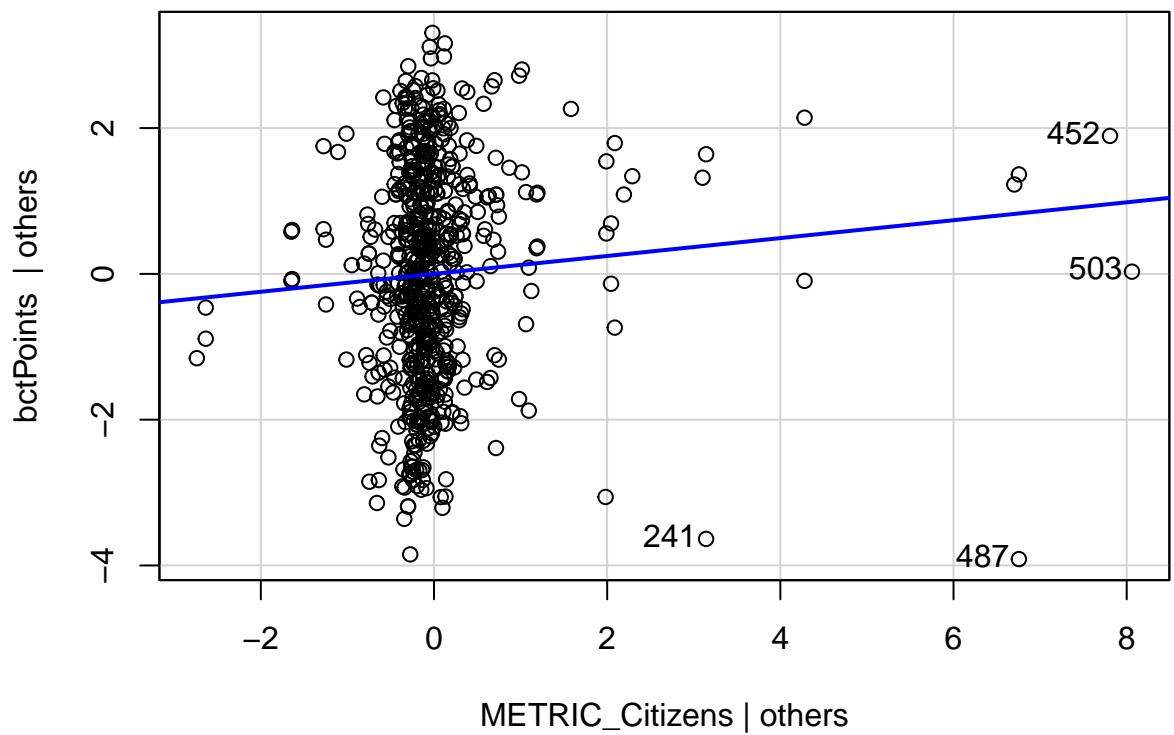
Leverage Plots

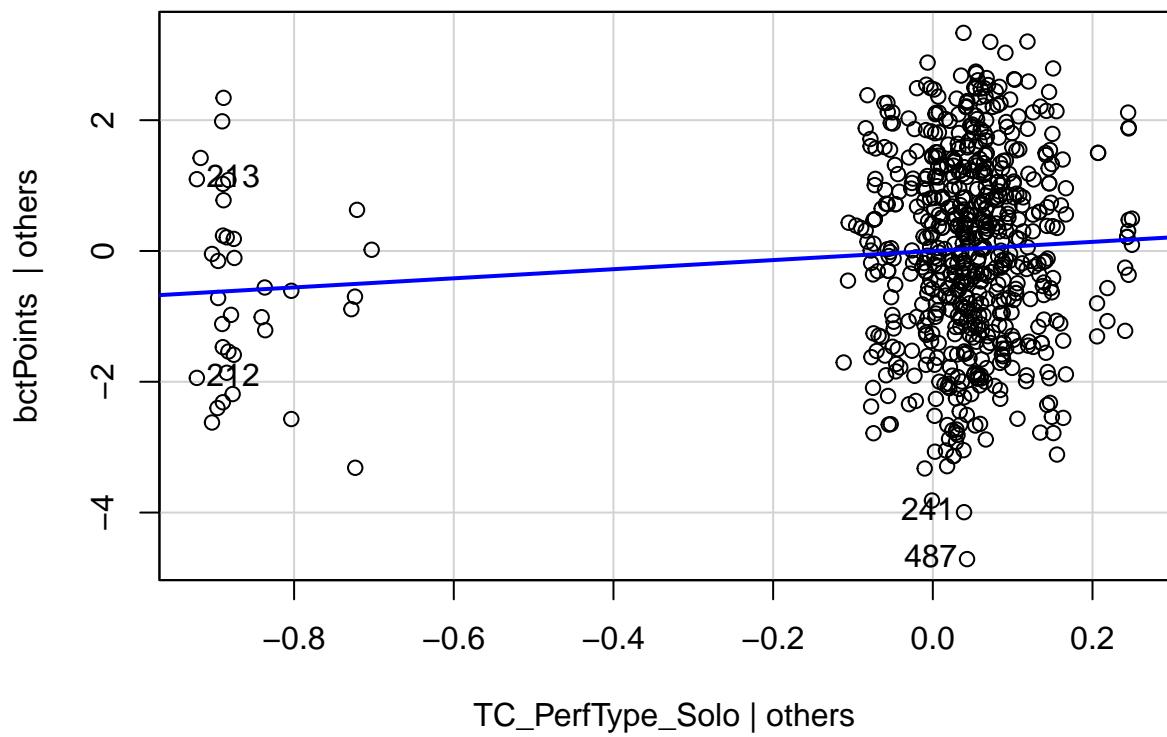


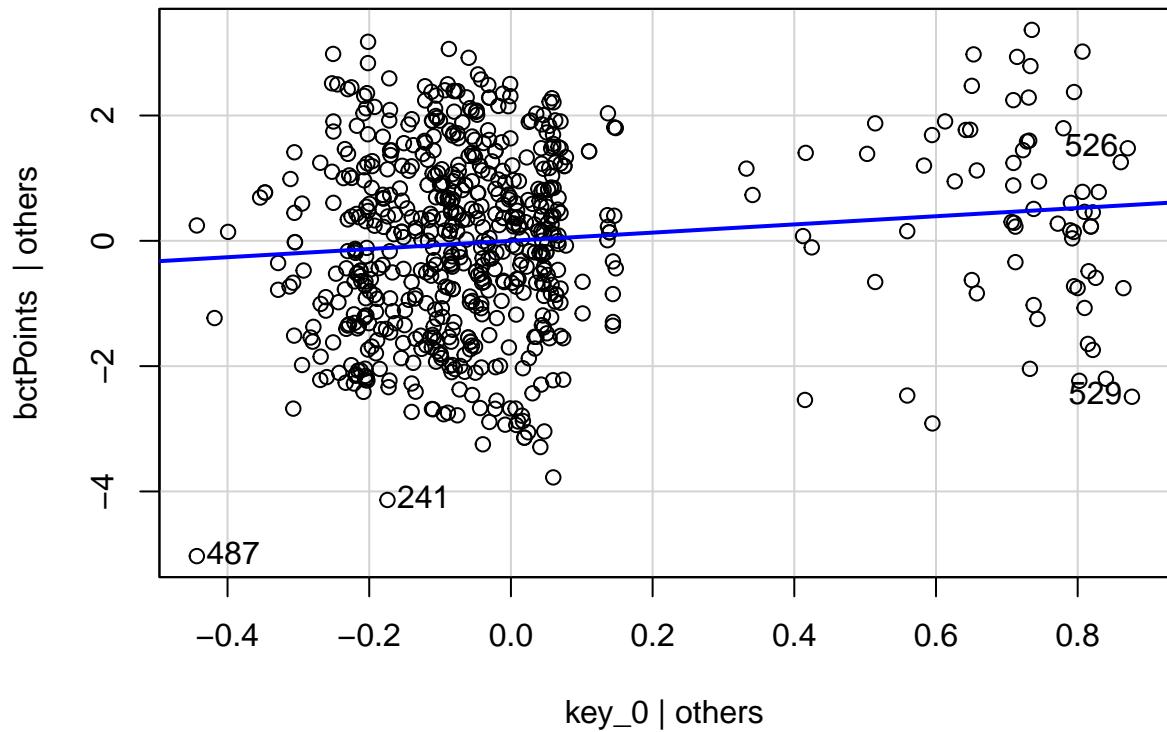
Added-Variable Plots

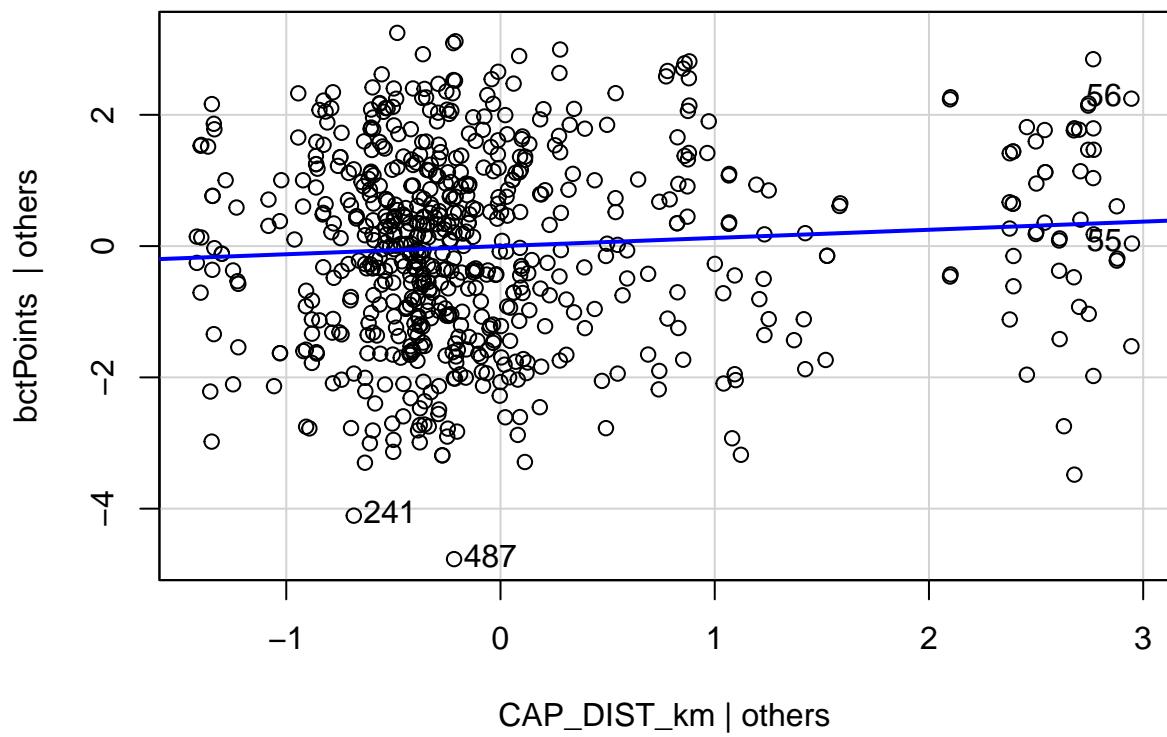


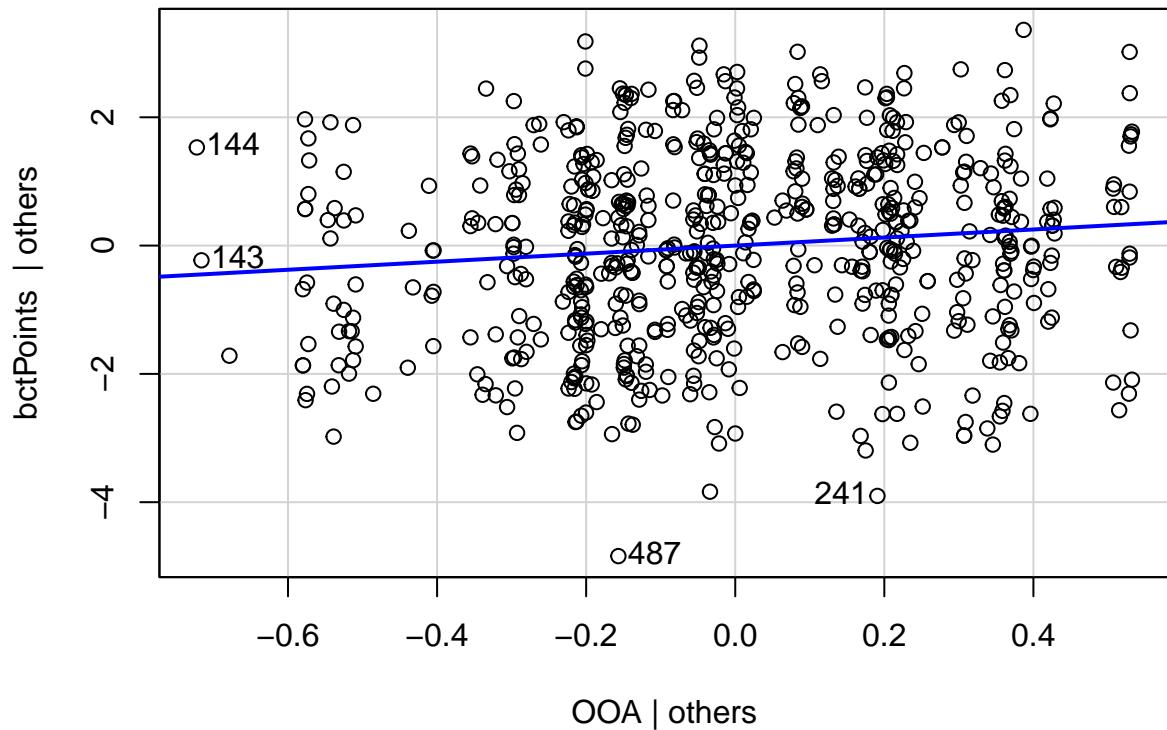


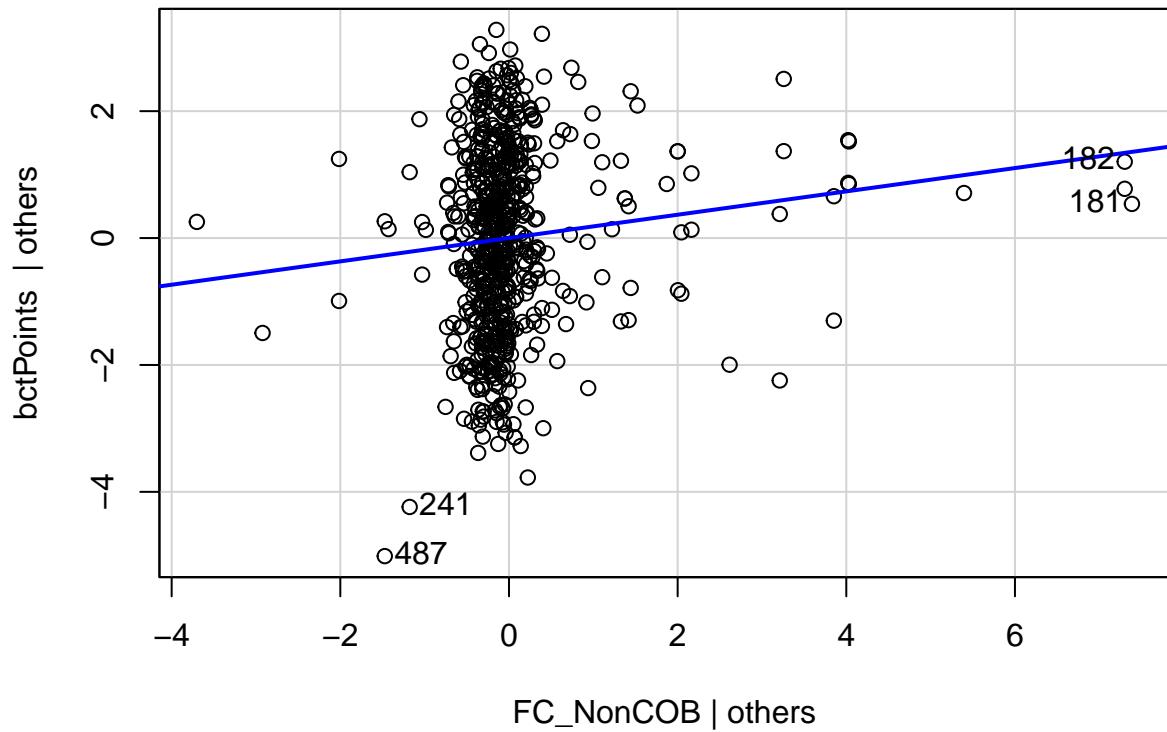




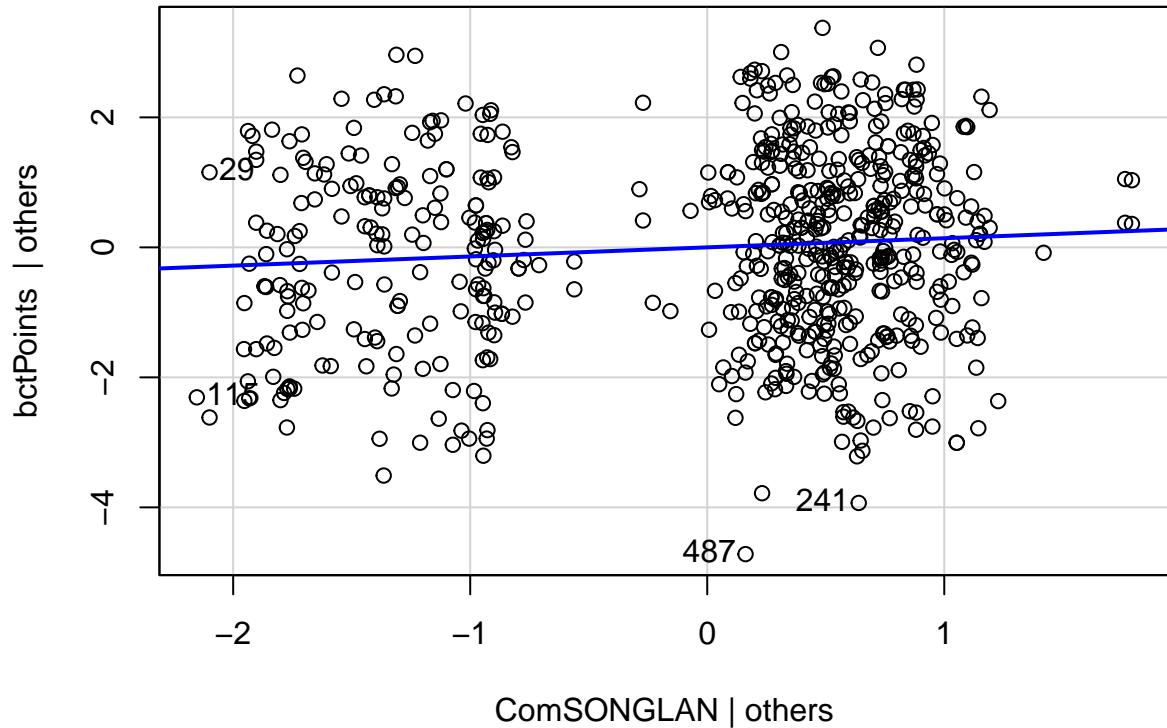




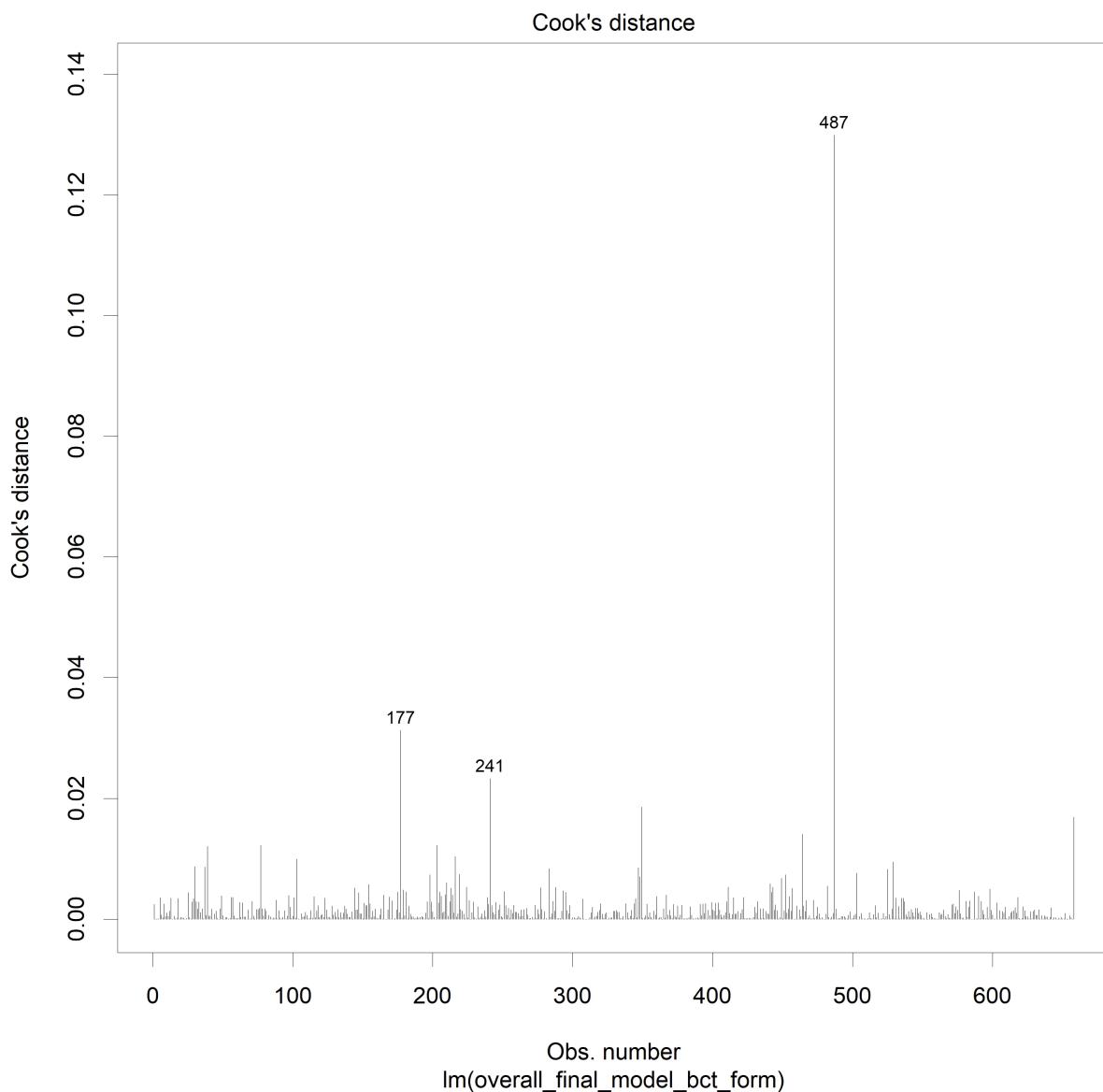




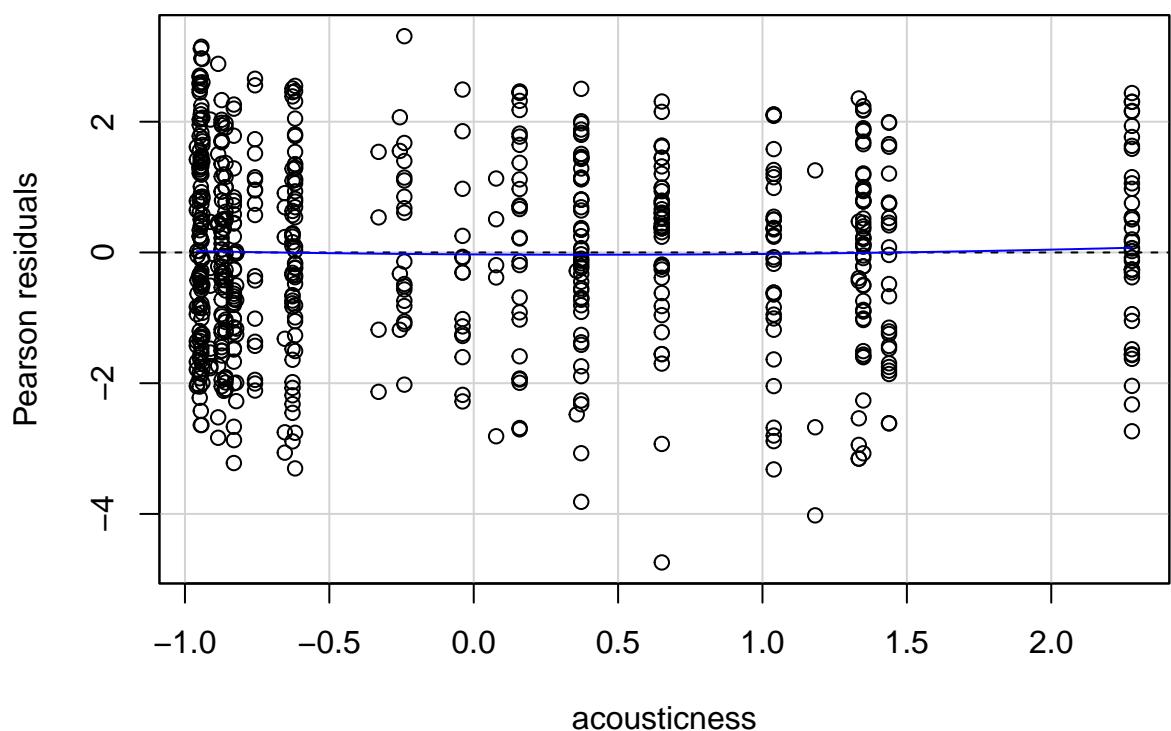
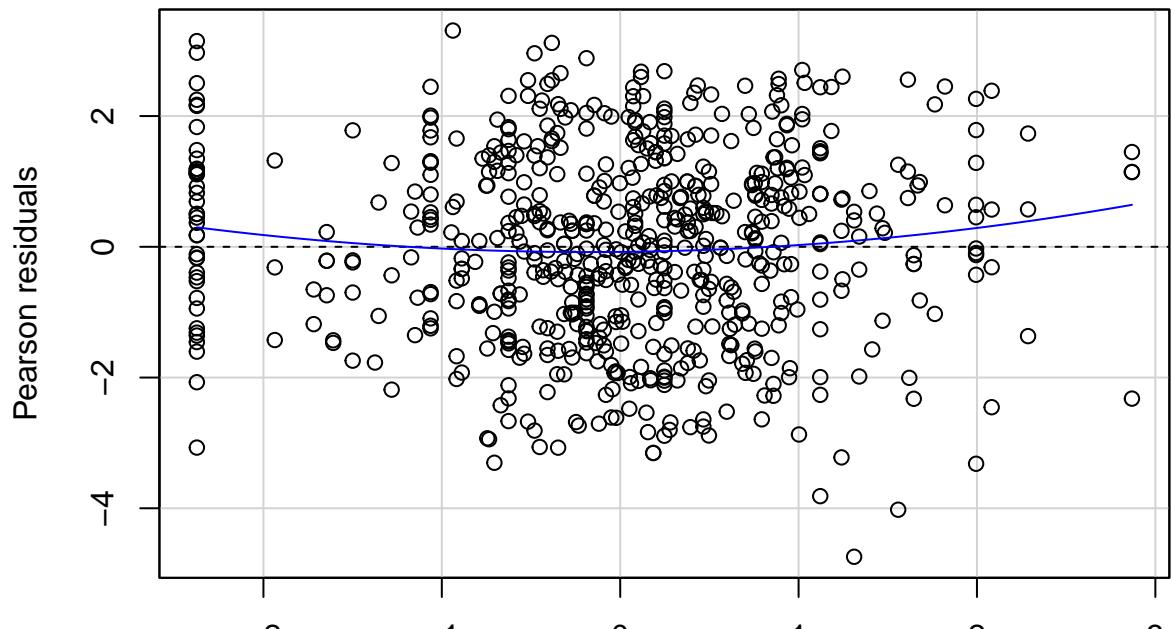
Added-Variable Plots

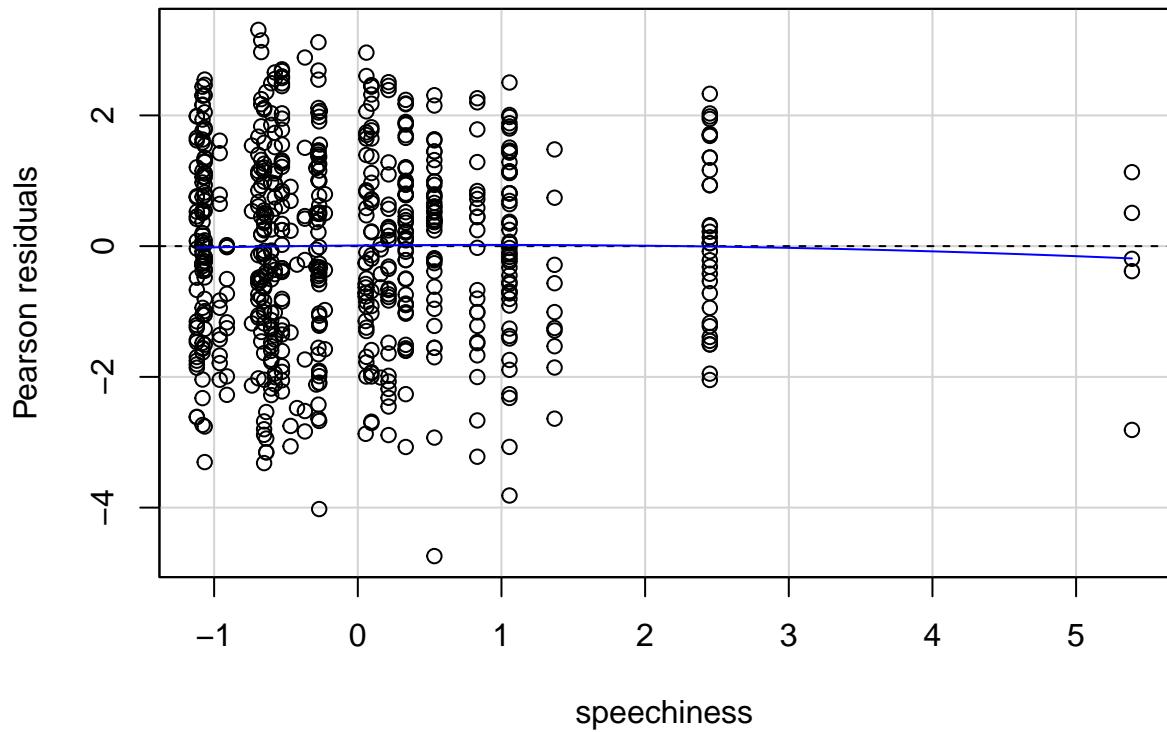


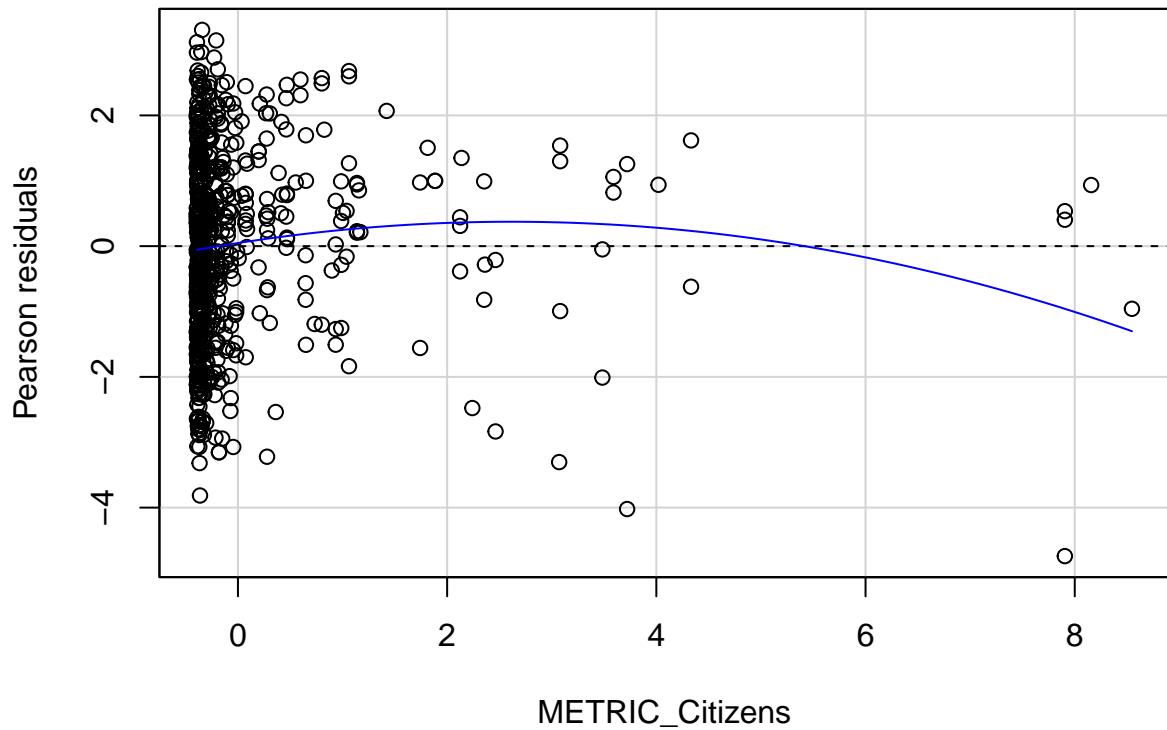
Cooks Distance Plot

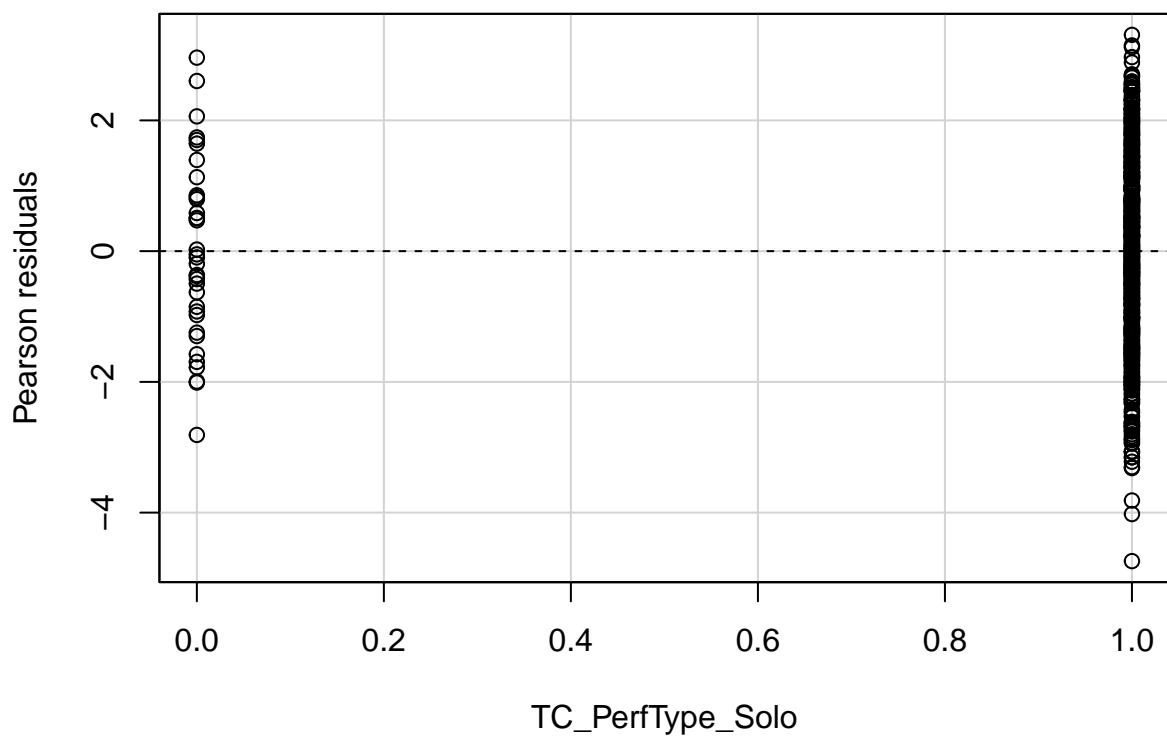


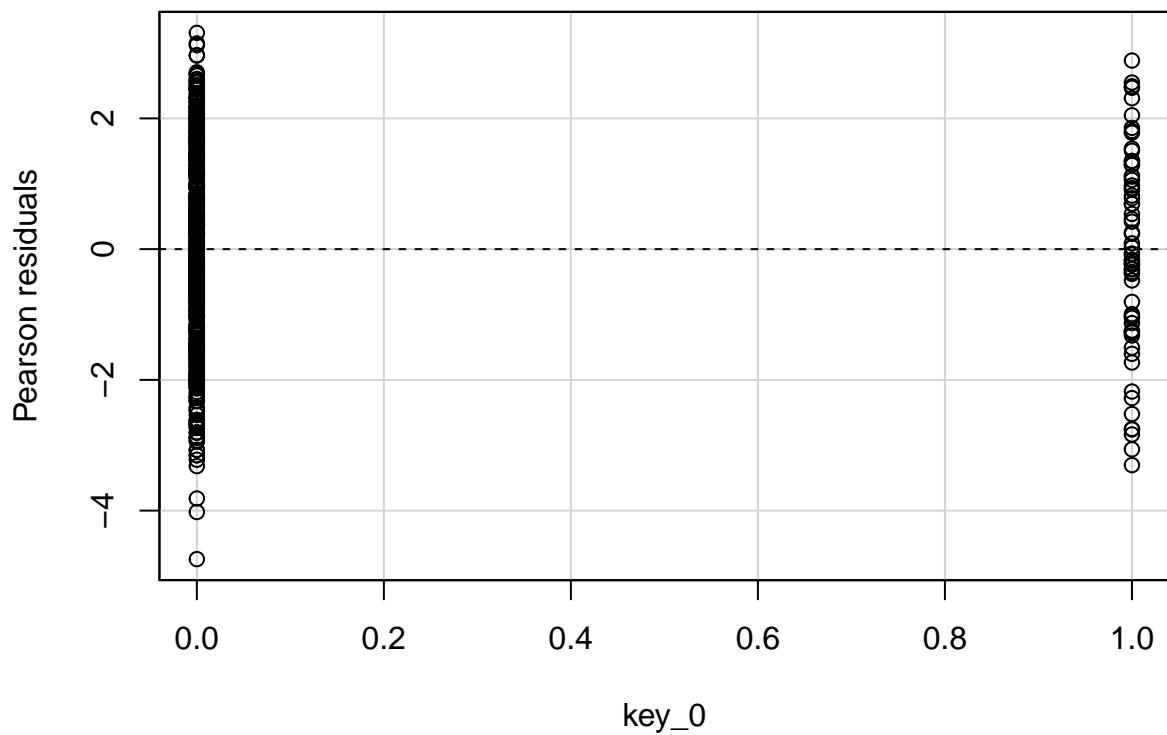
Residual Plots

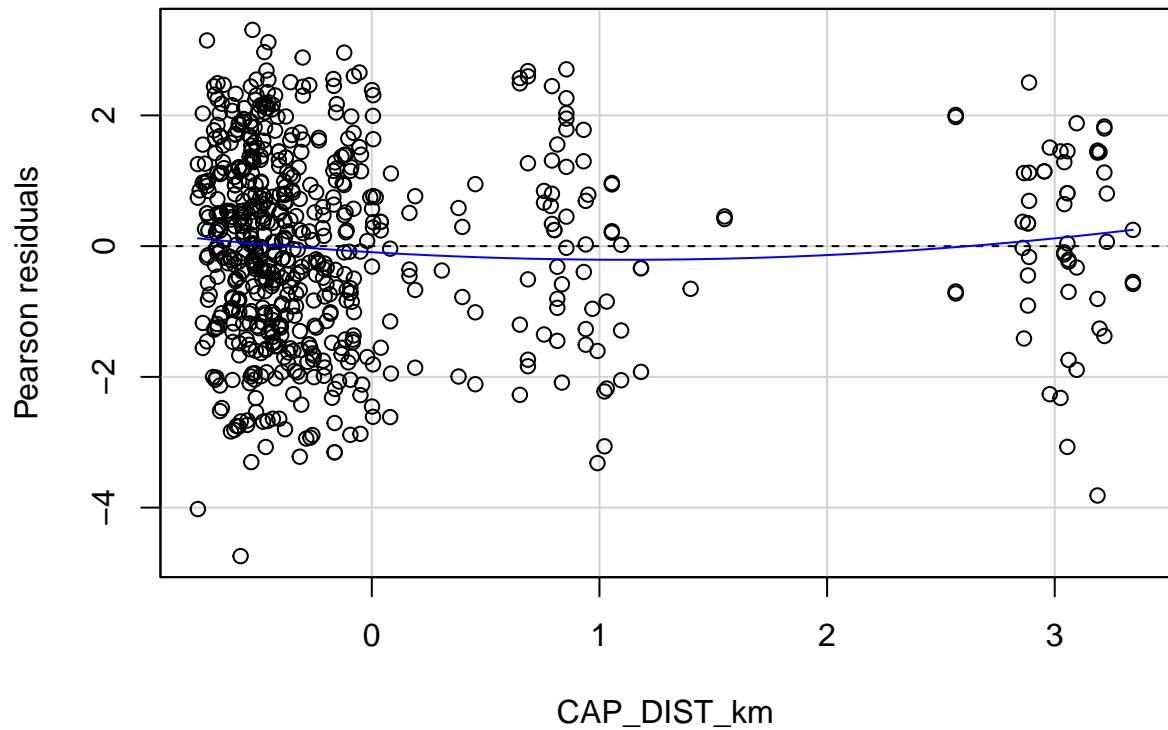


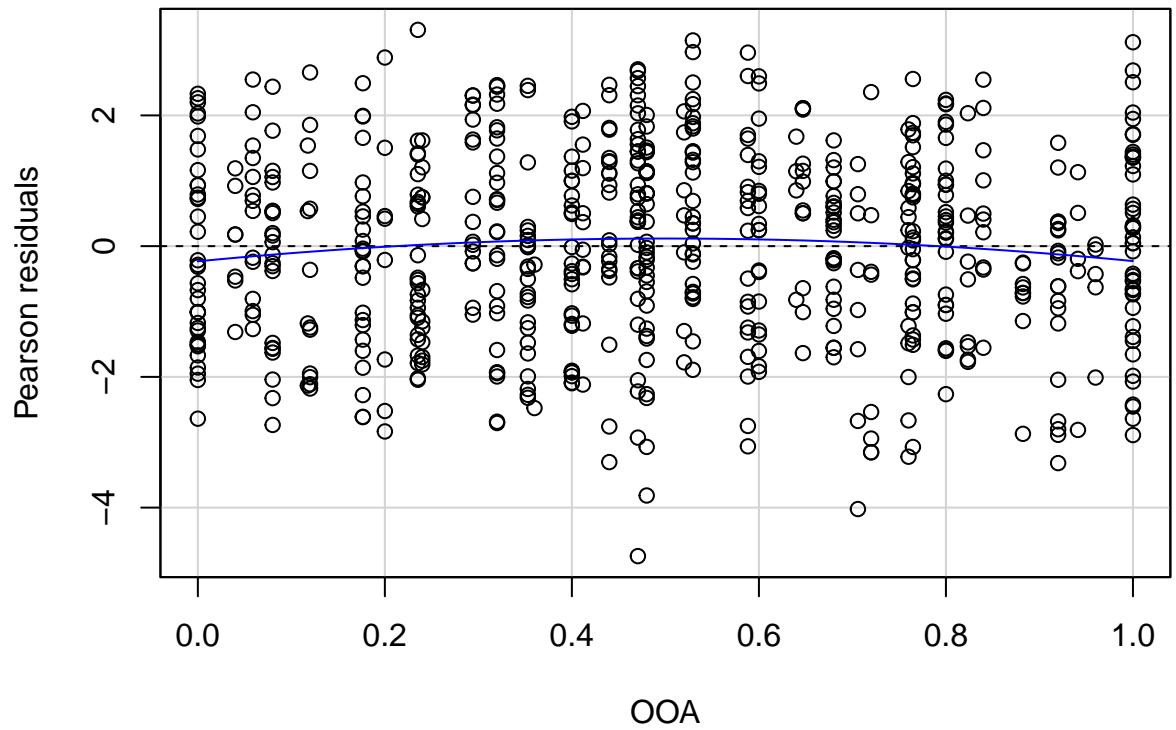


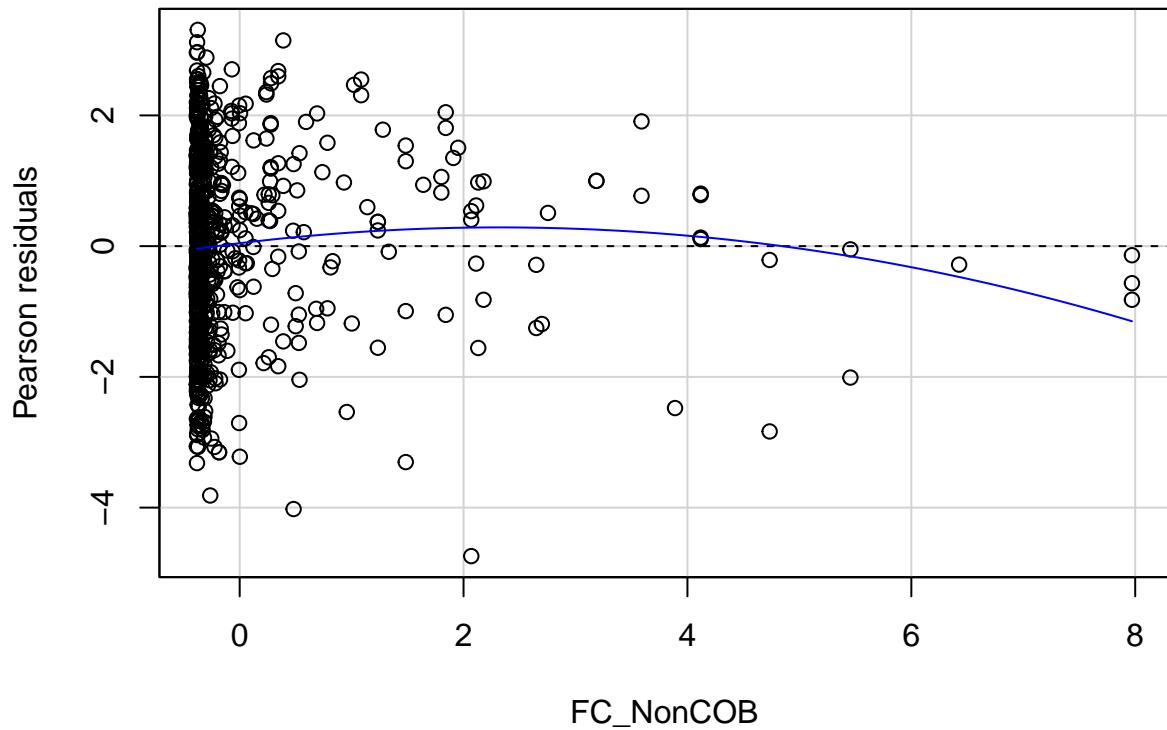


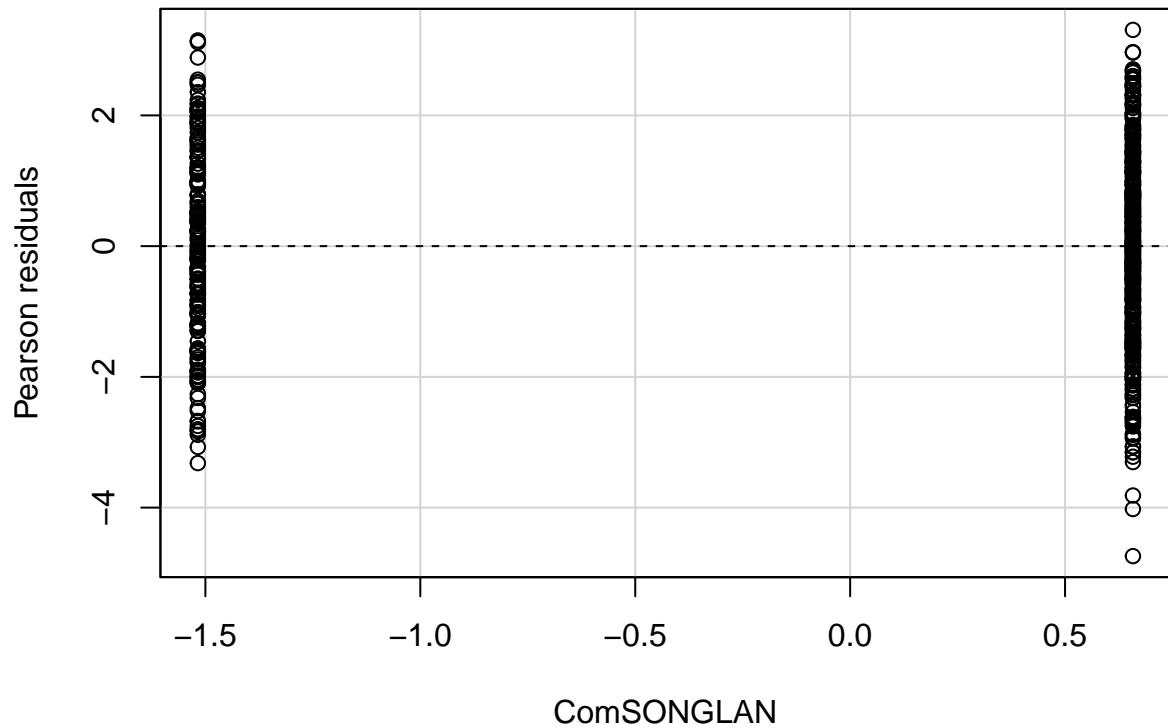


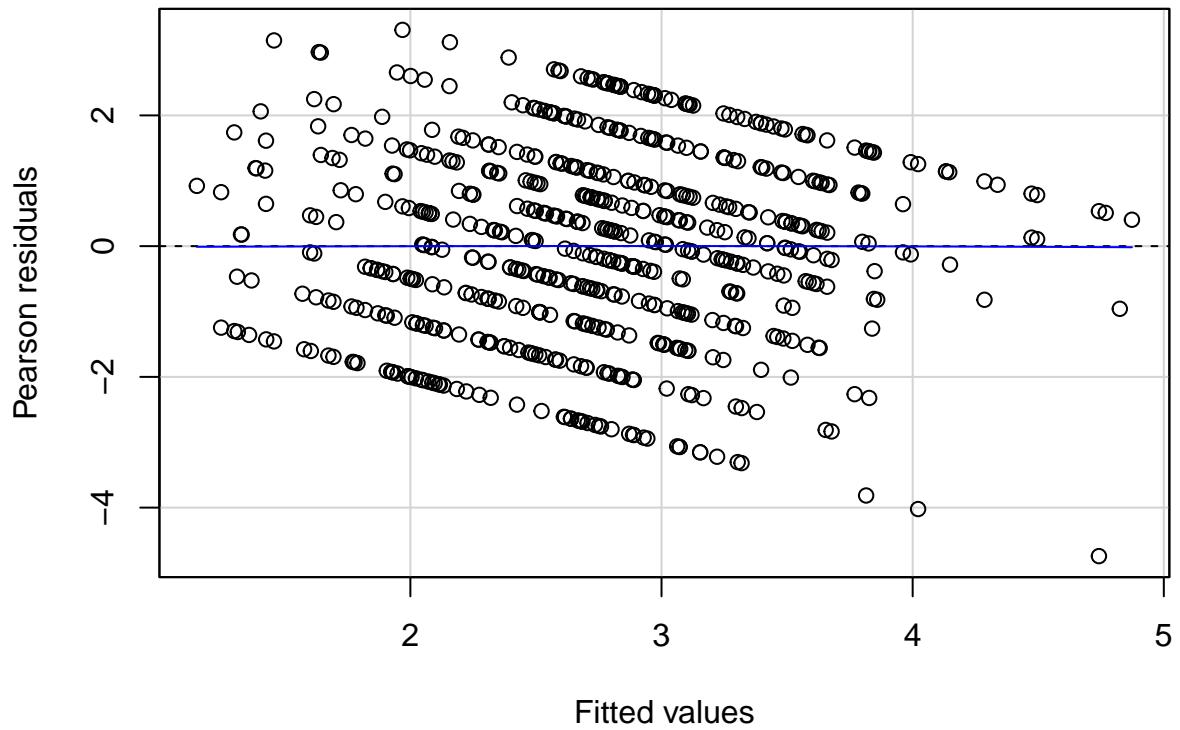




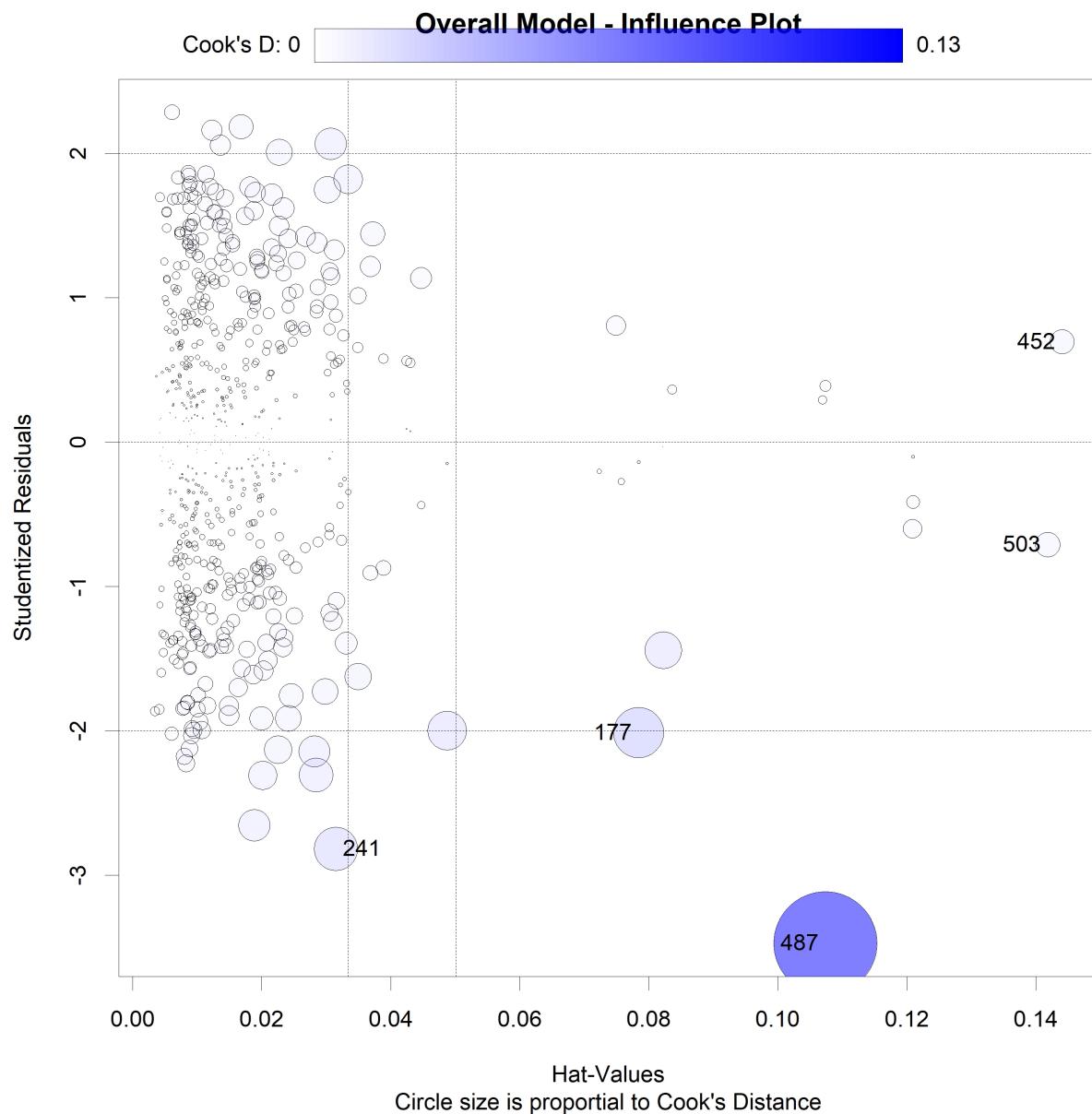








Influence Plot



Normality Assumption

Normality Tests

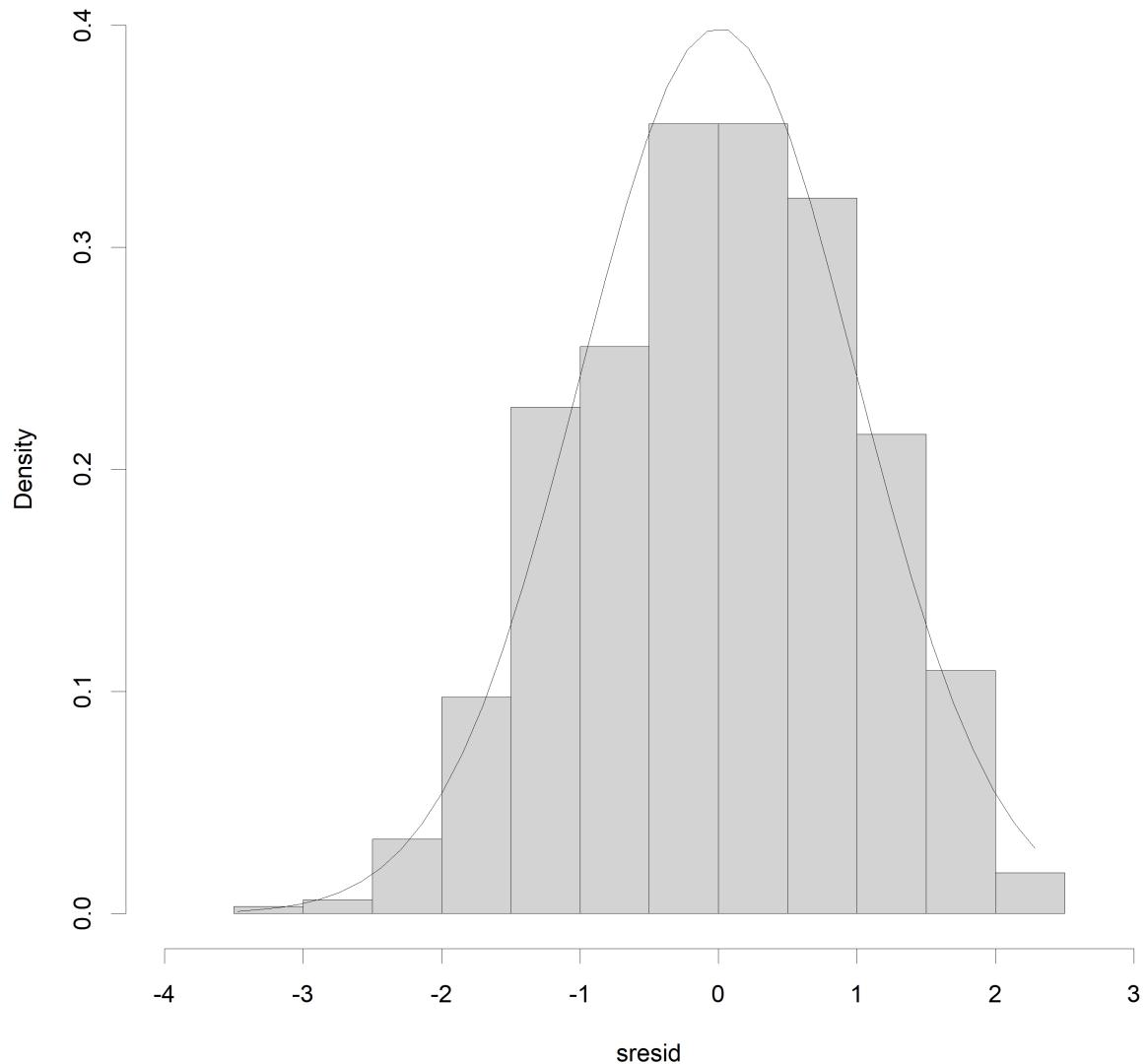
Normality Test

- Ho: The data is normally distributed
- Ha: the data is not normally distributed

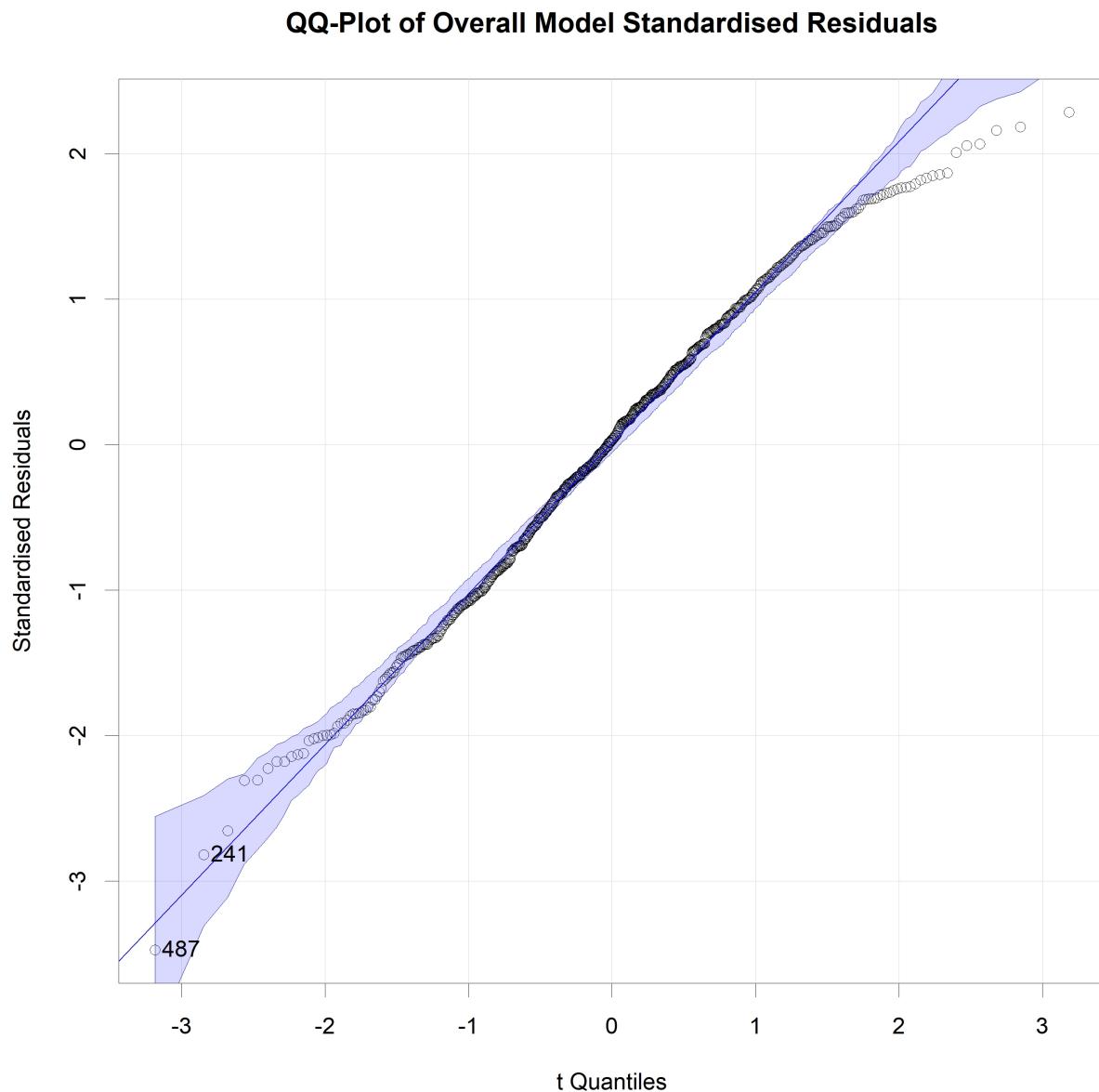
| NormTest | Stat | Pval |
|--------------|----------|---------|
| shapiro.test | 0.99127 | 0.00063 |
| ad.test | 1.17303 | 0.00458 |
| cvm.test | 0.16383 | 0.01564 |
| lille.test | 0.03283 | 0.08898 |
| person.test | 37.02432 | 0.04352 |
| sf.test | 0.99178 | 0.00149 |

Residual Histogram

Overall Model - Distribution of Standardised Residuals



Residual QQ-Plot



Constant Variance Assumption

Non-Constant Variance Test

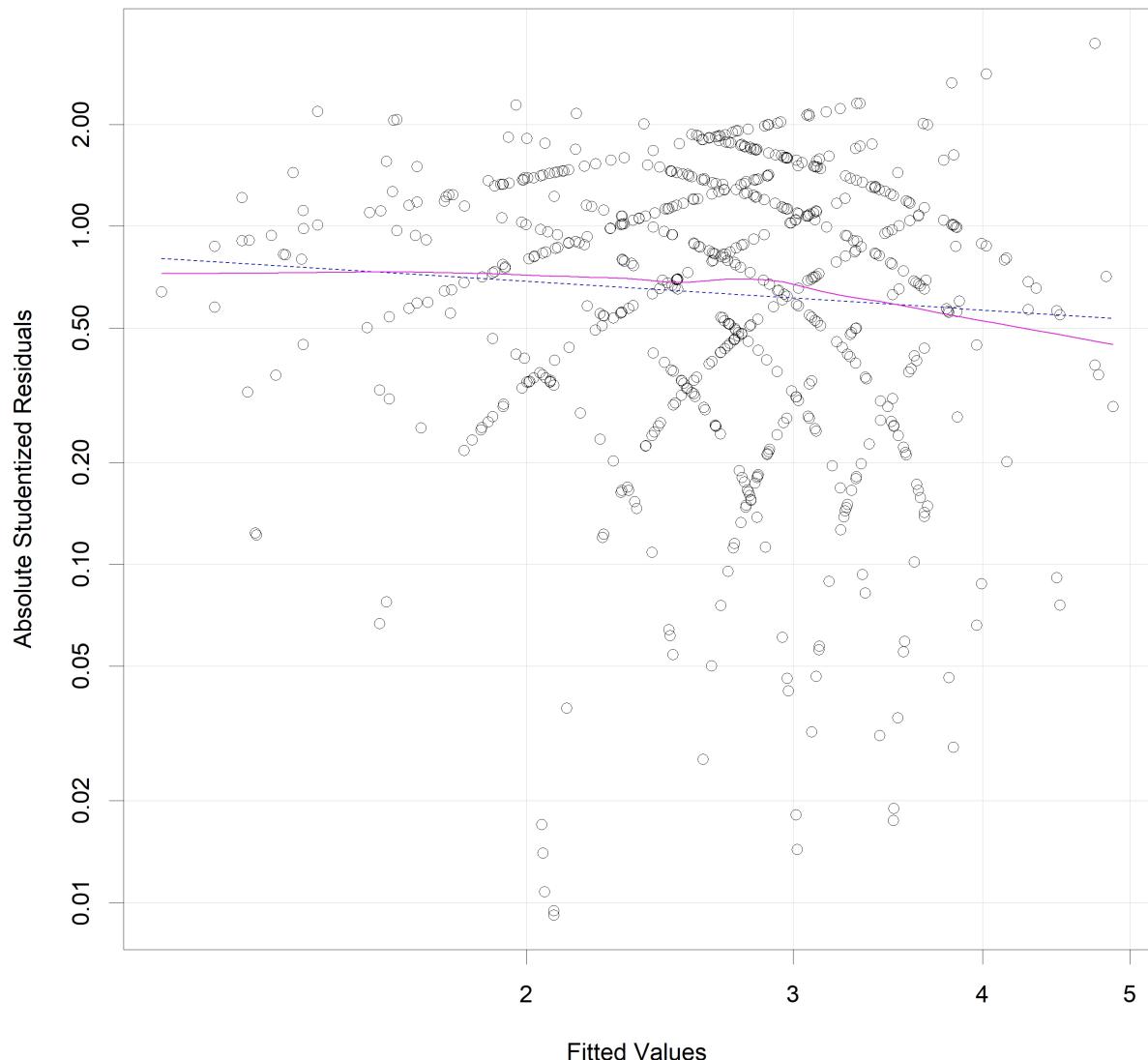
Non-Constant Error Variance Test

- Ho: constant error variance
- Ha: Non-constant error Variance

| Non-constant Variance Score Test | |
|----------------------------------|---------|
| Chi-Sq Statistic | 0.03663 |
| P-Value | 0.84821 |

Spread-Level Plot

Spread-Level Plot for Overall Model



Variance Inflation Factors

| | VIF | sqrt(VIF) > 2 |
|------------------|----------|---------------|
| Average_Points | 1.091139 | 0 |
| acousticness | 1.179141 | 0 |
| speechiness | 1.289927 | 0 |
| METRIC_Citizens | 1.360161 | 0 |
| TC_PerfType_Solo | 1.104542 | 0 |
| key_0 | 1.246838 | 0 |

| | VIF | sqrt(VIF) > 2 |
|-------------|----------|---------------|
| CAP_DIST_km | 1.139690 | 0 |
| OOA | 1.188927 | 0 |
| FC_NonCOB | 1.344230 | 0 |
| ComSONGLAN | 1.150996 | 0 |

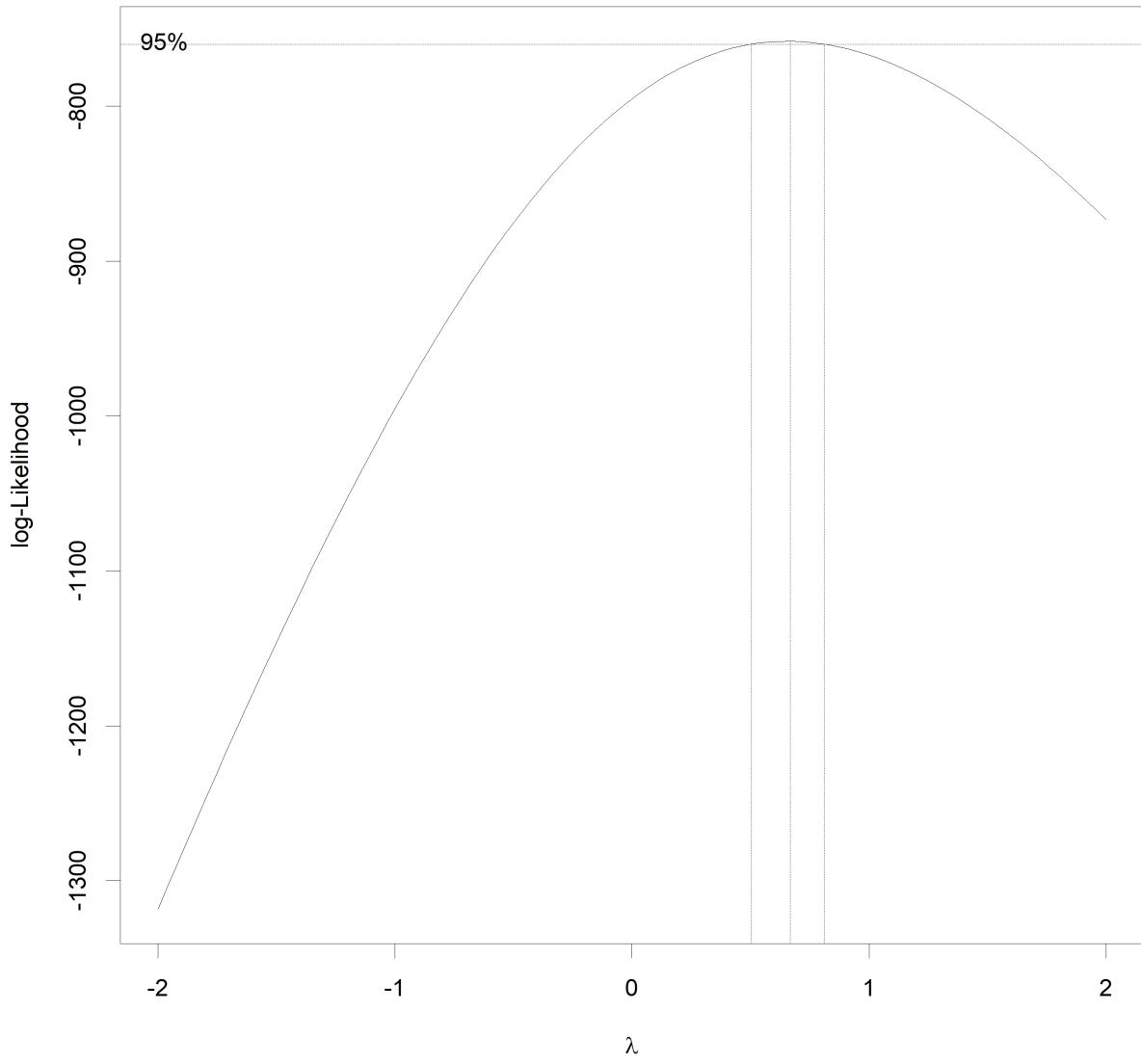
Televote Model

```
##  
## Call:  
## lm(formula = televote_final_model_form, data = televote_data)  
##  
## Residuals:  
##      Min       1Q   Median      3Q      Max  
## -7.3561 -1.9688 -0.0461  1.7443  6.7011  
##  
## Coefficients:  
##             Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 5.1314    0.3466 14.806 < 2e-16 ***  
## METRIC_Citizens 0.5344    0.1555  3.436 0.000668 ***  
## Average_Points 0.8126    0.1607  5.057 7.22e-07 ***  
## TC_NumNeigh 0.7464    0.1742  4.286 2.42e-05 ***  
## speechiness 0.5175    0.1656  3.125 0.001943 **  
## acousticness 0.4804    0.1681  2.858 0.004550 **  
## FC_NonCitizens 0.6452    0.1767  3.652 0.000304 ***  
## VBlocs1_TC_13 -6.8165    2.1841 -3.121 0.001968 **  
## OOA 0.8913    0.6028  1.479 0.140203  
## CAP_DIST_km 0.3029    0.1726  1.755 0.080254 .  
## ---  
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ',' 1  
##  
## Residual standard error: 2.772 on 317 degrees of freedom  
## Multiple R-squared: 0.3384, Adjusted R-squared: 0.3196  
## F-statistic: 18.02 on 9 and 317 DF, p-value: < 2.2e-16
```

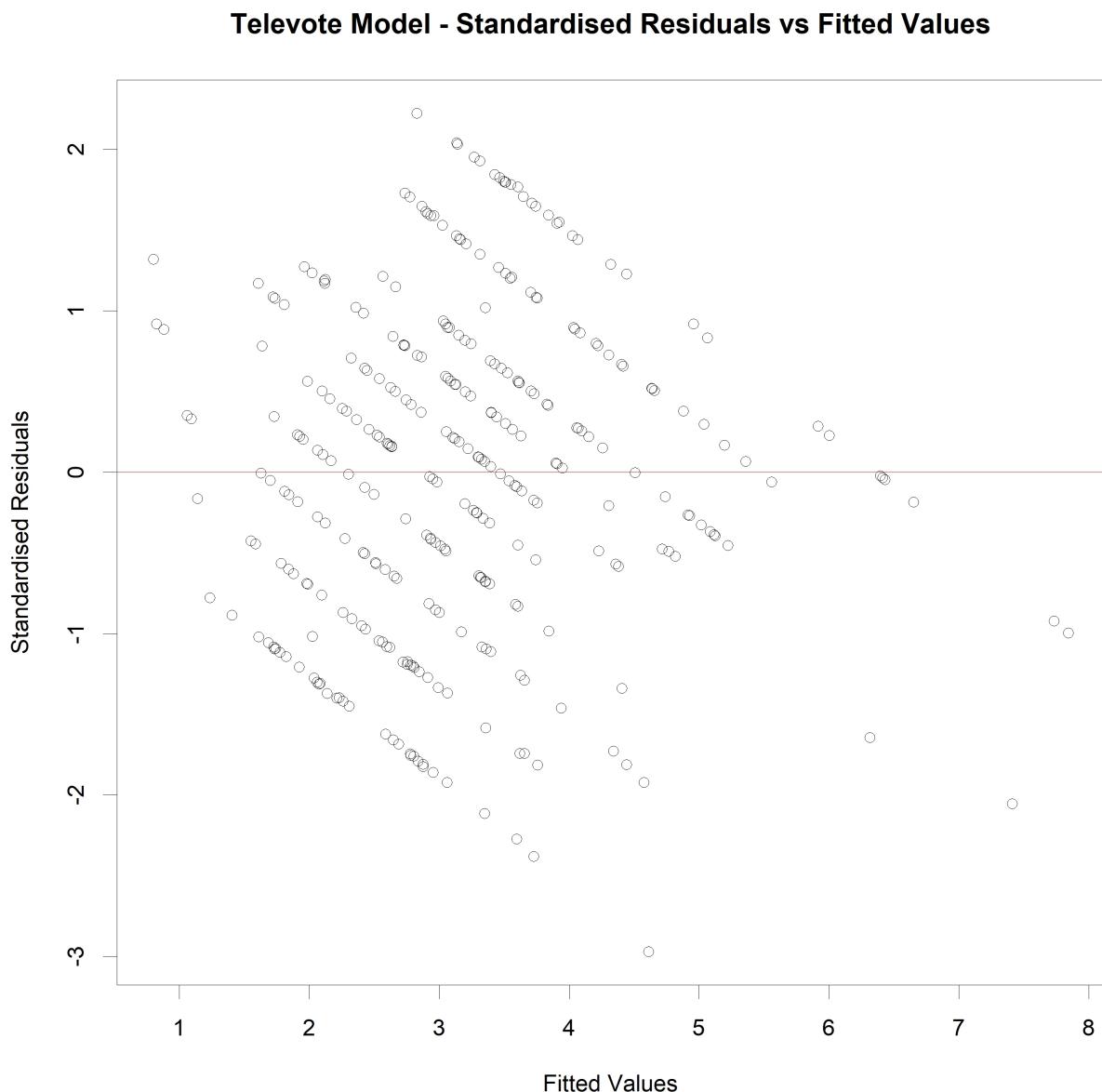
Response Variable Transformation

Box-Cox Power Transformation

```
##  
## Call:  
## lm(formula = televote_final_model_bct_form, data = televote_data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -4.6127 -1.0874  0.0907  1.1155  3.5345  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept)  2.75365  0.20088 13.708 < 2e-16 ***  
## METRIC_Citizens 0.28085  0.09013  3.116 0.002000 **  
## Average_Points  0.44003  0.09313  4.725 3.47e-06 ***  
## TC_NumNeigh    0.44883  0.10095  4.446 1.21e-05 ***  
## speechiness     0.30365  0.09599  3.163 0.001711 **  
## acousticsness   0.28053  0.09743  2.879 0.004257 **  
## FC_NonCitizens 0.35982  0.10241  3.514 0.000506 ***  
## VBllocs1_TC_13 -3.80137  1.26592 -3.003 0.002888 **  
## OOA            0.52110  0.34938  1.492 0.136818  
## CAP_DIST_km     0.19110  0.10006  1.910 0.057054 .  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 1.607 on 317 degrees of freedom  
## Multiple R-squared:  0.3246, Adjusted R-squared:  0.3054  
## F-statistic: 16.92 on 9 and 317 DF,  p-value: < 2.2e-16
```



Resdiauls vs Fitted Values



Model Outliers

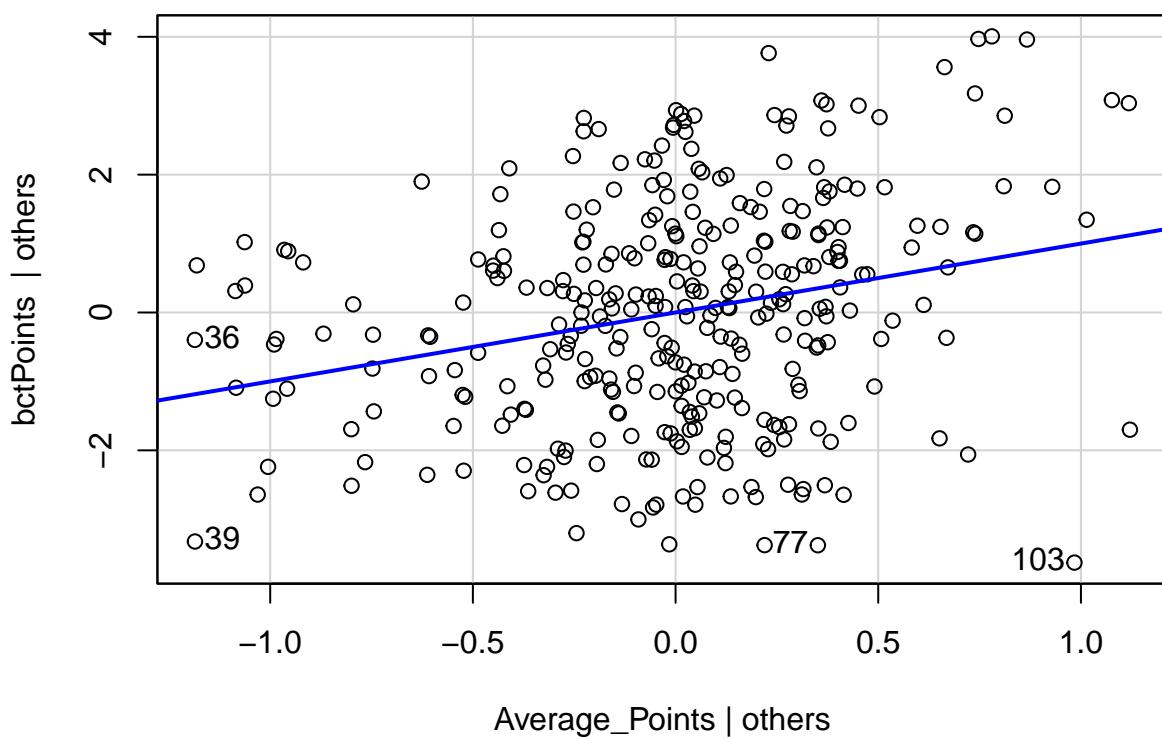
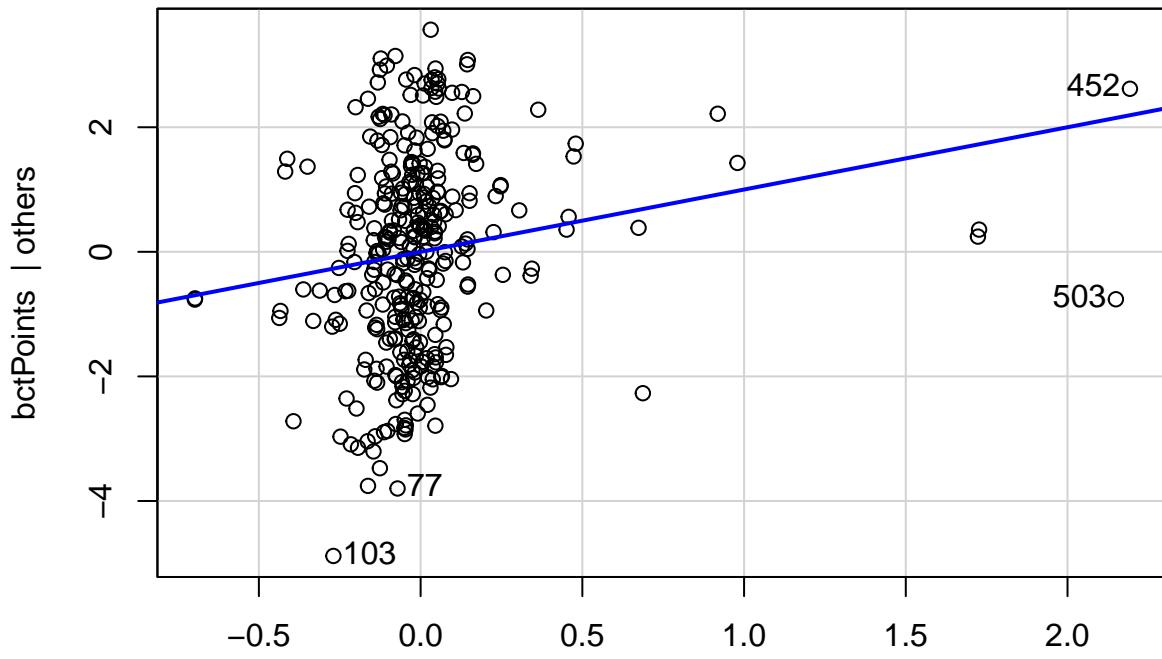
Bonferroni Outlier Test

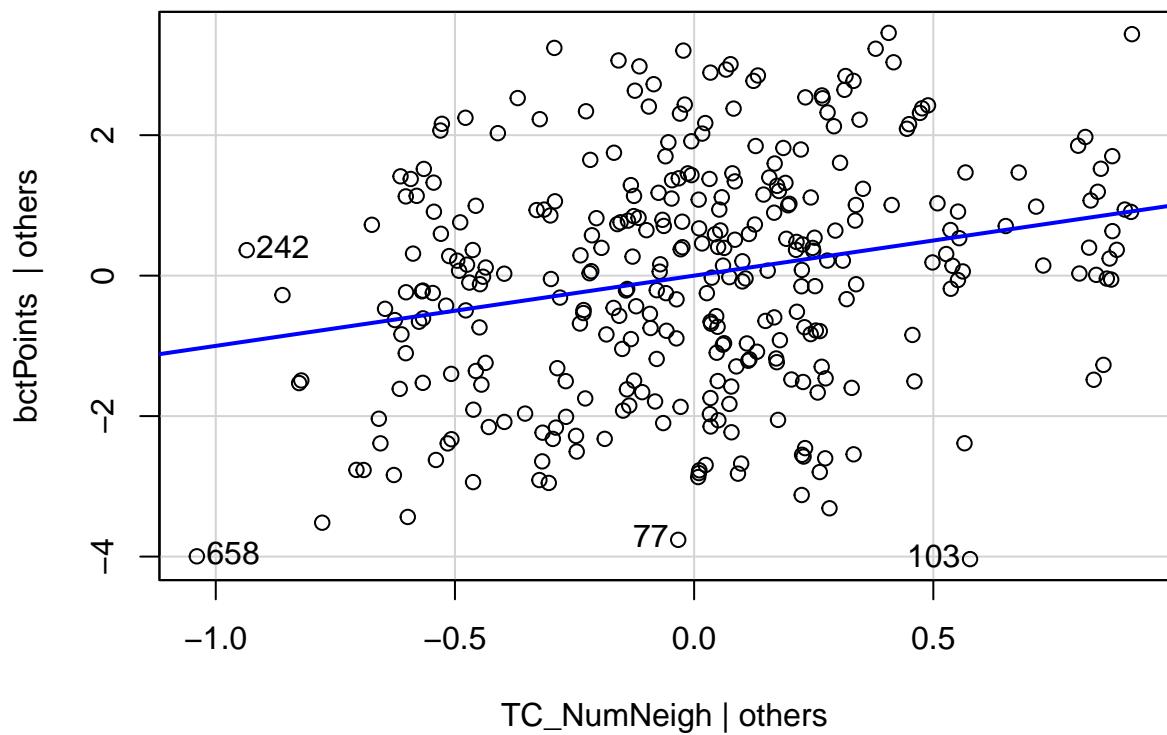
| | rstudent | p | bonf.p | signif | cutoff |
|-----|-----------|-----------|----------|--------|--------|
| 103 | -2.970711 | 0.0031989 | 1.046038 | 0 | 0.05 |

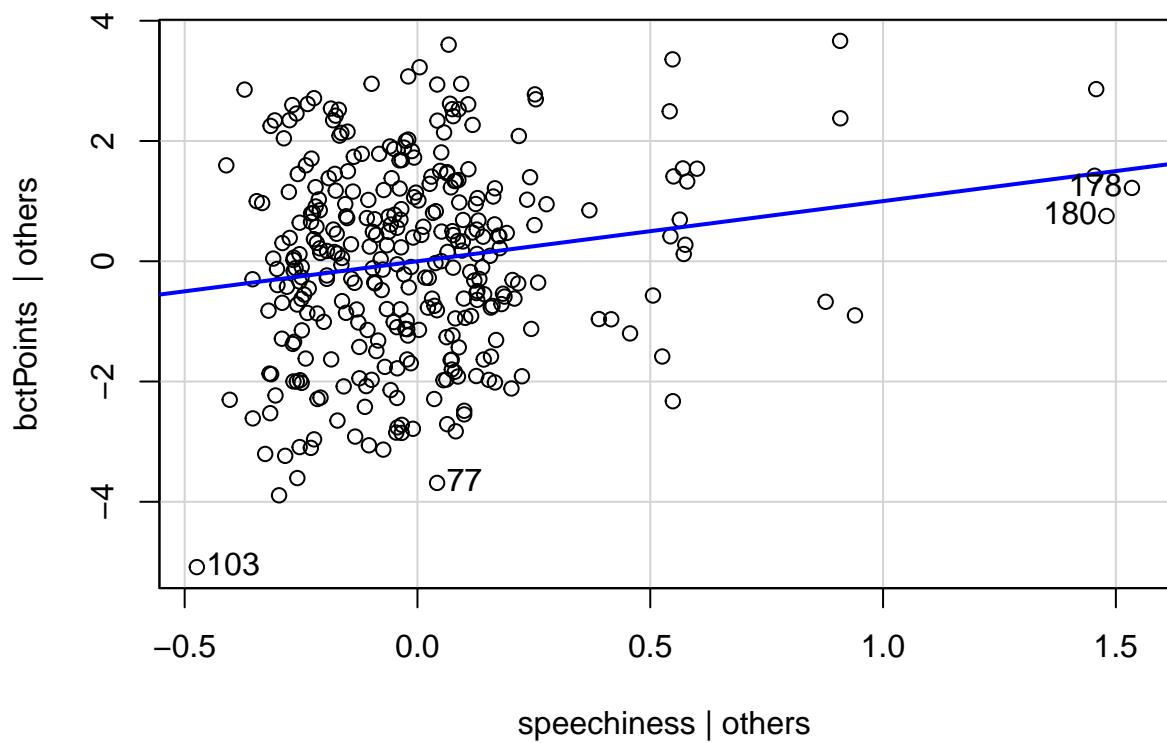
Residual Outliers

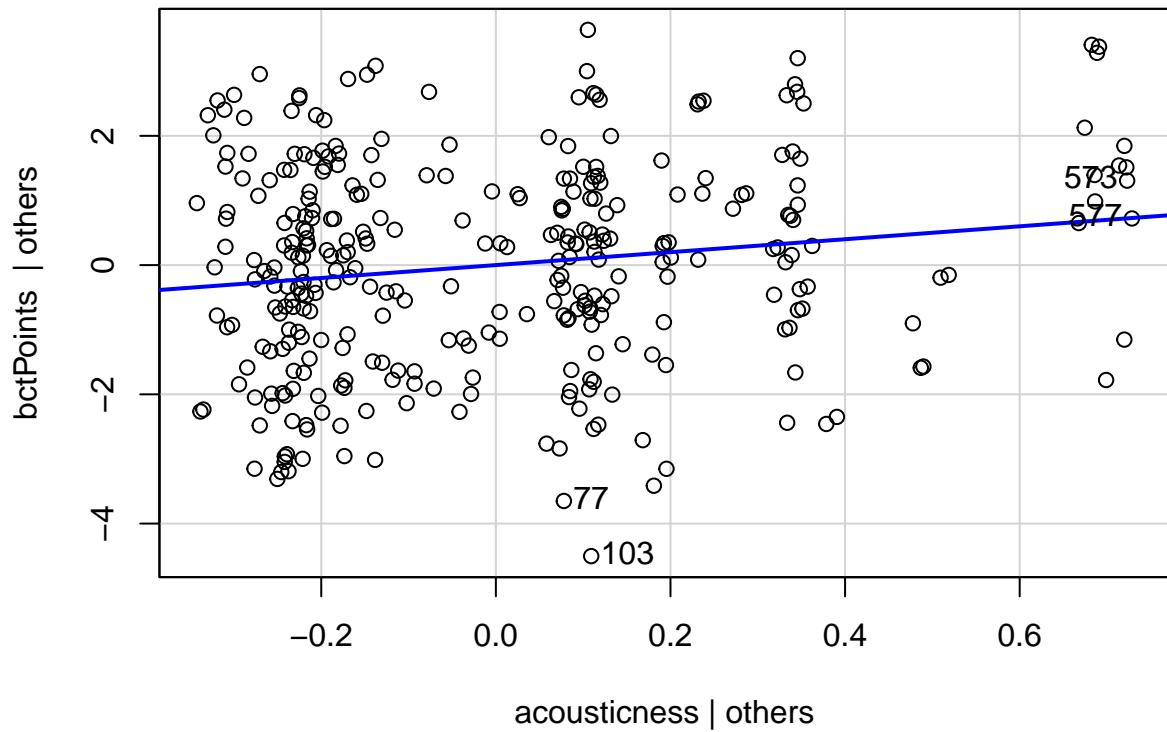
| outlier_residuals |
|-------------------|
| 77 |
| 88 |
| 101 |
| 103 |
| 503 |

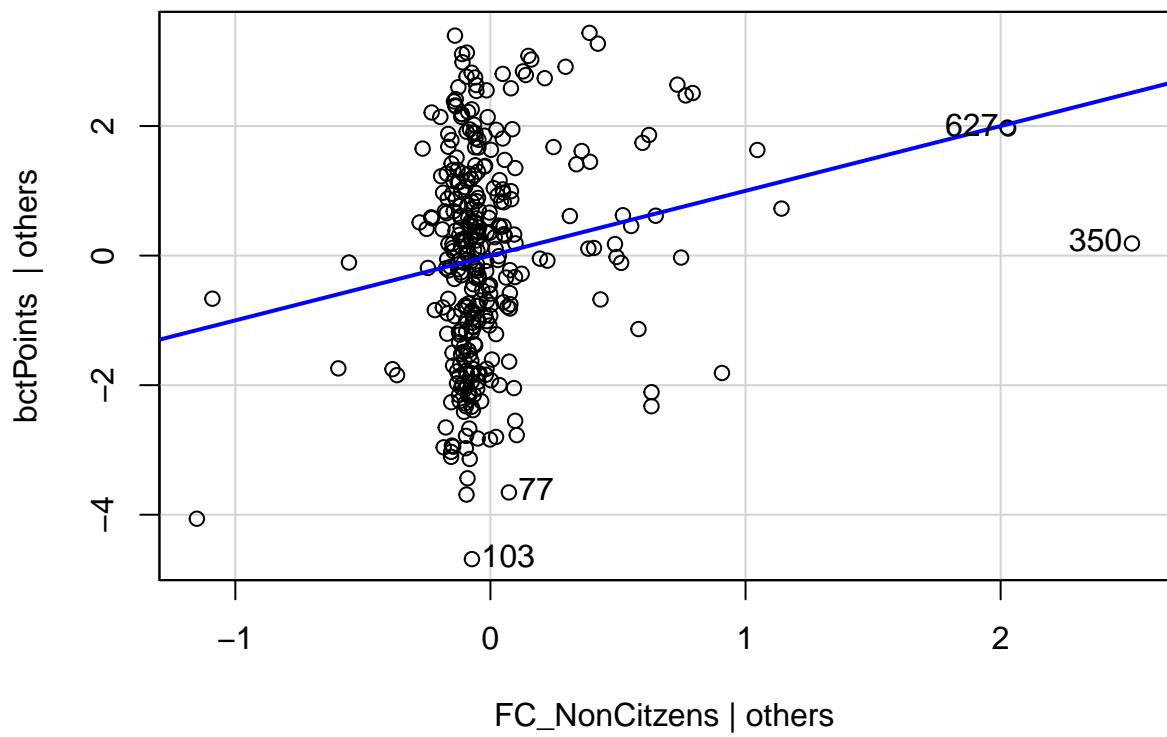
Leverage Plots

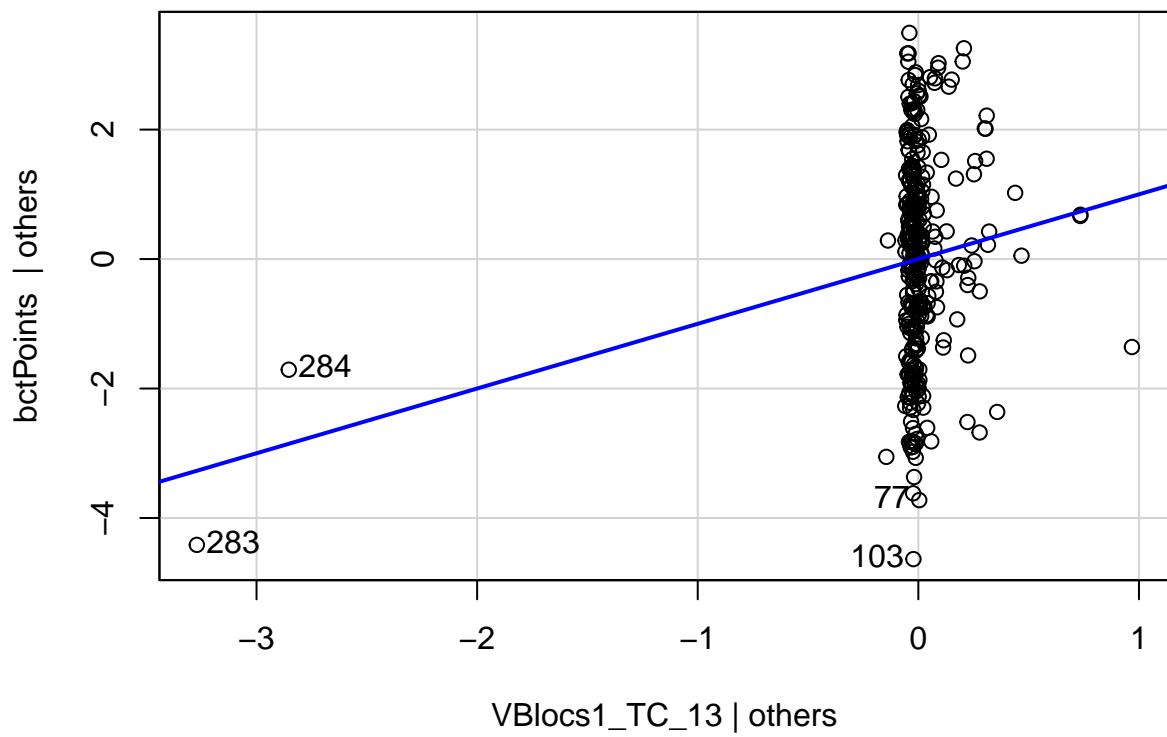


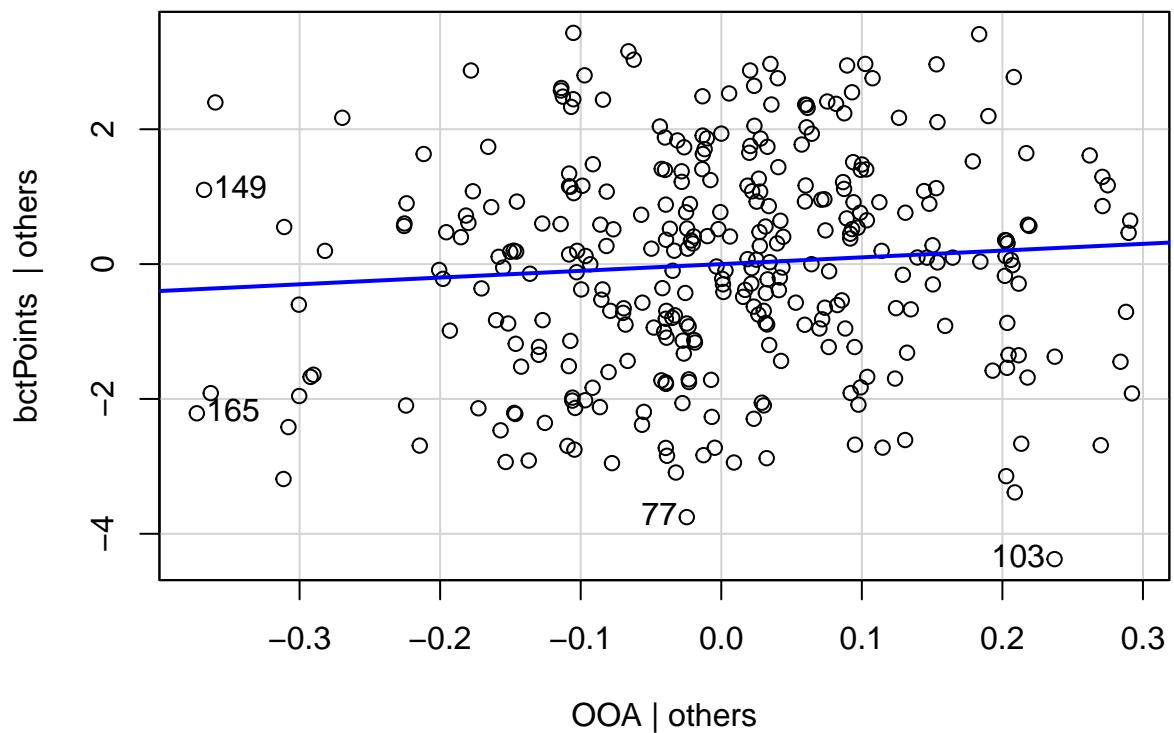




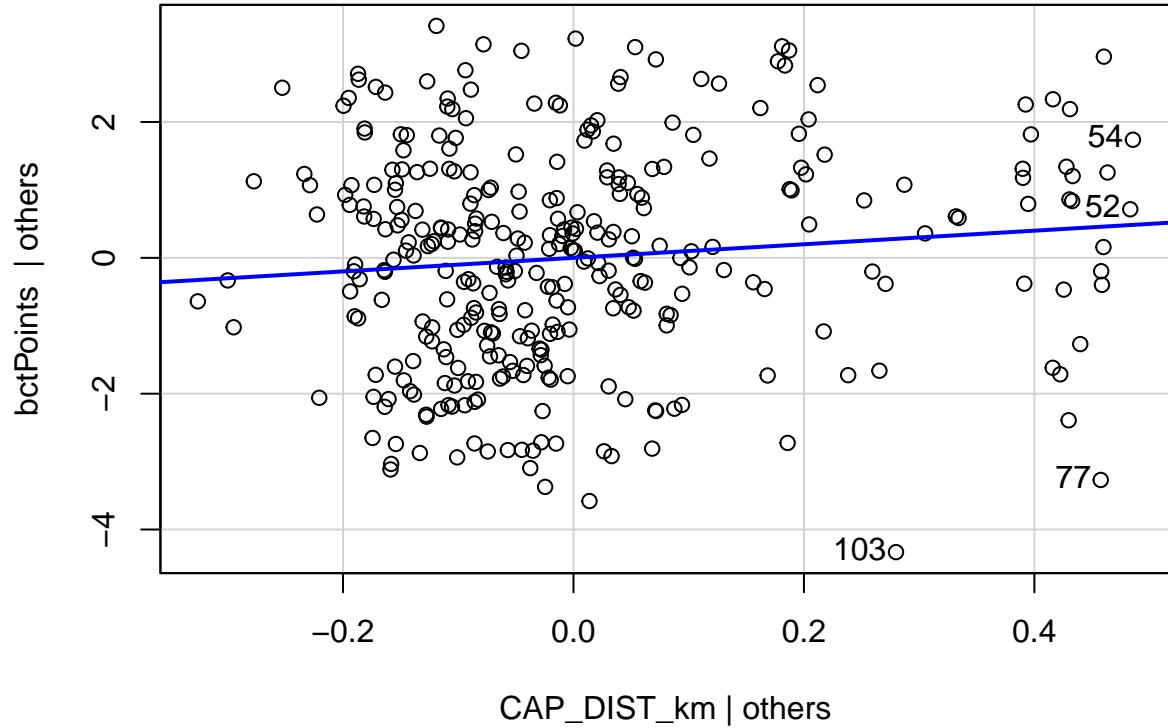




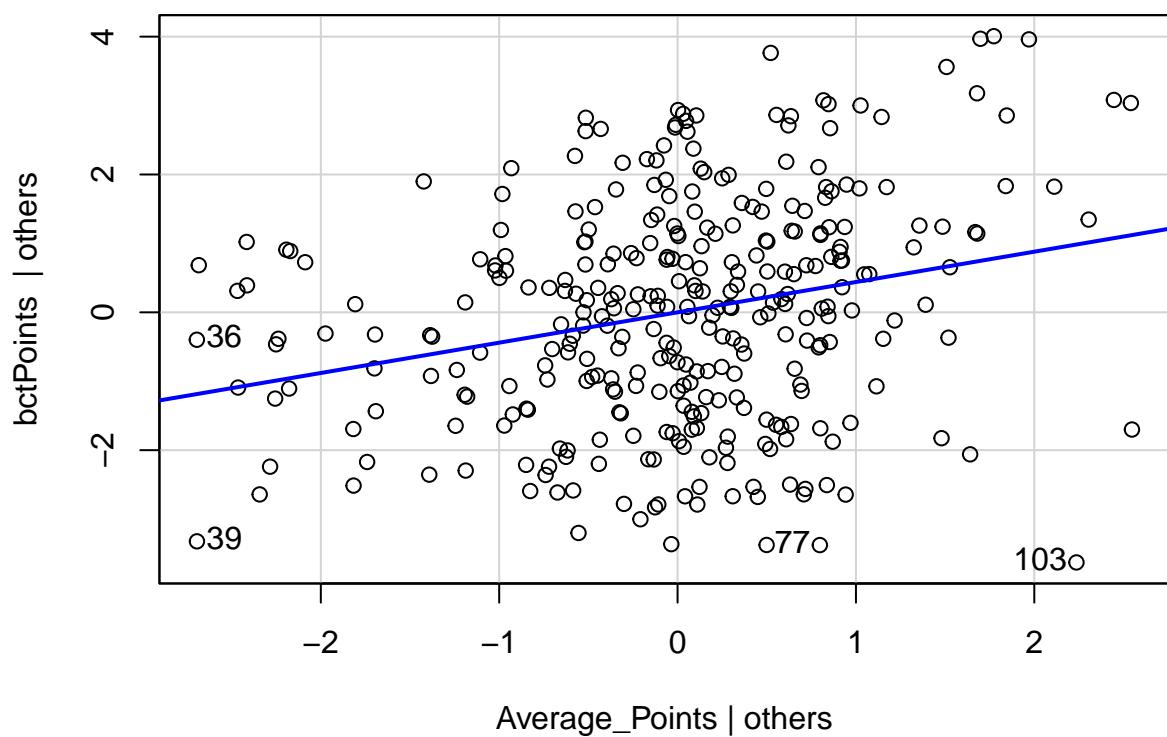
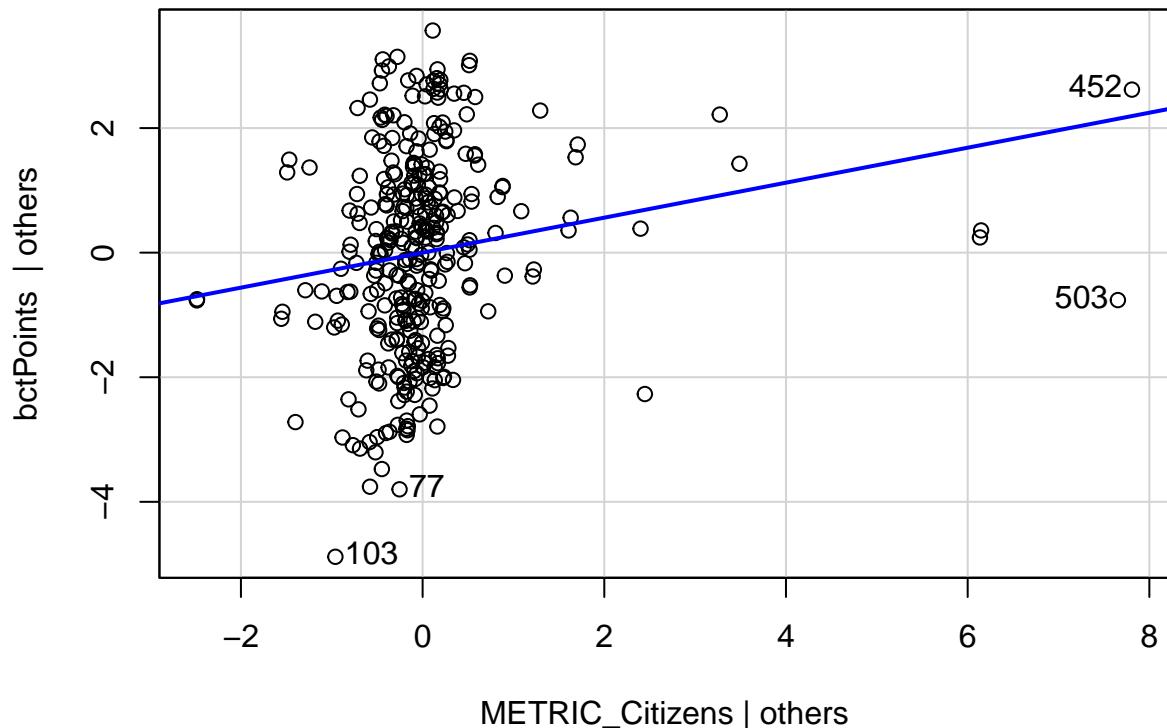


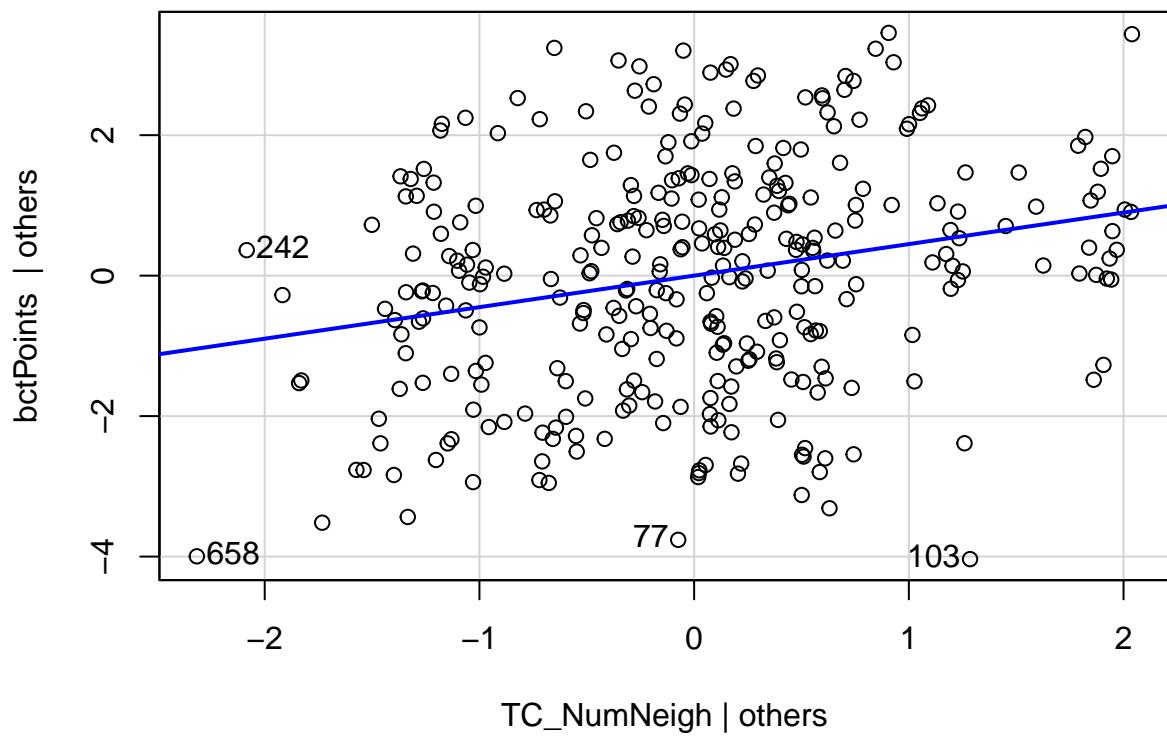


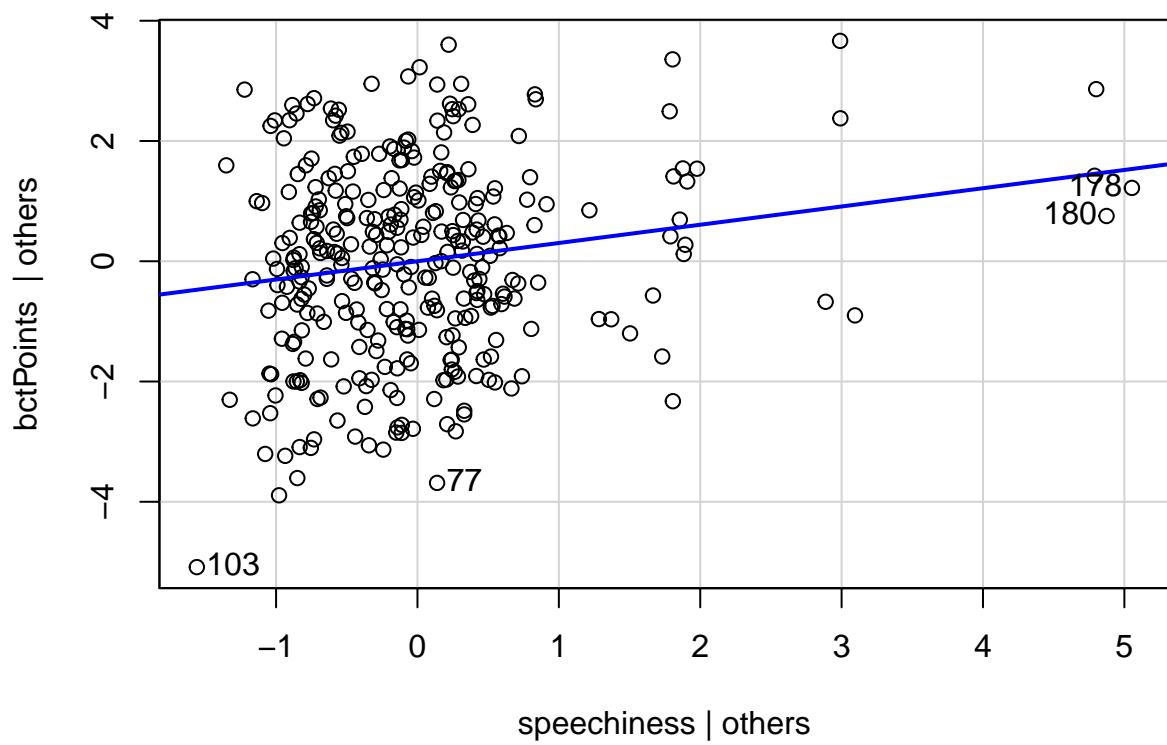
Leverage Plots

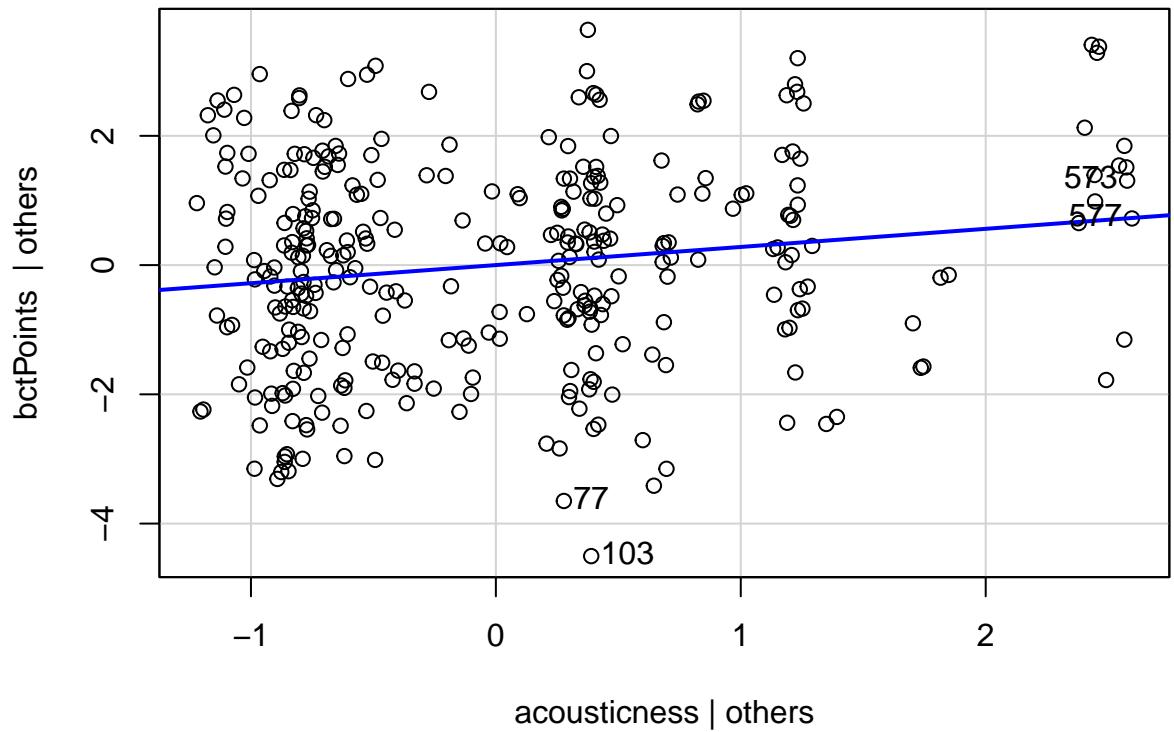


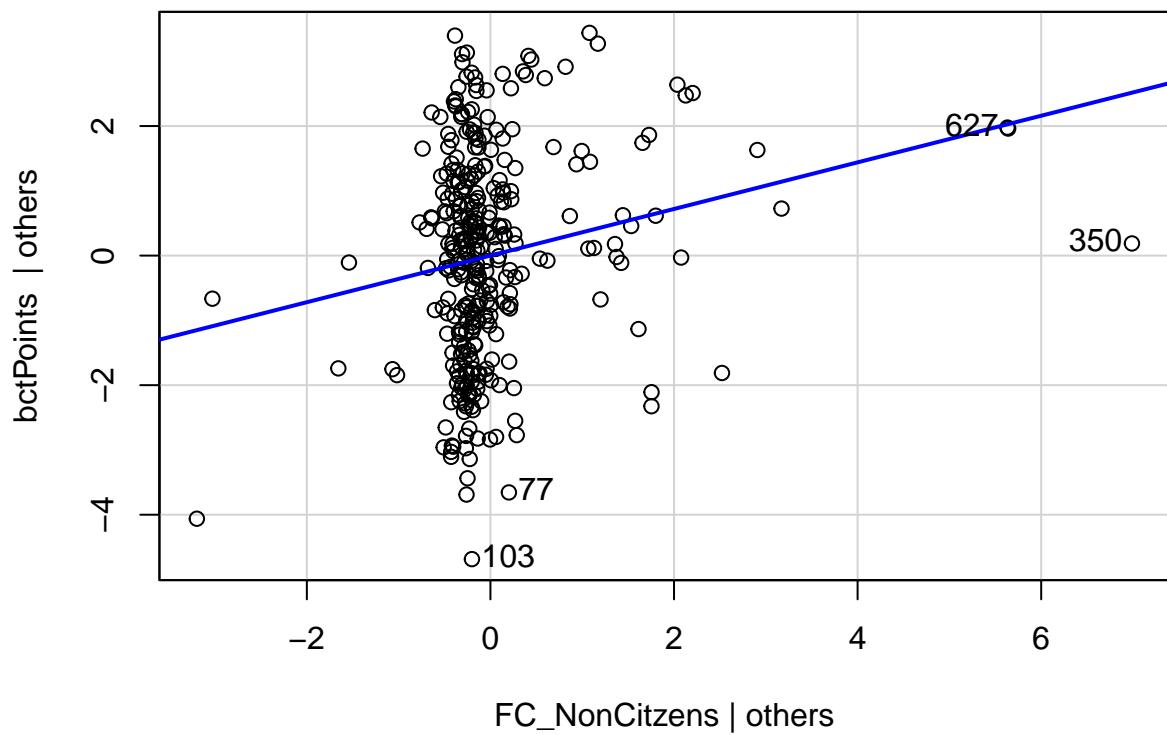
Added Variable Plots

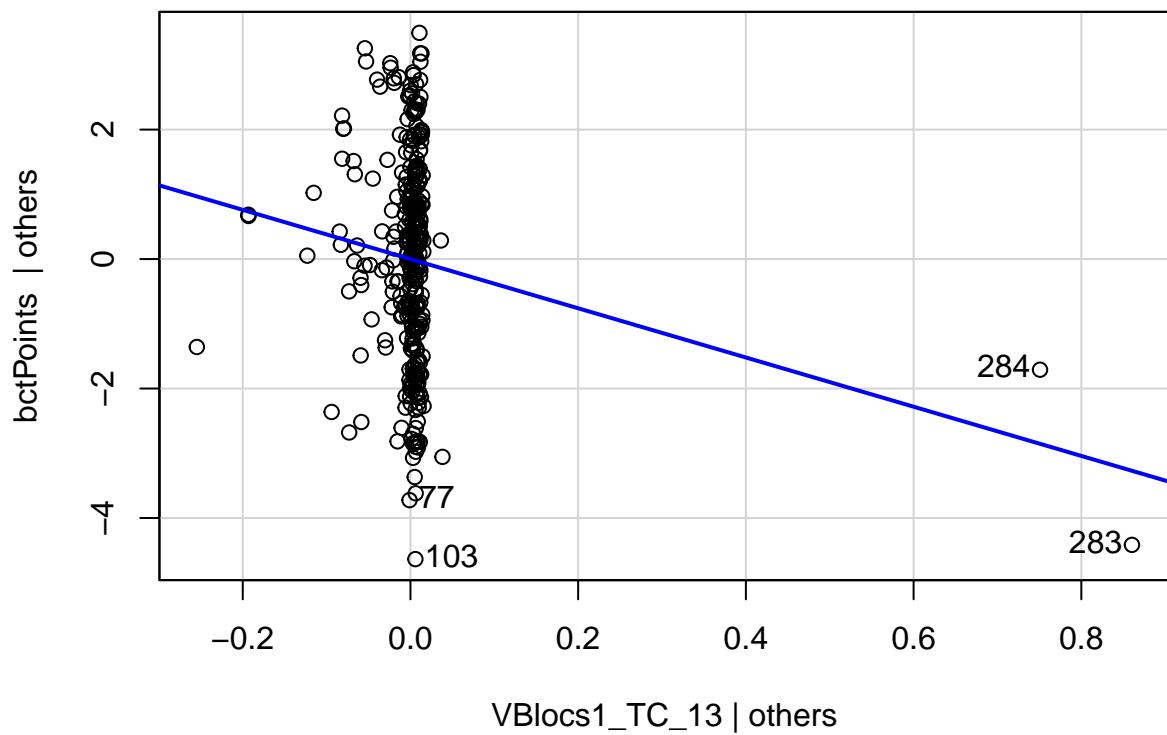


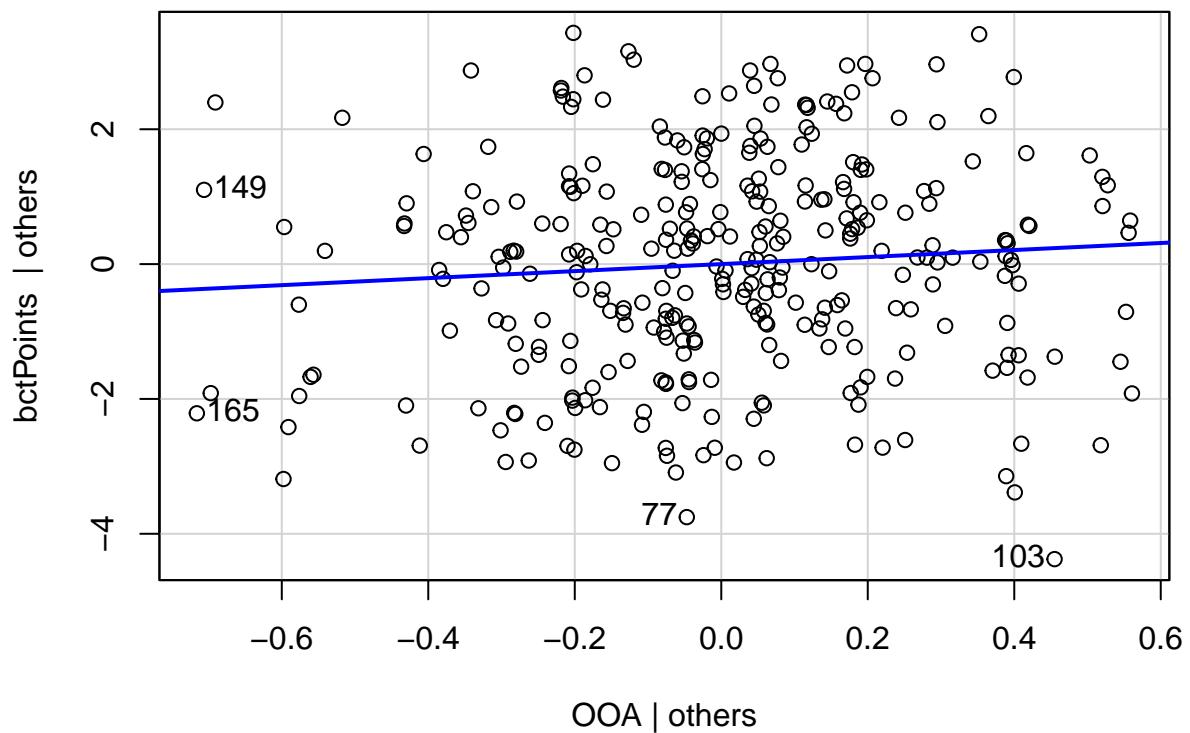




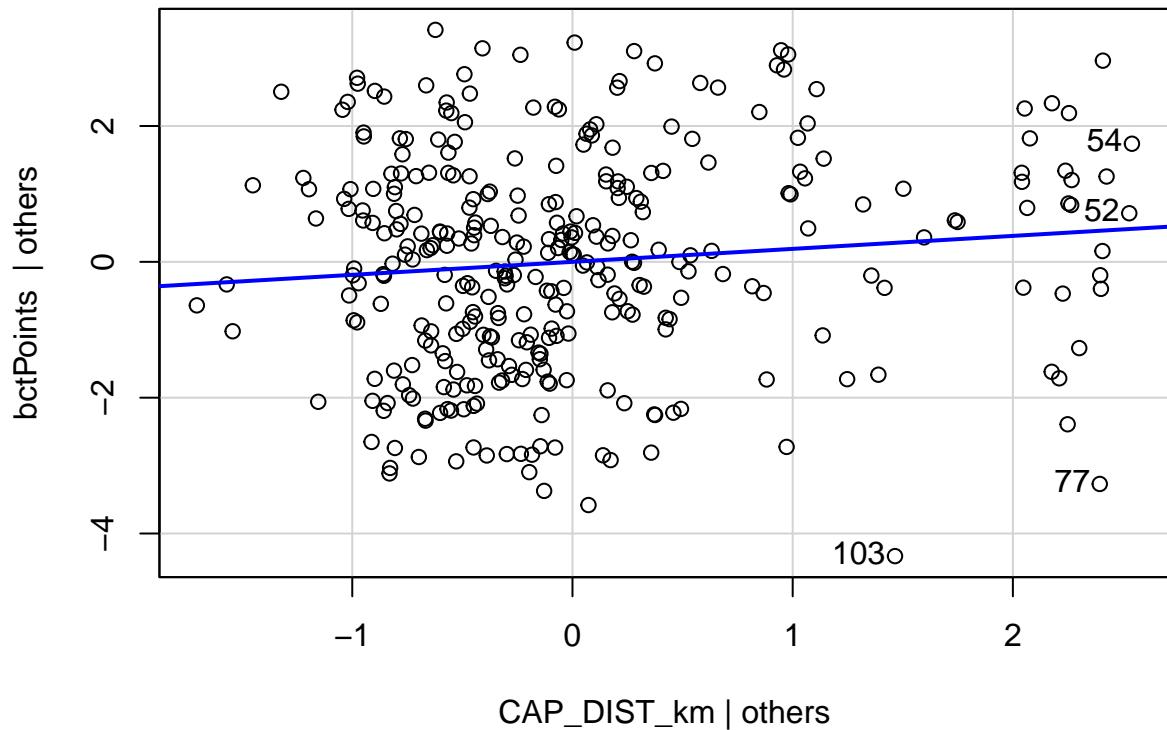




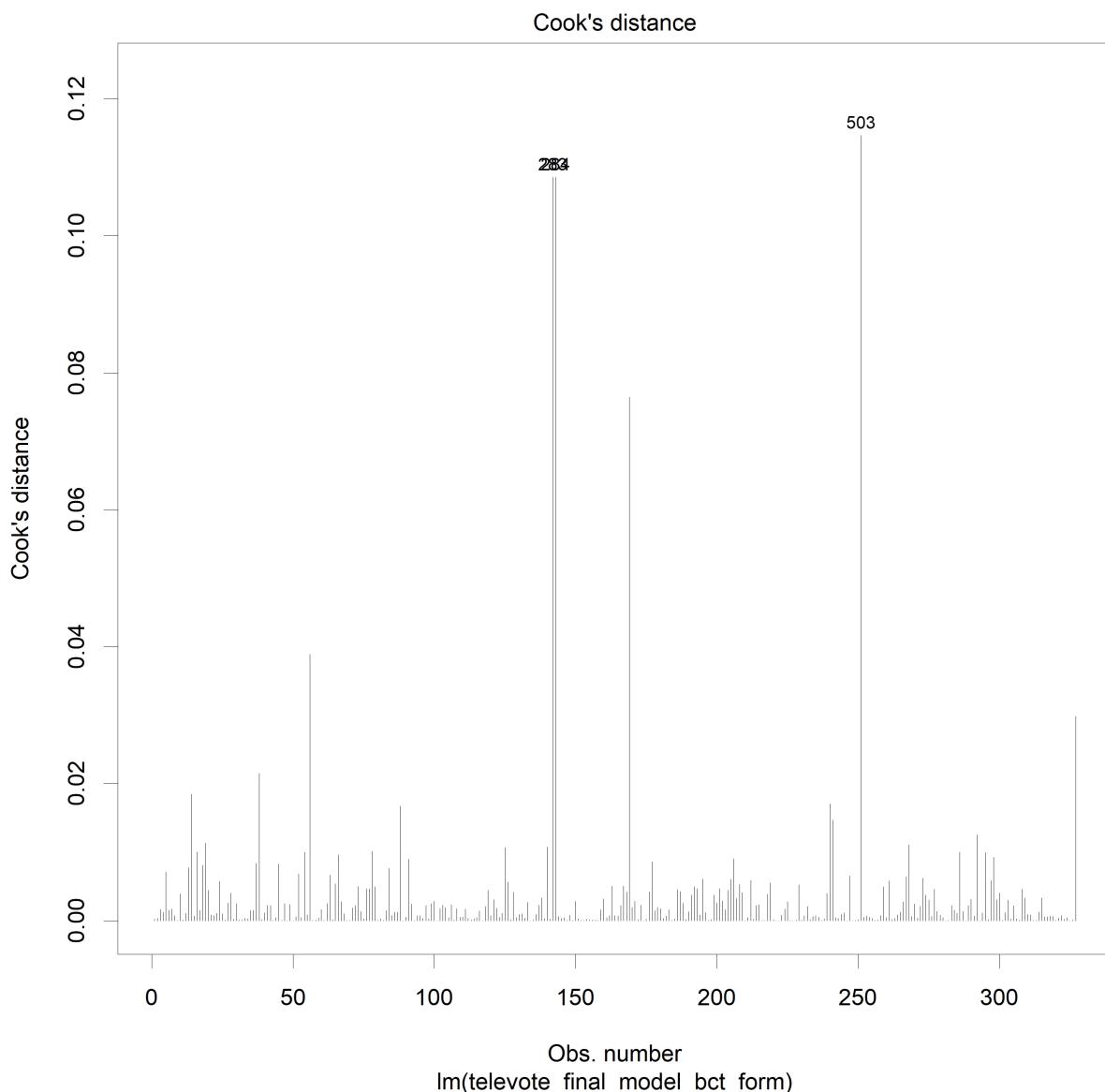




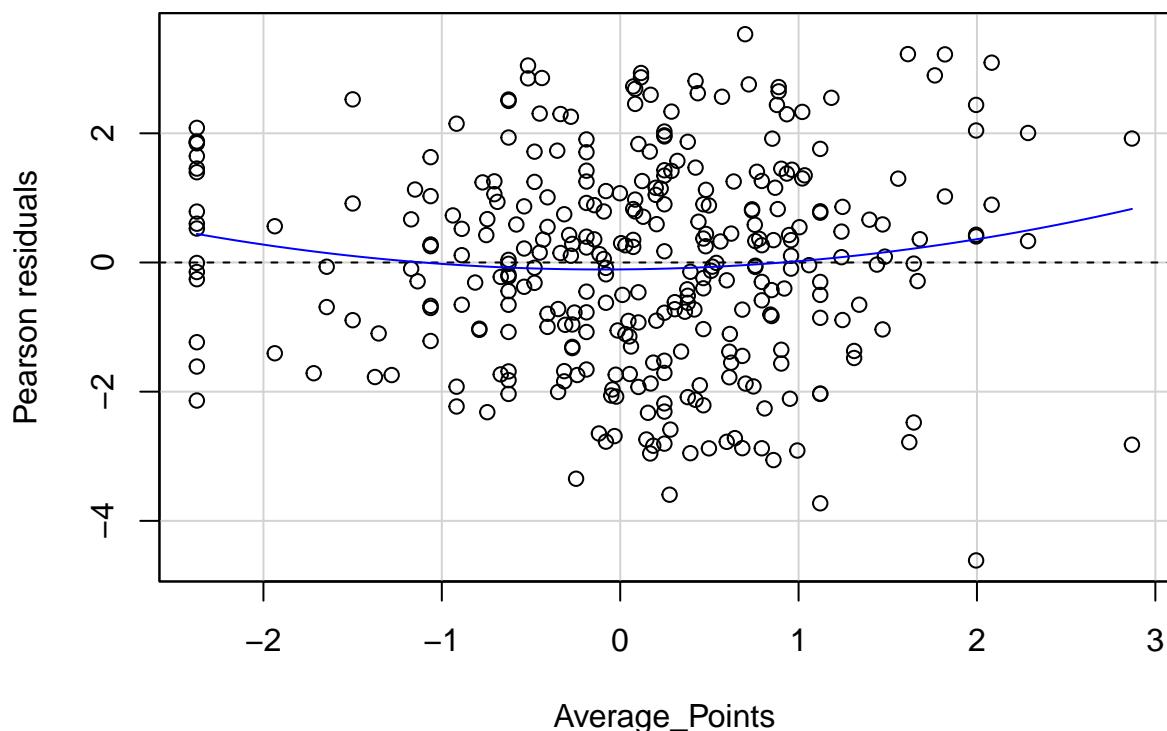
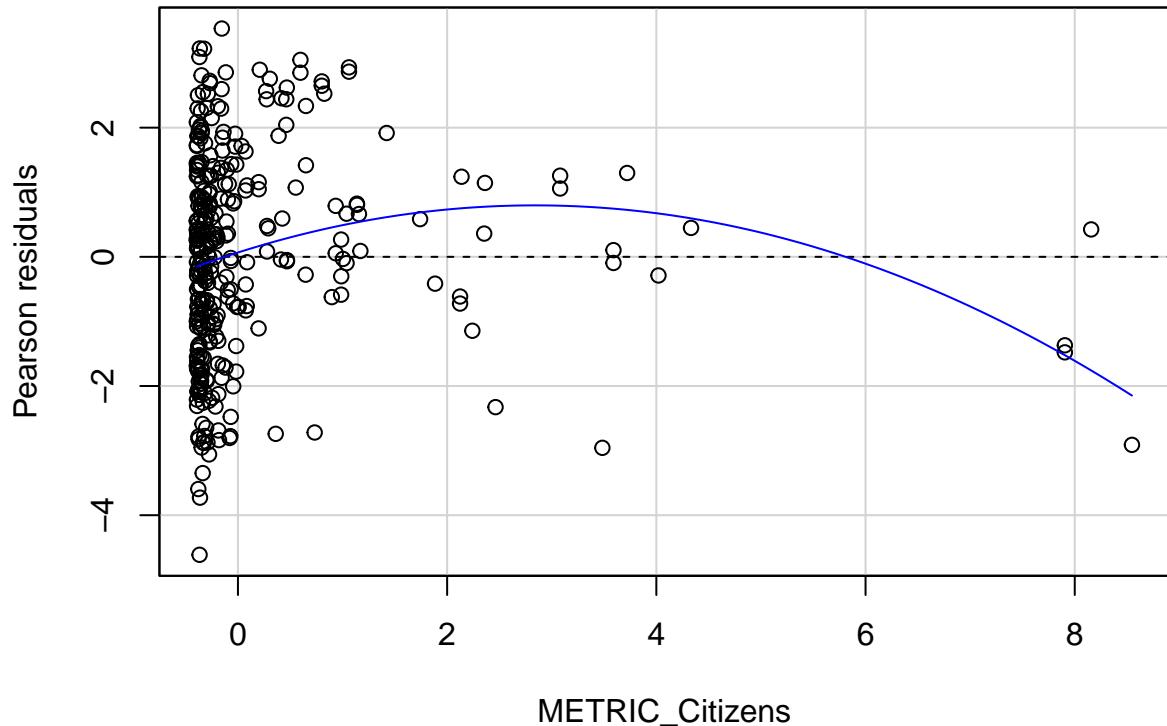
Added-Variable Plots

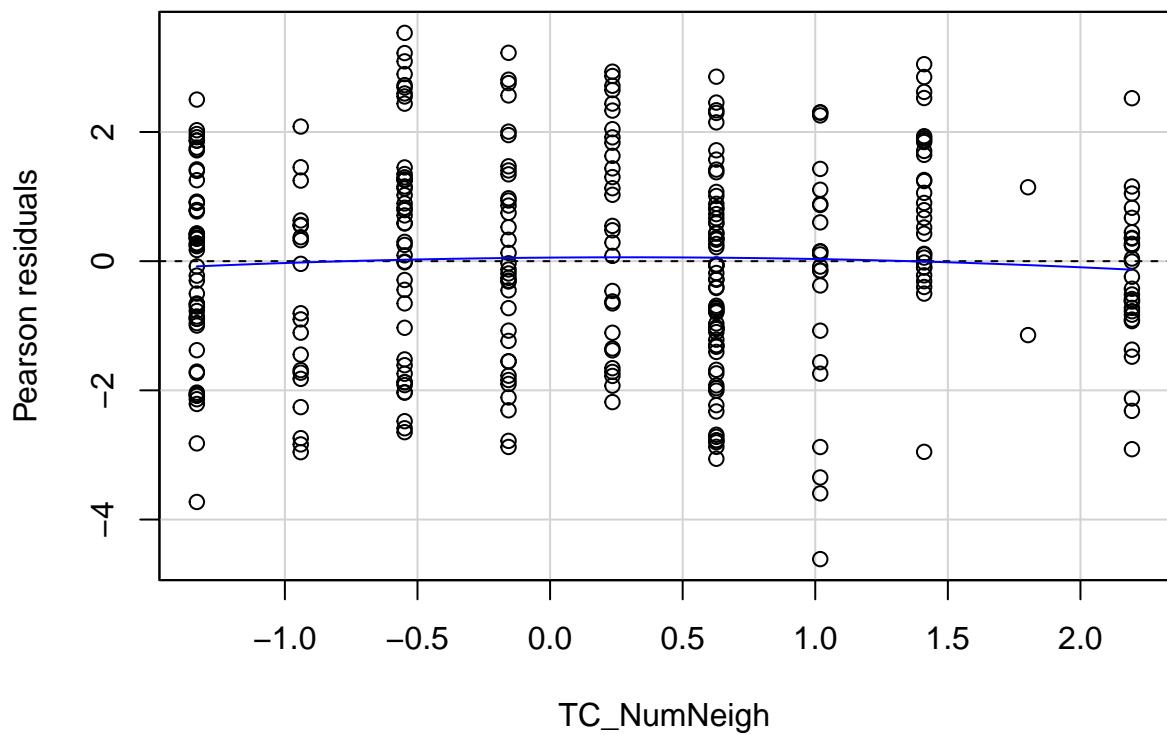


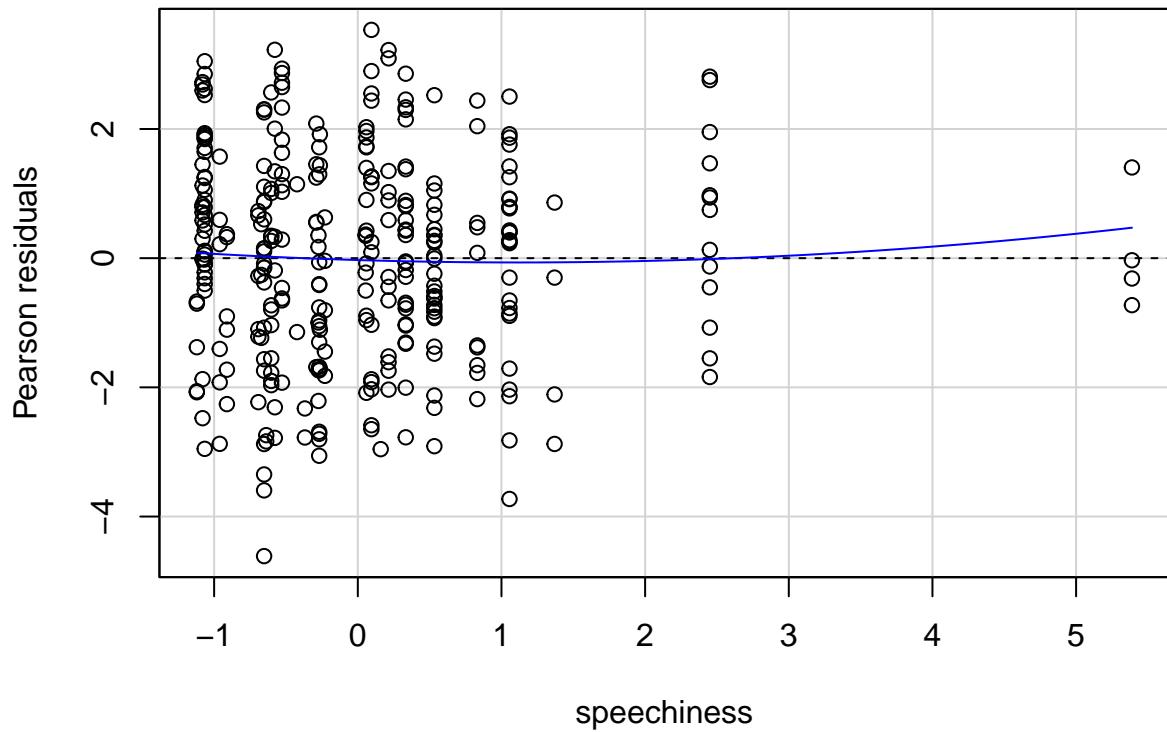
Cooks Distance Plot

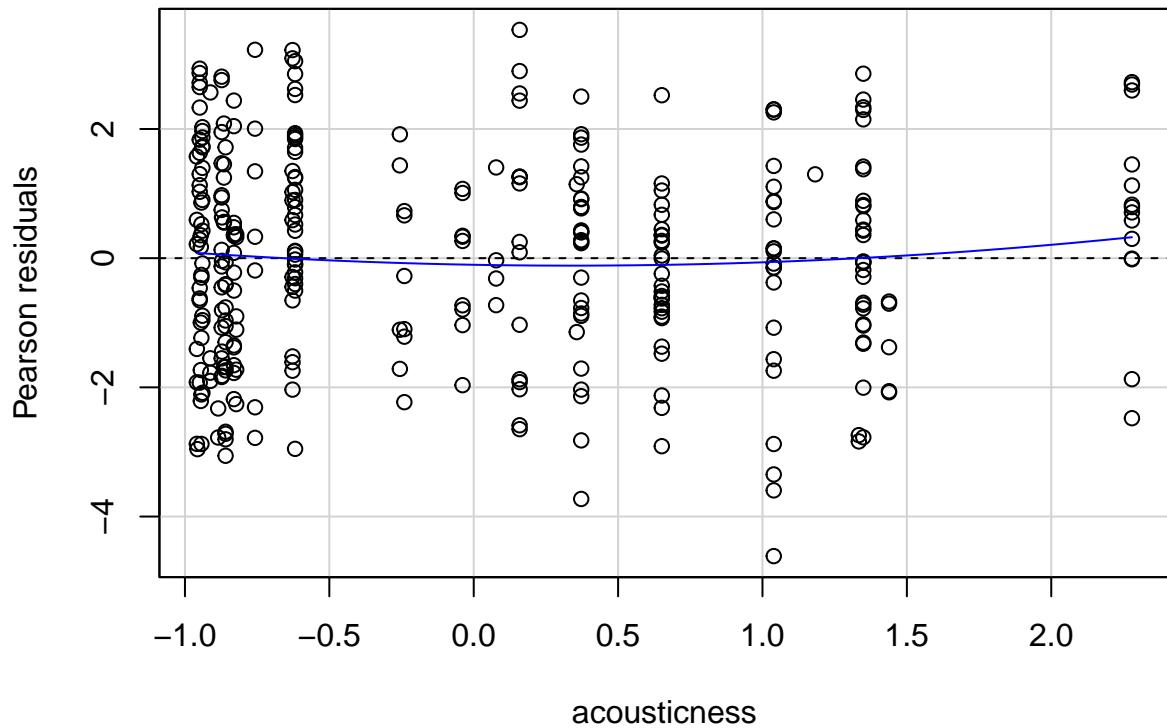


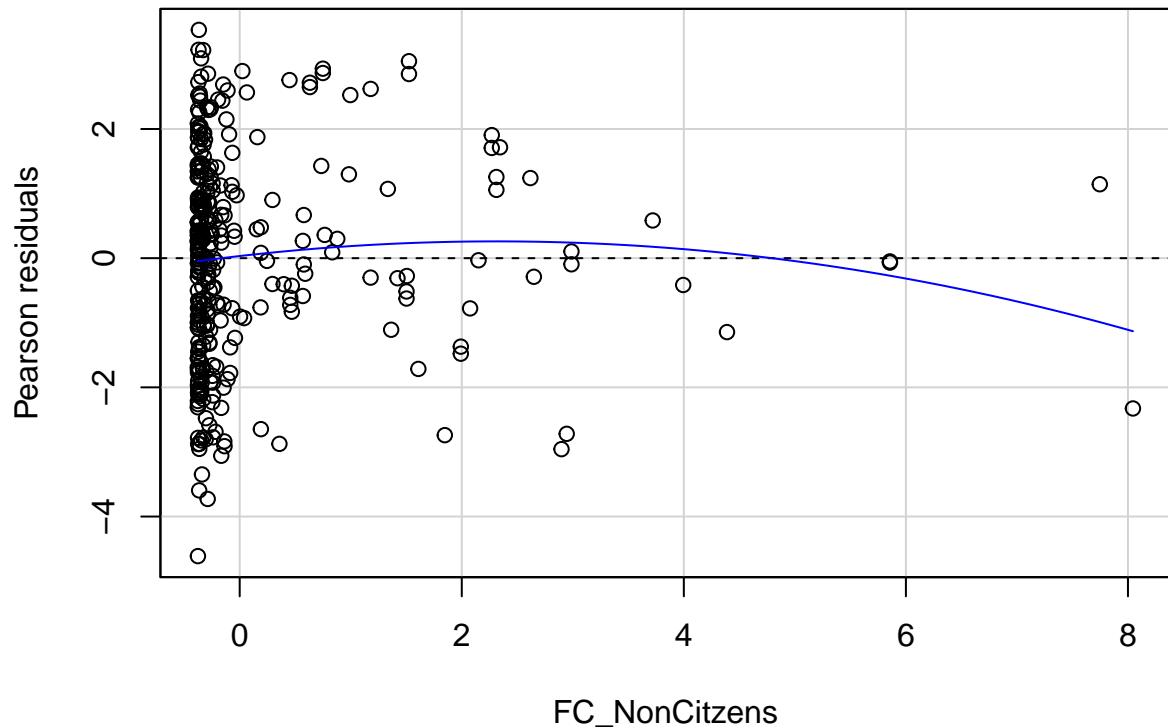
Residual Plots

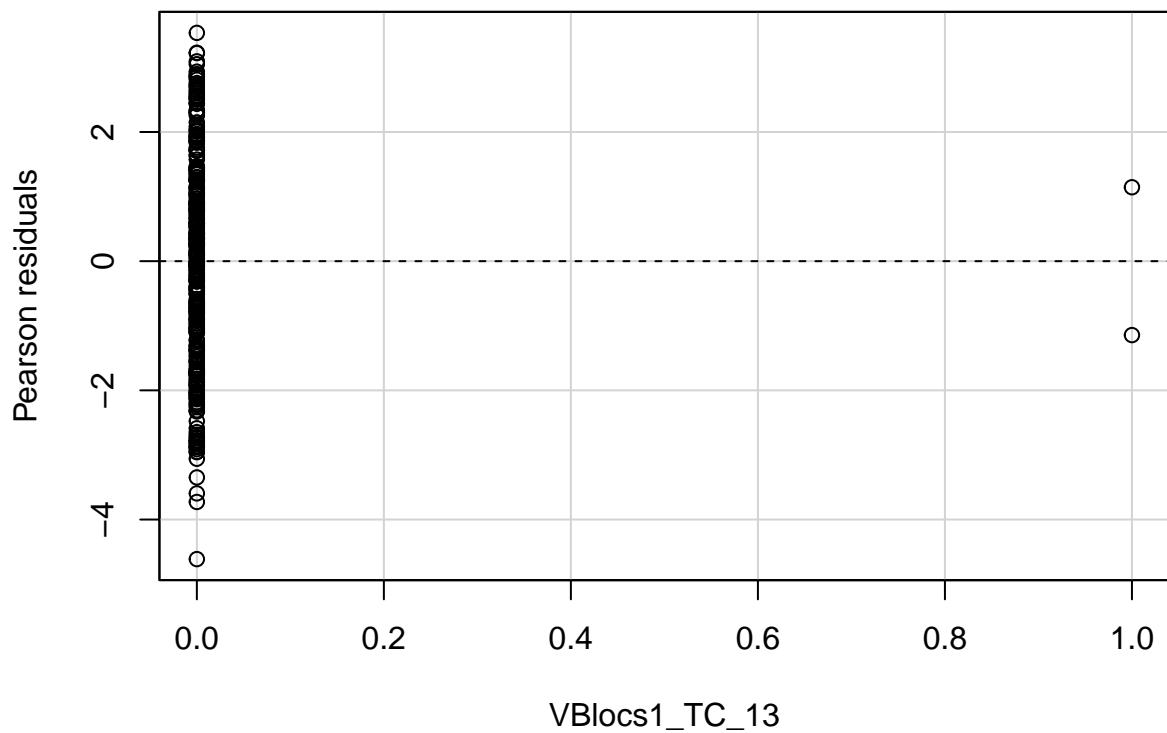


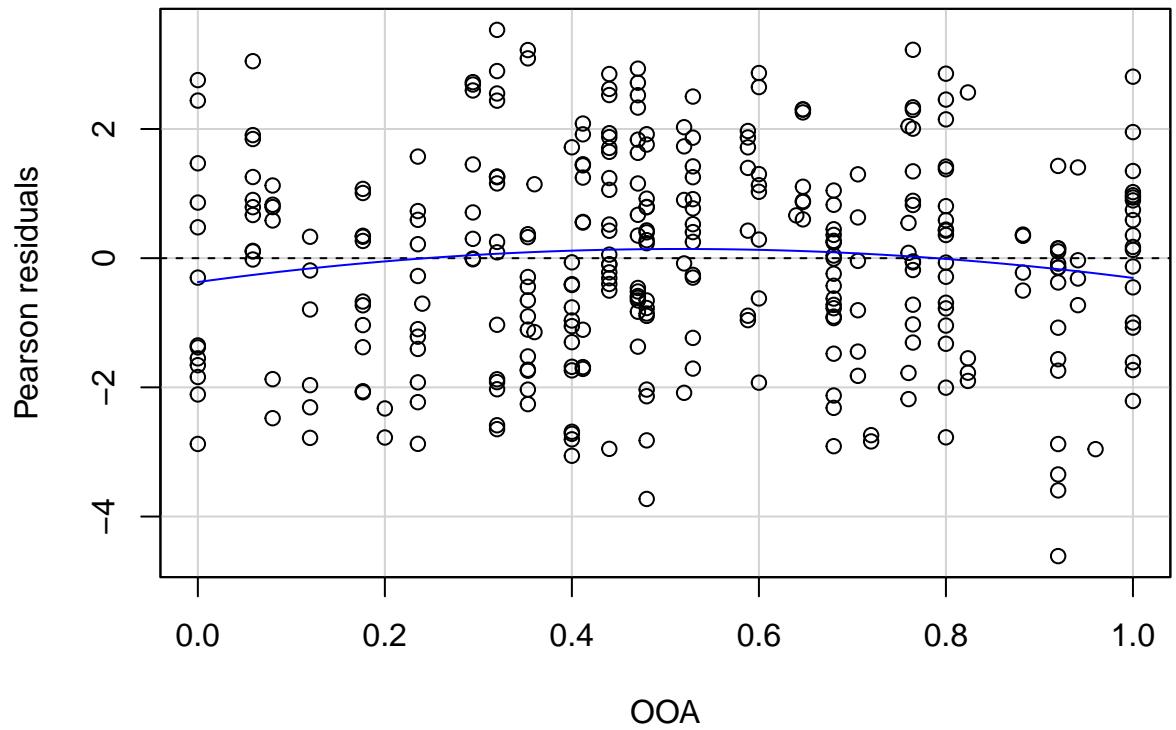


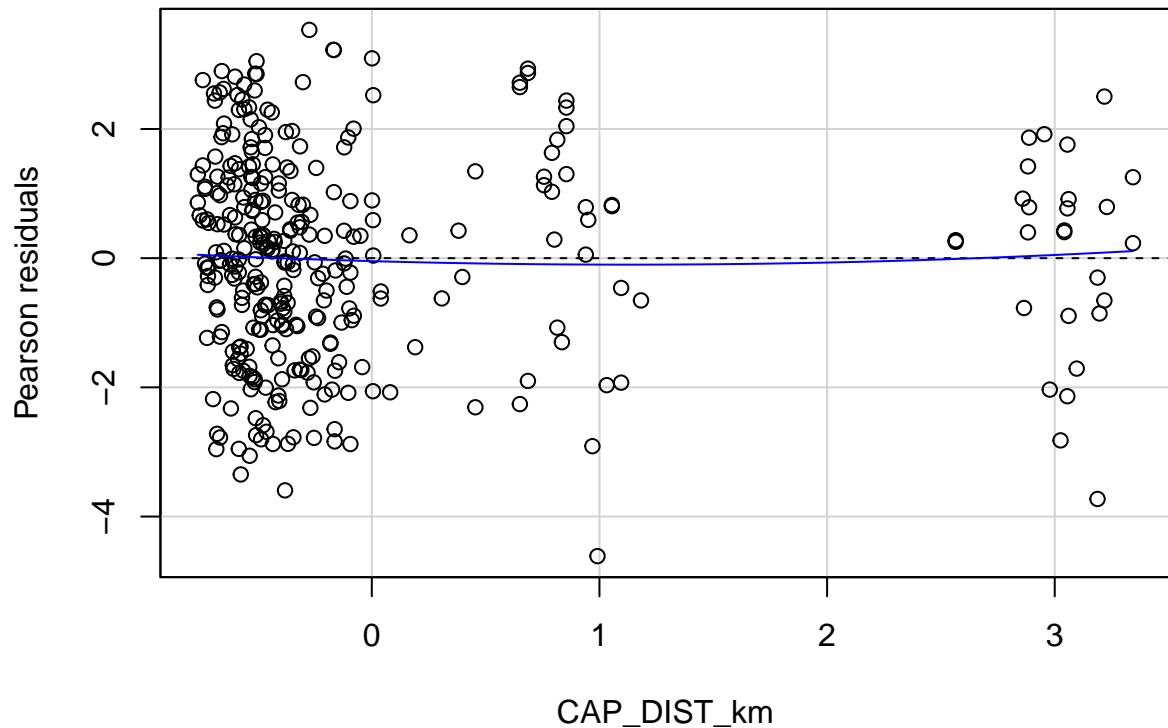


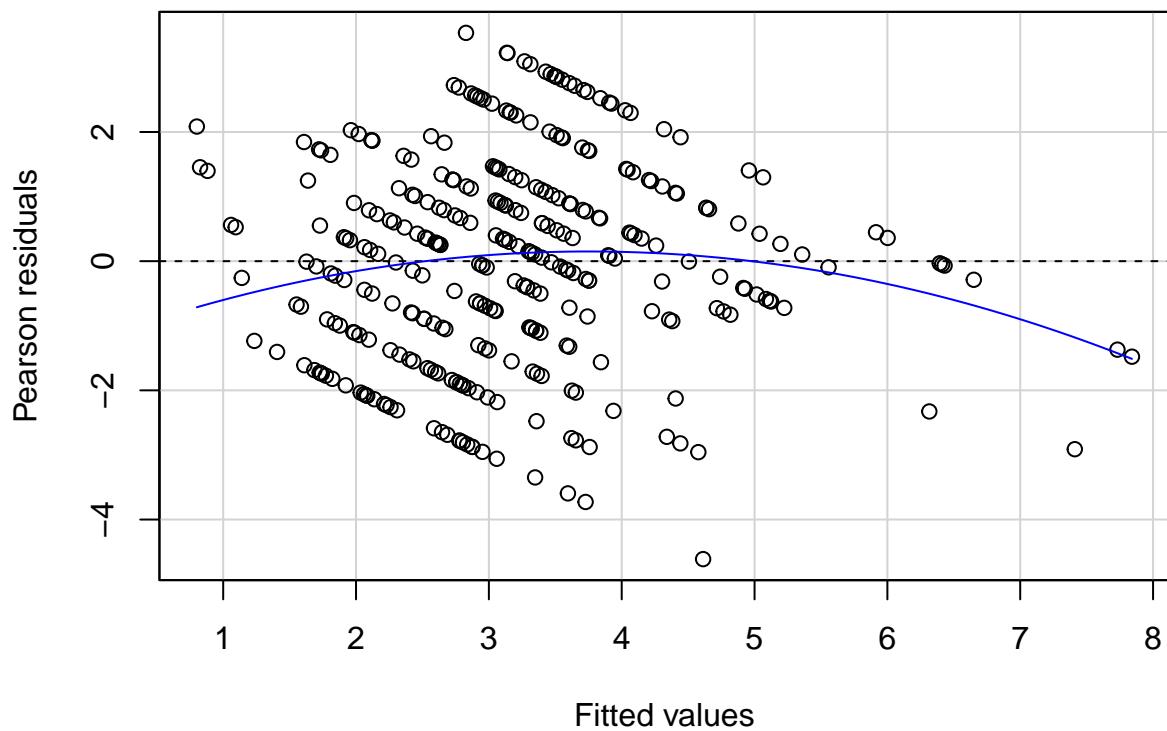




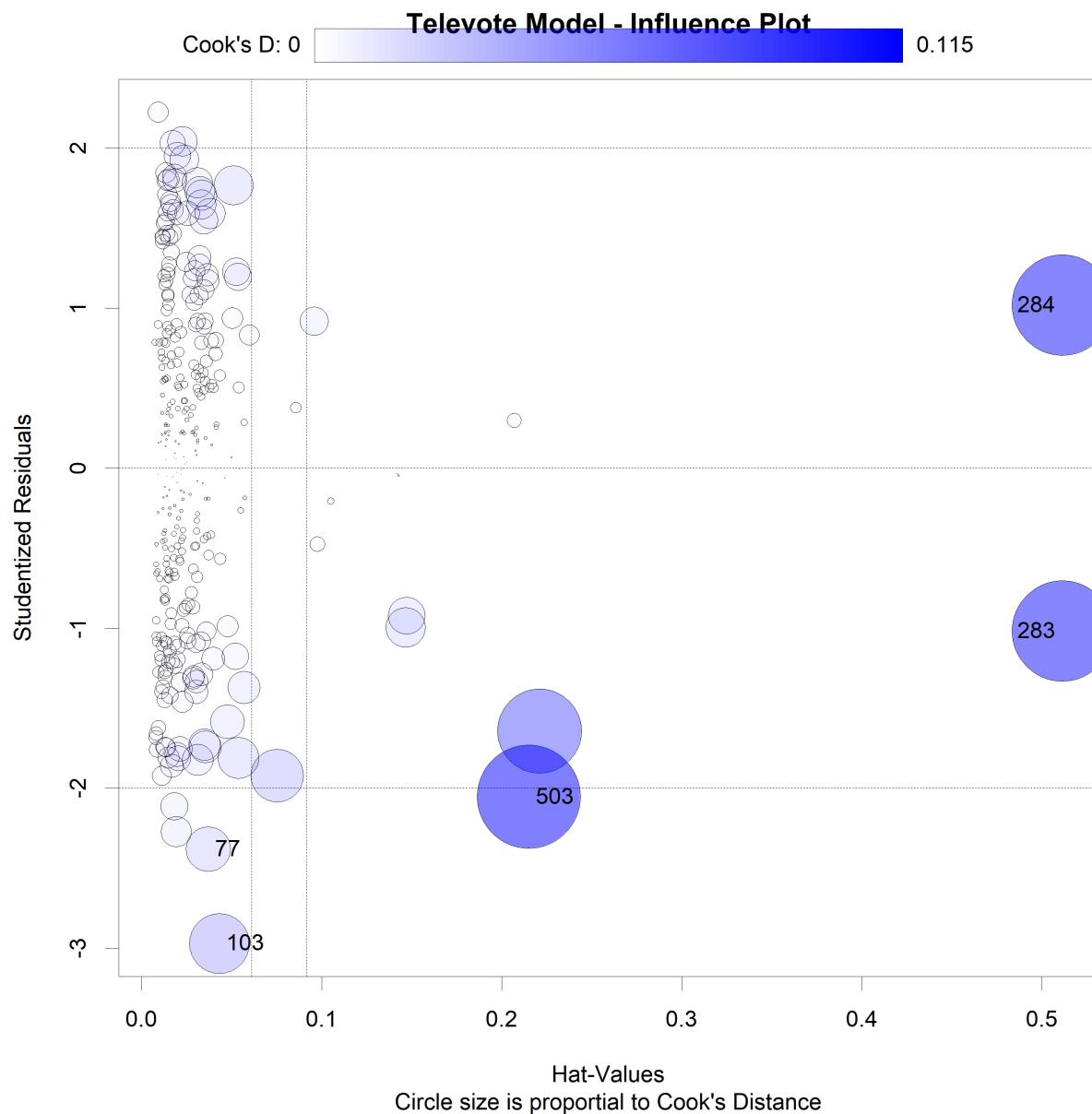








Influence Plot



Normality Assumption

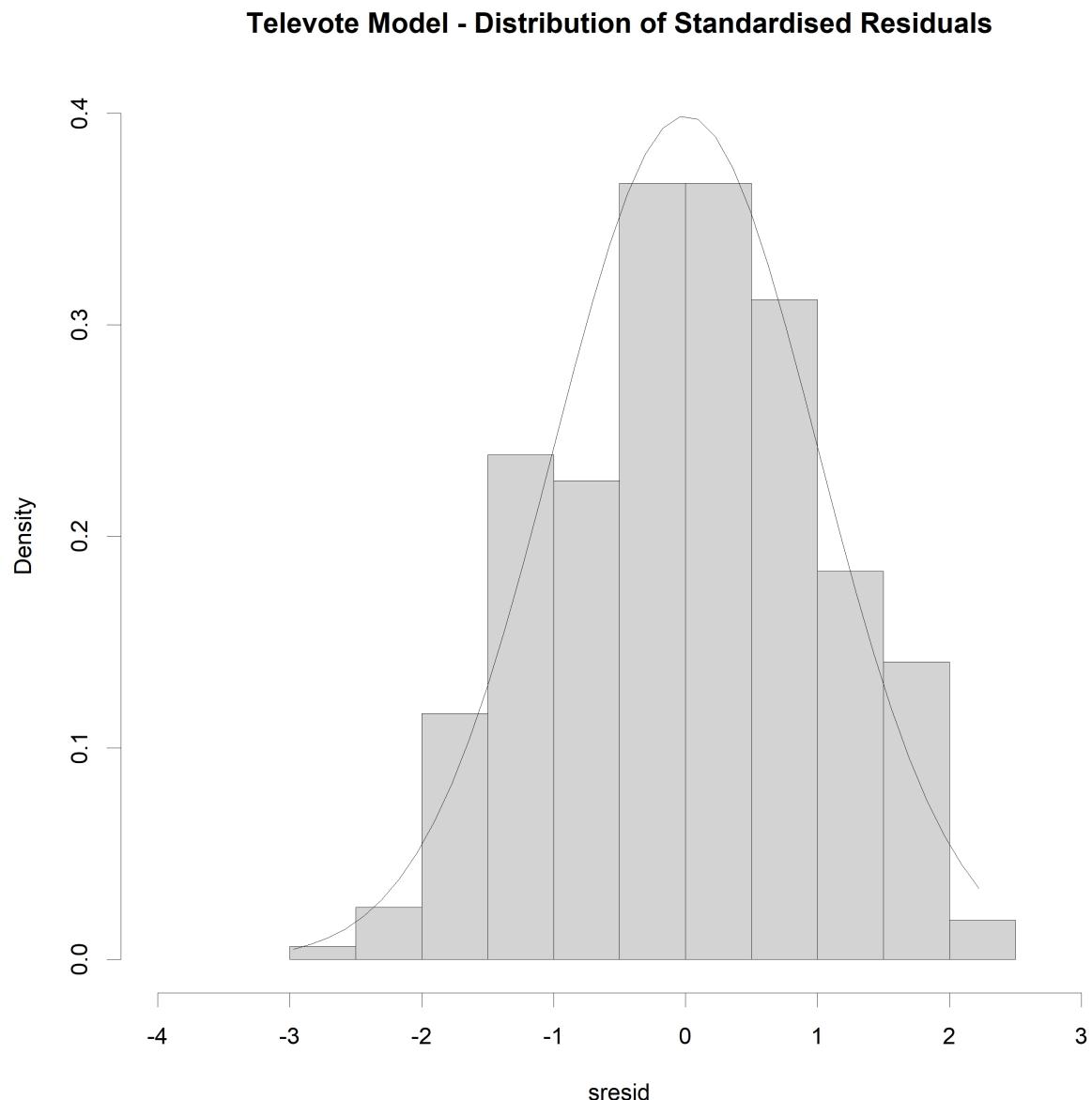
Normality Tests

Normality Test

- Ho: The data is normally distributed
- Ha: the data is not normally distributed

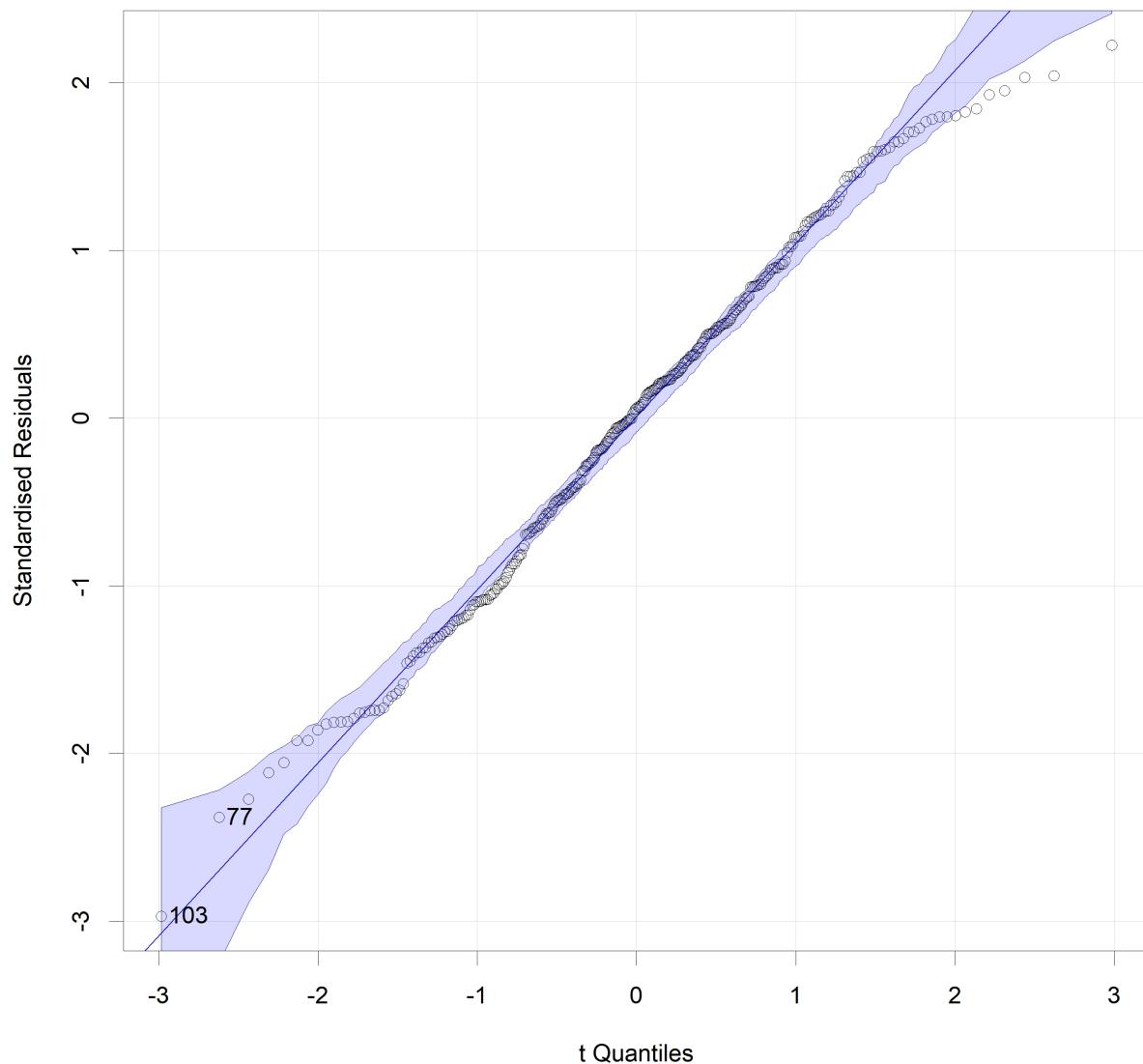
| NormTest | Stat | Pval |
|--------------|----------|---------|
| shapiro.test | 0.99075 | 0.03758 |
| ad.test | 0.59623 | 0.11856 |
| cvm.test | 0.07592 | 0.23336 |
| lille.test | 0.0381 | 0.29588 |
| person.test | 21.13761 | 0.27253 |
| sf.test | 0.99202 | 0.07153 |

Residual Histogram



Residual QQ-Plot

QQ-Plot of Televote Model Standardised Residuals



Constant Variance Assumption

Non-Constant Variance Test

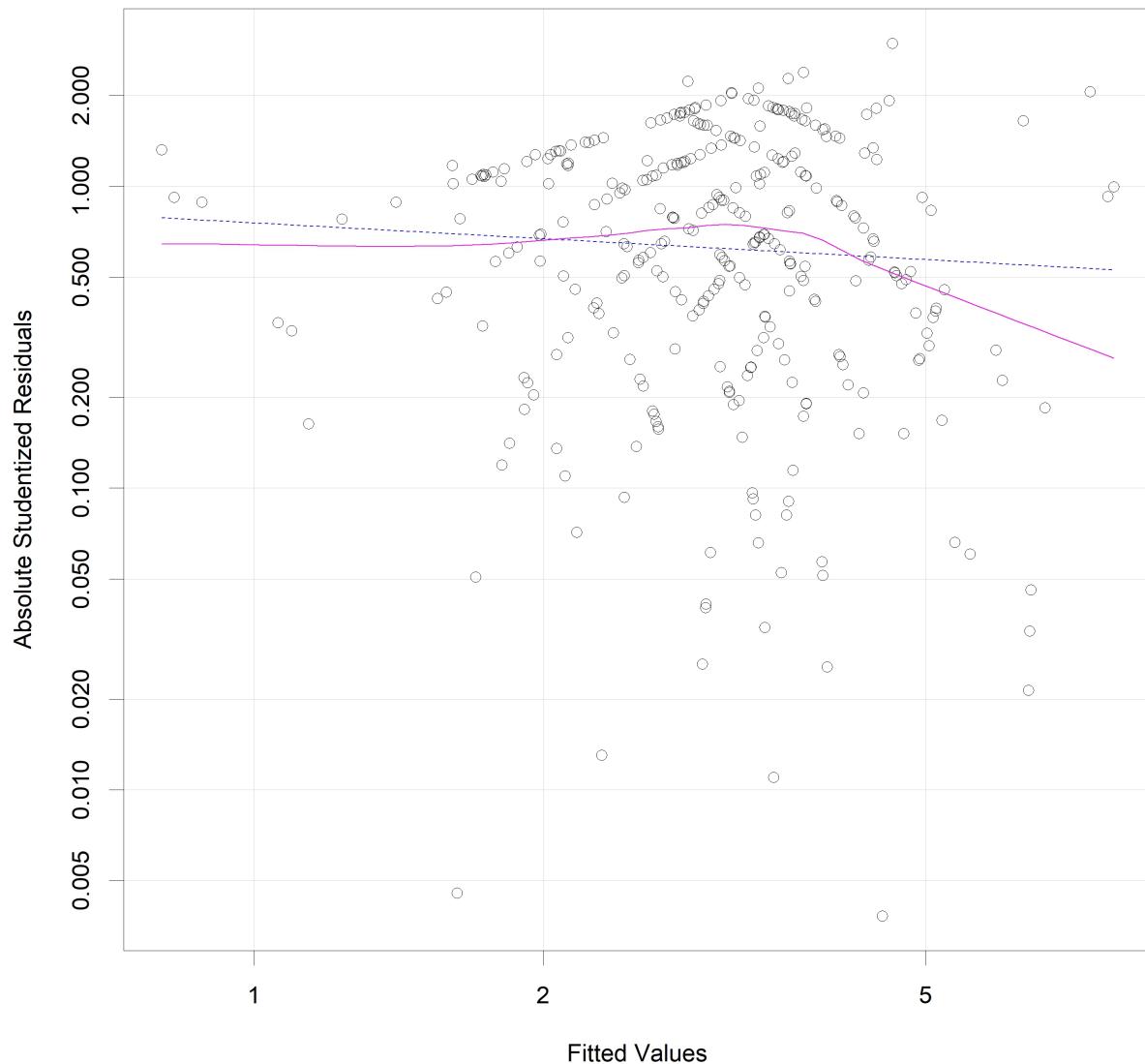
Non-Constant Error Variance Test

- Ho: constant error variance
- Ha: Non-constant error Variance

| Non-constant Variance Score Test | |
|----------------------------------|---------|
| Chi-Sq Statistic | 0.05524 |
| P-Value | 0.81418 |

Spread-Level Plot

Spread-Level Plot for Televote Model



Variance Inflation Factors

| | VIF | sqrt(VIF) > 2 |
|-----------------|----------|---------------|
| METRIC_Citizens | 1.440215 | 0 |
| Average_Points | 1.072688 | 0 |
| TC_NumNeigh | 1.440252 | 0 |
| speechiness | 1.231842 | 0 |
| acousticness | 1.059780 | 0 |
| FC_NonCitizens | 1.599009 | 0 |

| | VIF | sqrt(VIF) > 2 |
|---------------|----------|---------------|
| VBlocs1_TC_13 | 1.233766 | 0 |
| OOA | 1.147115 | 0 |
| CAP_DIST_km | 1.291723 | 0 |

Jury Model

```
##  
## Call:  
## lm(formula = jury_final_model_form, data = jury_data)  
##  
## Residuals:  
##      Min      1Q Median      3Q     Max  
## -6.136 -2.494 -0.291  2.024  8.297  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 4.0865    0.4637   8.812 < 2e-16 ***  
## CAP_DIST_km 0.6617    0.1854   3.568 0.000414 ***  
## acousticness 0.5032    0.1747   2.880 0.004247 **  
## speechiness  0.8932    0.2004   4.457 1.15e-05 ***  
## TC_PerfType_Mixed -9.6005   3.2765  -2.930 0.003632 **  
## TC_LANGFAM_Armenian -3.1767   0.9880  -3.215 0.001435 **  
## VBlocs1_TC_1 3.0611    0.6177   4.956 1.17e-06 ***  
## ComVBlocs1_y -2.2750   0.6857  -3.318 0.001011 **  
## VBlocs1_FC_1  0.8442    0.4283   1.971 0.049601 *  
## VBlocs2_TC_1  1.5367    0.4794   3.205 0.001484 **  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 3.027 on 321 degrees of freedom  
## Multiple R-squared:  0.2132, Adjusted R-squared:  0.1912  
## F-statistic: 9.667 on 9 and 321 DF,  p-value: 4.405e-13
```

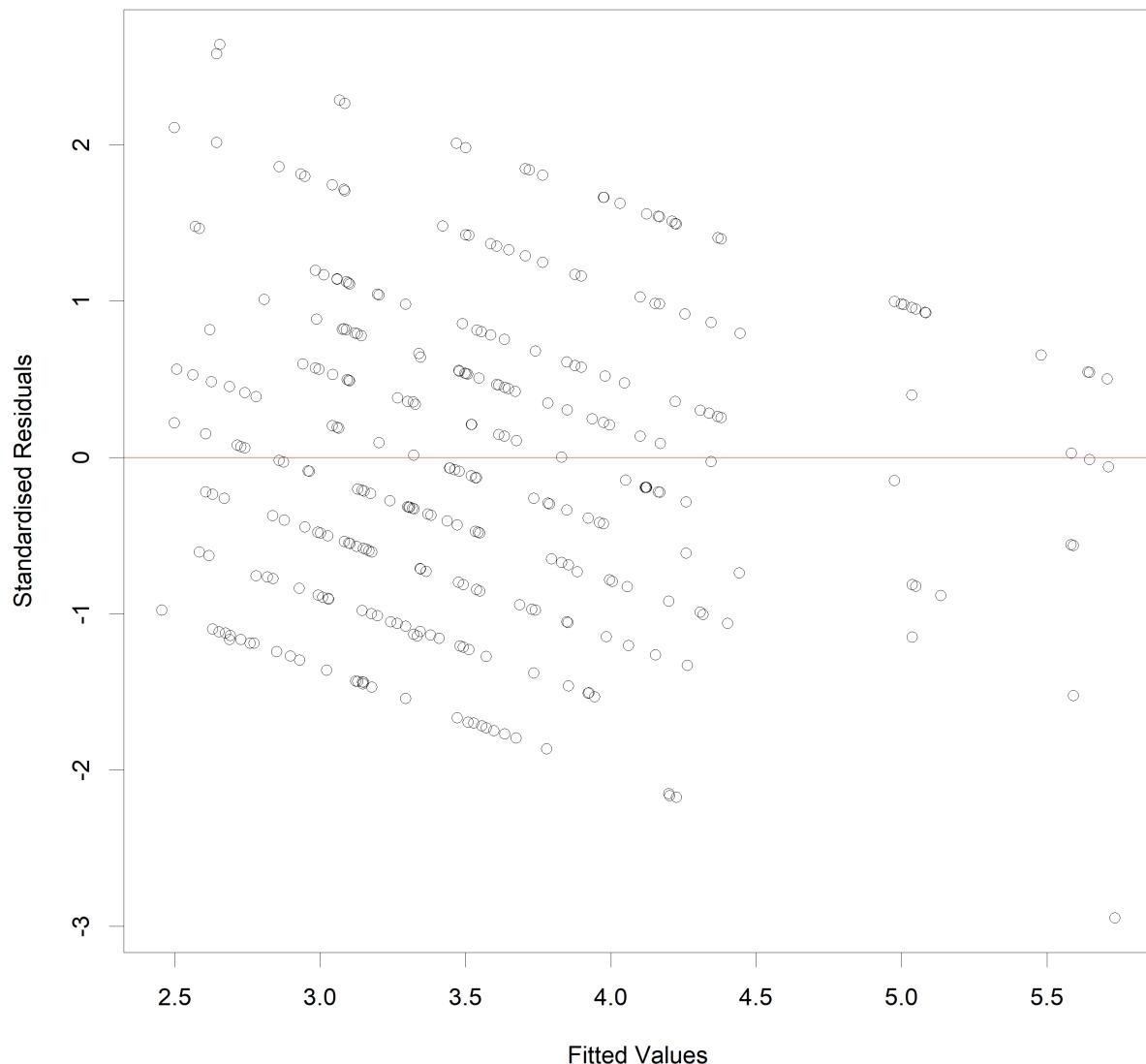
Response Variable Transformation

Power Transformation

```
##  
## Call:  
## lm(formula = jury_final_model_pt_form, data = jury_data)  
##  
## Residuals:  
##      Min      1Q Median      3Q     Max  
## -4.051 -1.185 -0.045  1.071  3.804  
##  
## Coefficients:  
##                               Estimate Std. Error t value Pr(>|t|)  
## (Intercept)             2.73582   0.23066 11.861 < 2e-16 ***  
## CAP_DIST_km            0.34953   0.09104  3.840 0.000148 ***  
## acousticness           0.22920   0.08669  2.644 0.008598 **  
## speechiness            0.32980   0.09305  3.544 0.000452 ***  
## TC_LANGFAM_Armenian -1.49410   0.49134 -3.041 0.002553 **  
## VBlocs1_TC_1          1.41307   0.30606  4.617 5.63e-06 ***  
## ComVBlocs1_y          -1.03563   0.34079 -3.039 0.002569 **  
## VBlocs1_FC_1          0.41954   0.21305  1.969 0.049787 *  
## VBlocs2_TC_1          0.81313   0.23839  3.411 0.000730 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 1.506 on 322 degrees of freedom  
## Multiple R-squared:  0.1852, Adjusted R-squared:  0.165  
## F-statistic: 9.149 on 8 and 322 DF,  p-value: 2.378e-11
```

Resdiauls vs Fitted Values

Jury Model - Standardised Residuals vs Fitted Values



Model Outliers

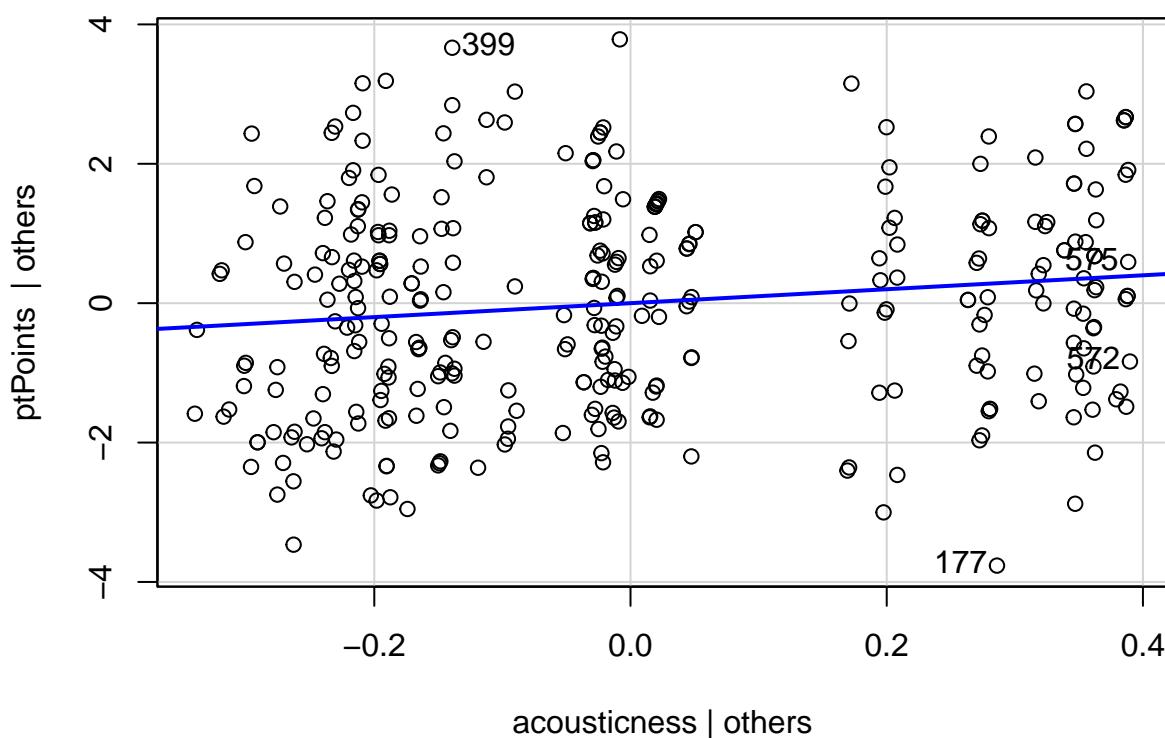
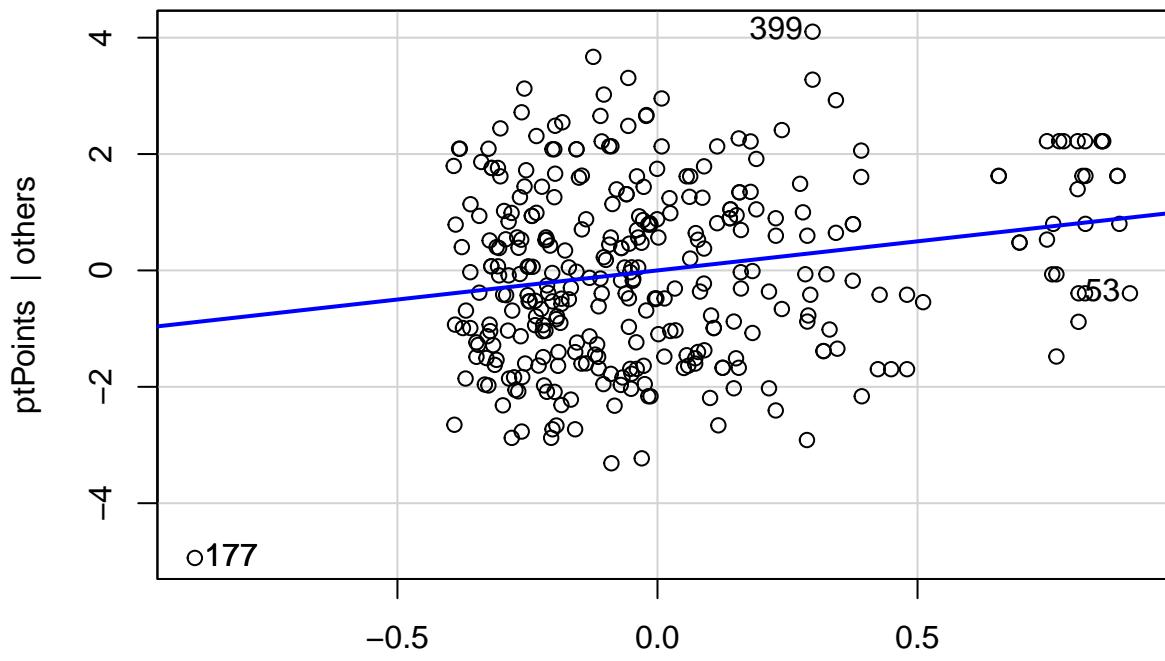
Bonferroni Outlier Test

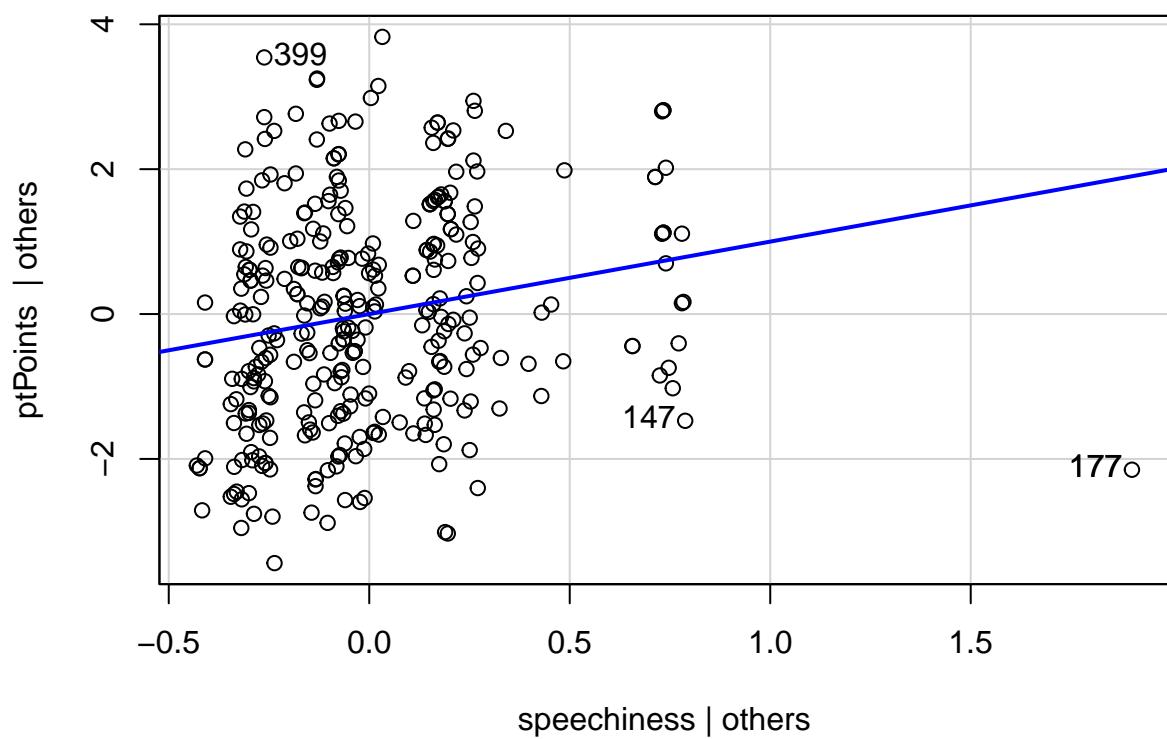
| | rstudent | p | bonf.p | signif | cutoff |
|-----|-----------|-----------|----------|--------|--------|
| 177 | -2.945099 | 0.0034643 | 1.146697 | 0 | 0.05 |

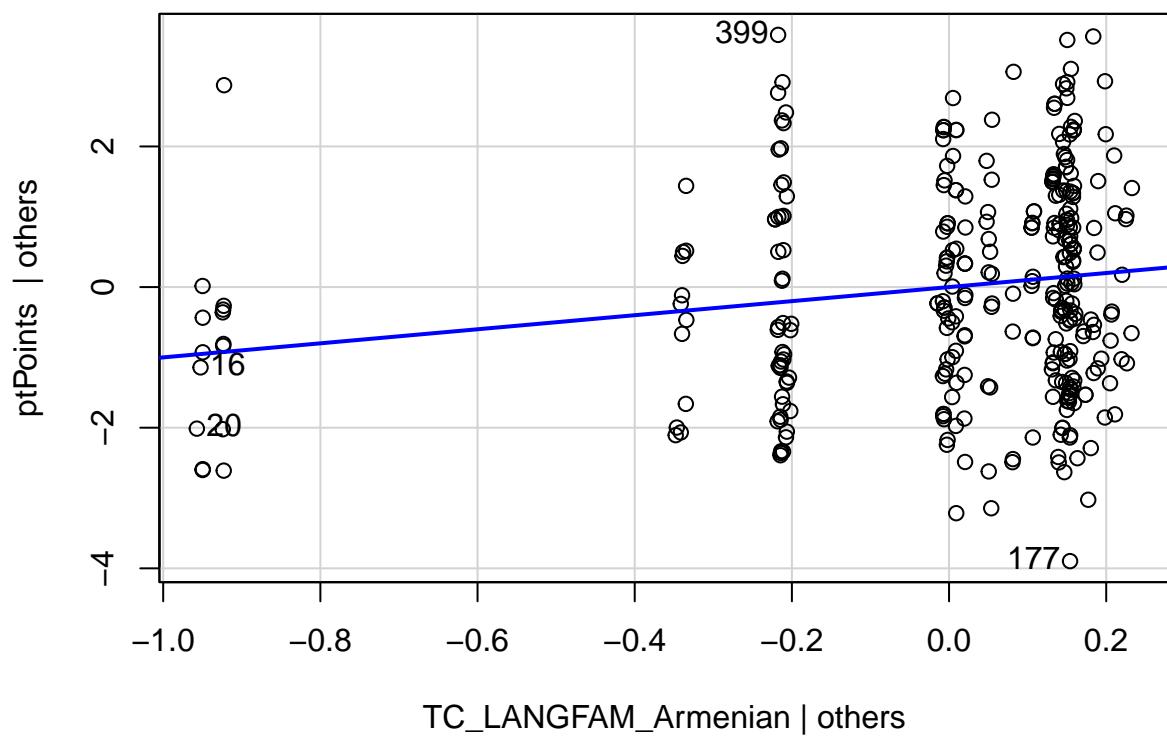
Outlier Residuals

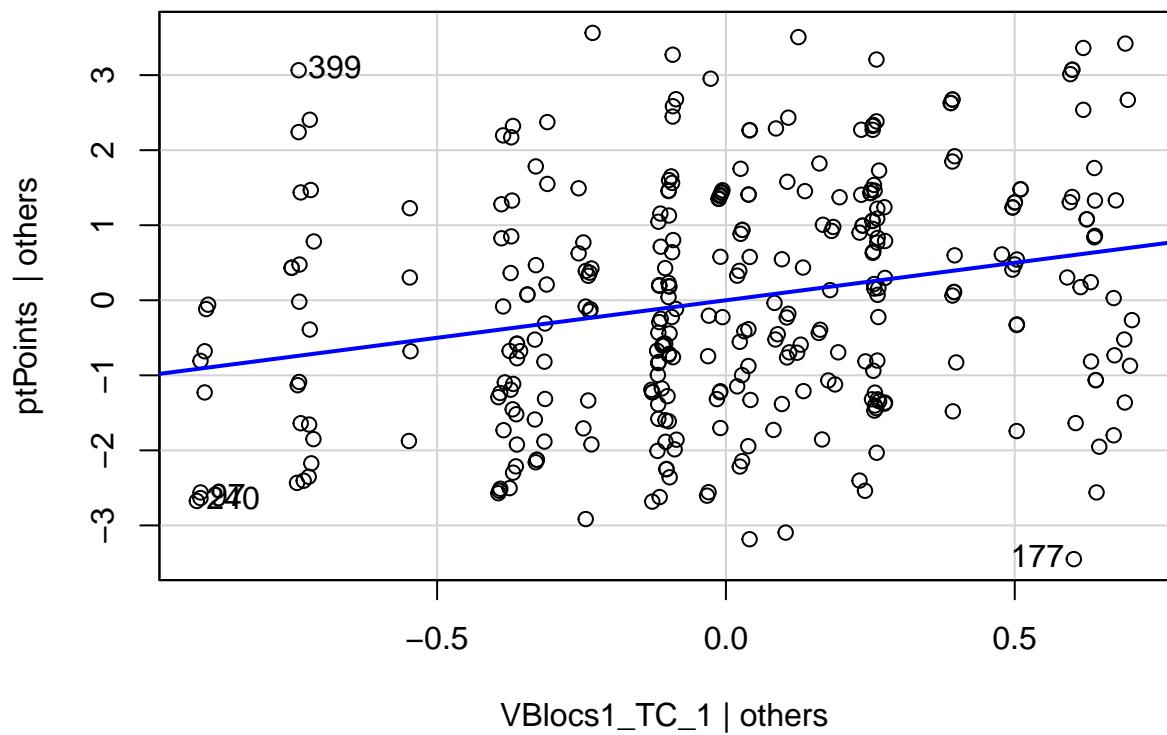
| outlier_residuals |
|-------------------|
| 177 |
| 516 |
| 529 |
| 618 |

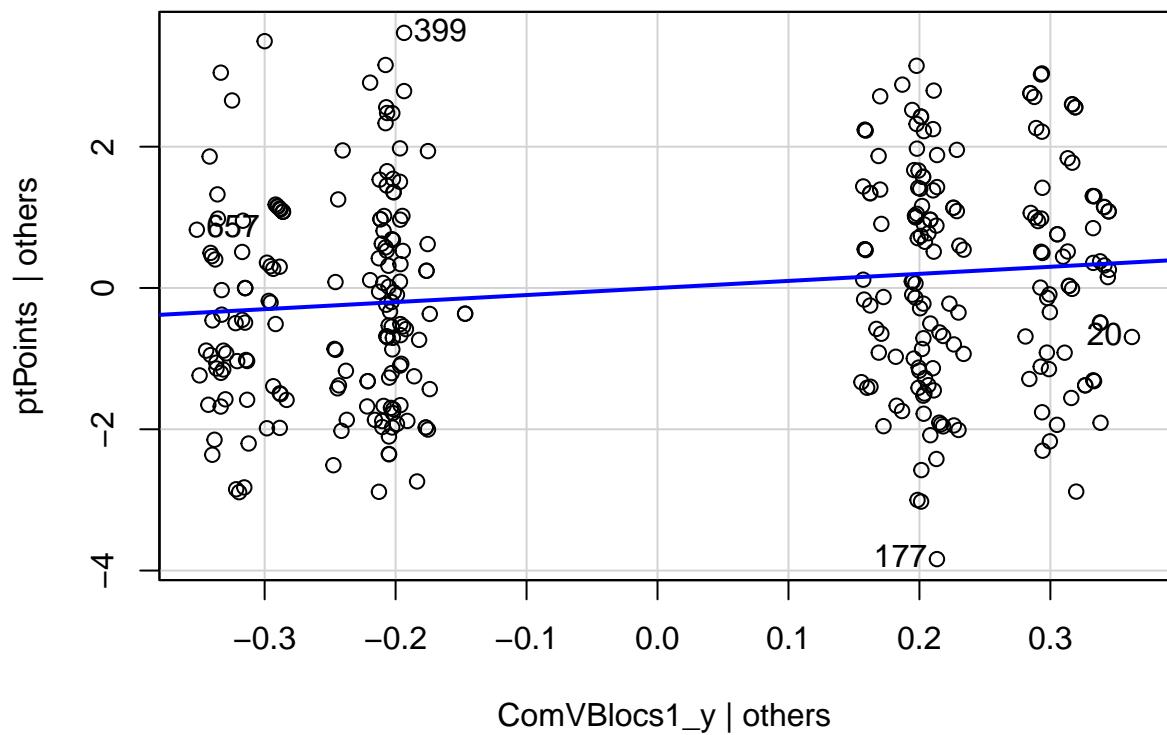
Leverage Plots

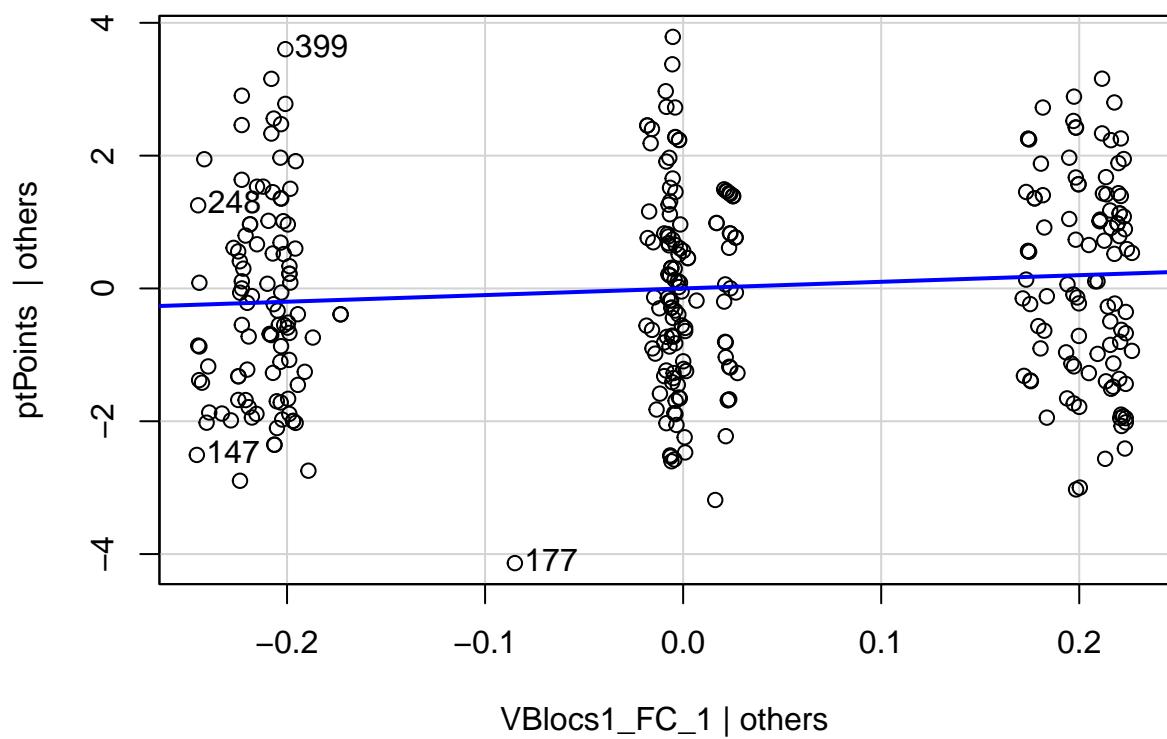




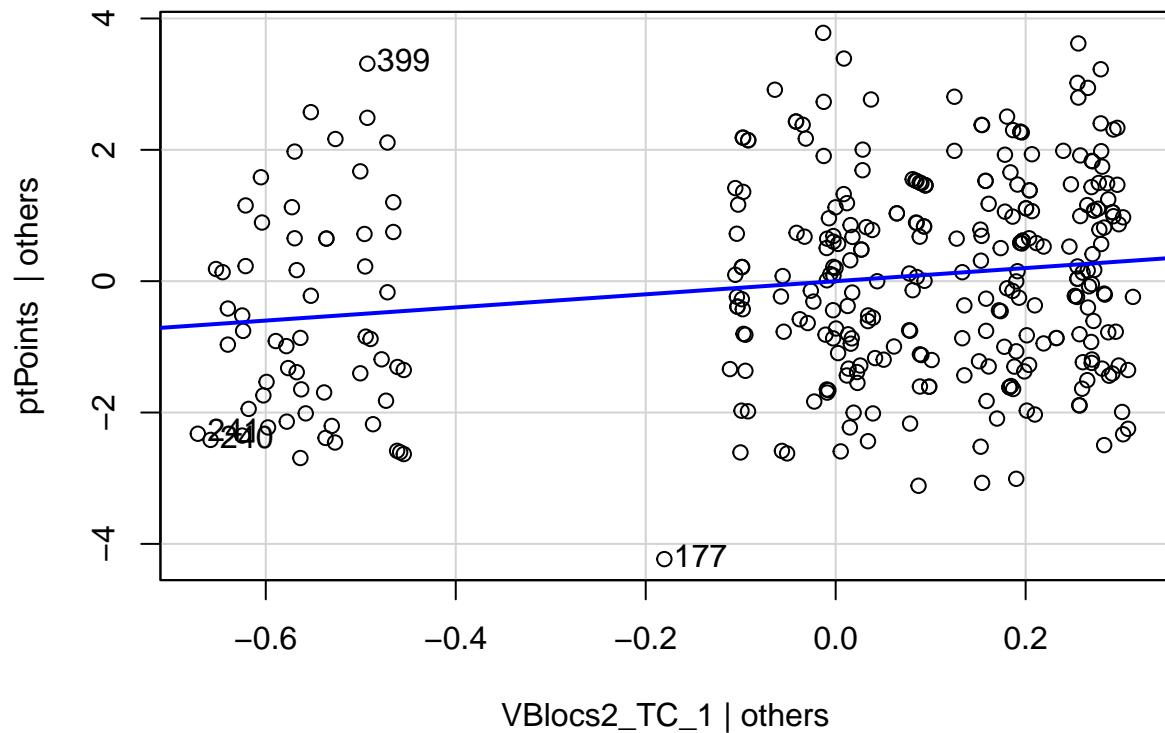




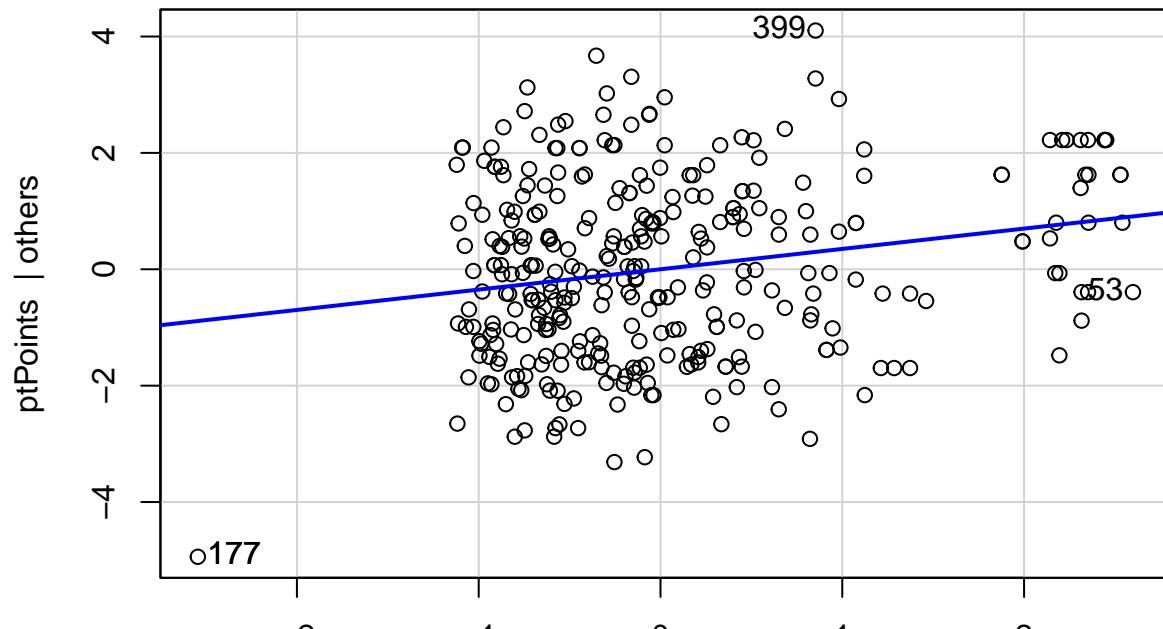




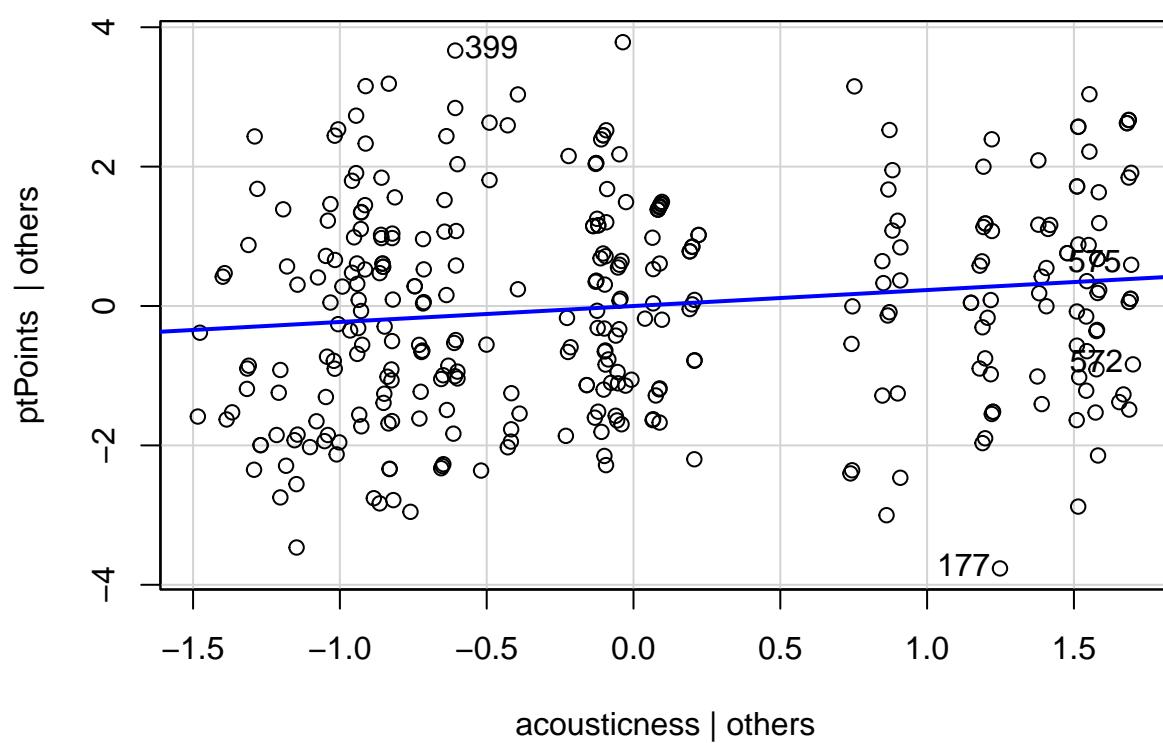
Leverage Plots



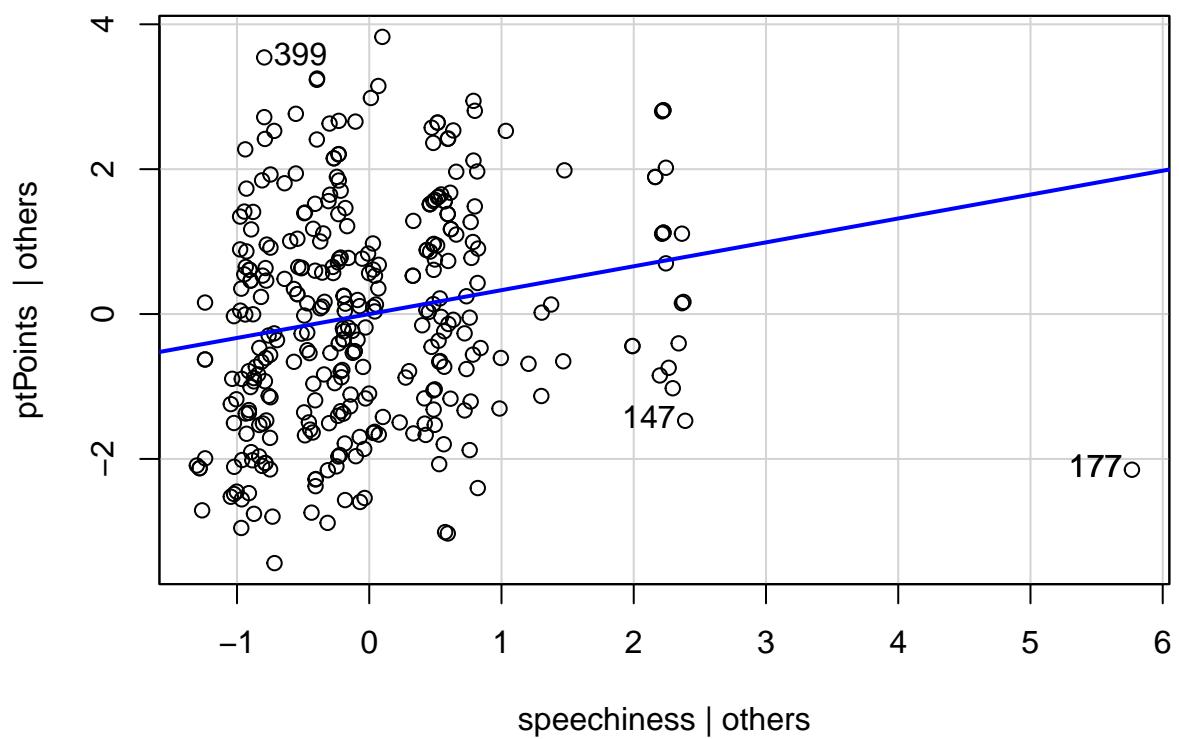
Added Variable Plots

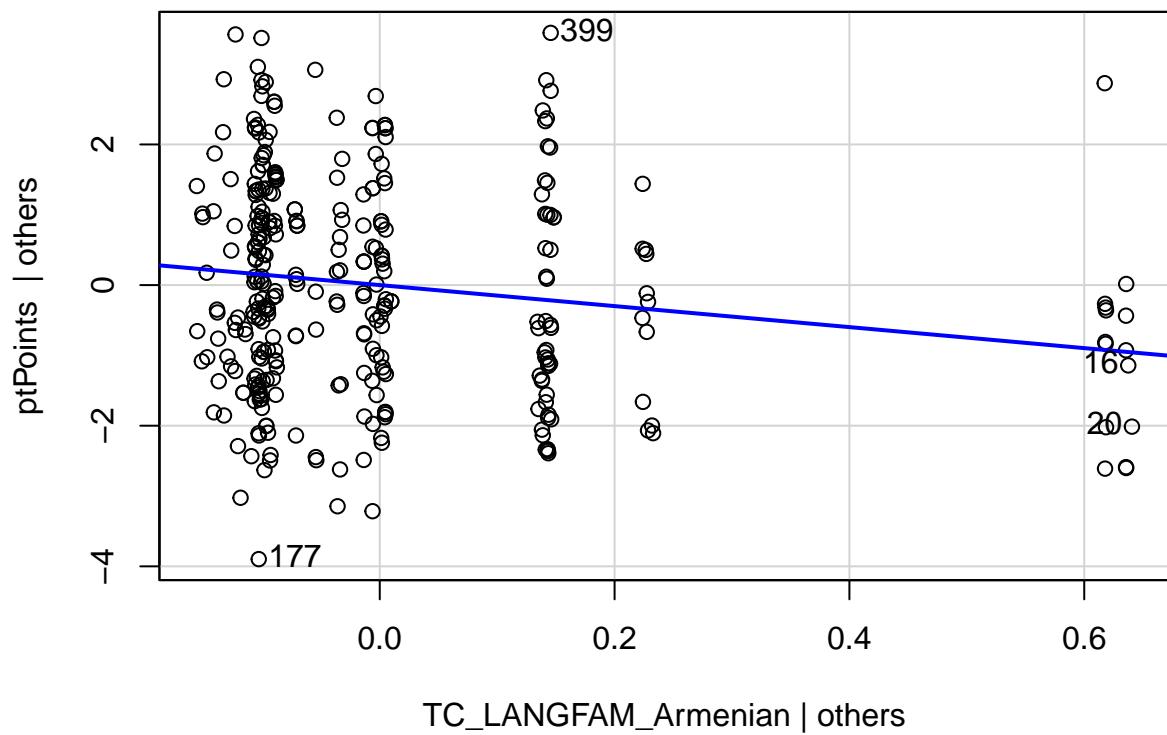


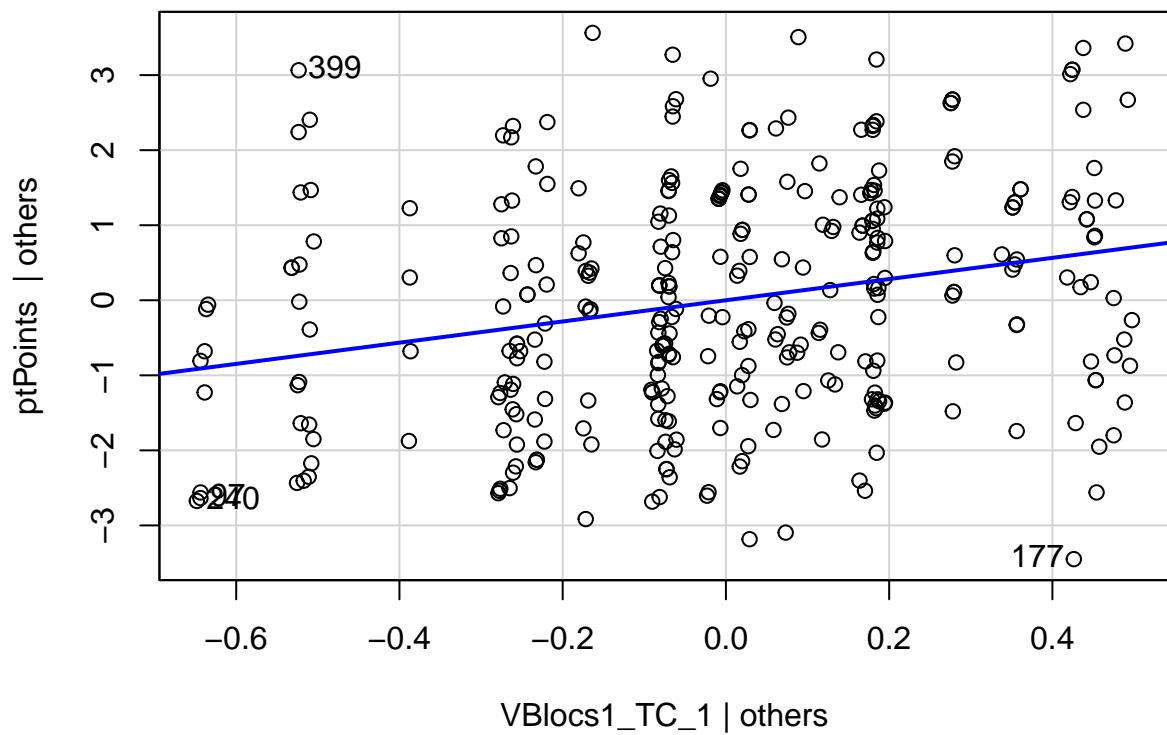
CAP_DIST_km | others

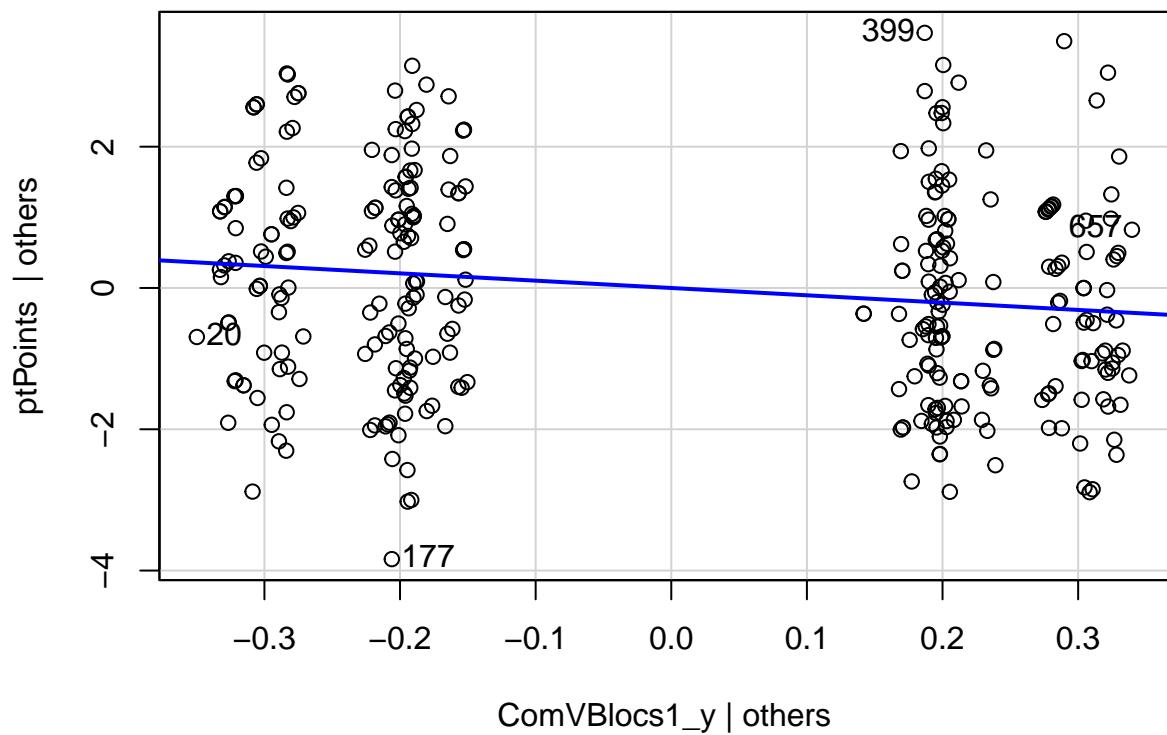


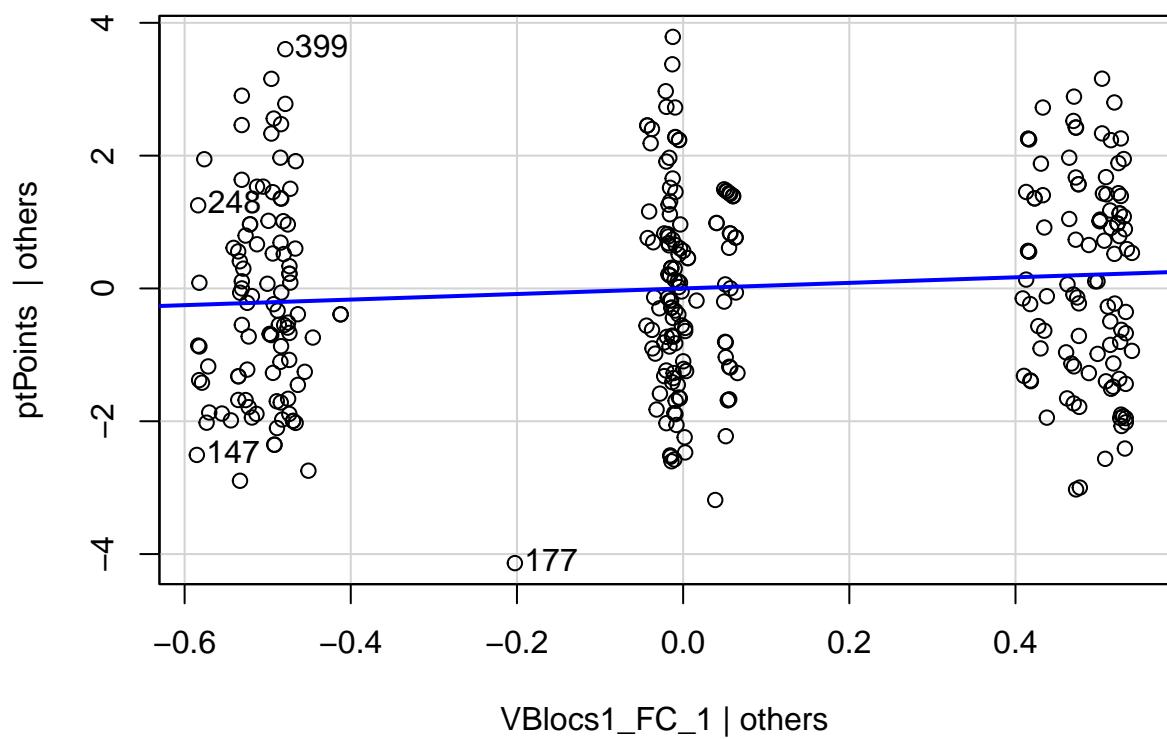
acousticness | others



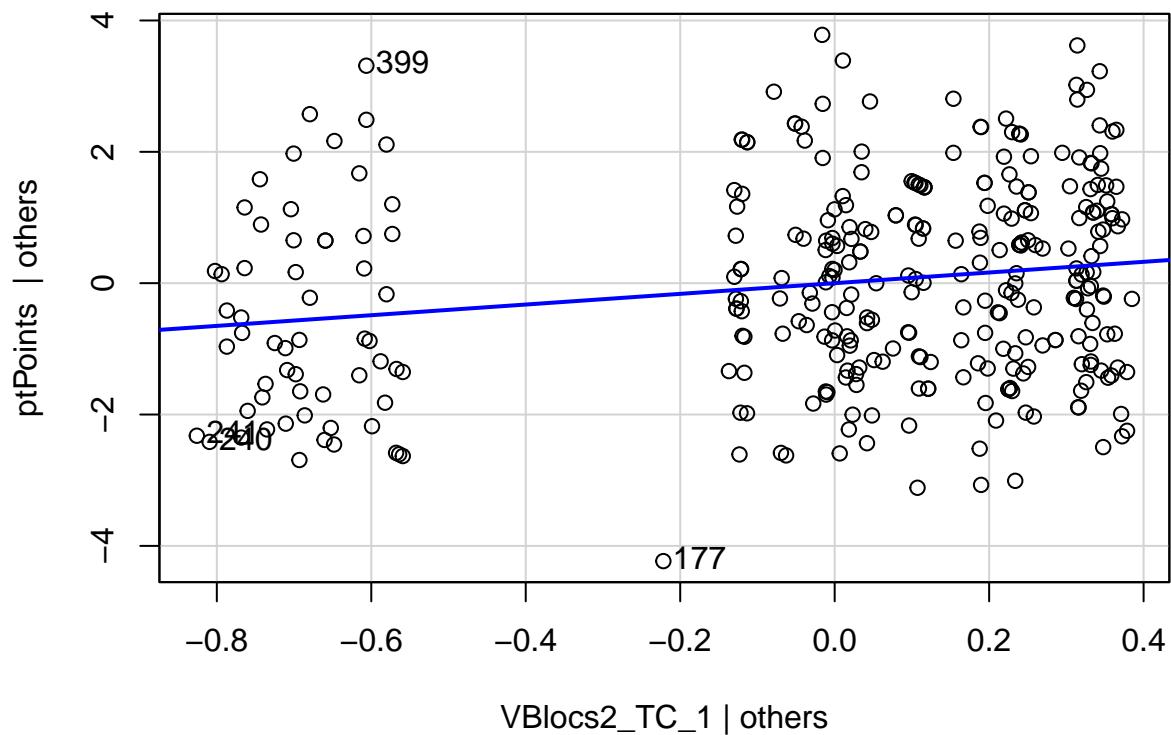




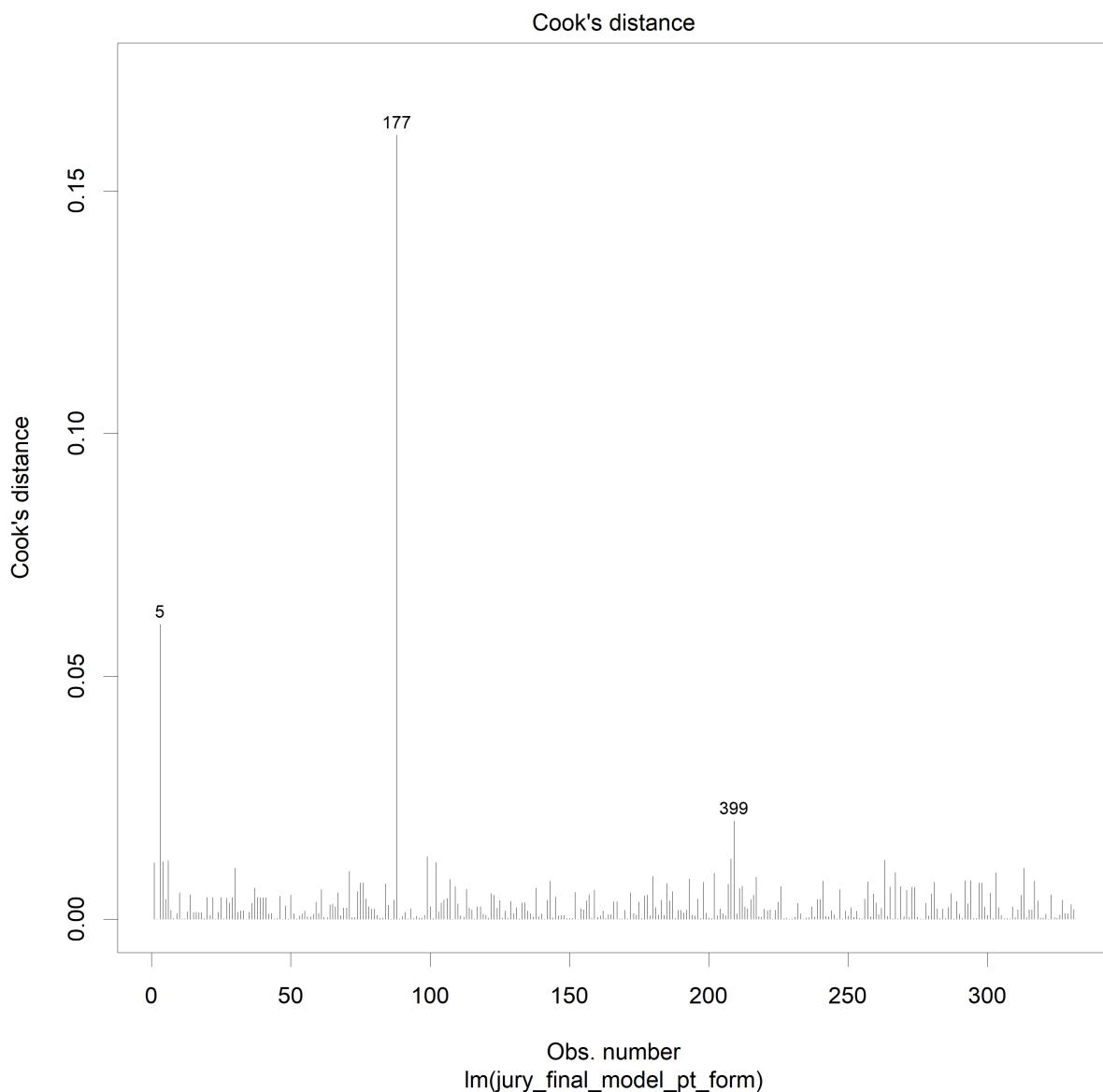




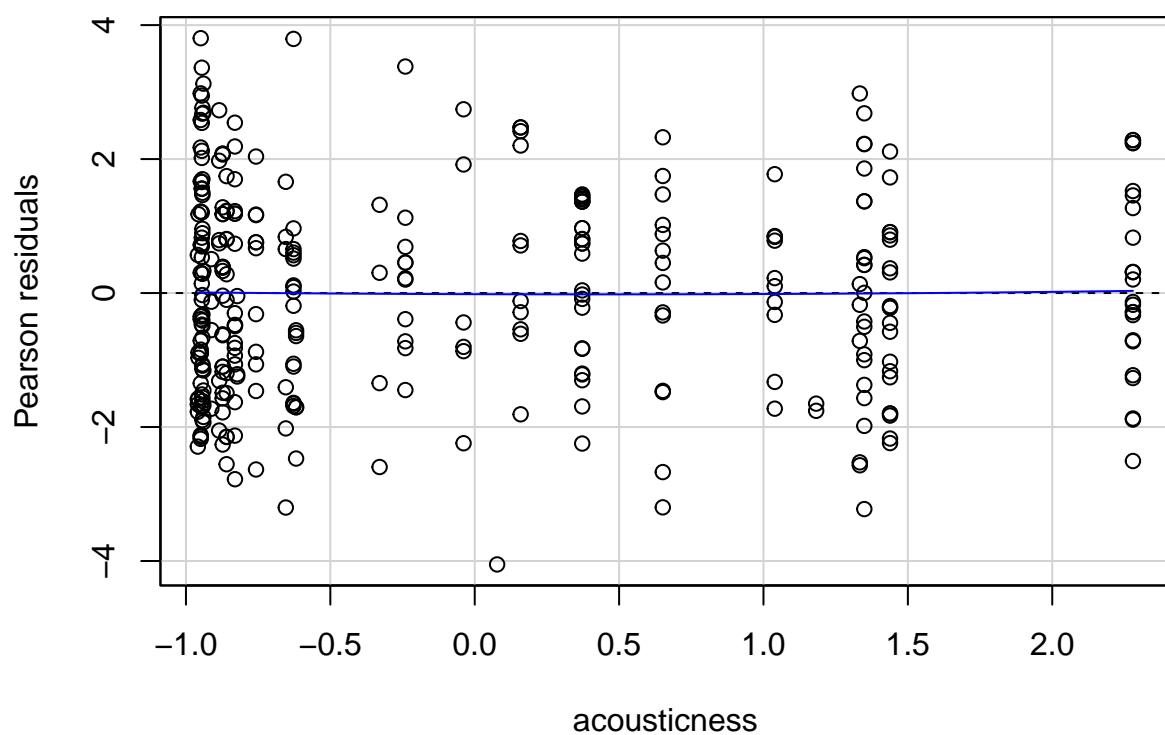
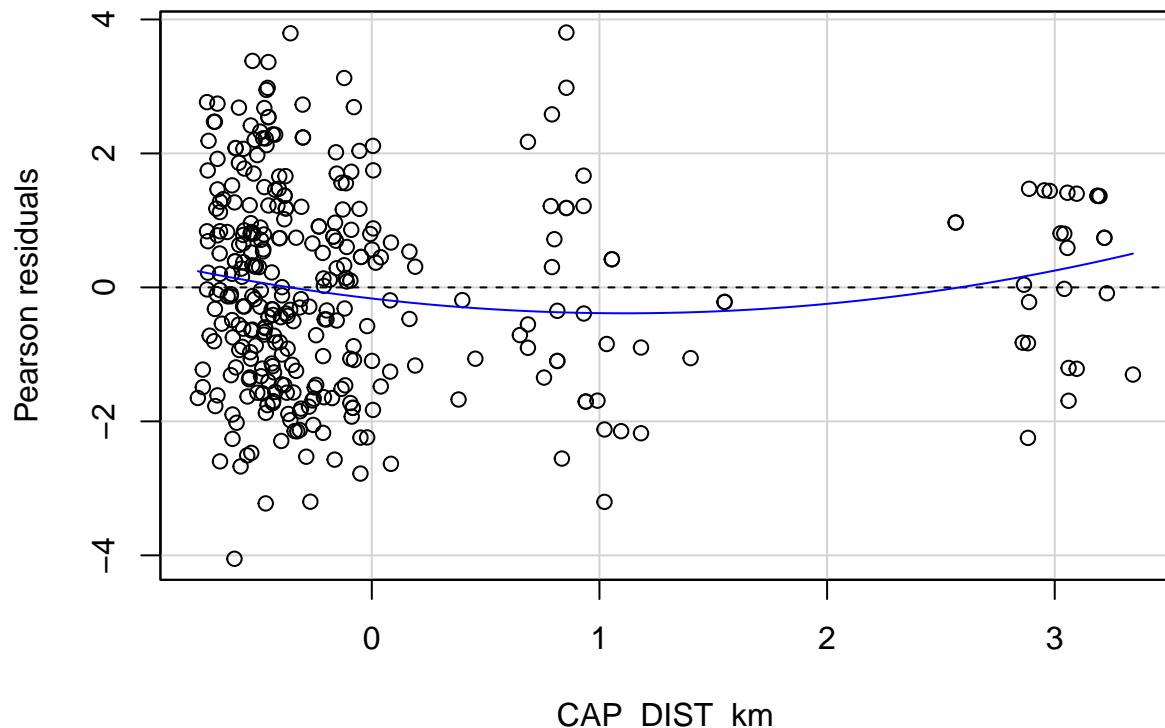
Added-Variable Plots

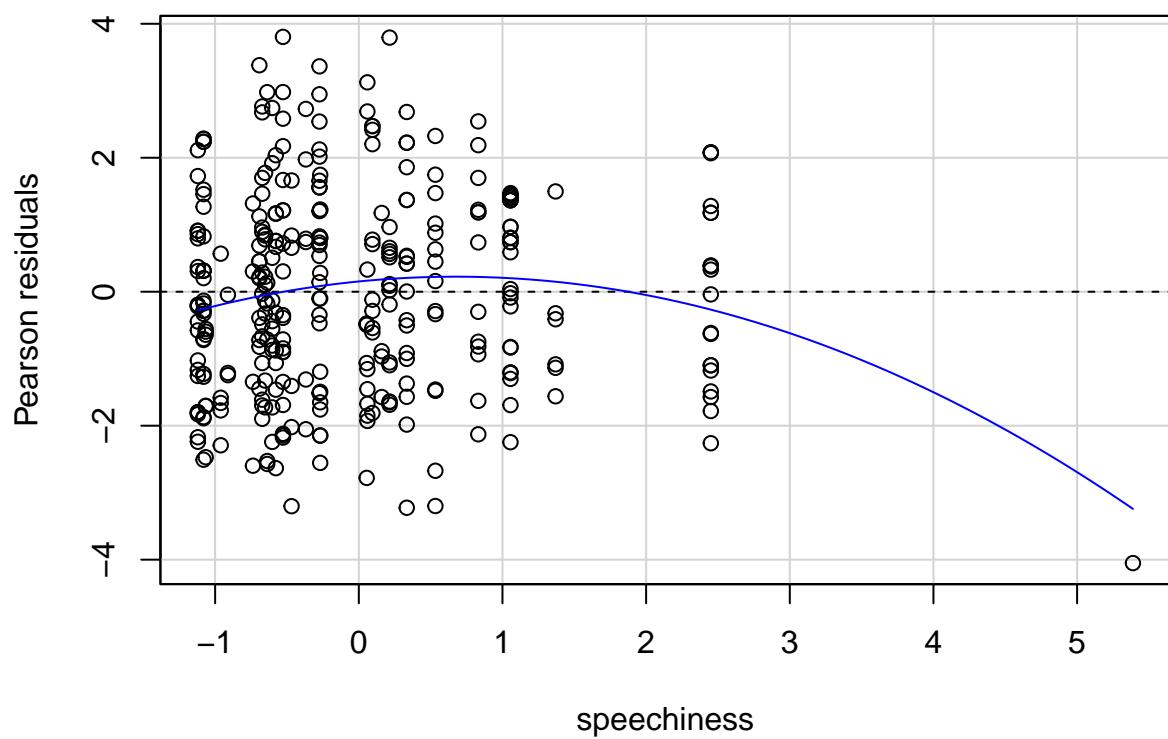


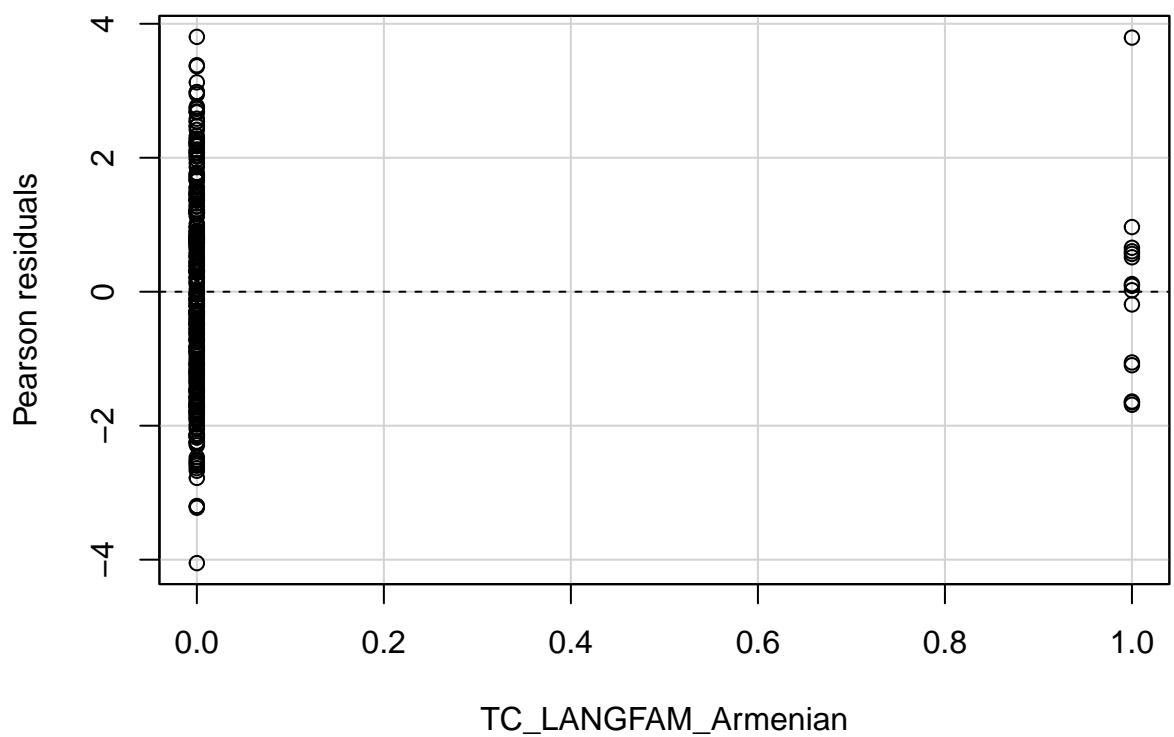
Cooks Distance Plot

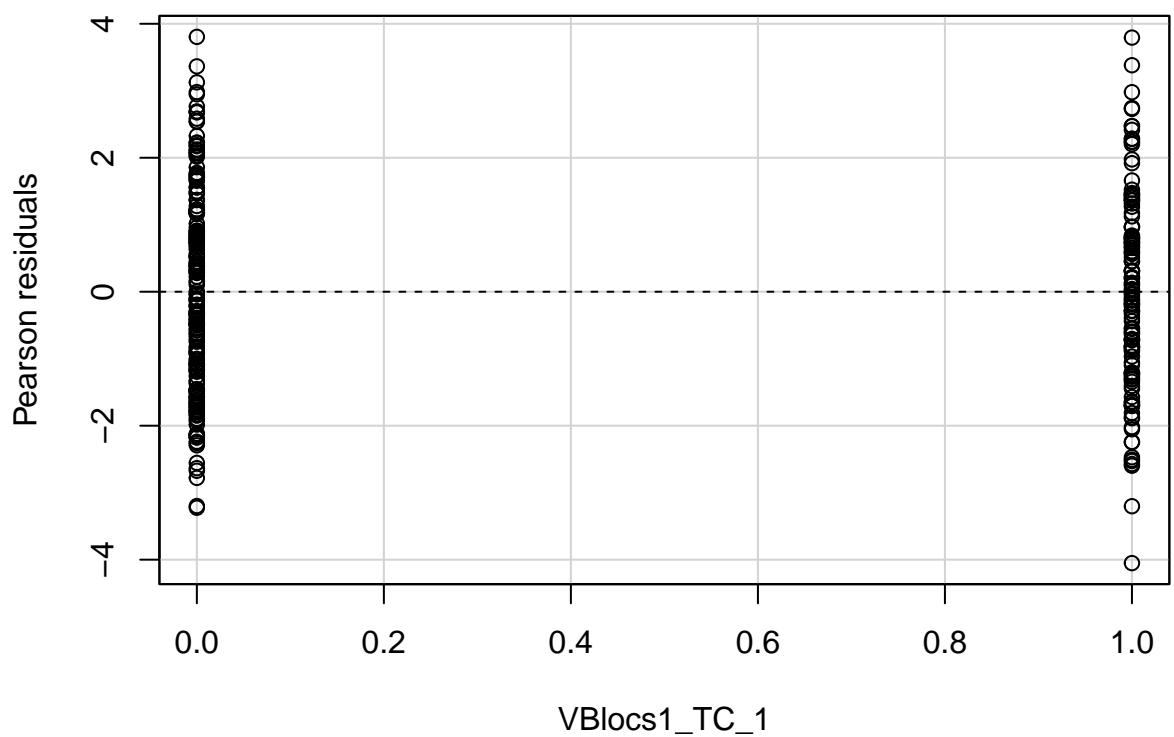


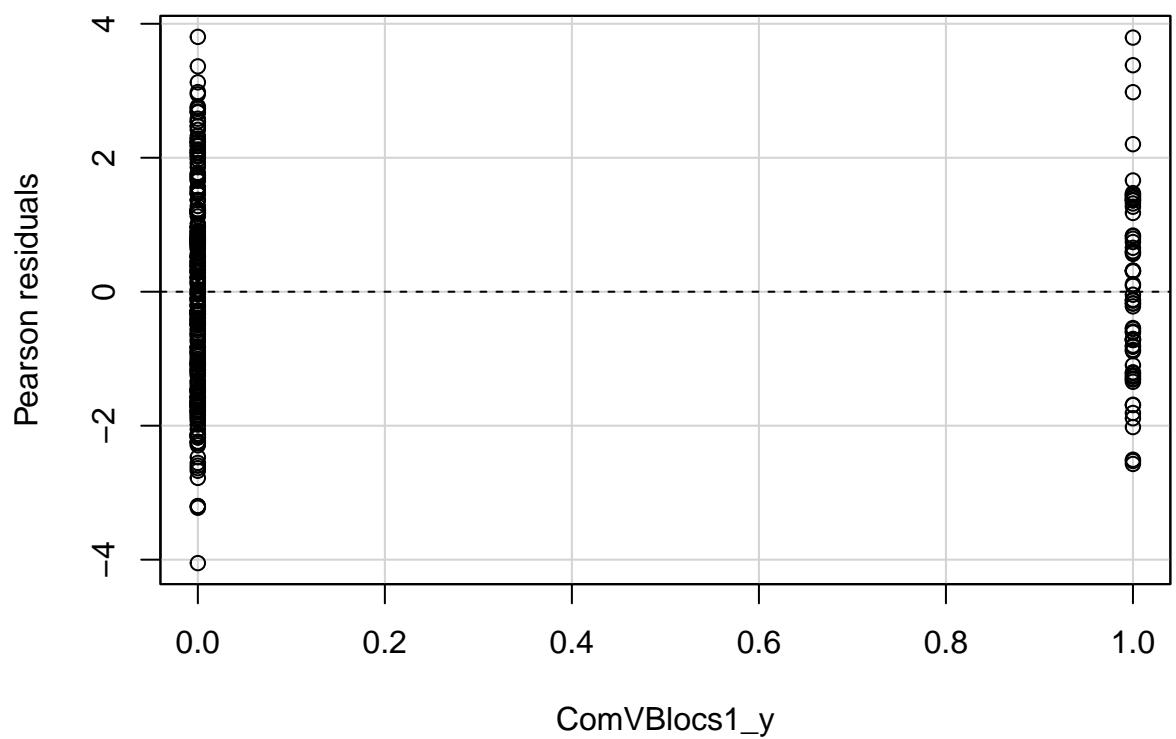
Residual Plots

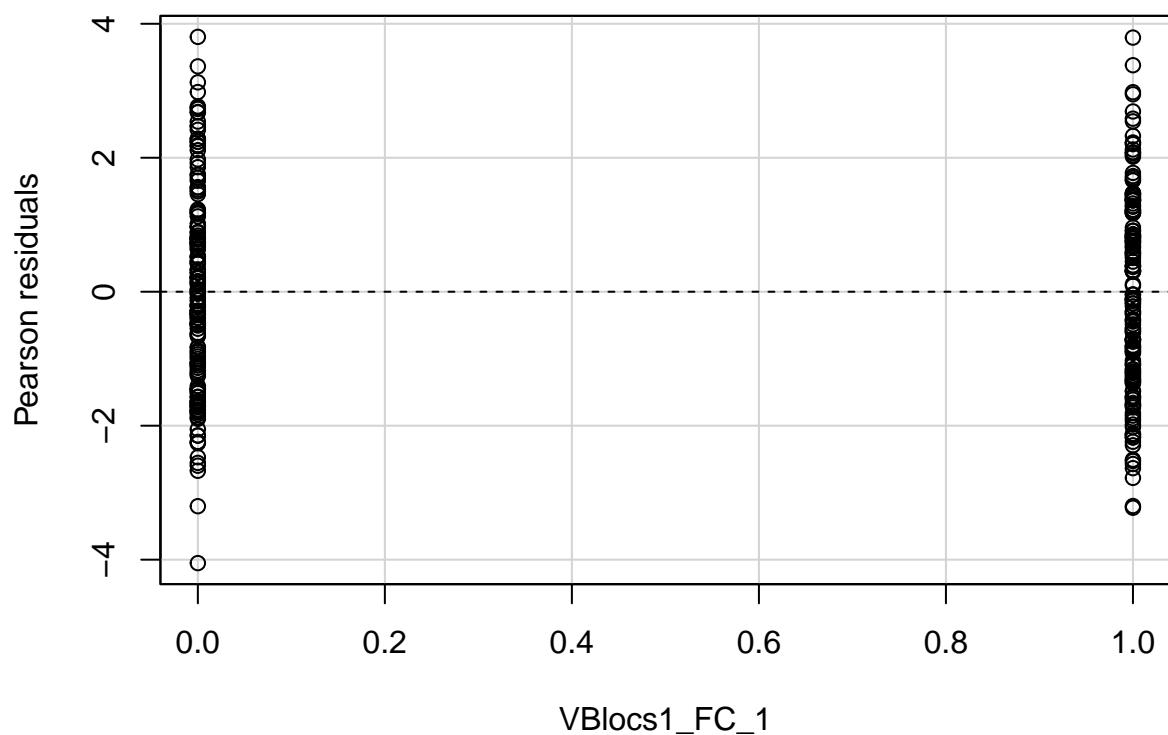


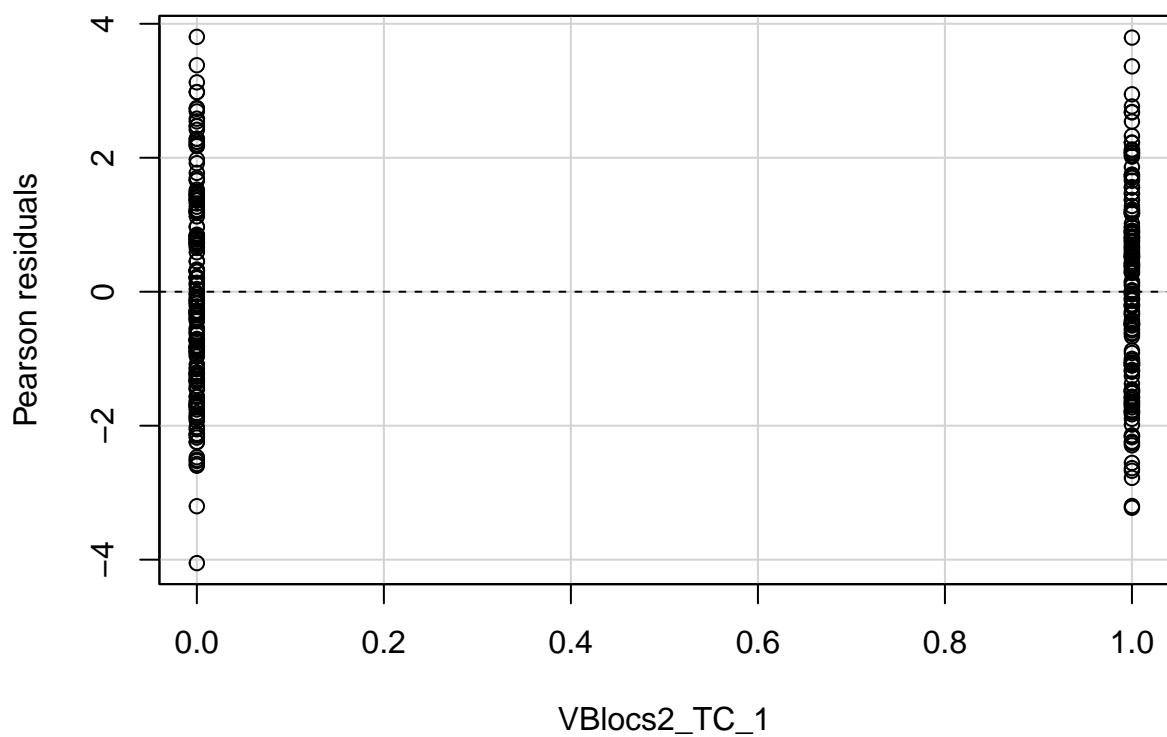


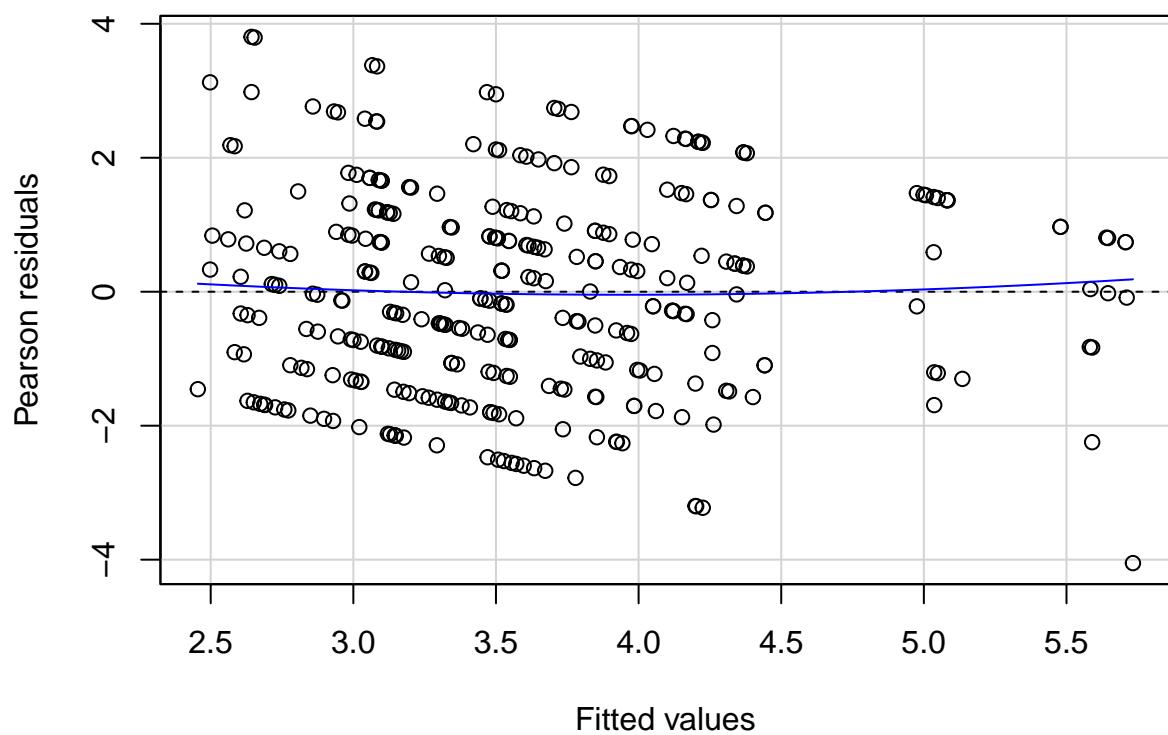




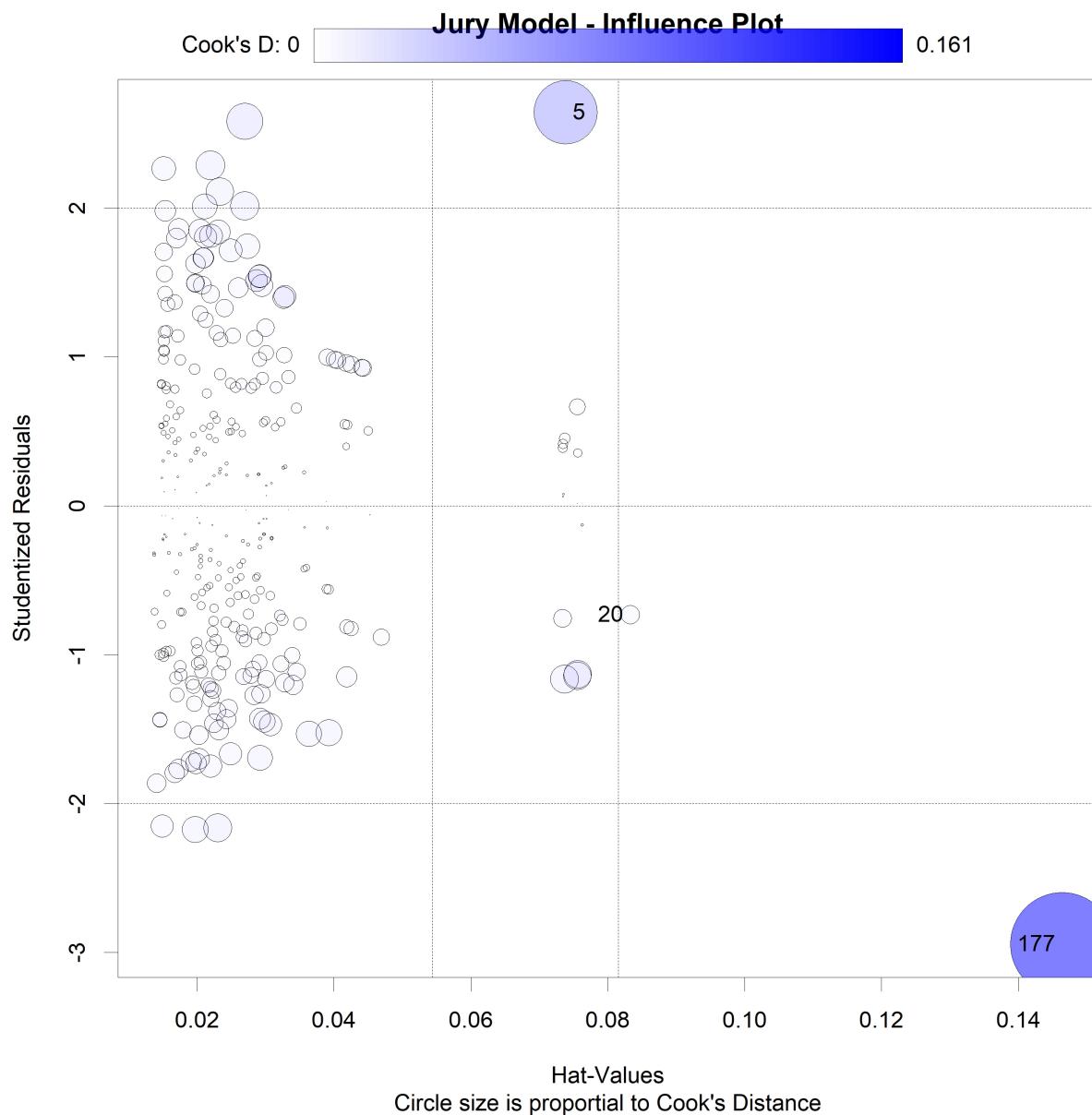








Influence Plot



Normality Assumption

Normality Tests

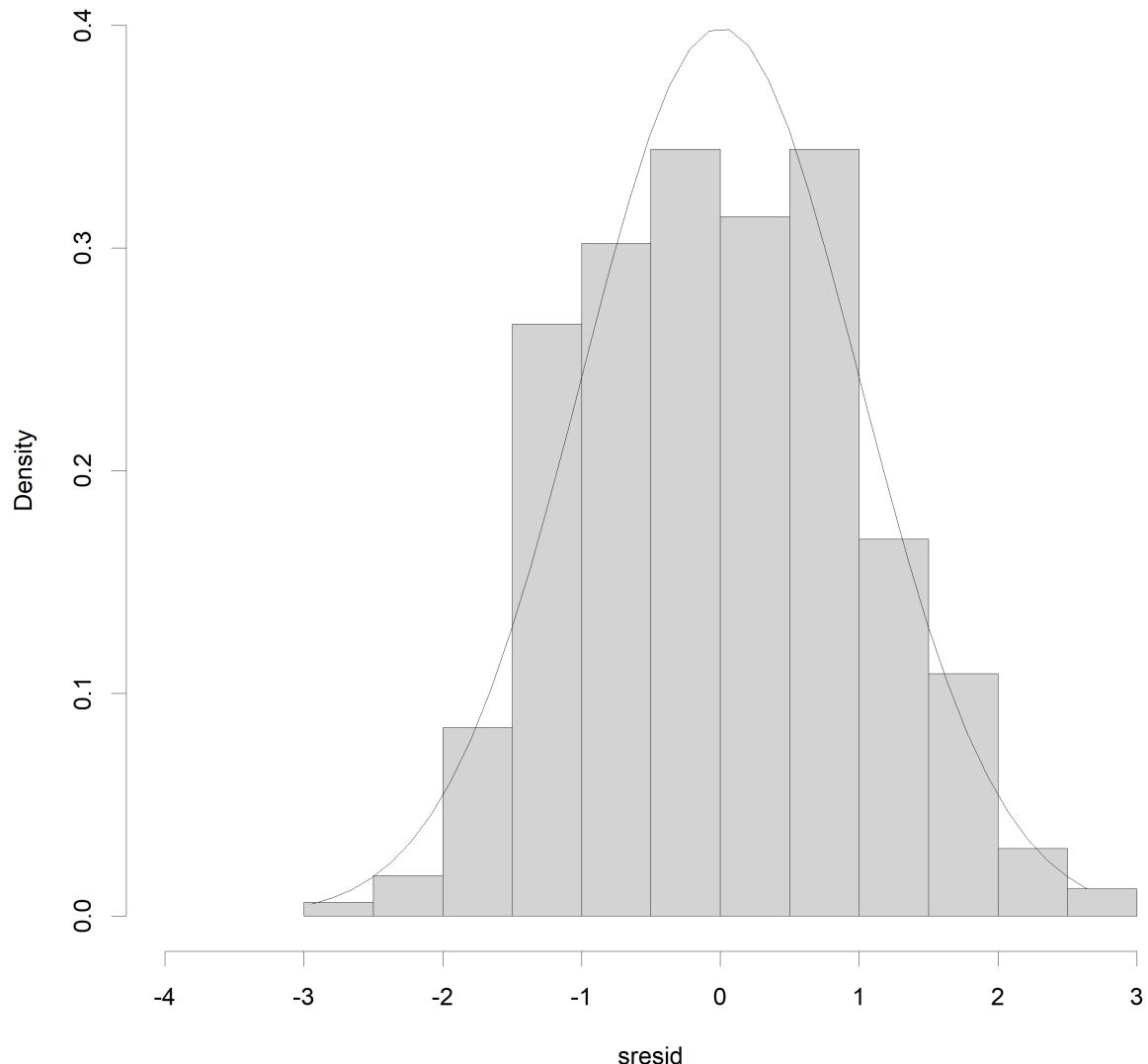
Normality Test

- Ho: The data is normally distributed
- Ha: the data is not normally distributed

| NormTest | Stat | Pval |
|--------------|----------|---------|
| shapiro.test | 0.99153 | 0.05511 |
| ad.test | 0.89016 | 0.02271 |
| cvm.test | 0.13742 | 0.03478 |
| lille.test | 0.0473 | 0.0716 |
| person.test | 30.56798 | 0.03228 |
| sf.test | 0.99221 | 0.07562 |

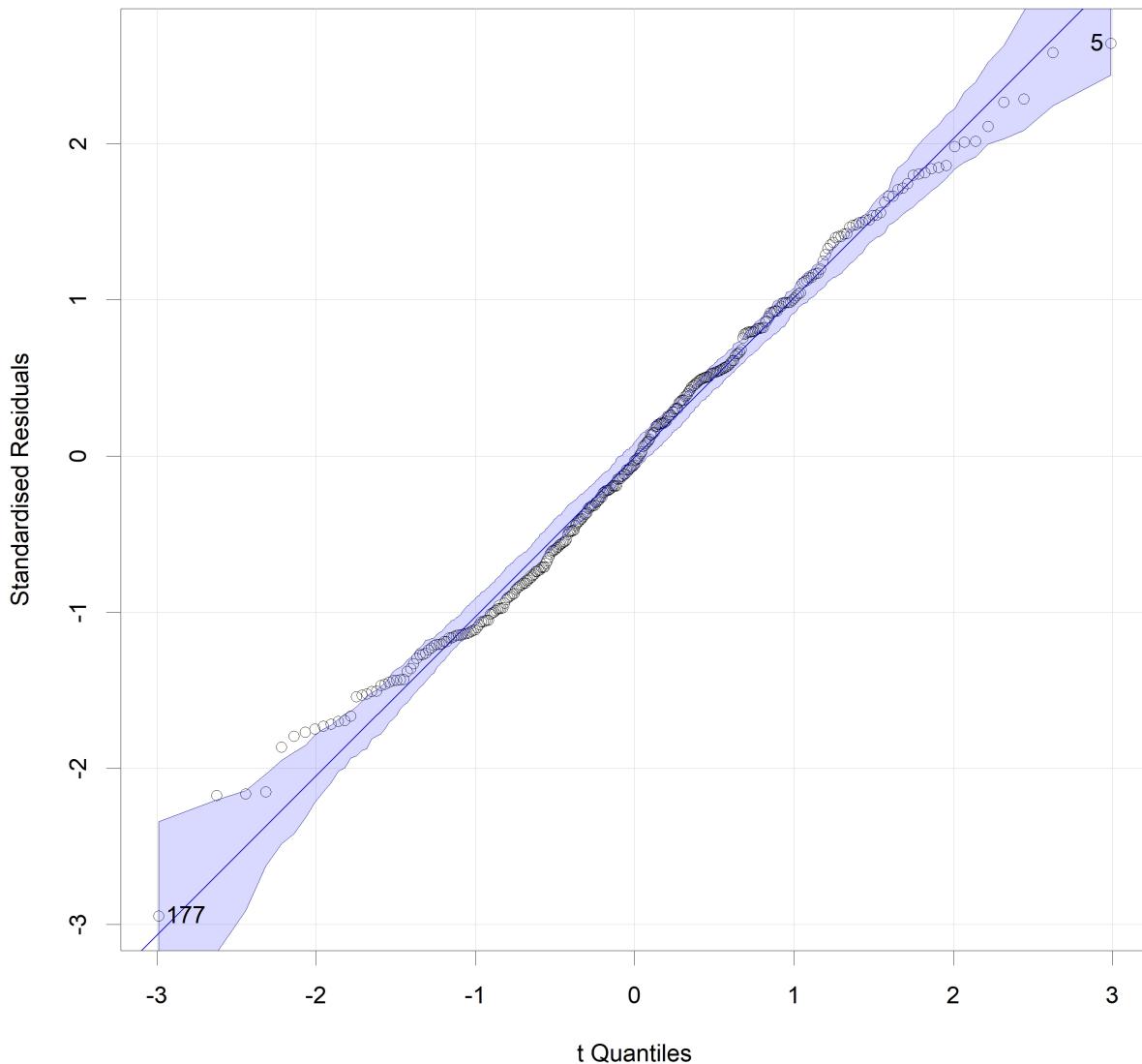
Residual Histogram

Jury Model - Distribution of Standardised Residuals



Residual QQ-Plot

QQ-Plot of Jury Vote Model Standardised Residuals



Constant Variance Assumption

Non-Constant Variance Test

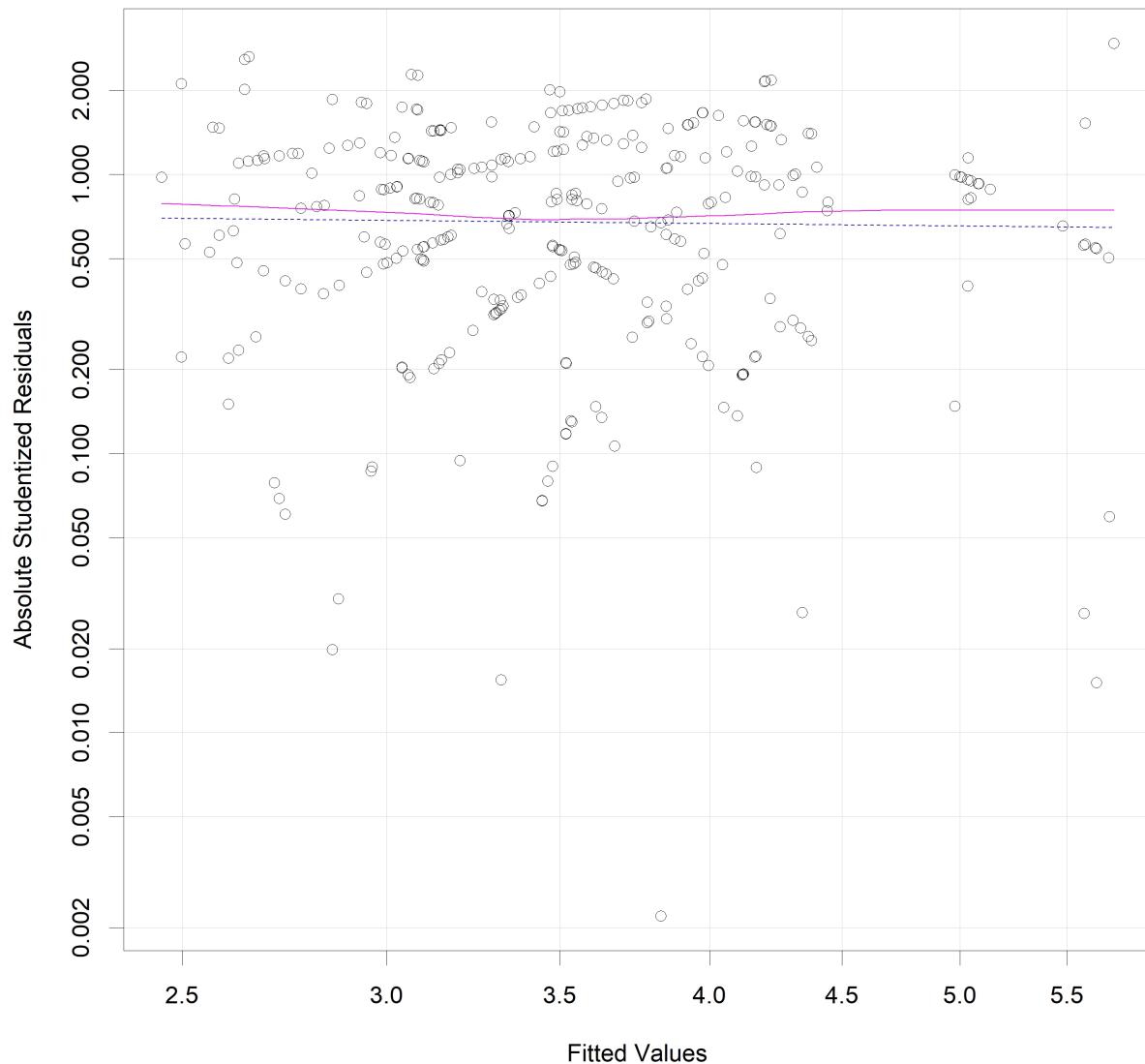
Non-Constant Error Variance Test

- Ho: constant error variance
- Ha: Non-constant error Variance

| Non-constant Variance Score Test | |
|----------------------------------|---------|
| Chi-Sq Statistic | 0.21531 |
| P-Value | 0.64264 |

Spread-Level Plot

Spread-Level Plot for Jury Model



Variance Inflation Factors

| | VIF | sqrt(VIF) > 2 |
|---------------------|----------|---------------|
| CAP_DIST_km | 1.181514 | 0 |
| acousticness | 1.220900 | 0 |
| speechiness | 1.187223 | 0 |
| TC_LANGFAM_Armenian | 1.523284 | 0 |
| VBlocs1_TC_1 | 3.249223 | 0 |
| ComVBlocs1_y | 2.641876 | 0 |

| | VIF | sqrt(VIF) > 2 |
|--------------|----------|---------------|
| VBlocs1_FC_1 | 1.654895 | 0 |
| VBlocs2_TC_1 | 2.067919 | 0 |