

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

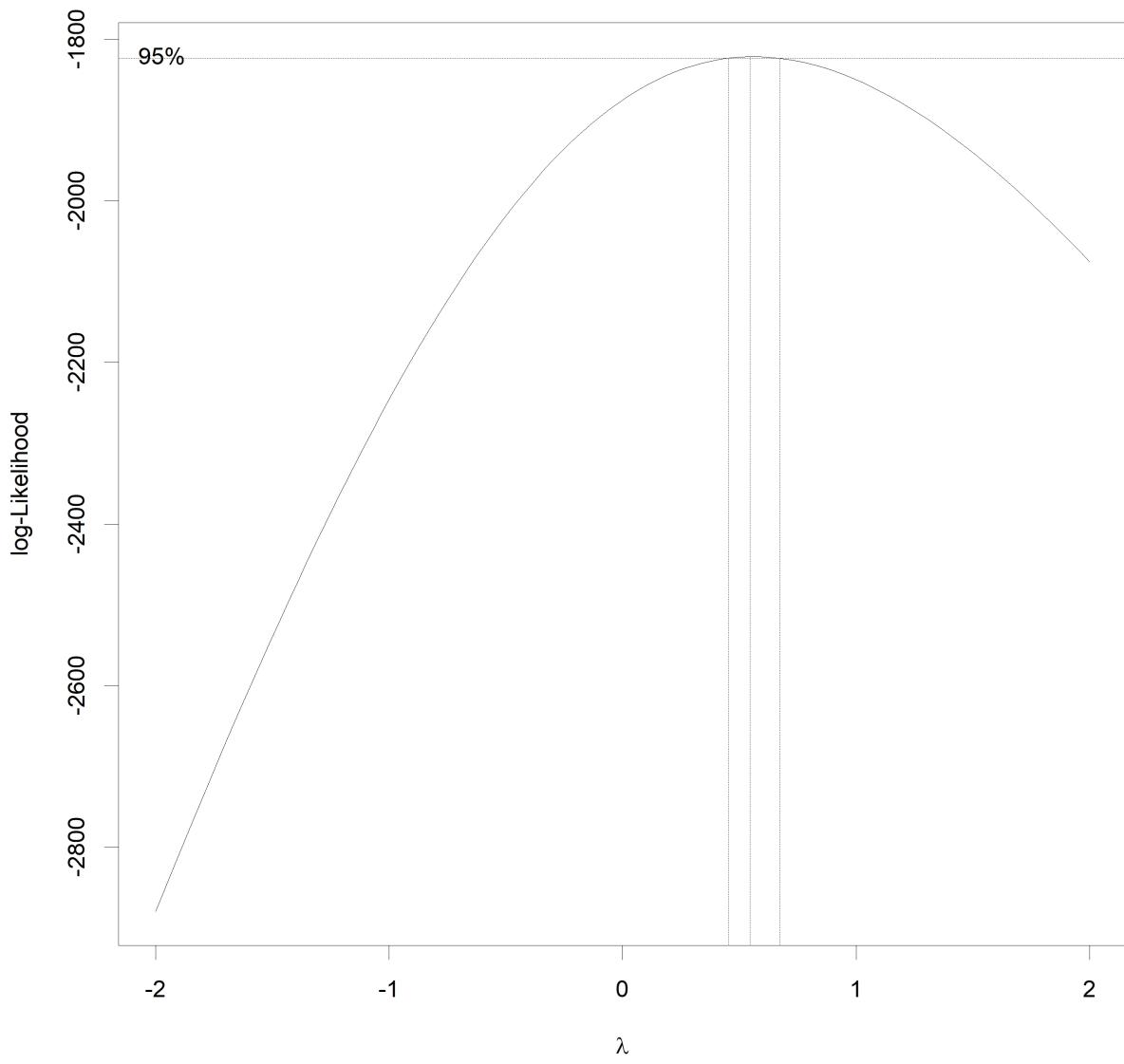
Overall Model

```
##  
## 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
```

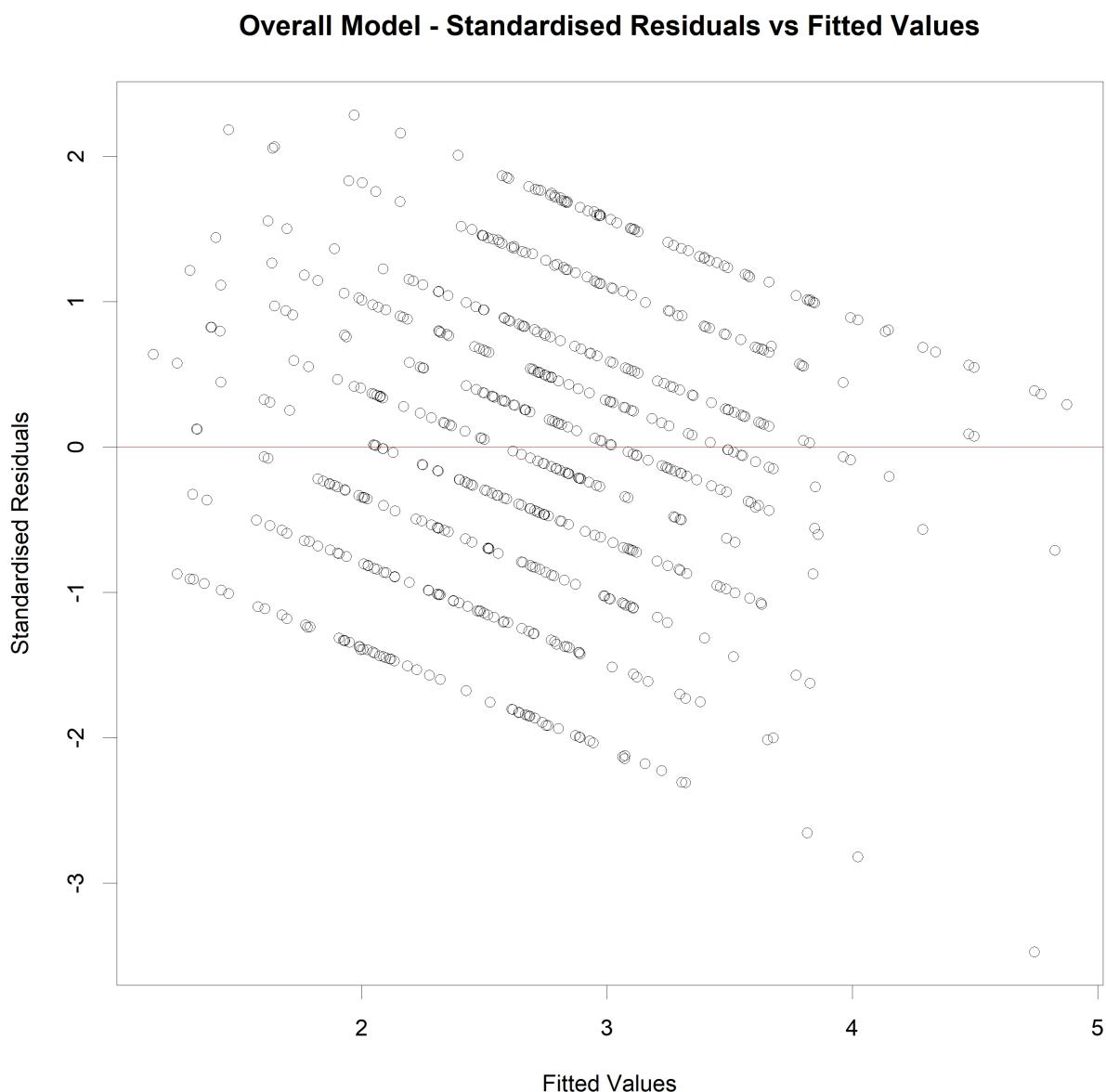
Response Variable Transformation

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

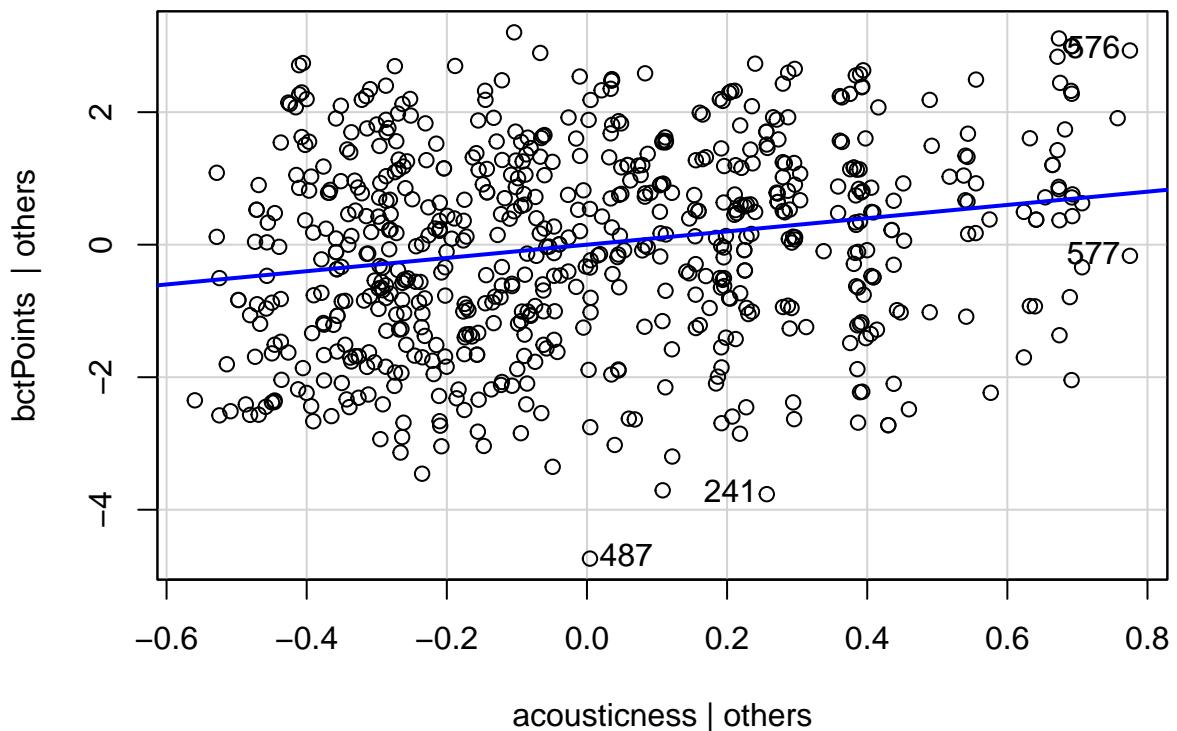
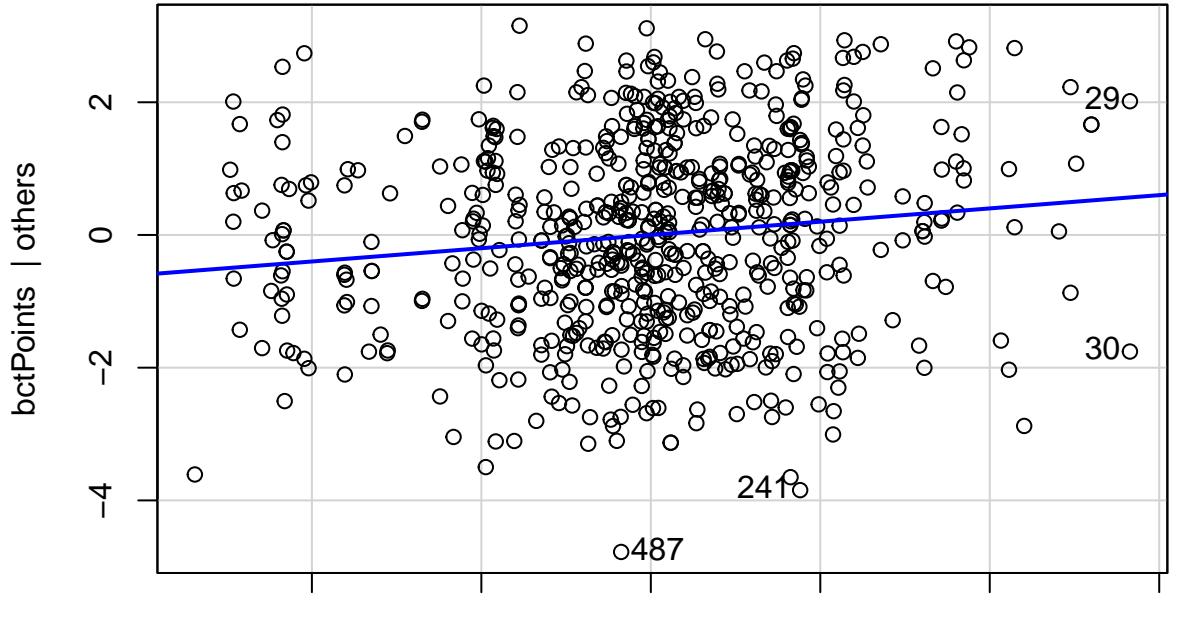
Bonferroni Outlier Test

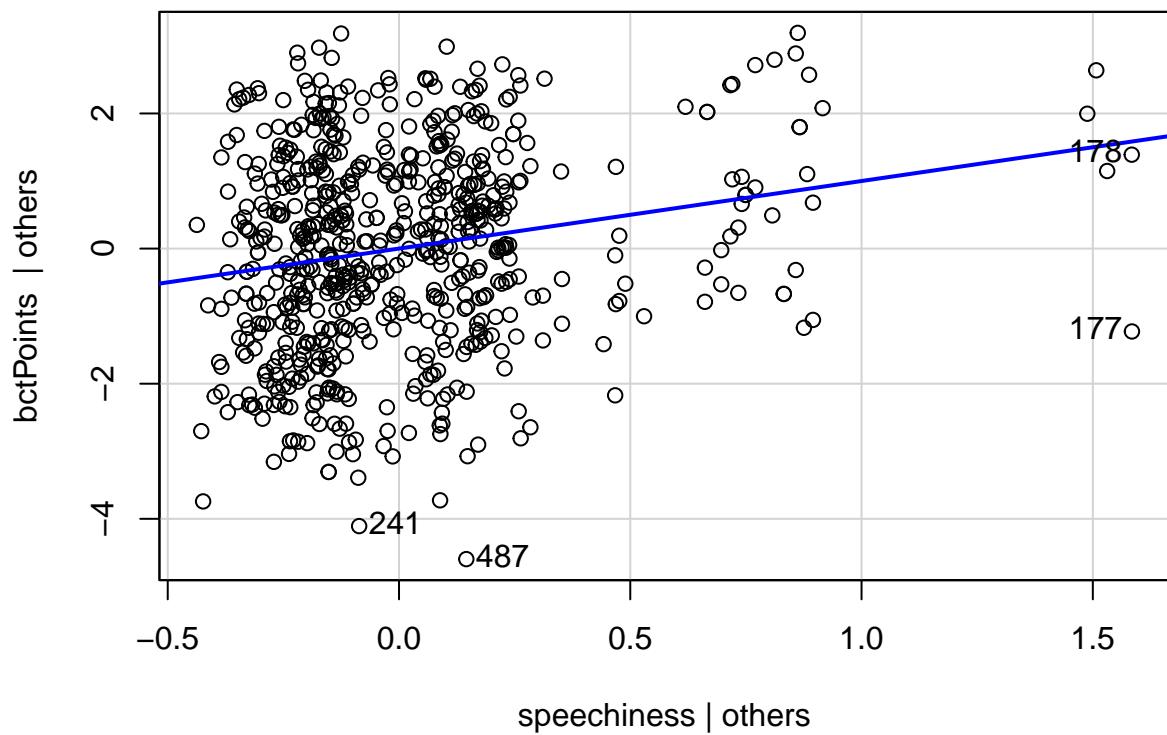
	rstudent	p	bonf.p	signif	cutoff
487	-3.473914	0.0005472	0.3600624	0	0.05

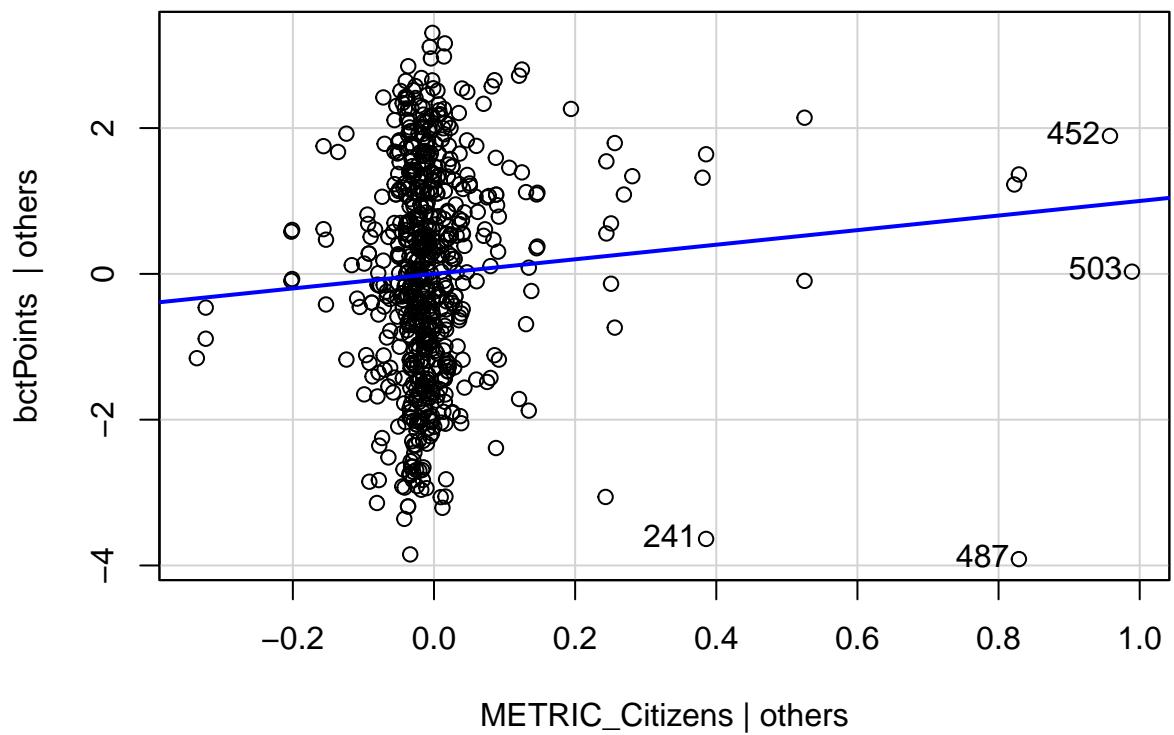
Outlier Residuals

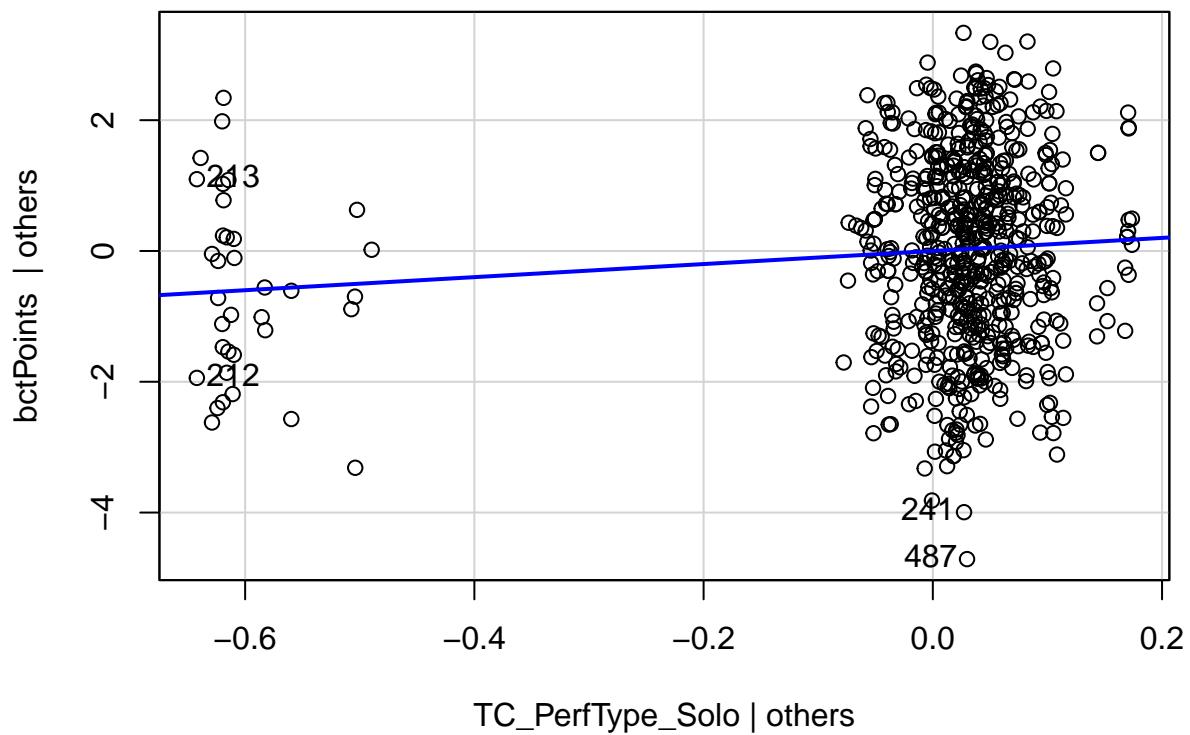
outlier_residuals
39
77
103
177
241
360

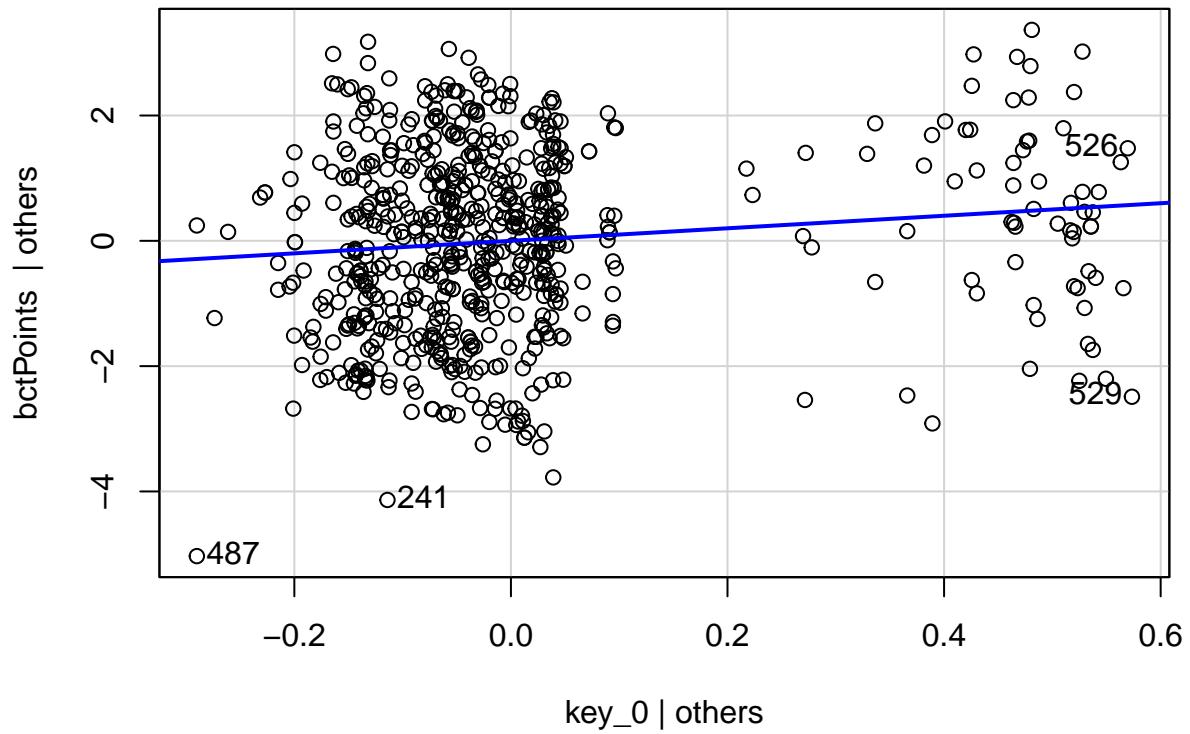
Leverage Plots

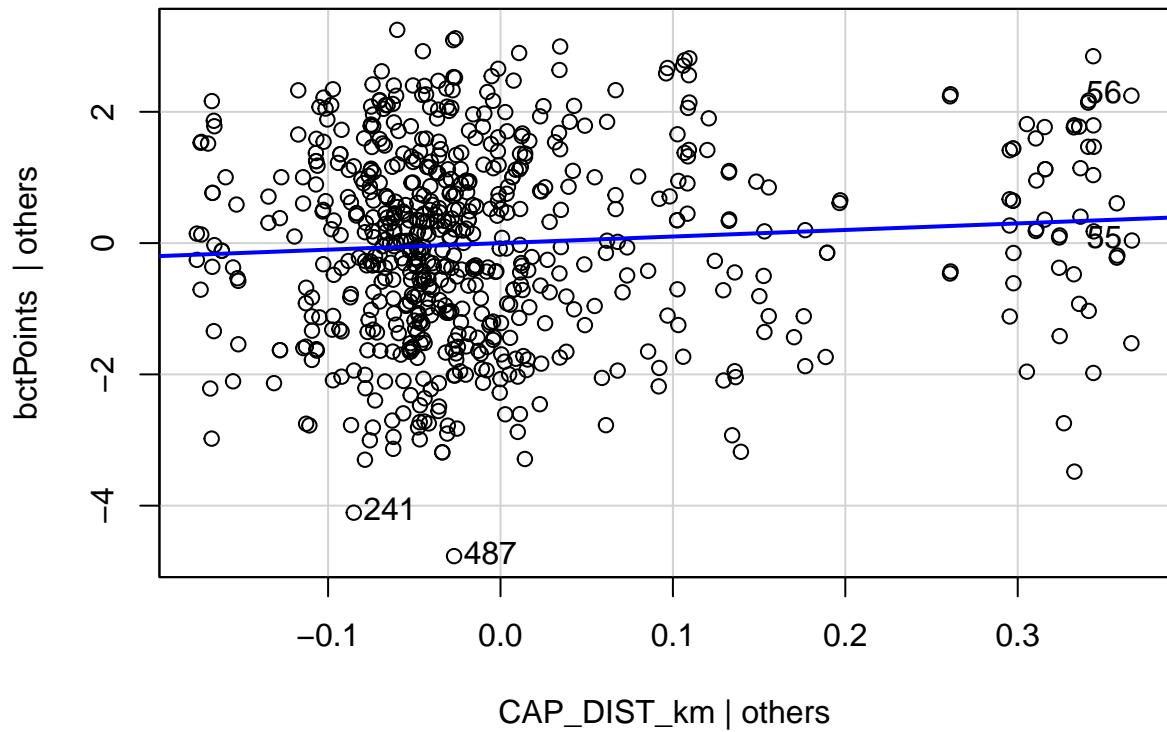


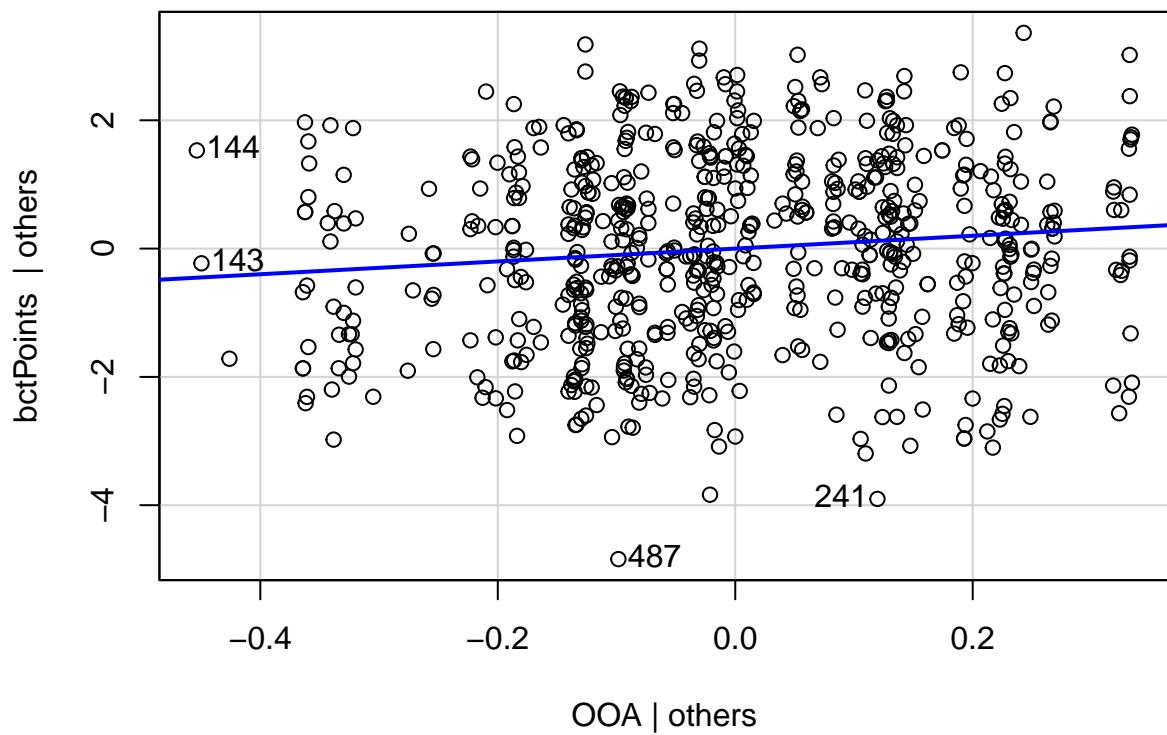


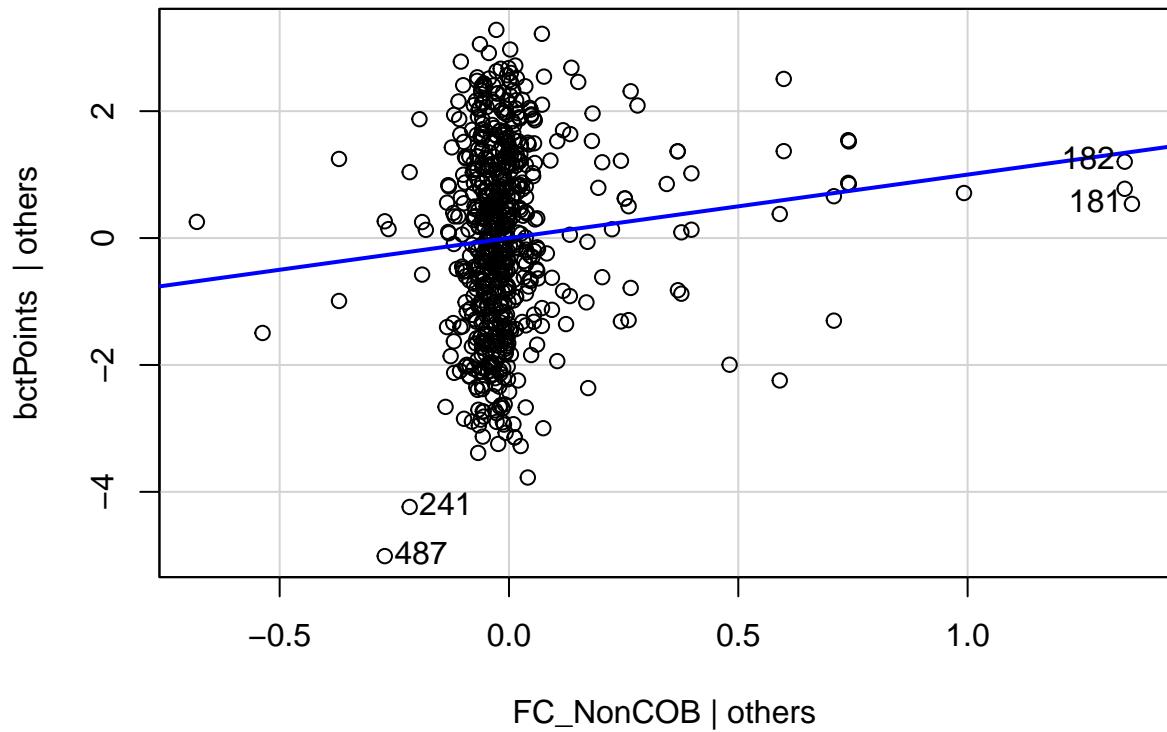




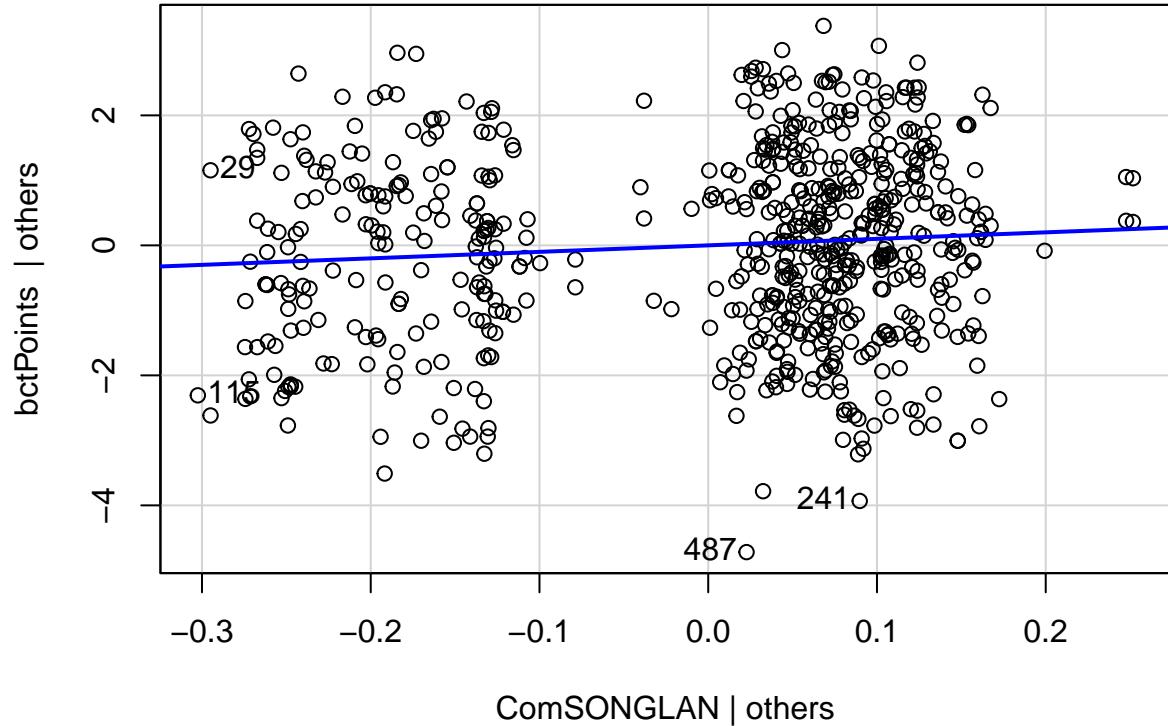




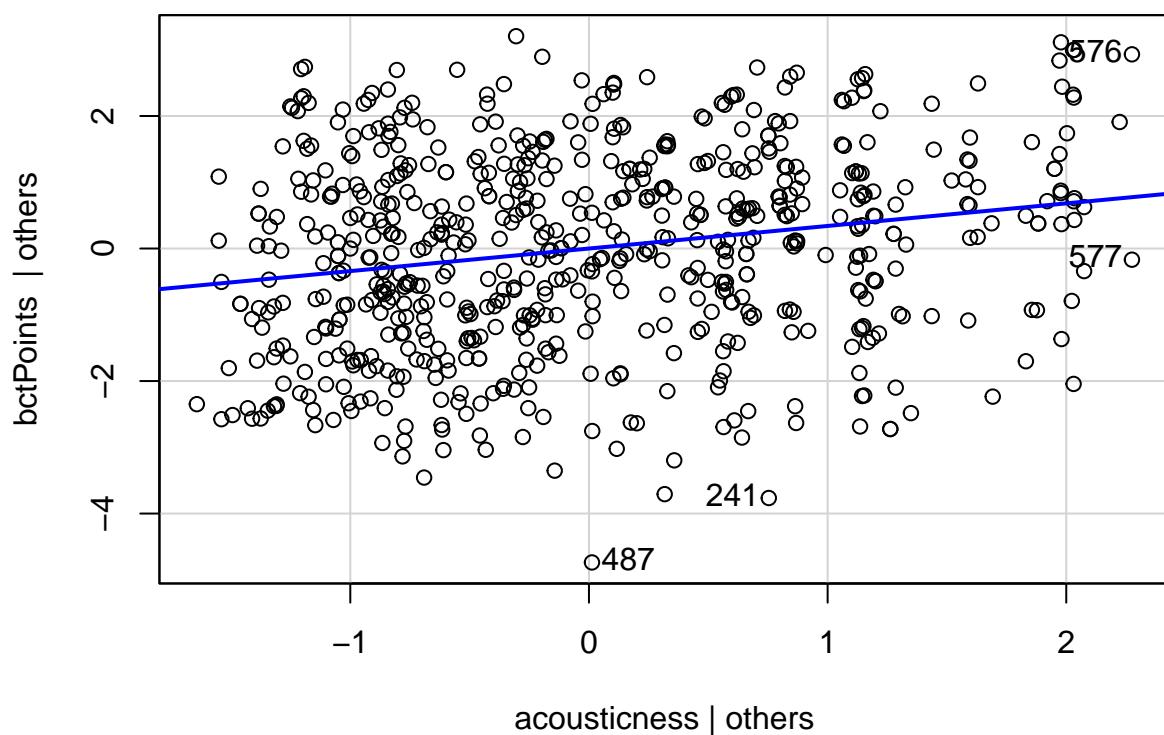
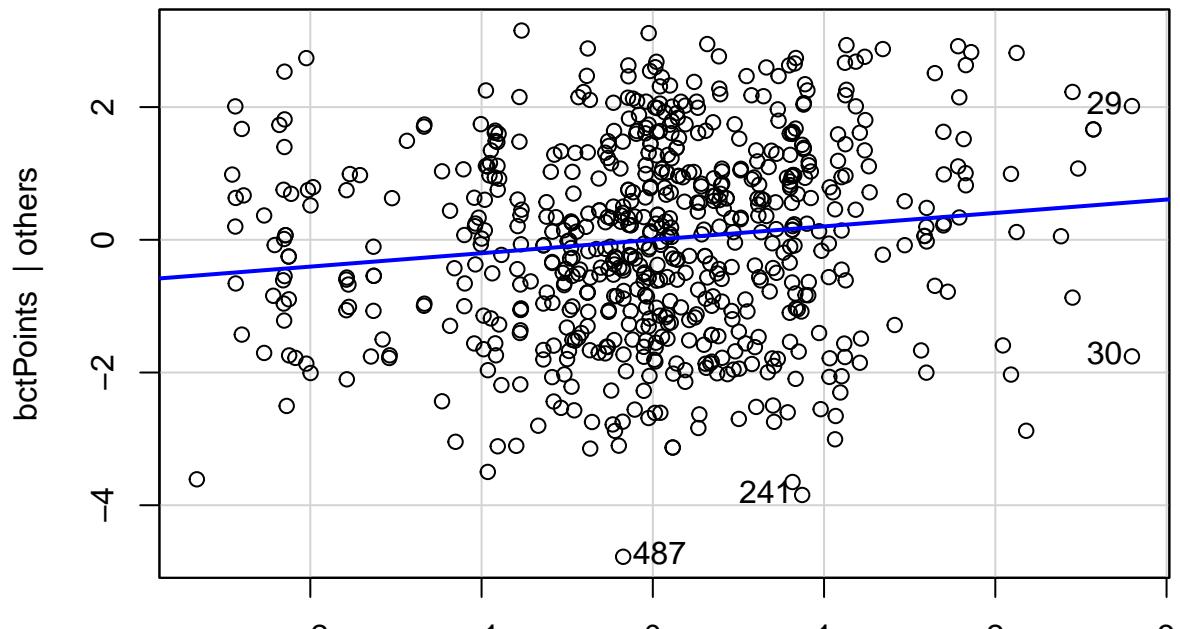


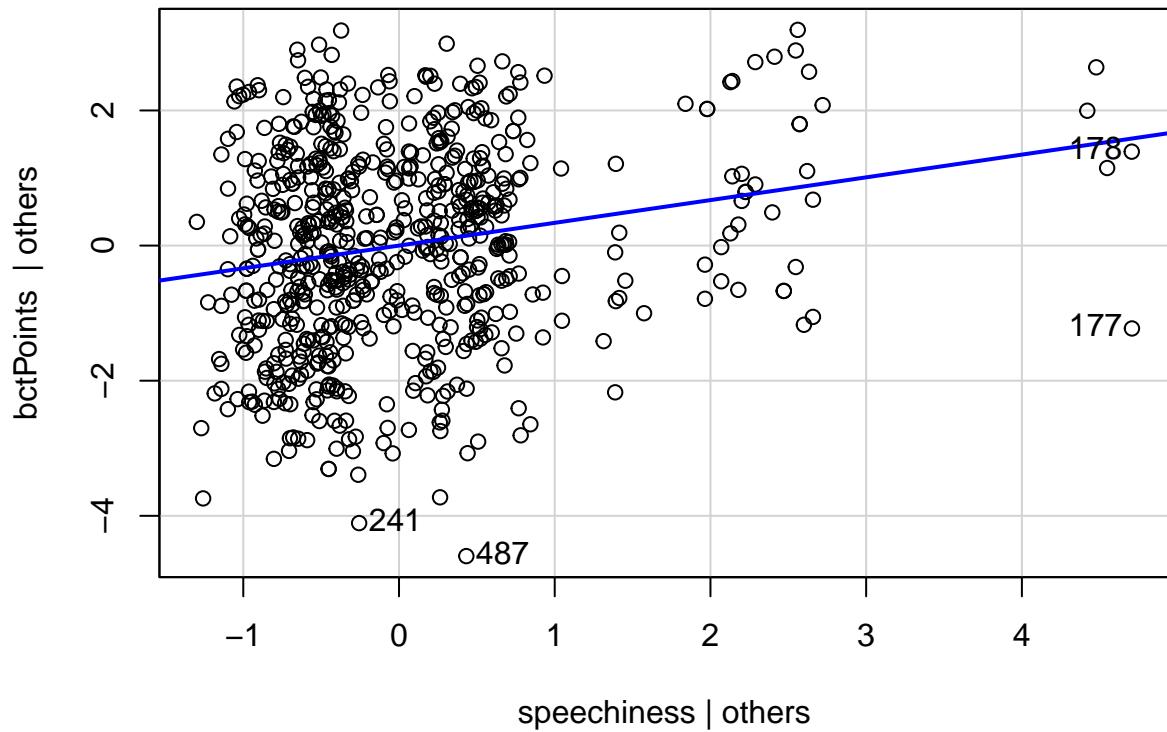


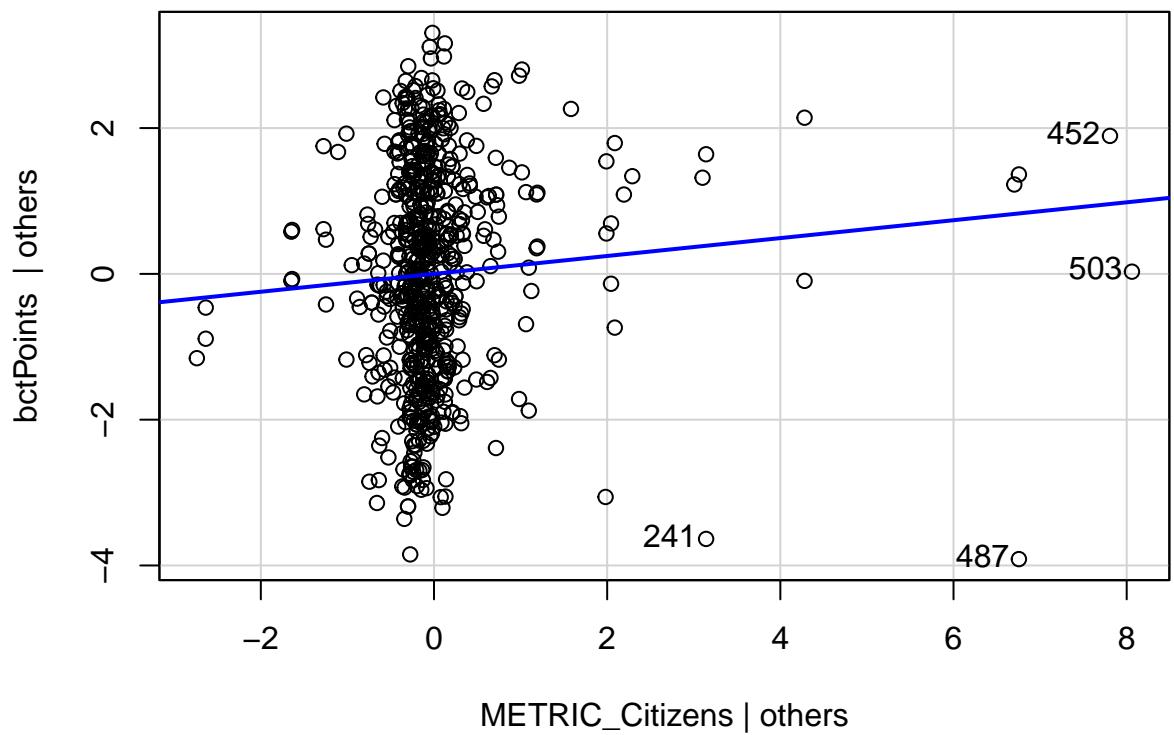
Leverage Plots

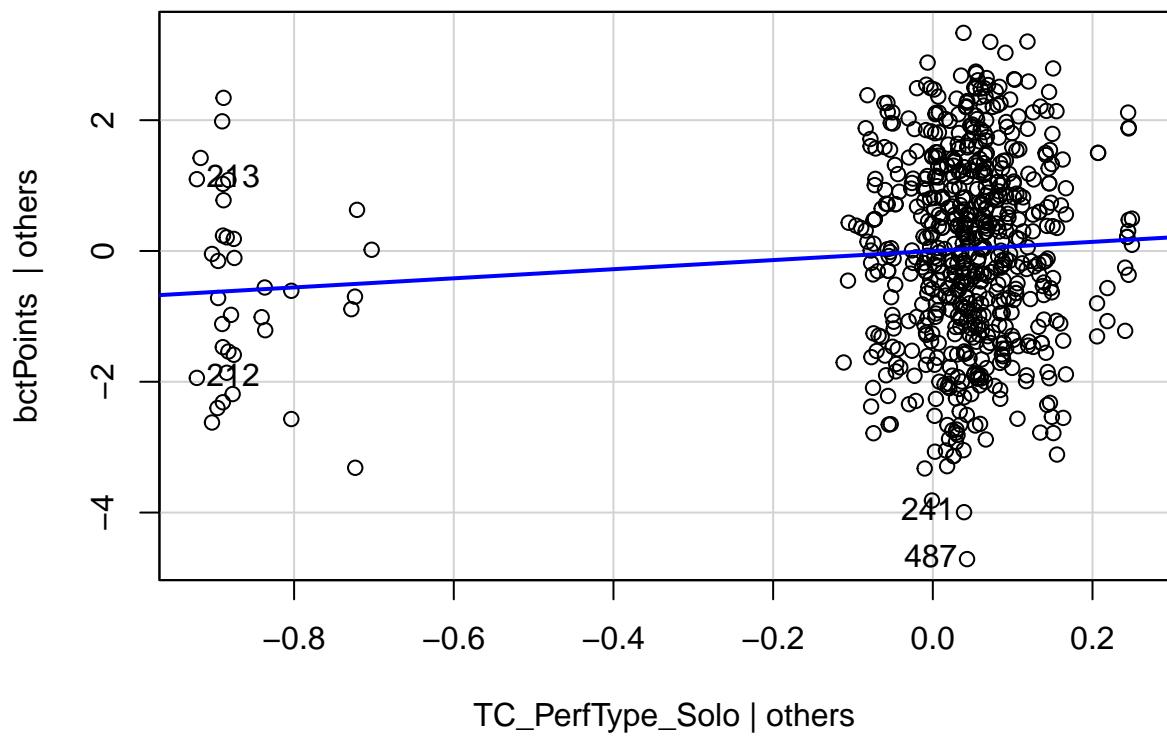


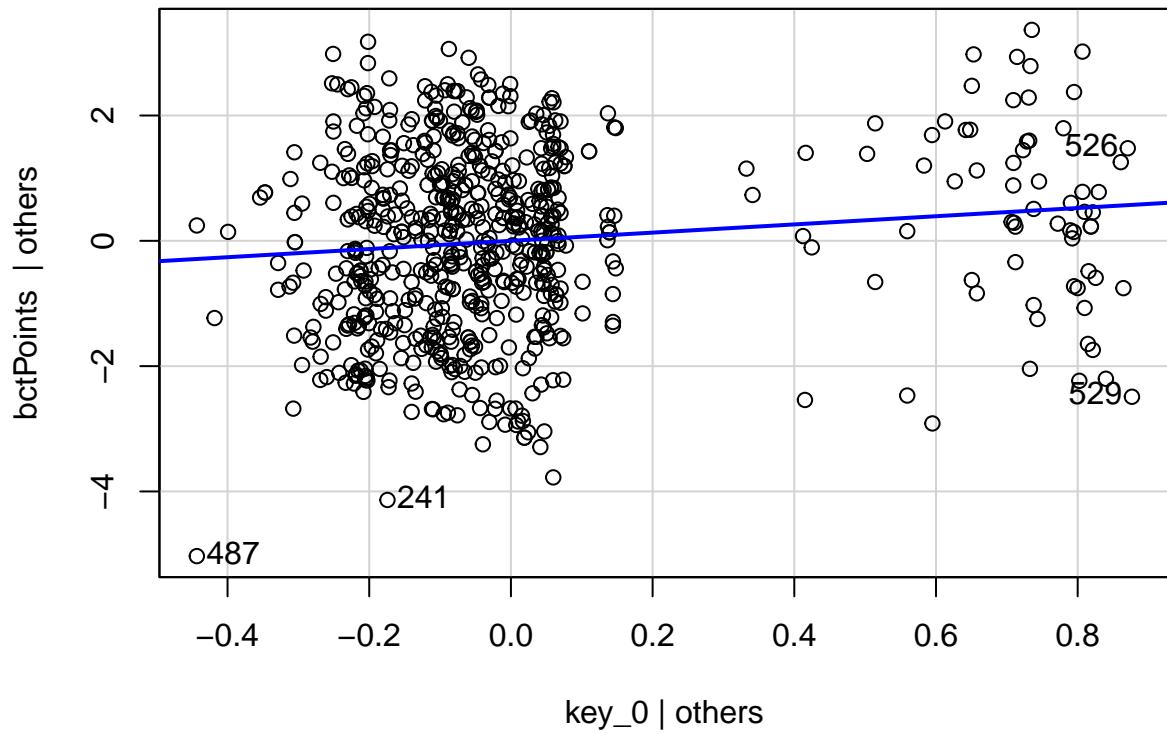
Added-Variable Plots

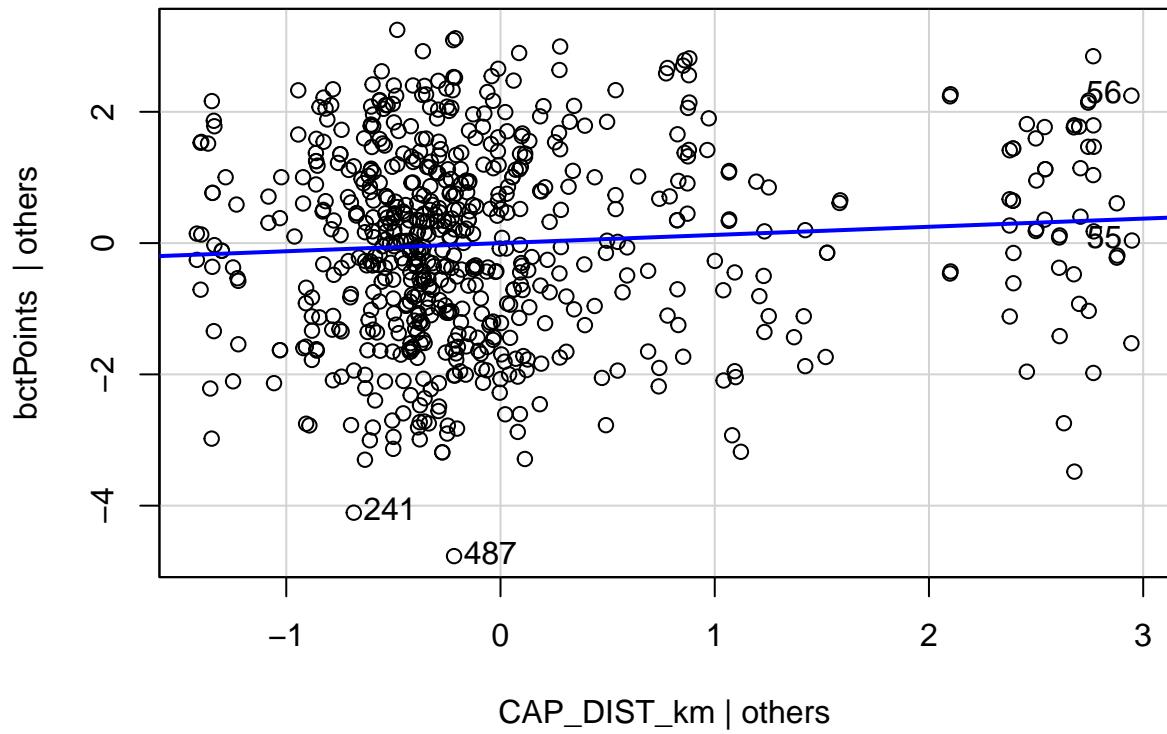


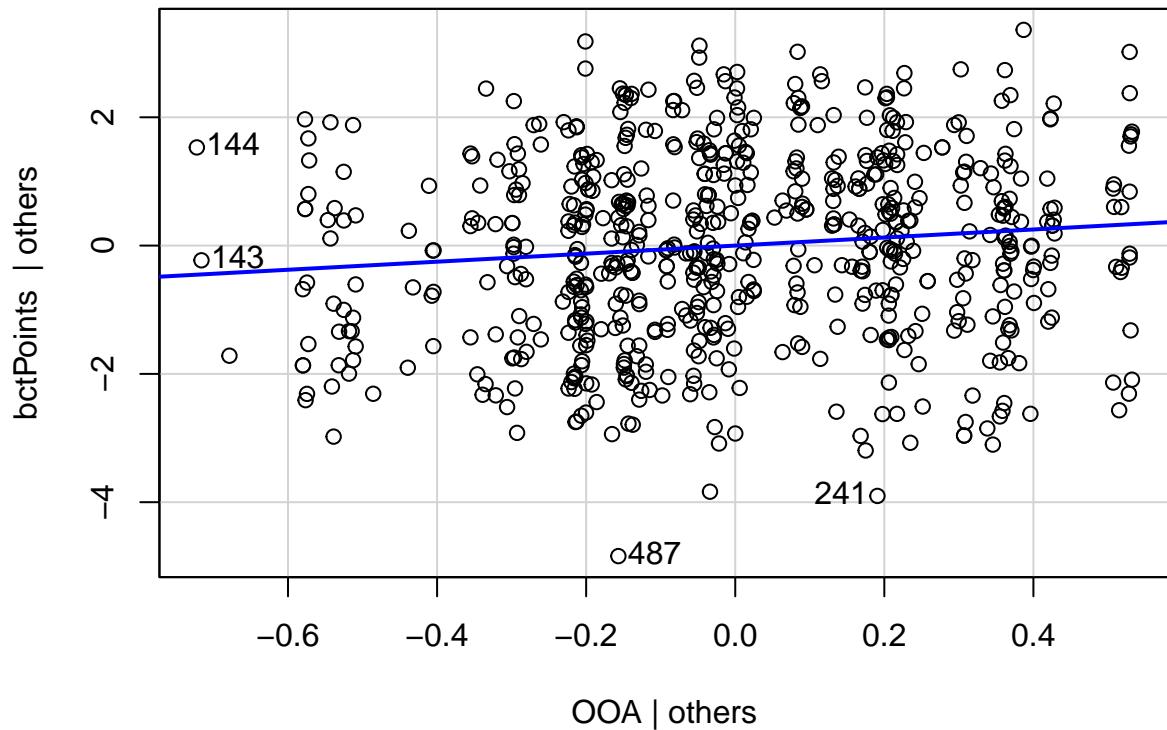


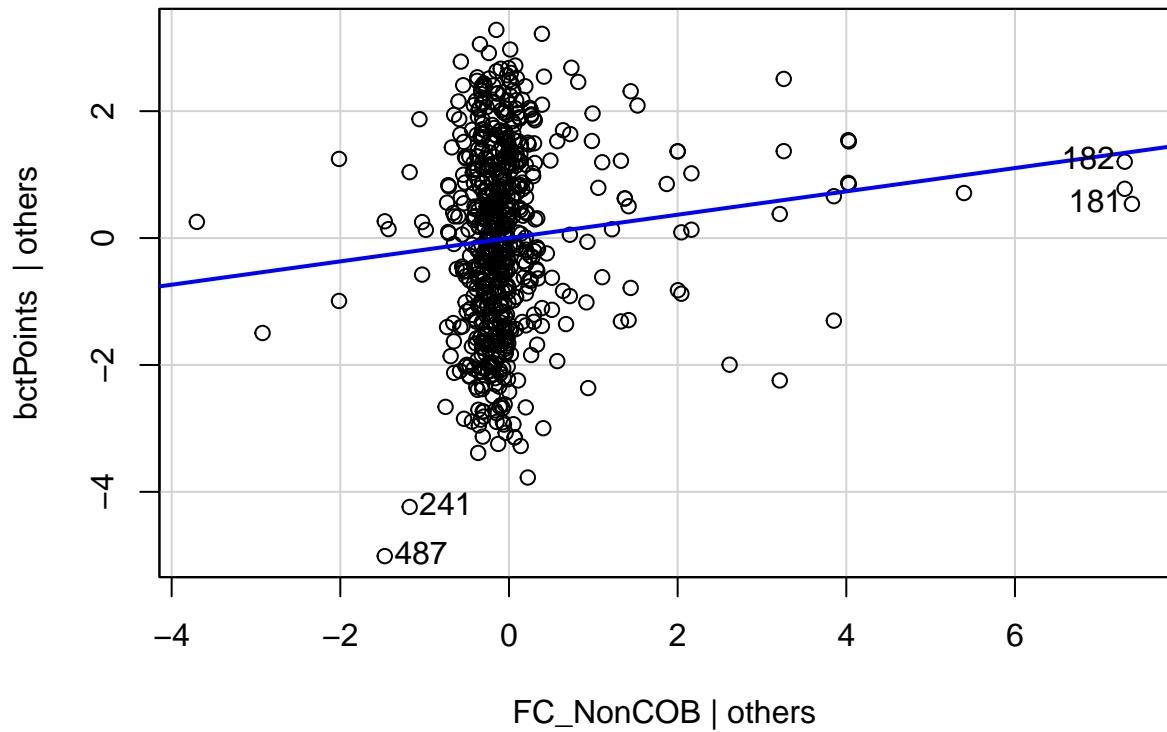




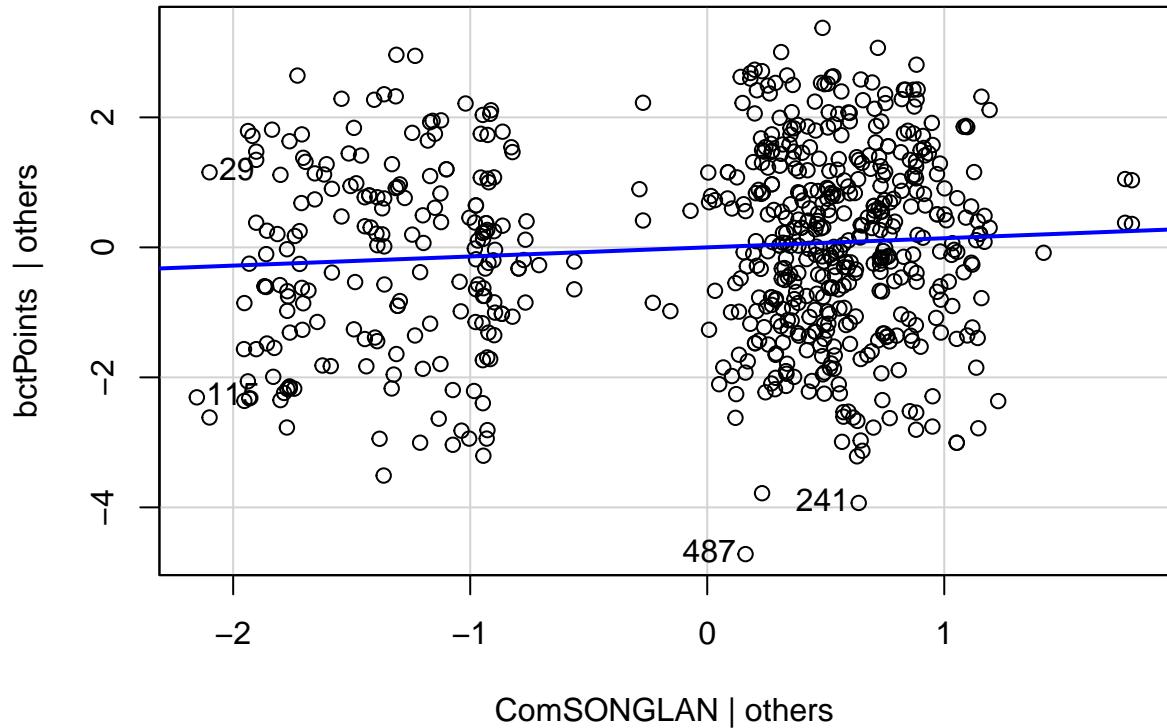




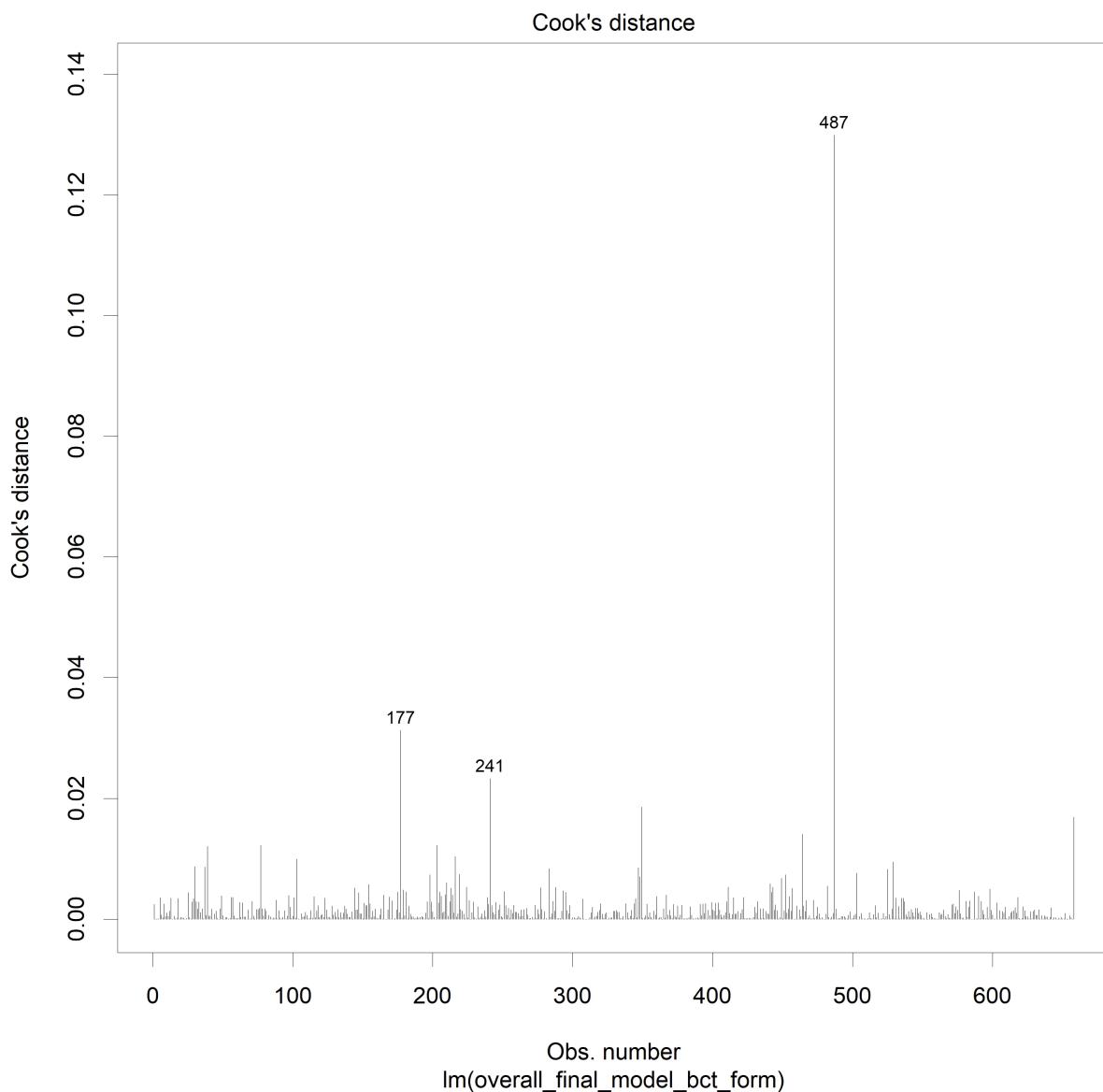




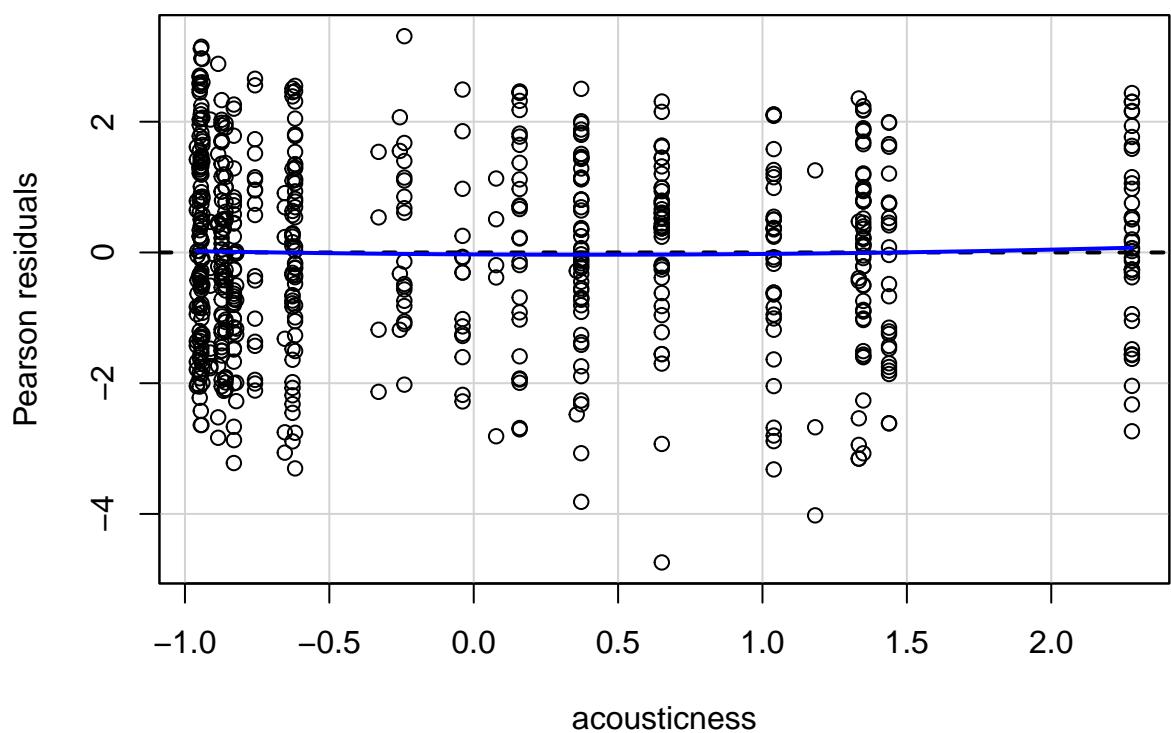
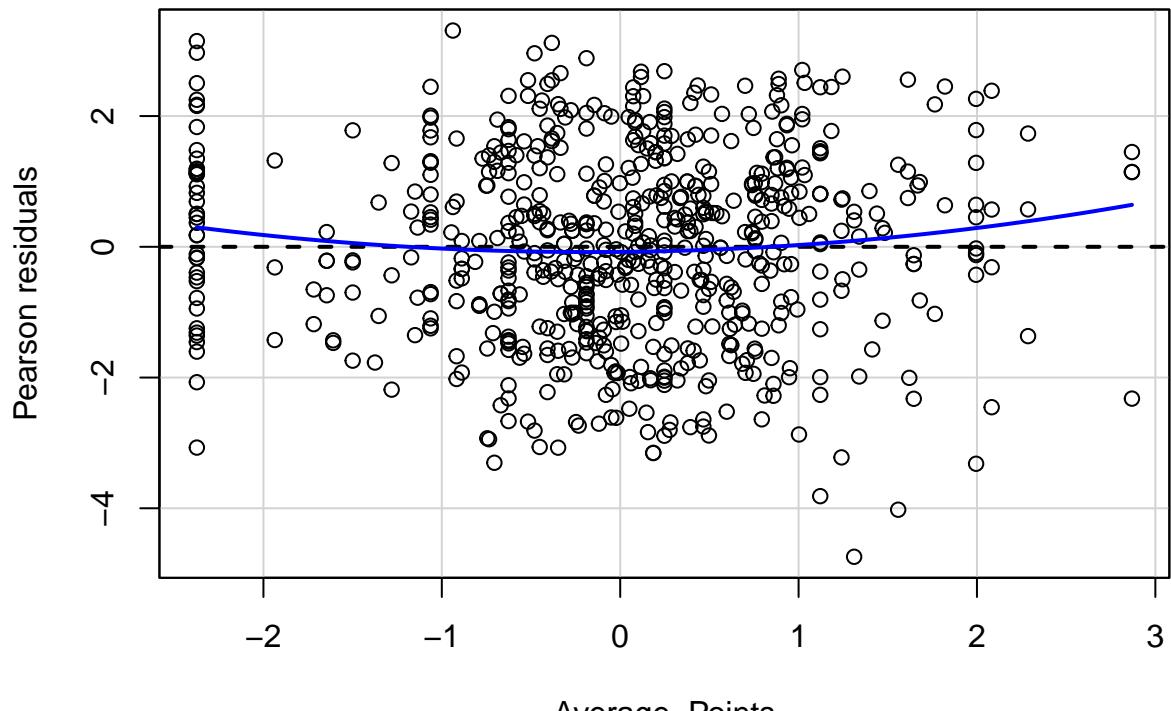
Added-Variable Plots

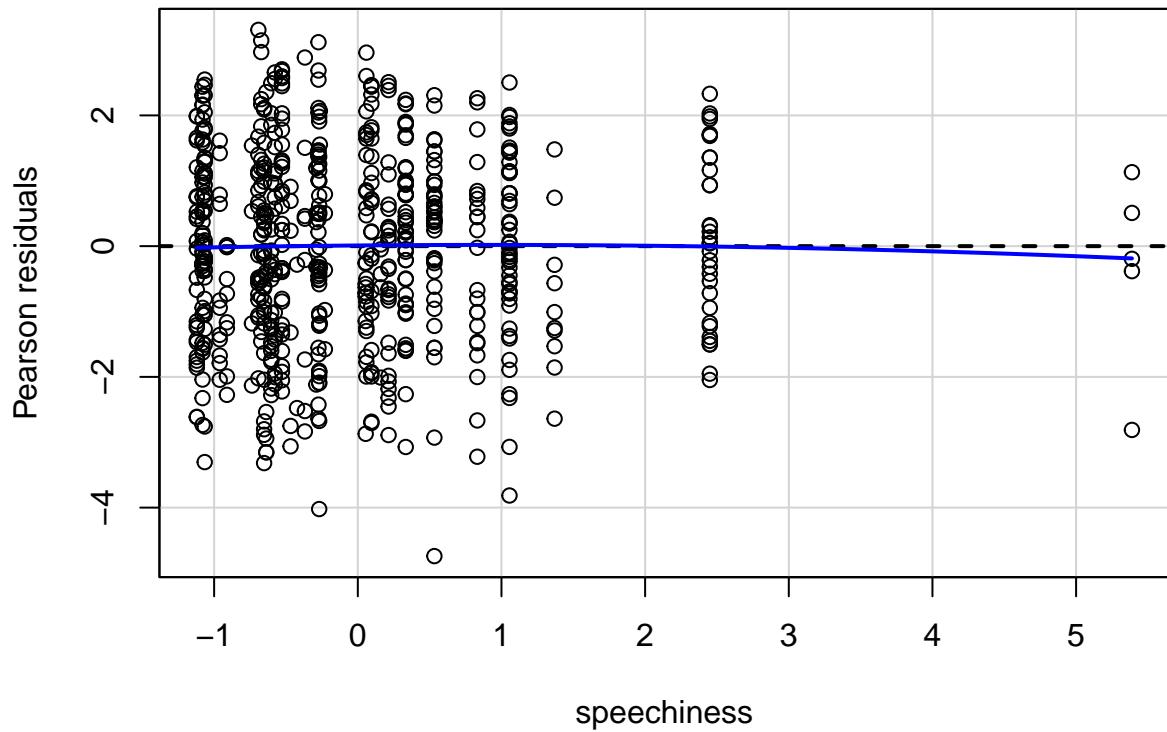


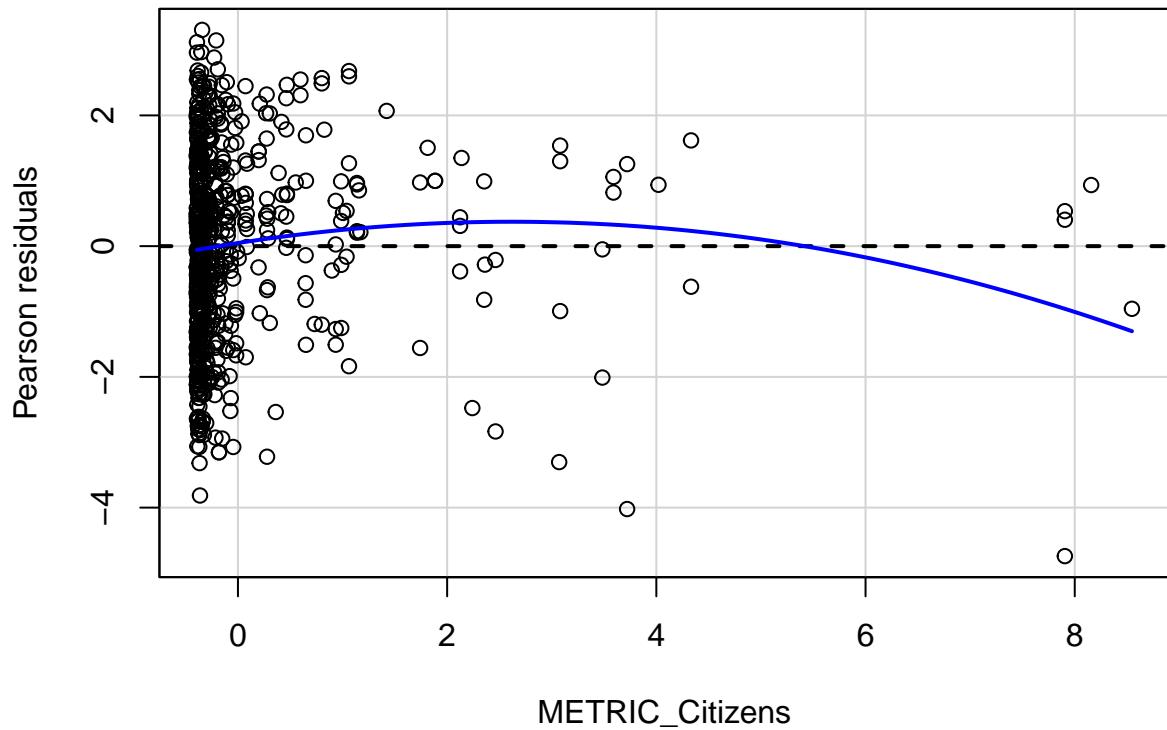
Cooks Distance Plot

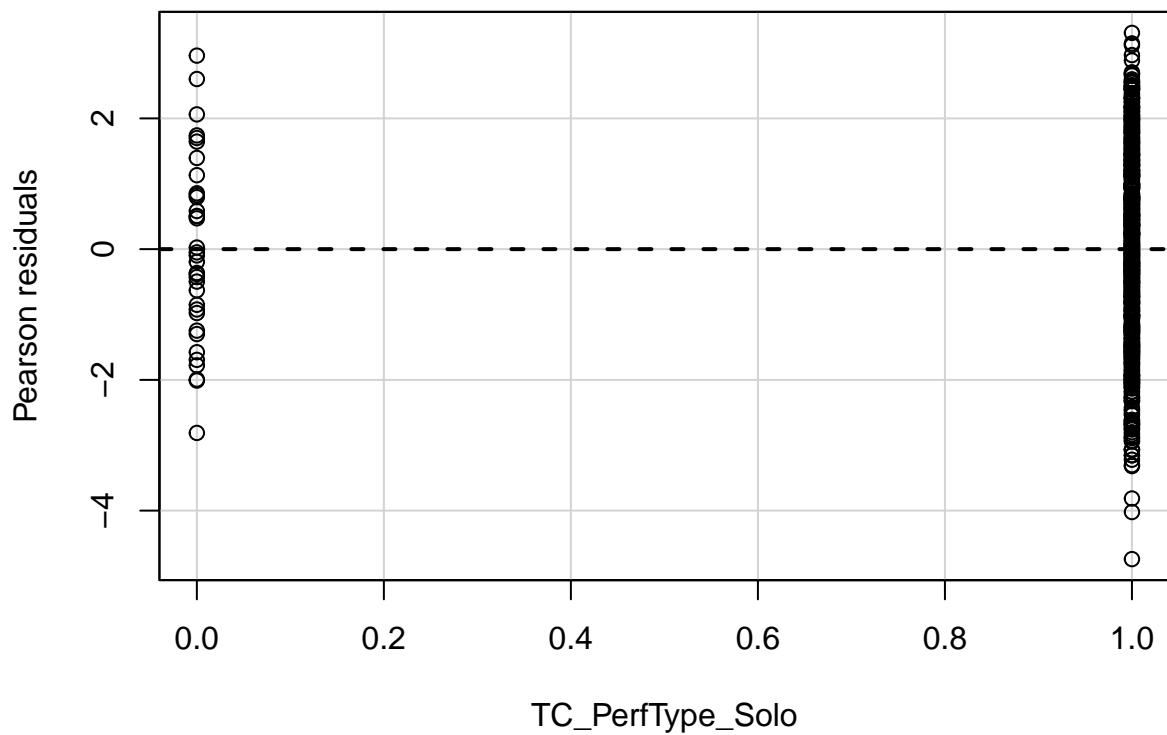


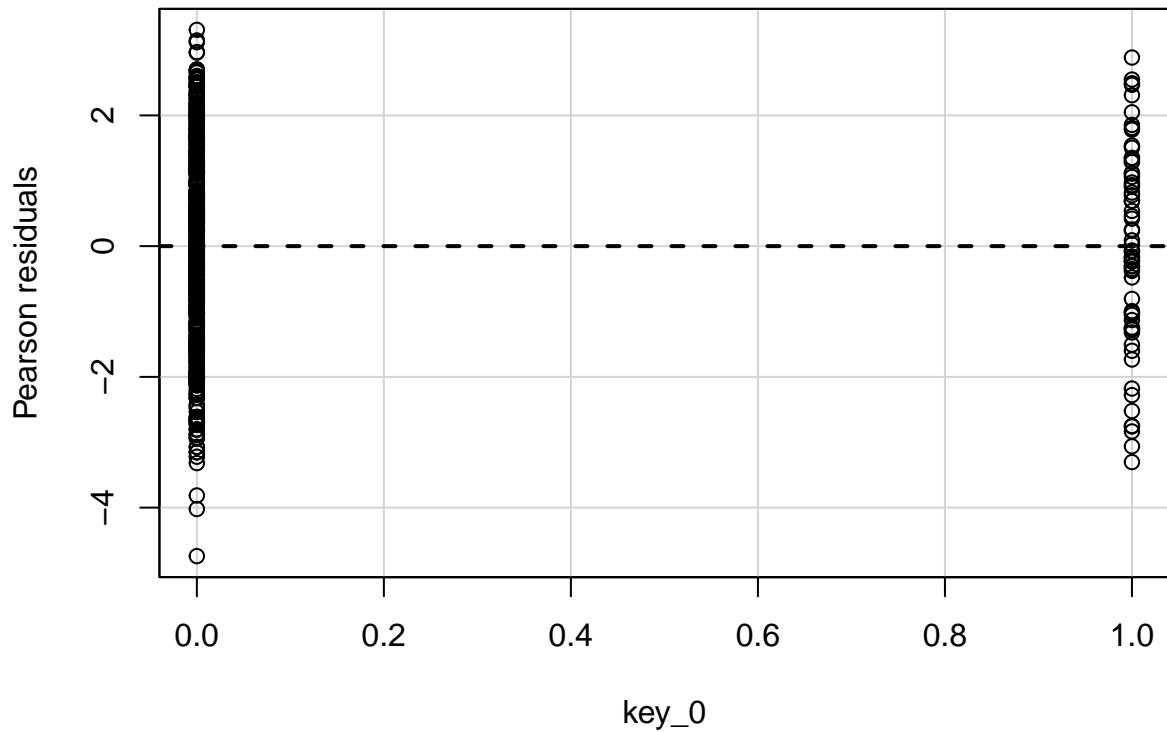
Residual Plots

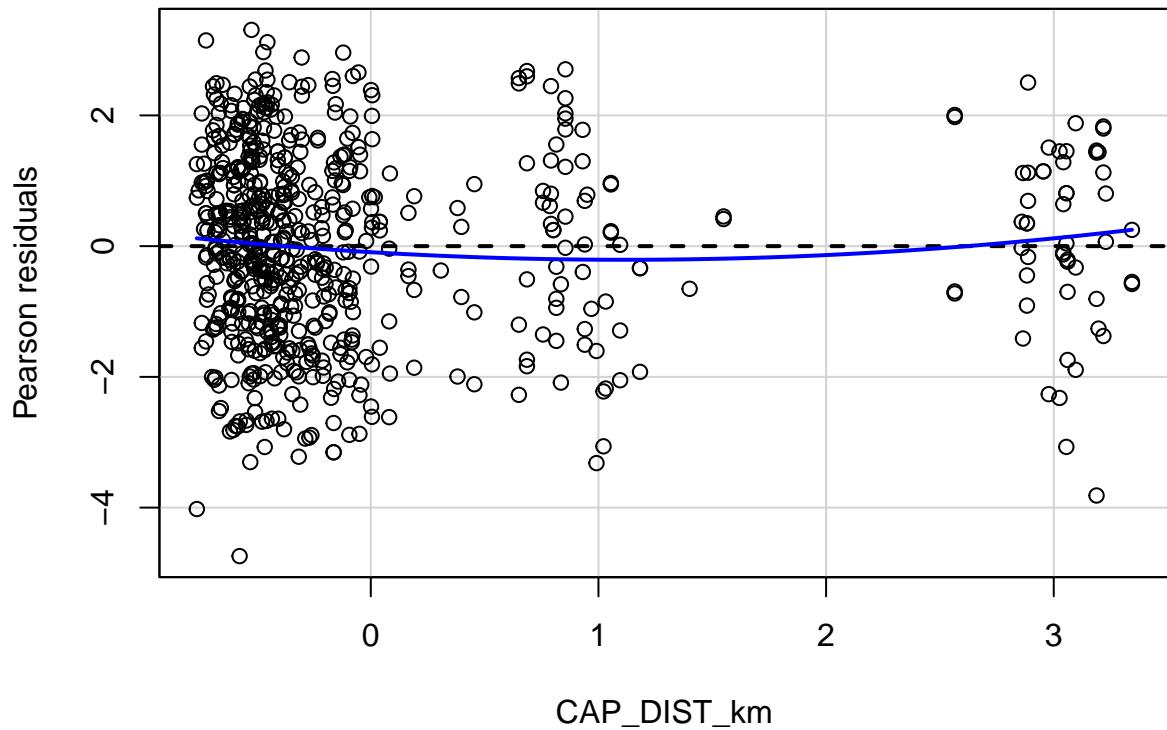


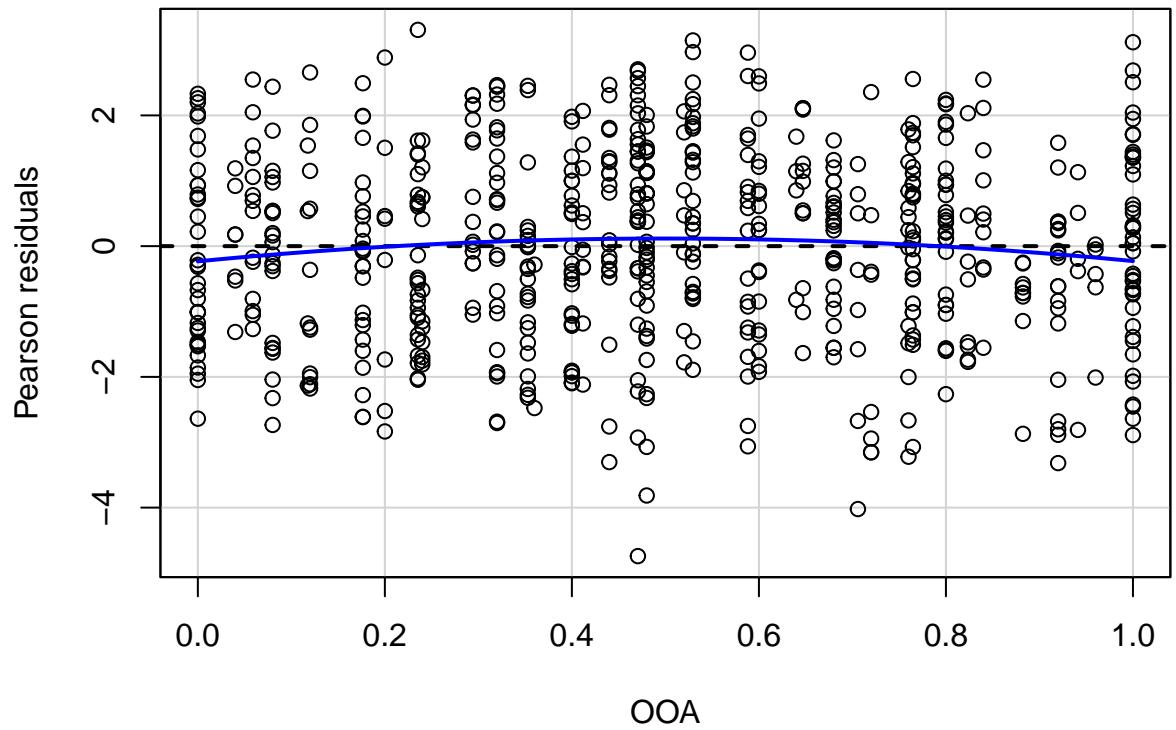


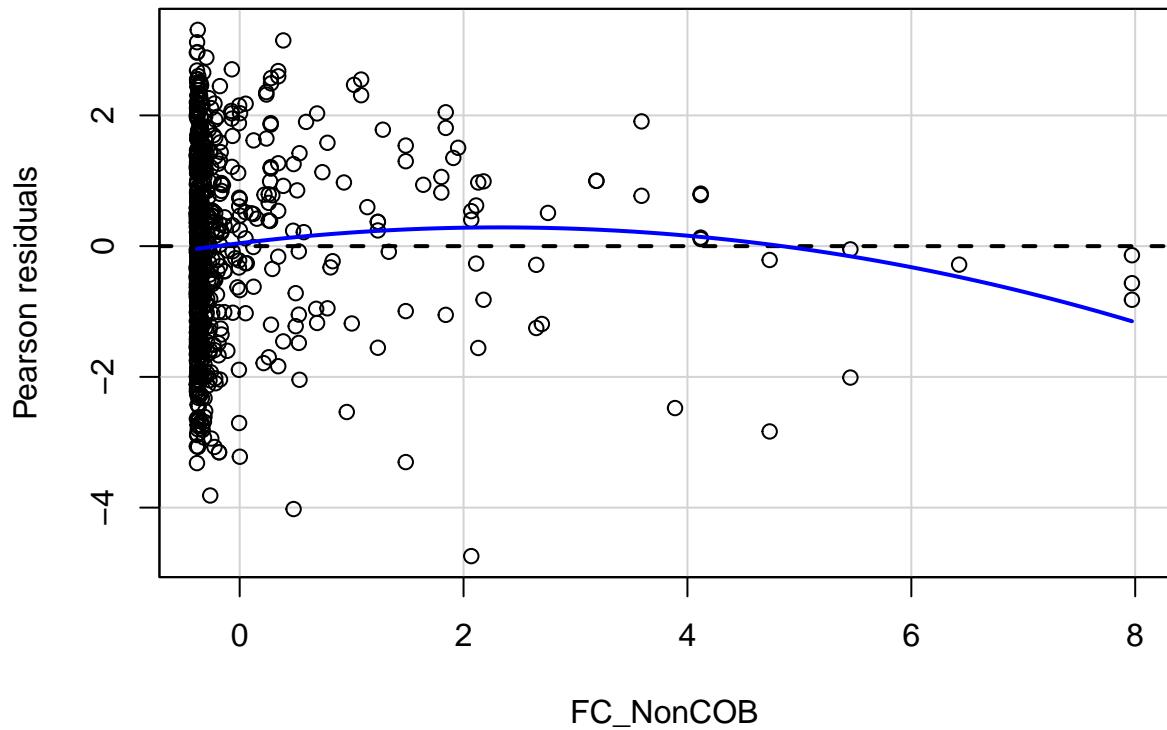


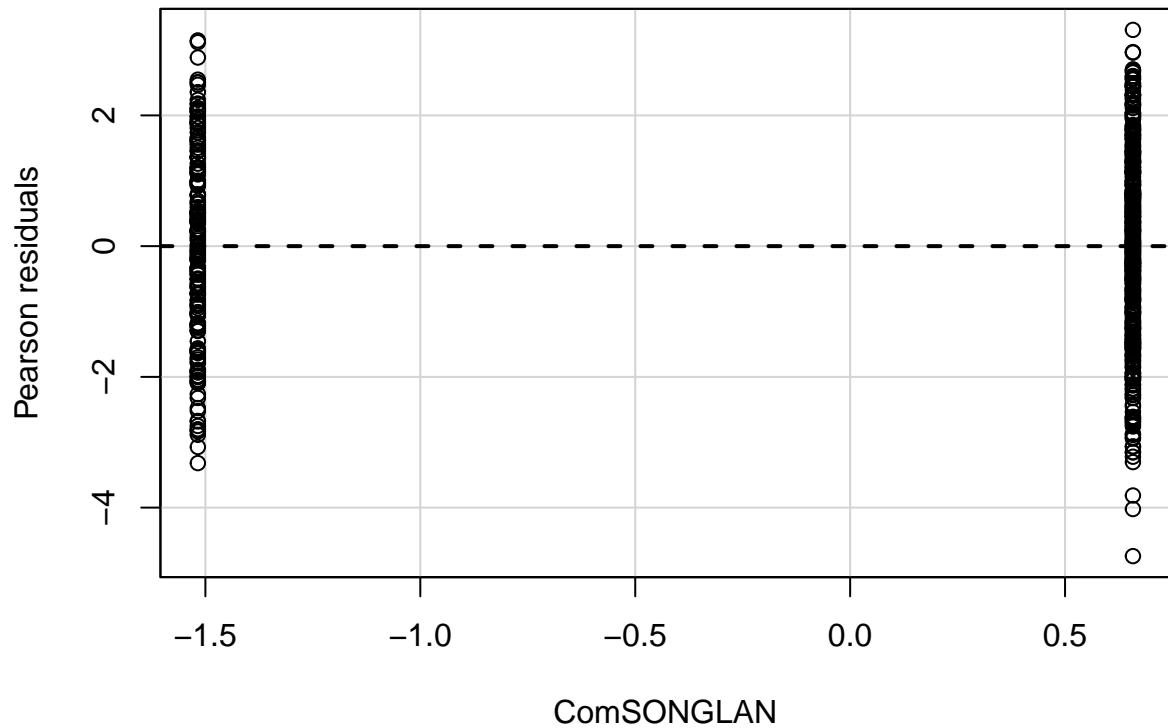


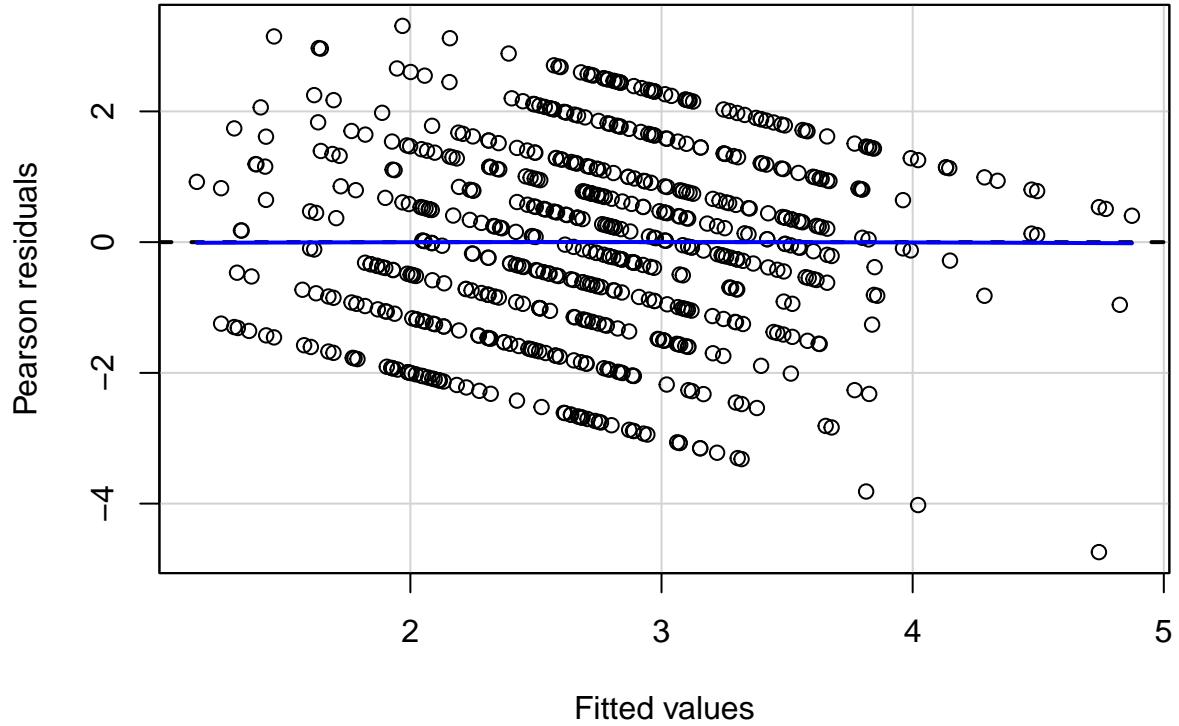












Influence Plot

```

## Warning in plot.window(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy, type, ...): "id.method" is not a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

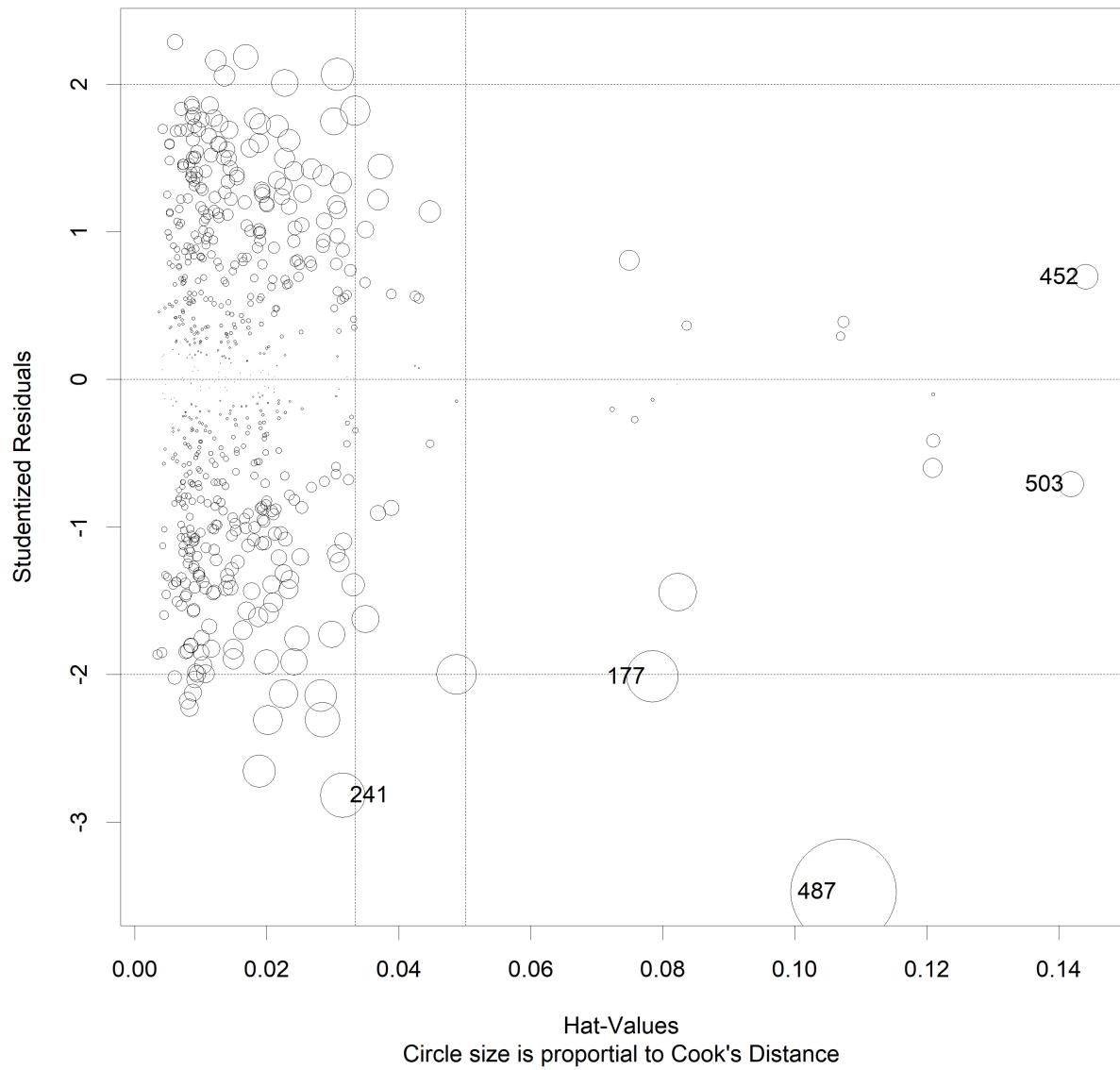
## Warning in box(...): "id.method" is not a graphical parameter

## Warning in title(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "id.method" is not a
## graphical parameter

```

Overall Model - Influence Plot



Normality Assumption

Normality Tests

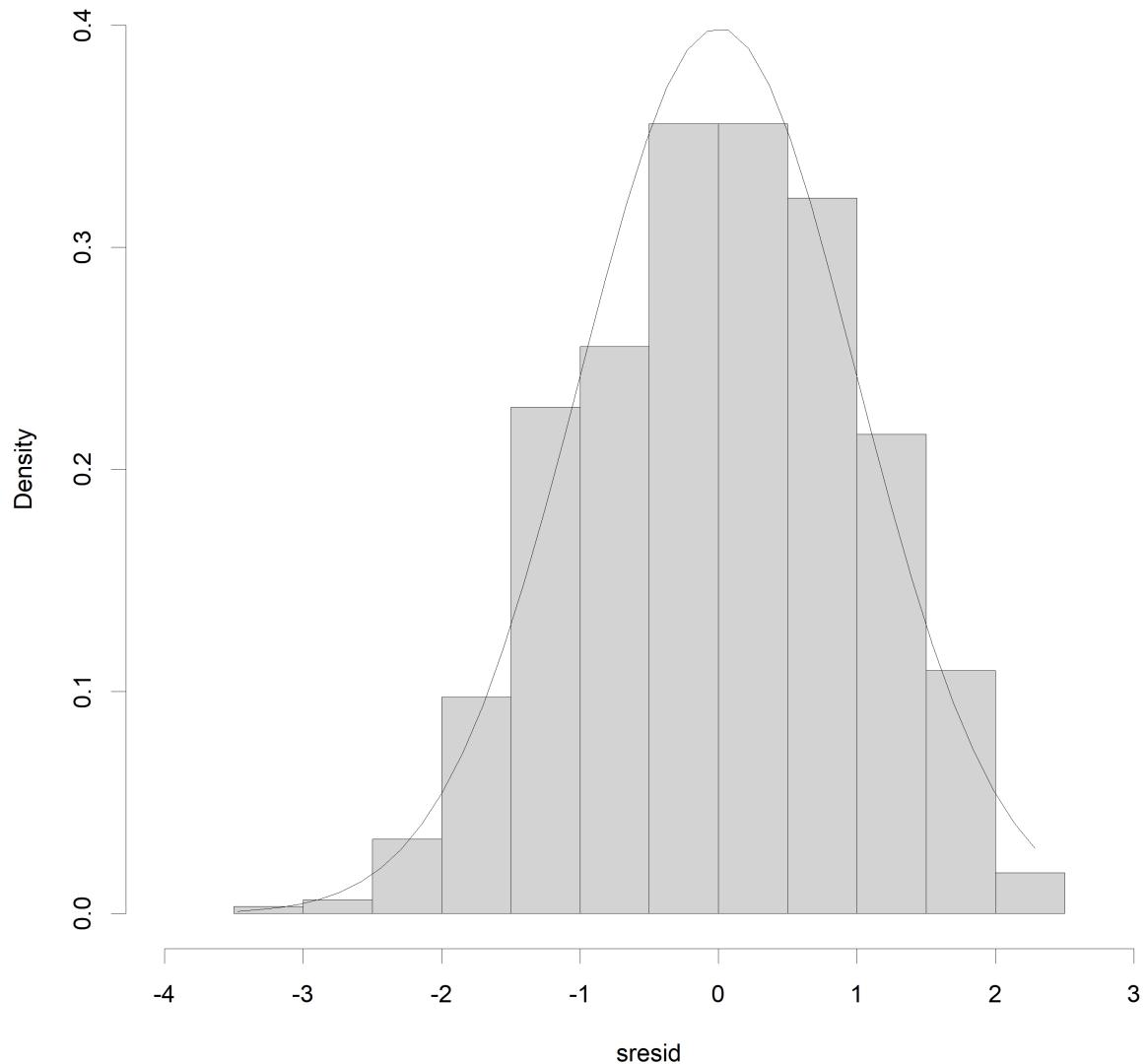
Normality Test

- 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

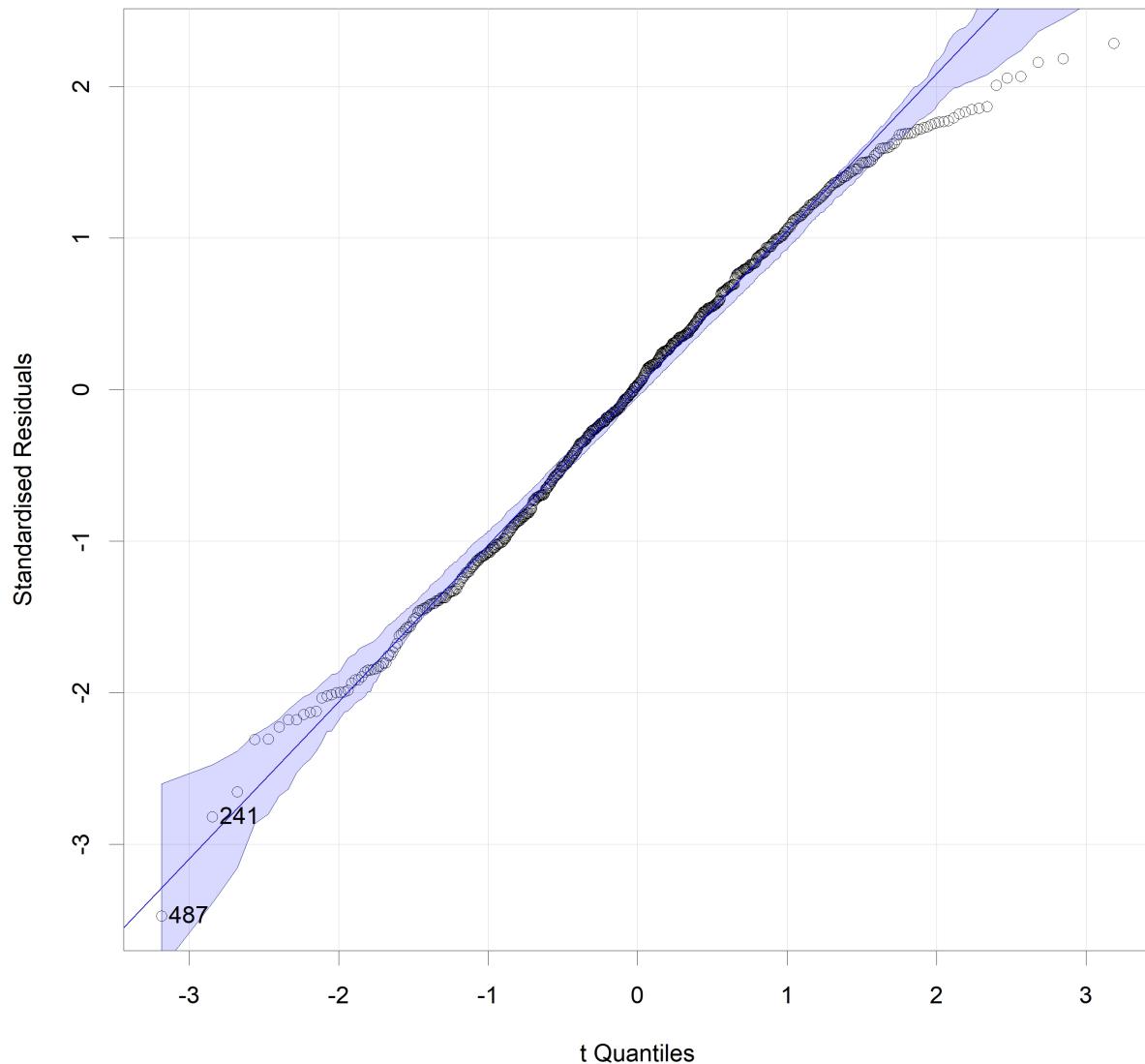
Residual Histogram

Overall Model - Distribution of Standardised Residuals



Residual QQ-Plot

QQ-Plot of Overall Model Standardised Residuals



Constant Variance Assumption

Non-Constant Variance Test

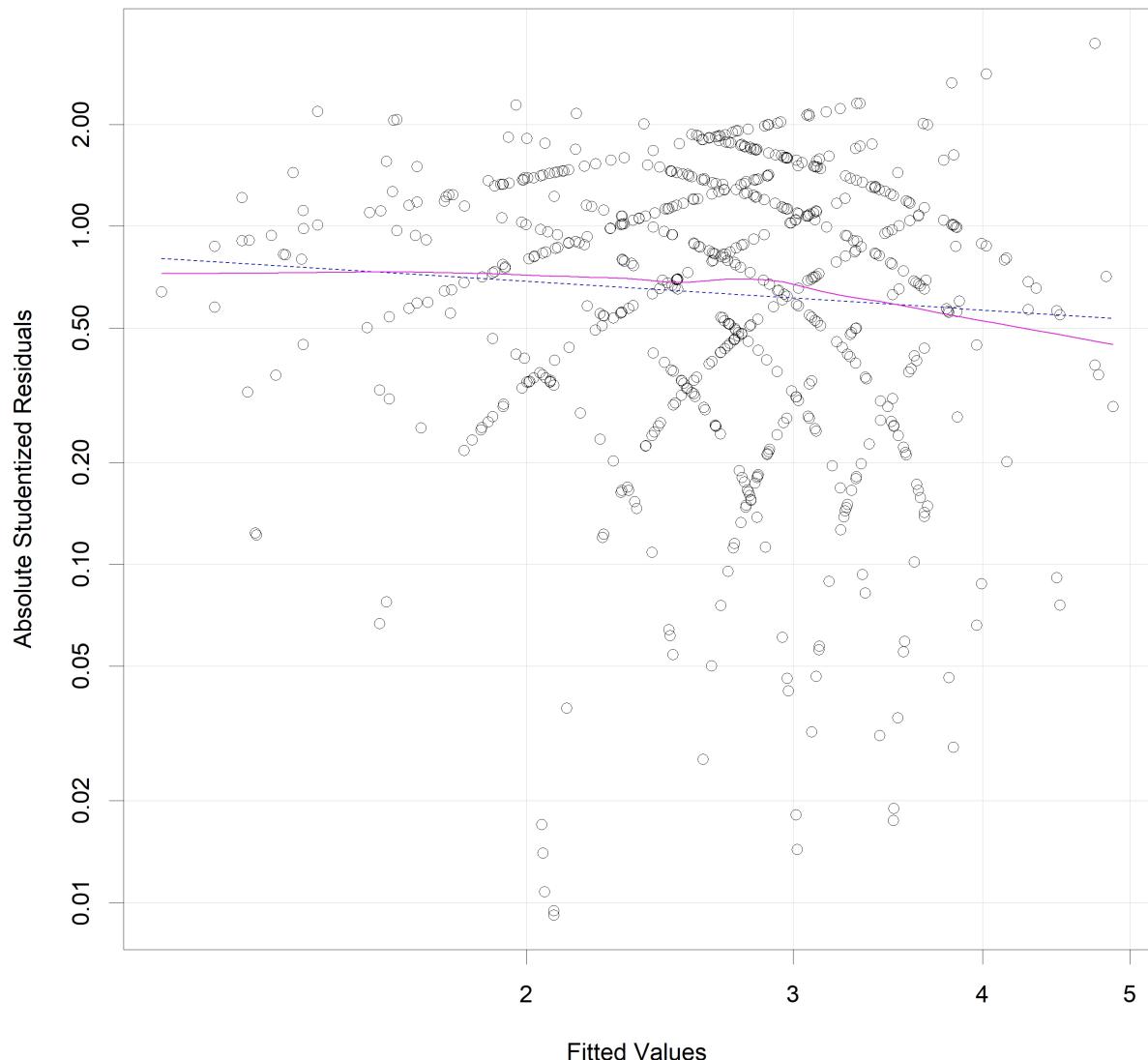
Non-Constant Error Variance Test

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

Non-constant Variance Score Test	
Chi-Sq Statistic	0.03663
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

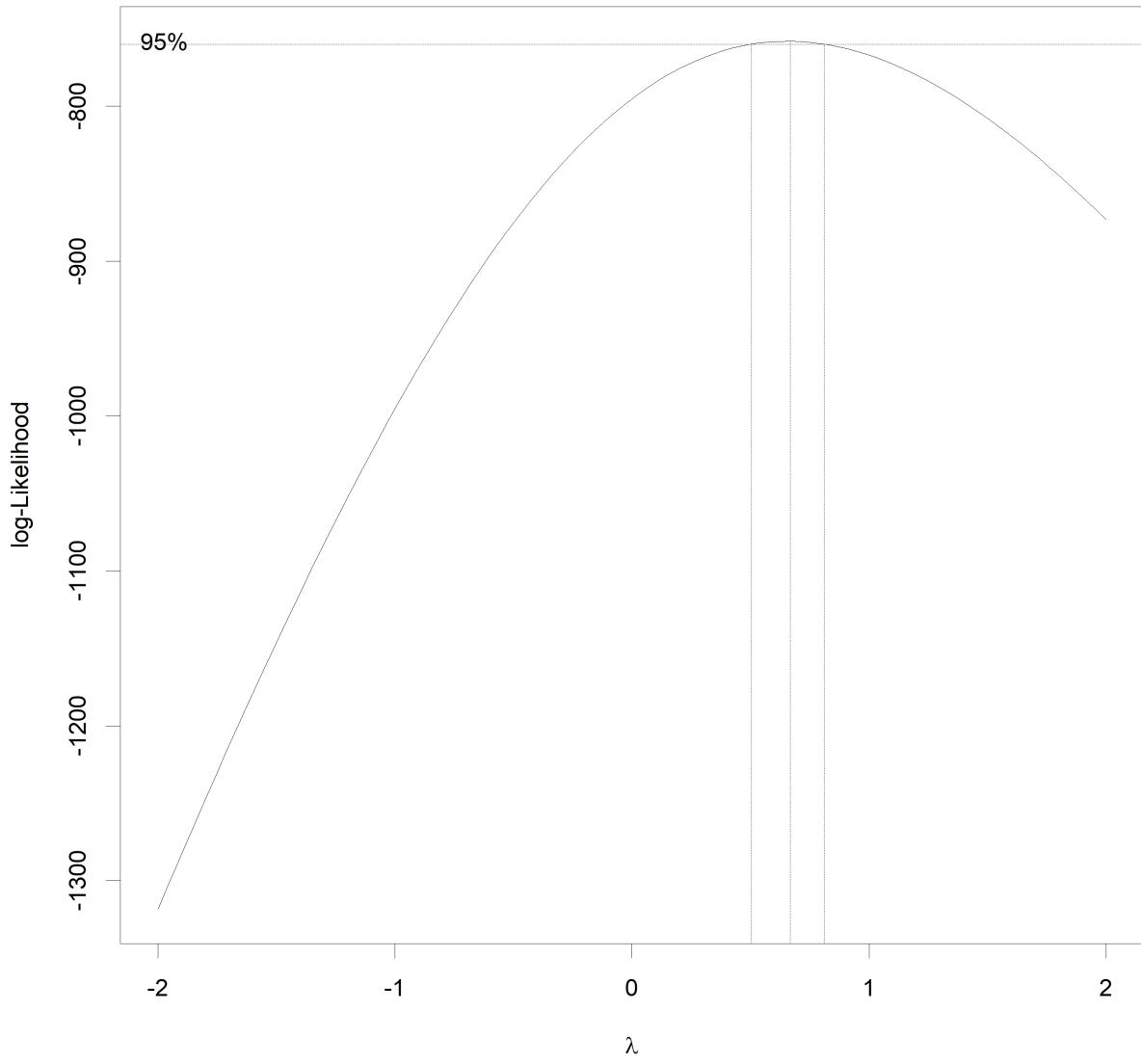
Televote Model

```
##  
## 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
```

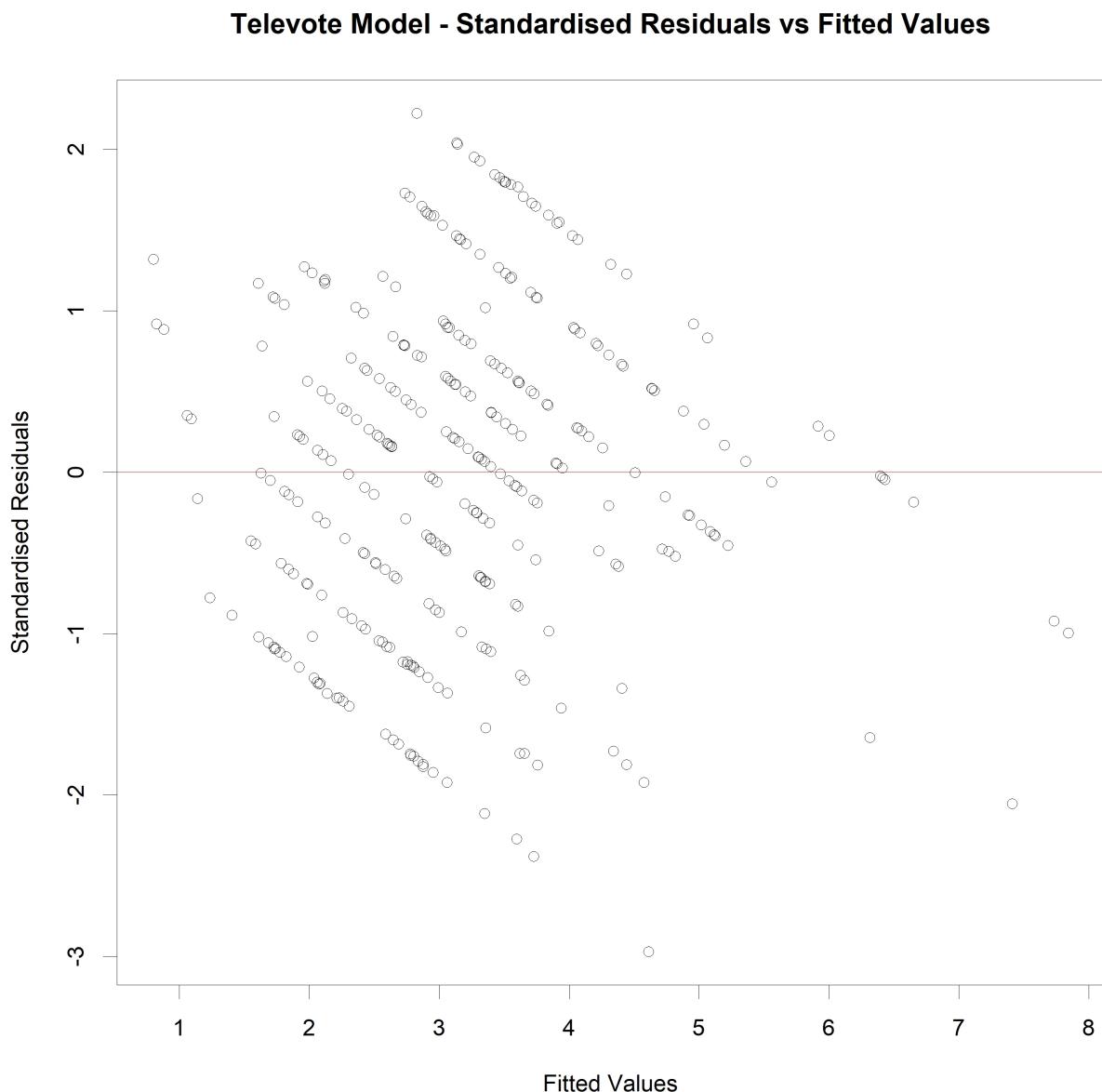
Response Variable Transformation

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

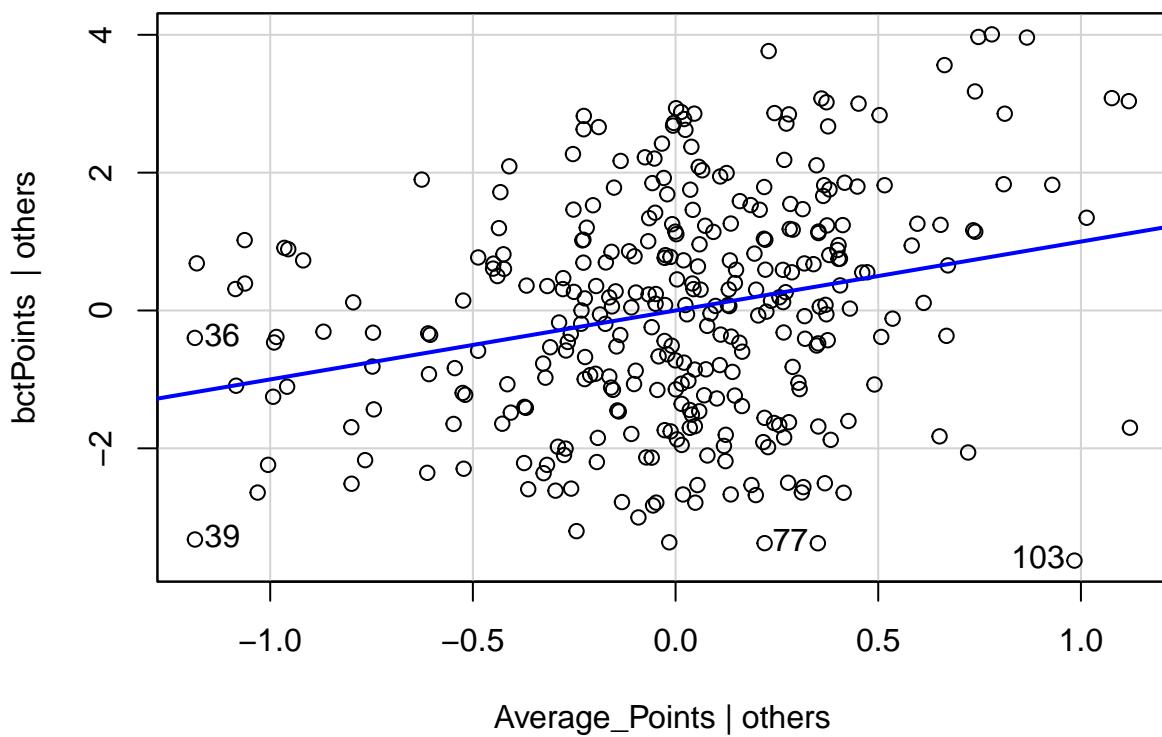
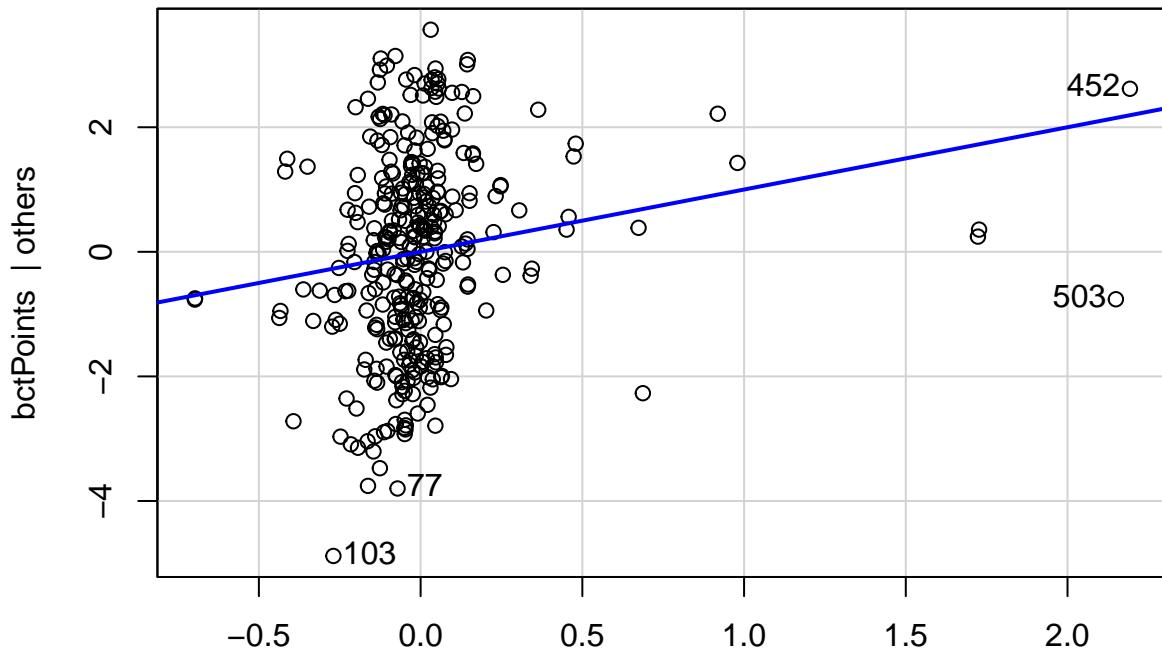
Bonferroni Outlier Test

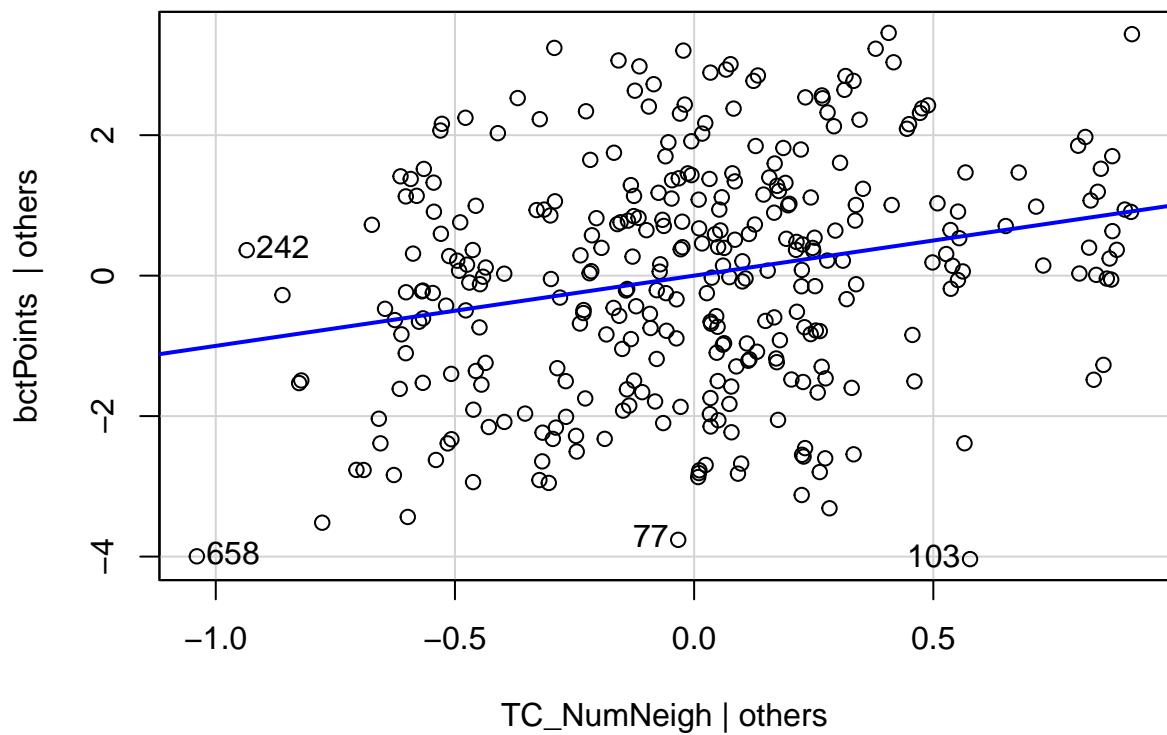
	rstudent	p	bonf.p	signif	cutoff
103	-2.970711	0.0031989	1.046038	0	0.05

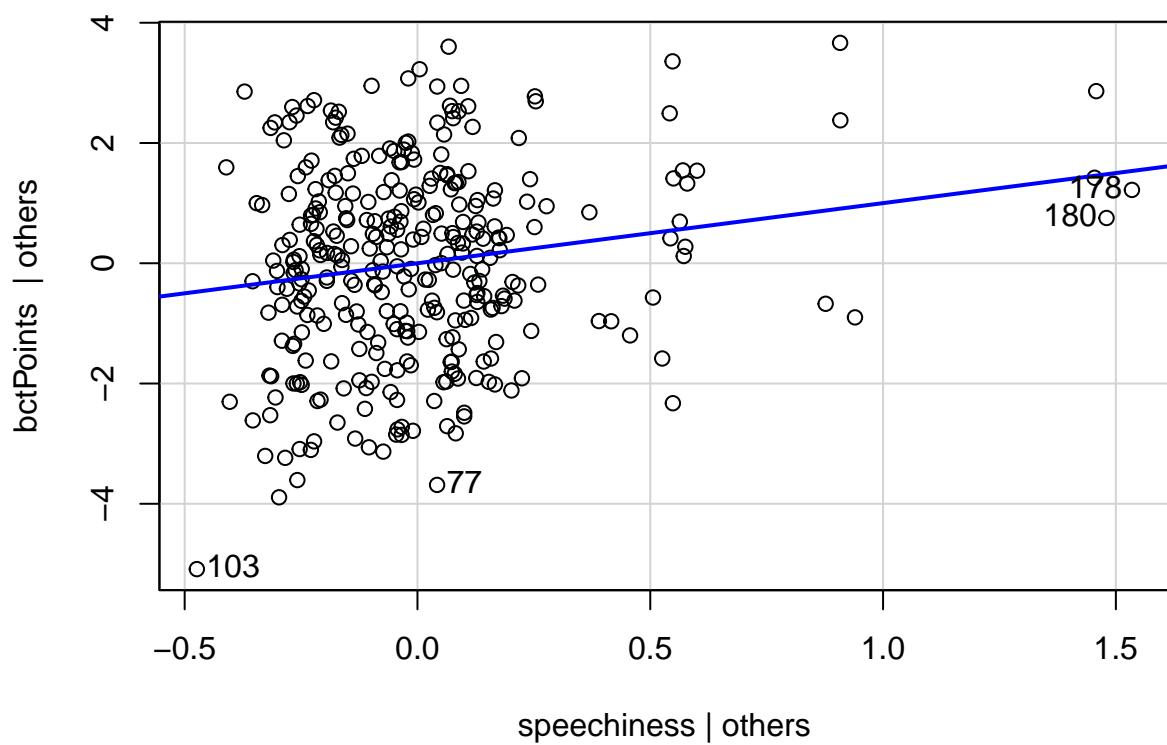
Residual Outliers

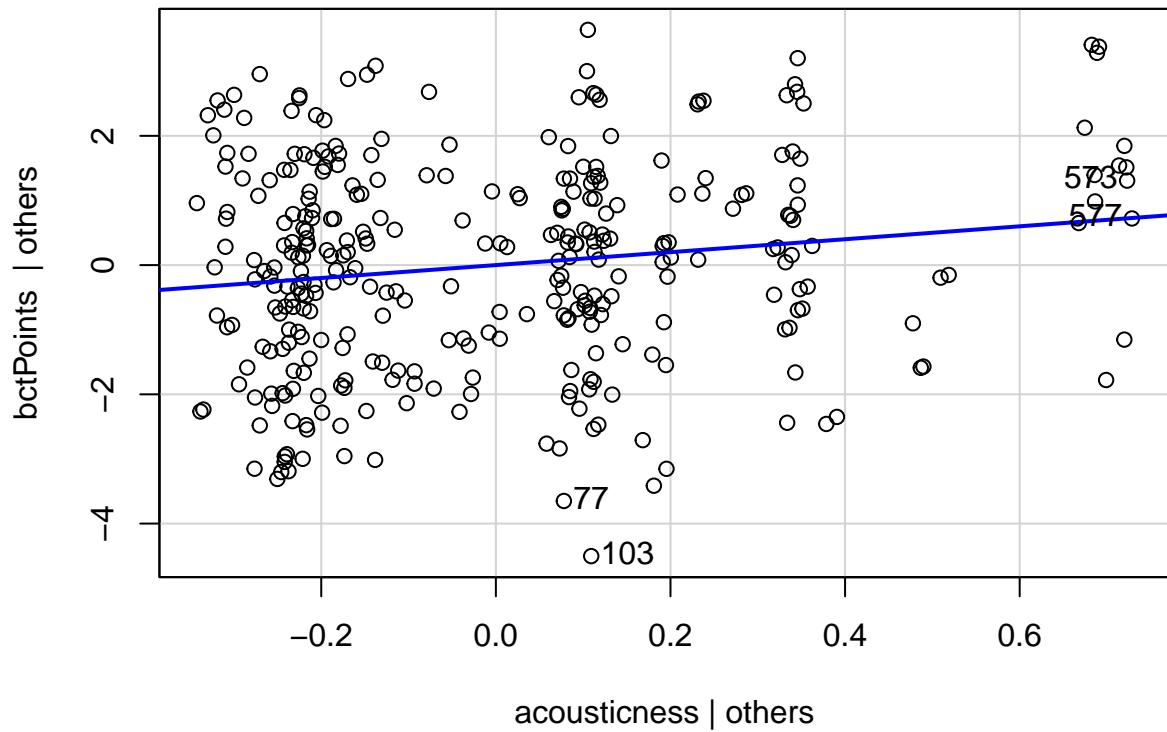
outlier_residuals
77
88
101
103
503

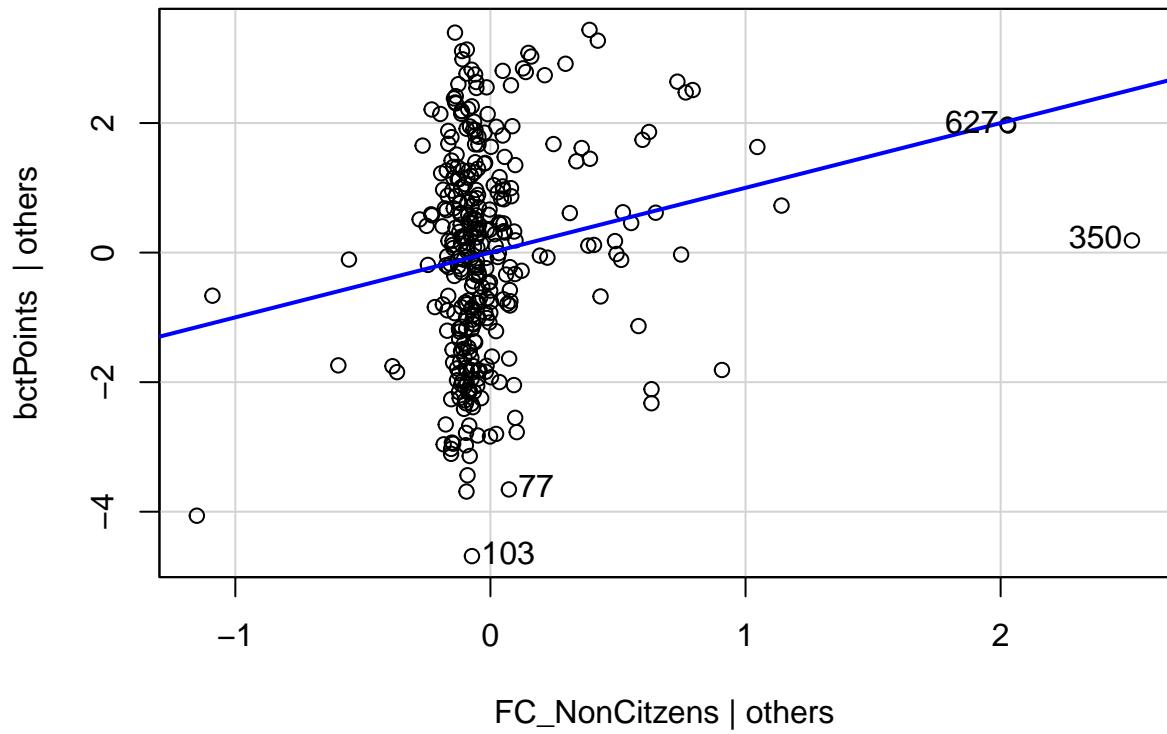
Leverage Plots

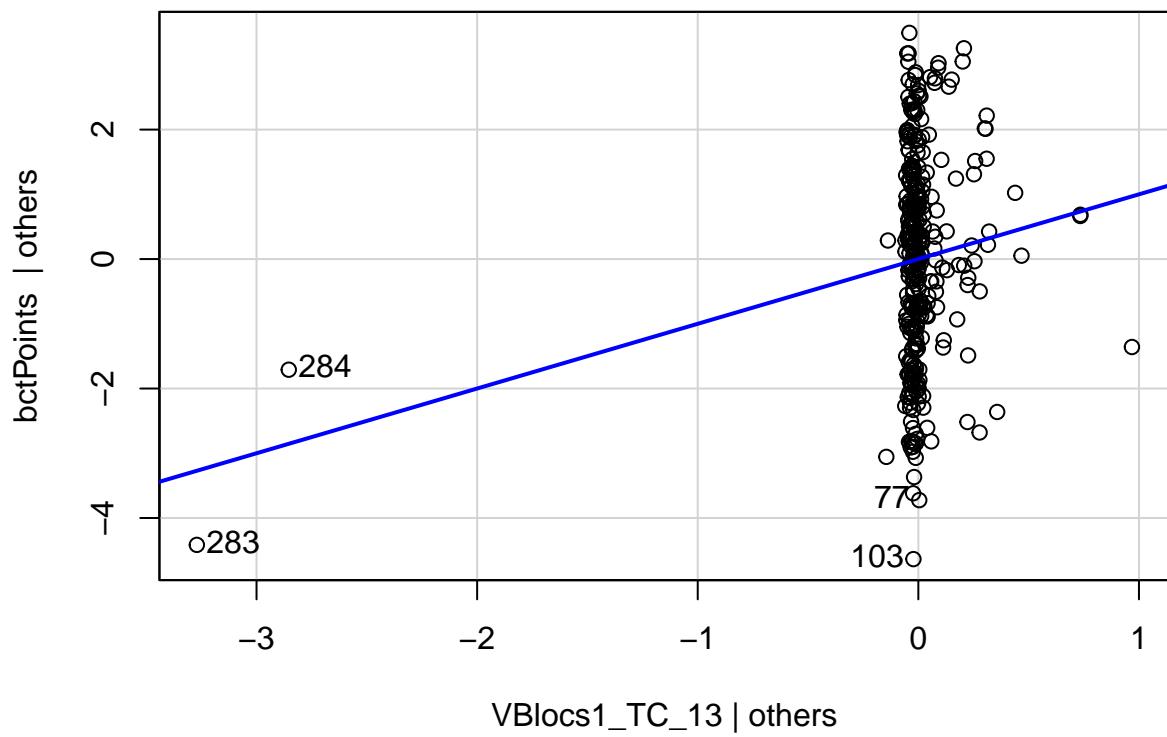


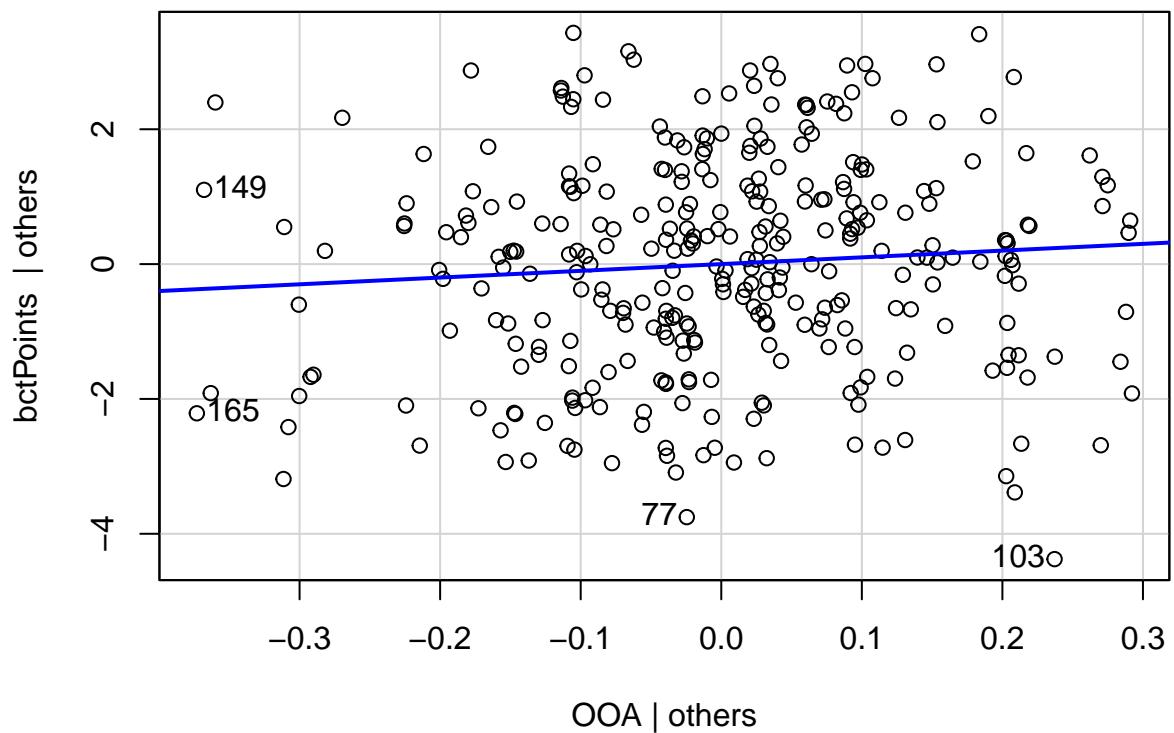




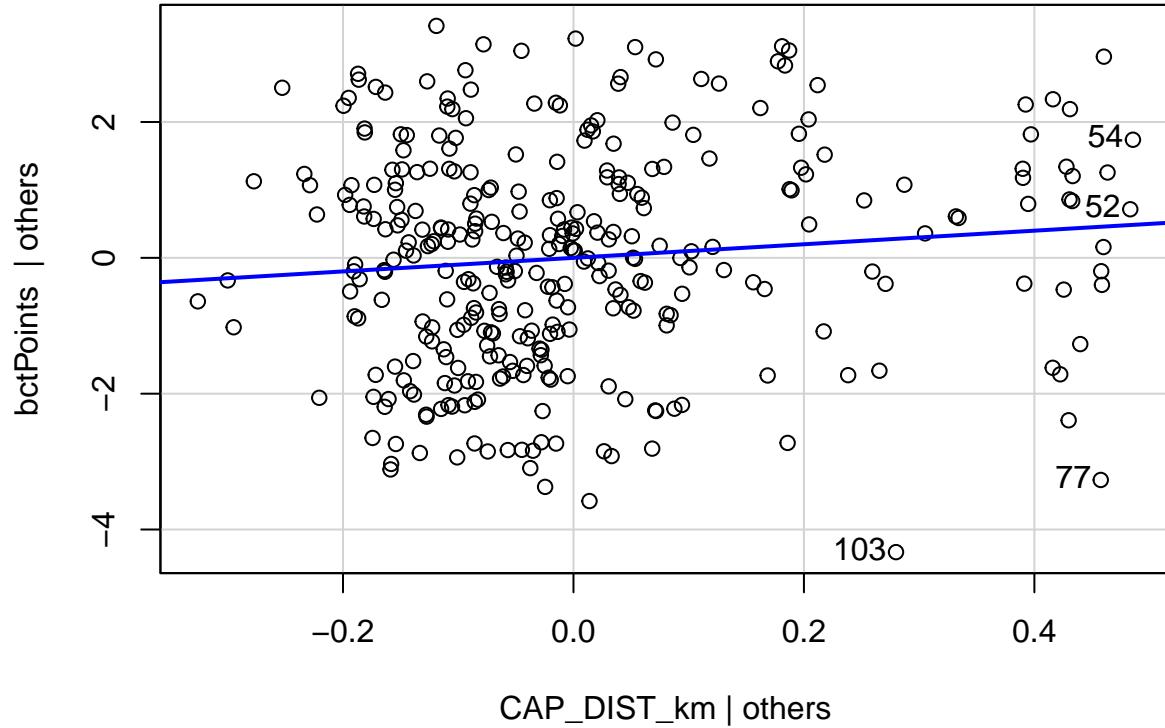




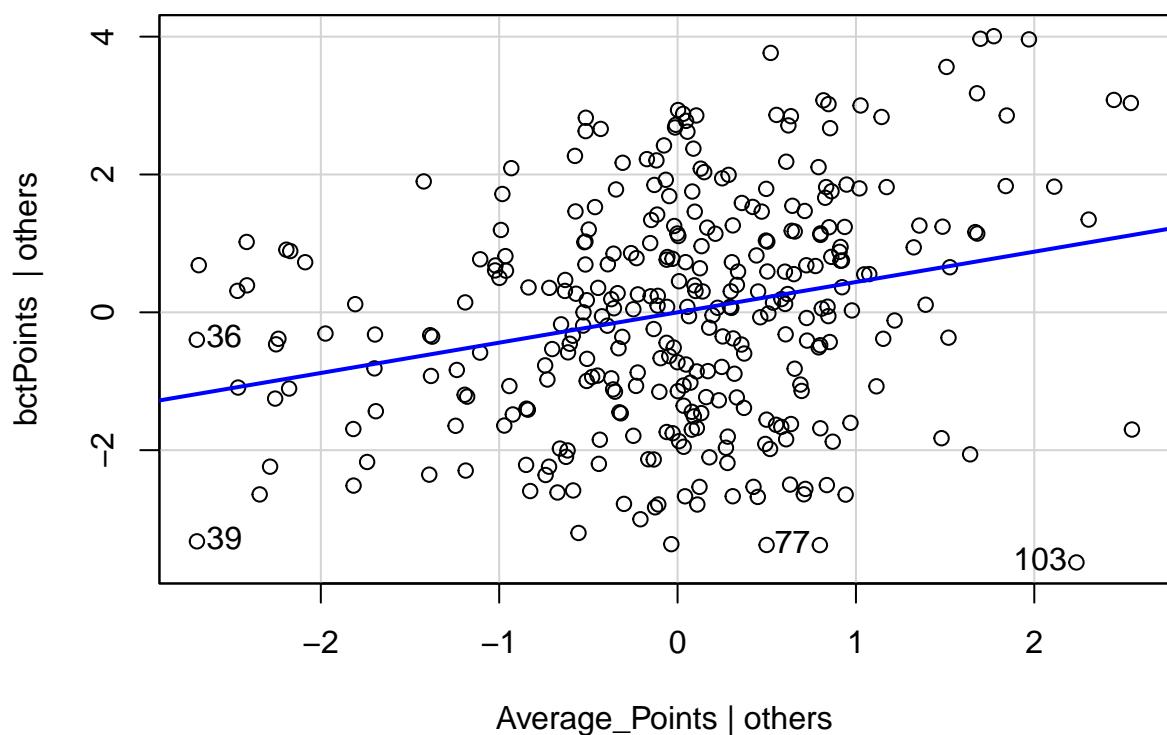
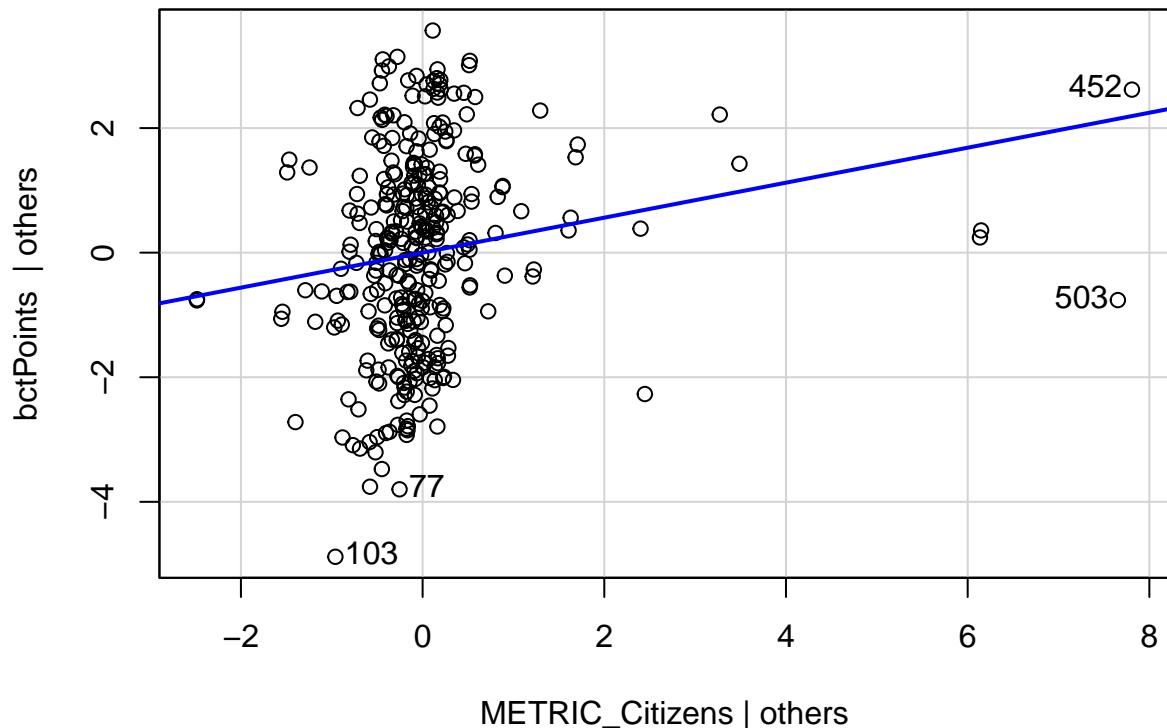


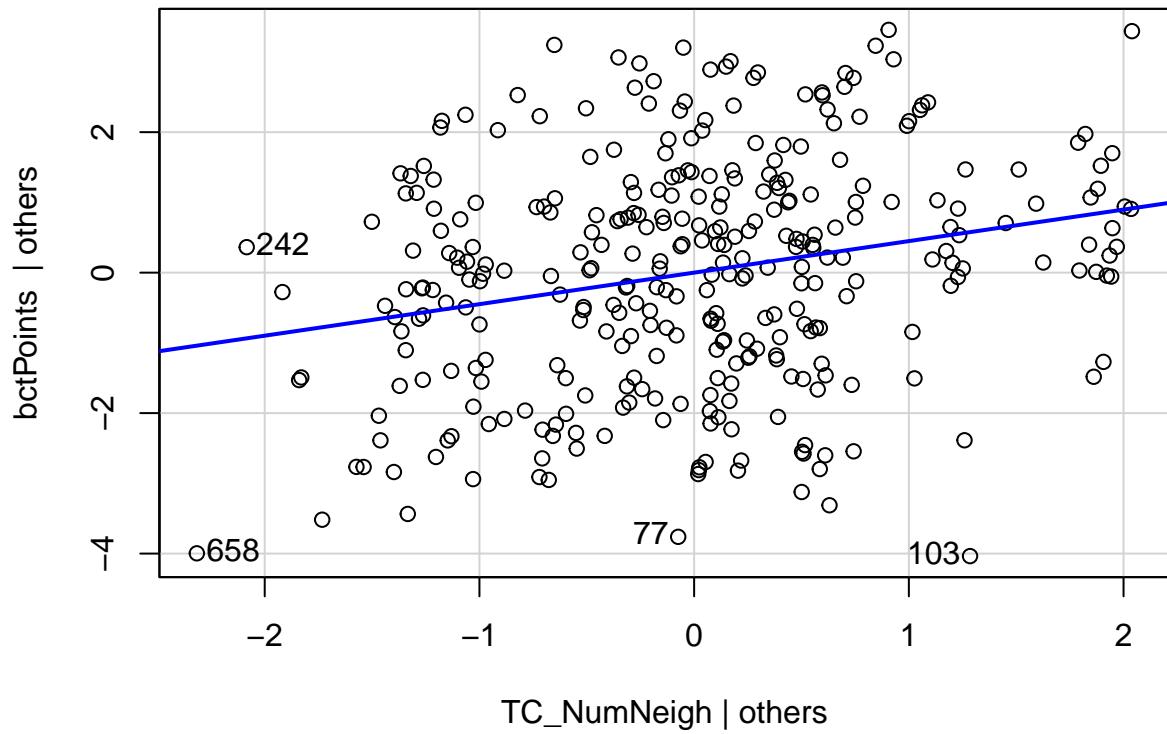


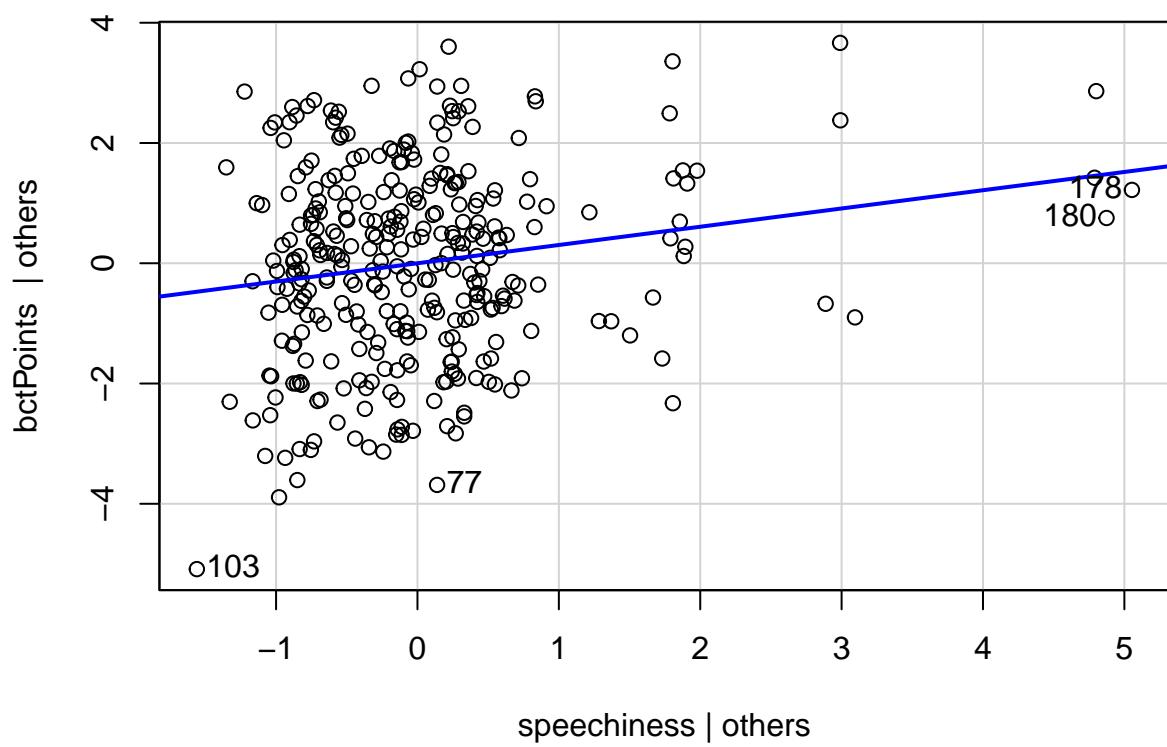
Leverage Plots

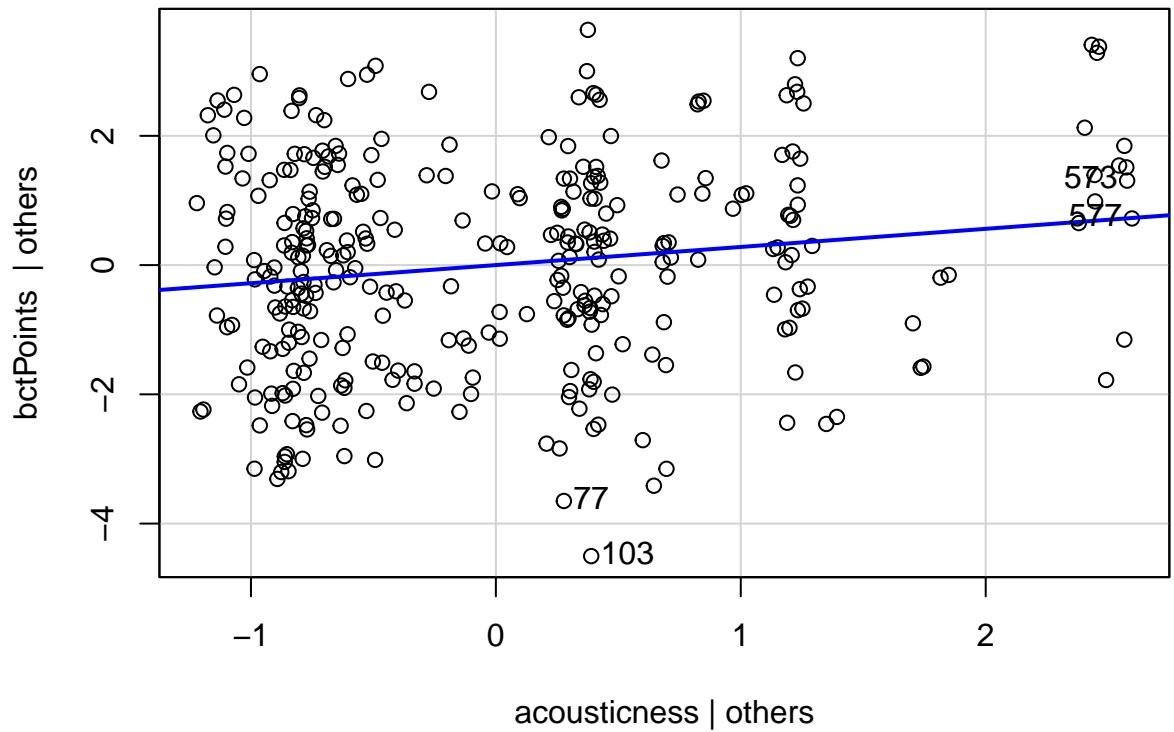


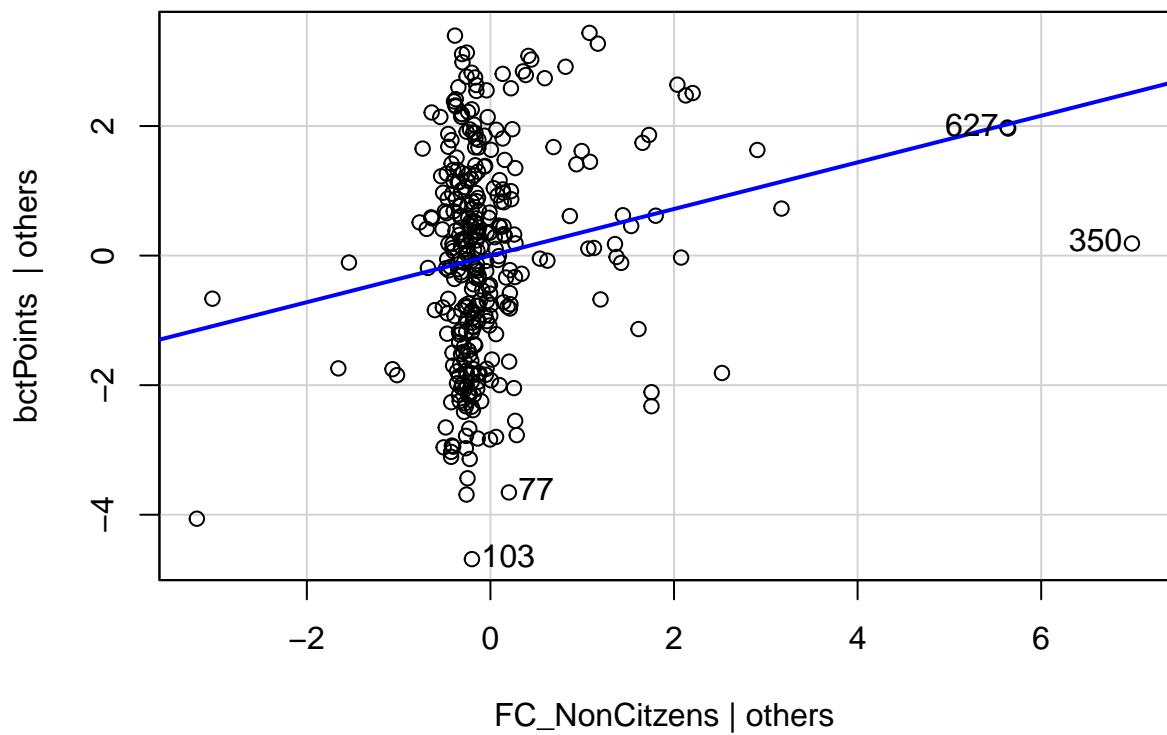
Added Variable Plots

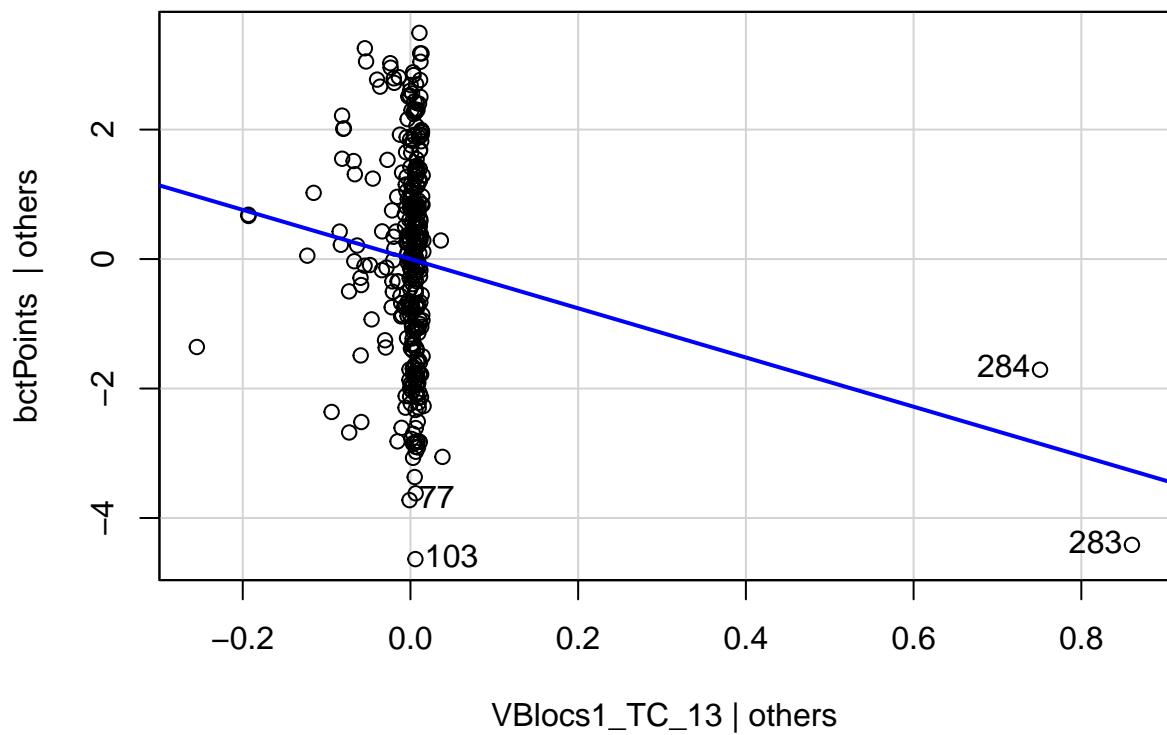


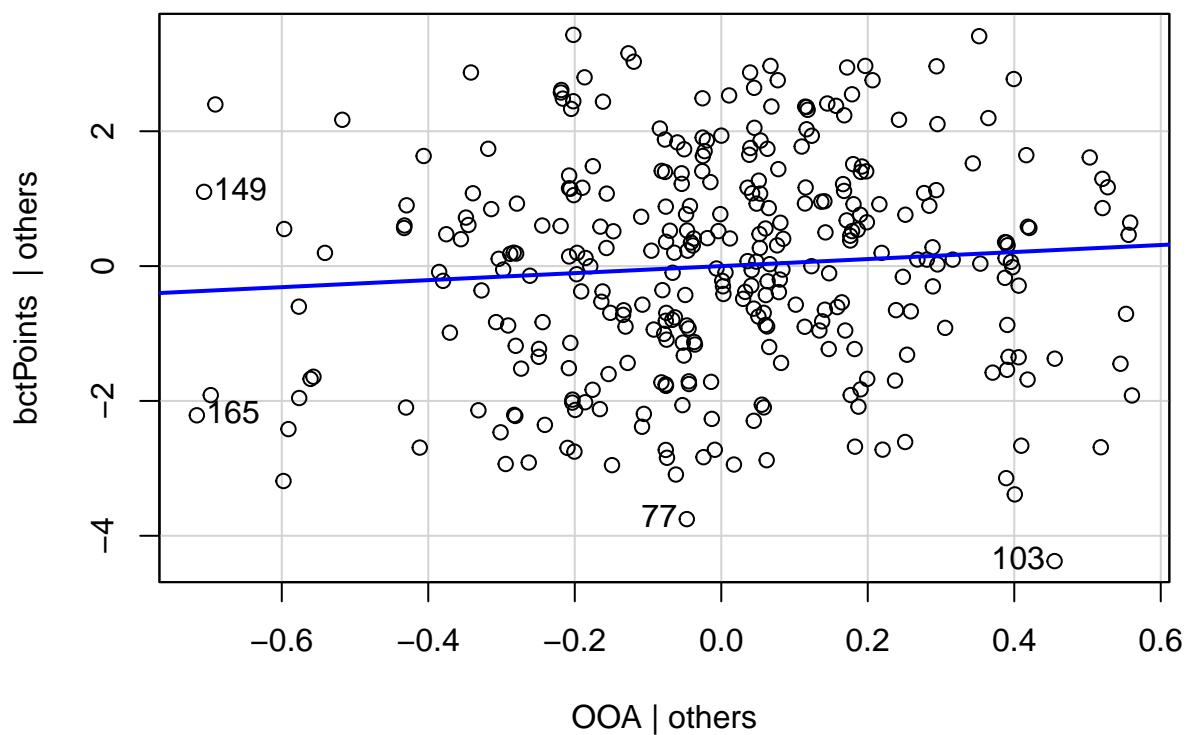




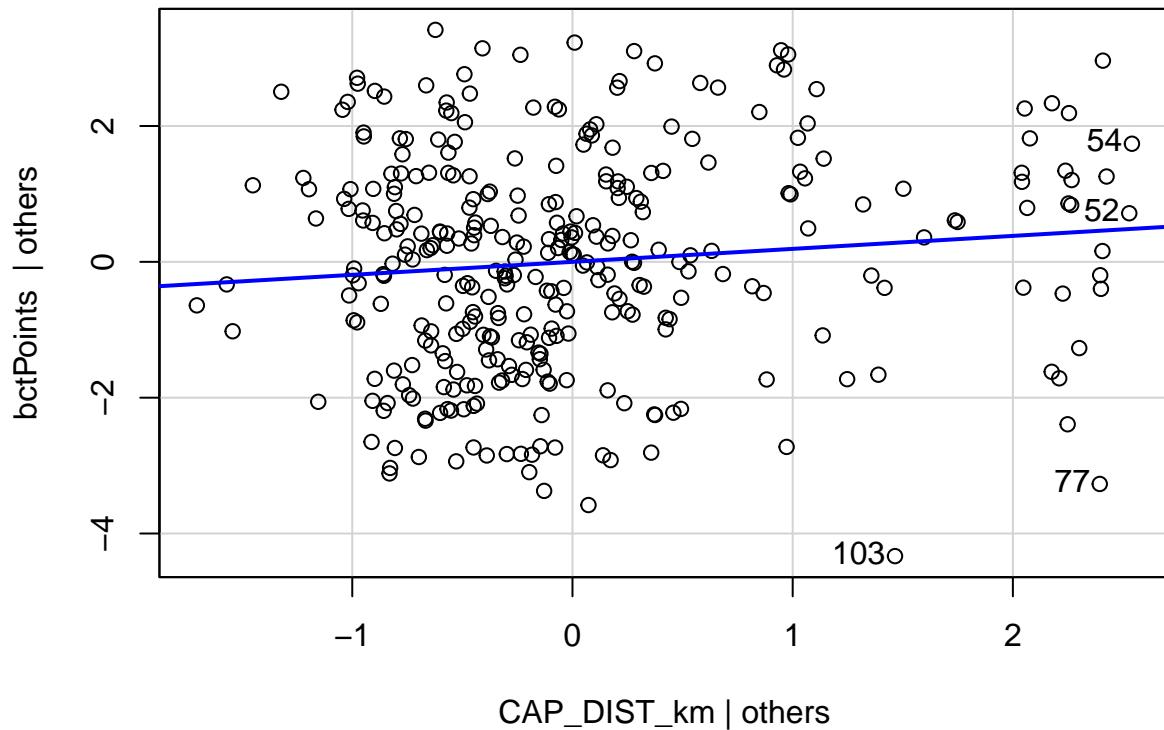




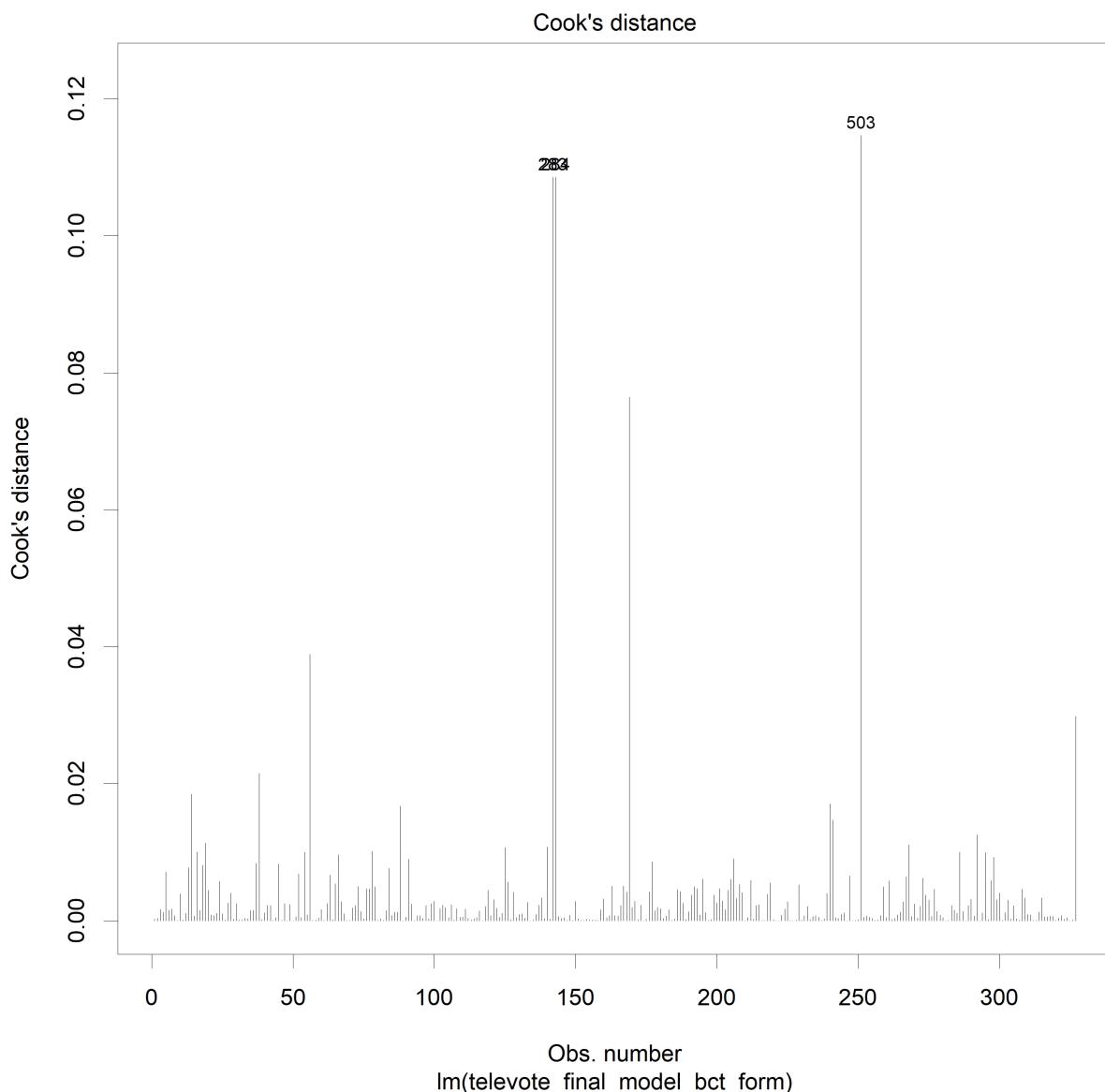




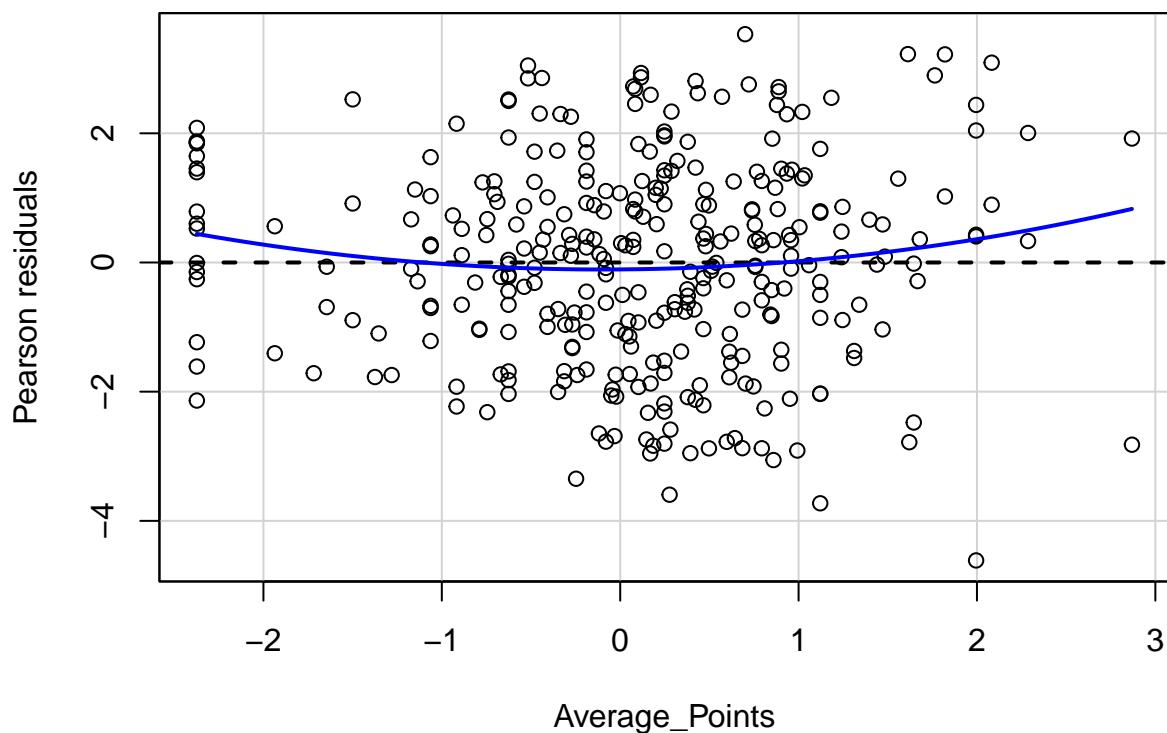
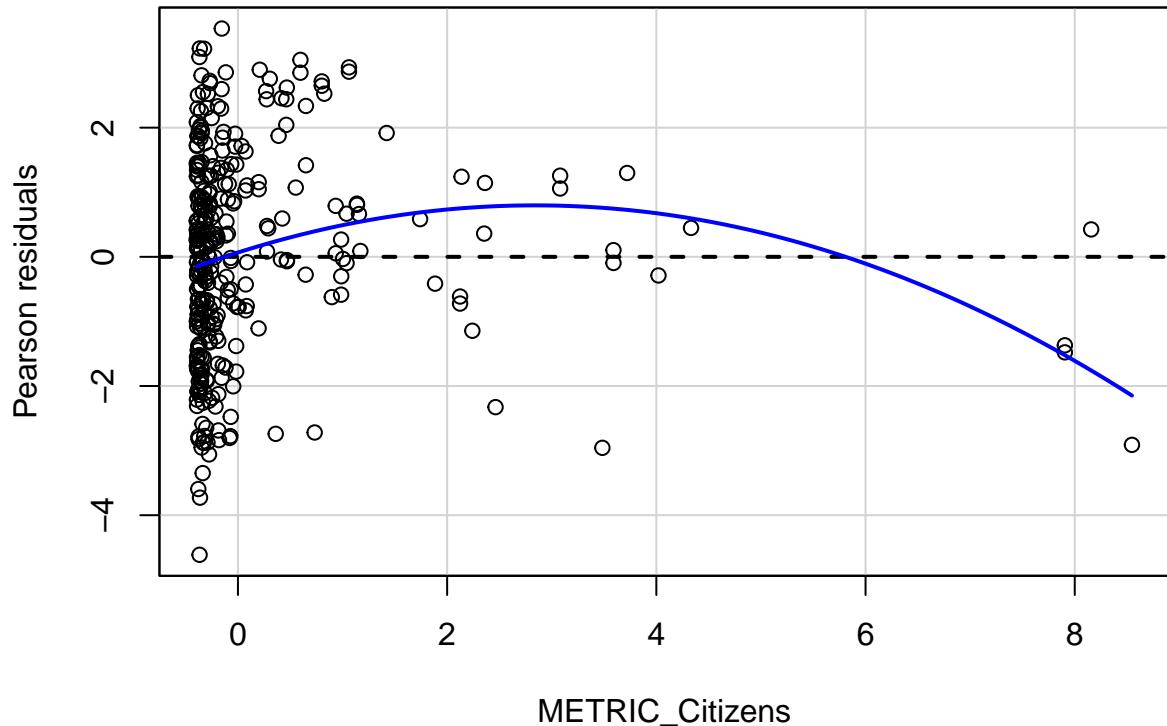
Added-Variable Plots

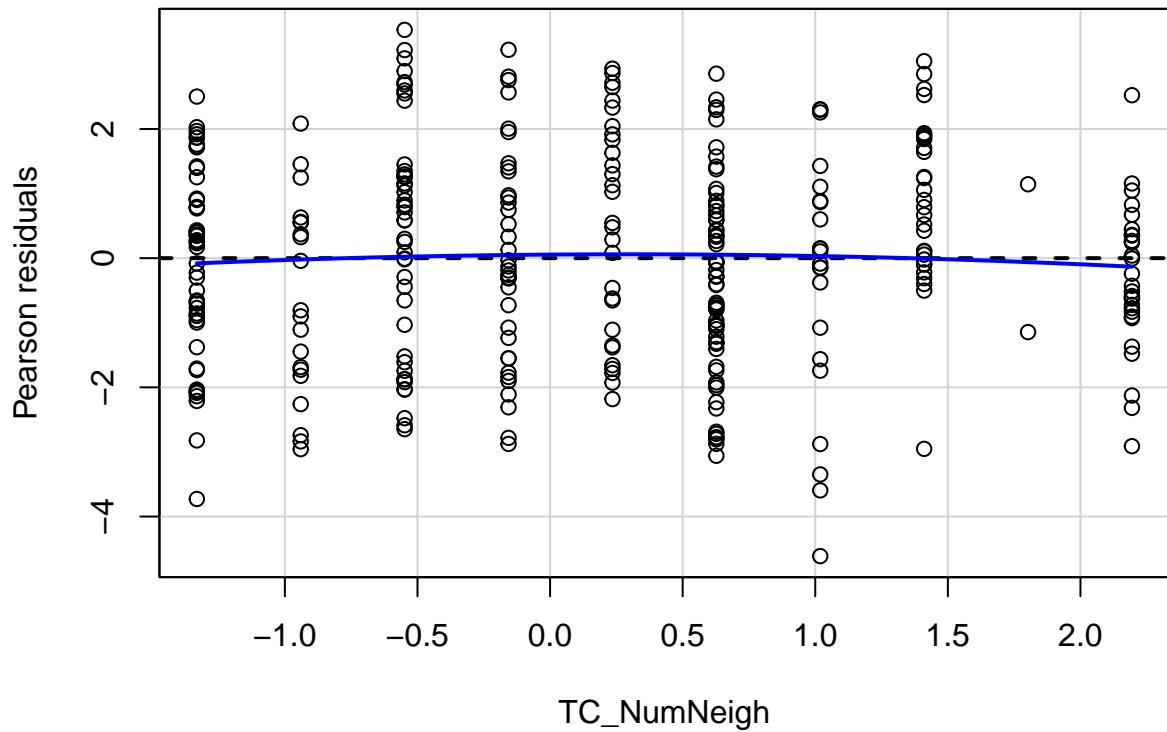


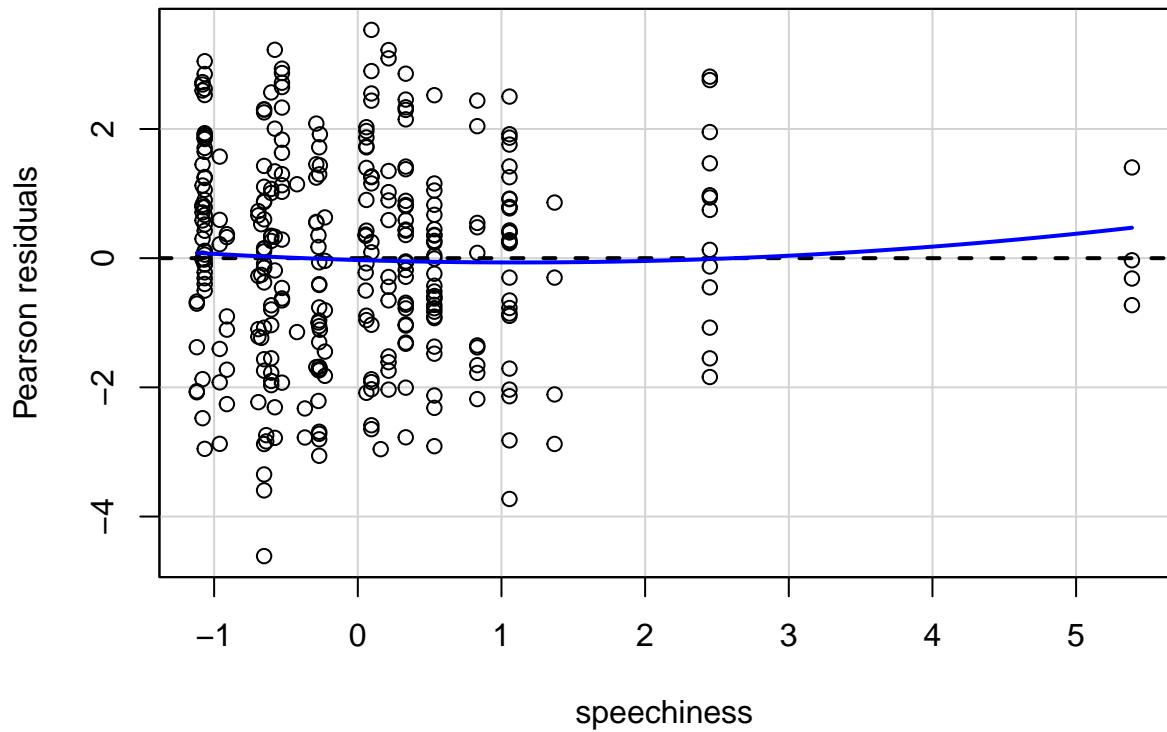
Cooks Distance Plot

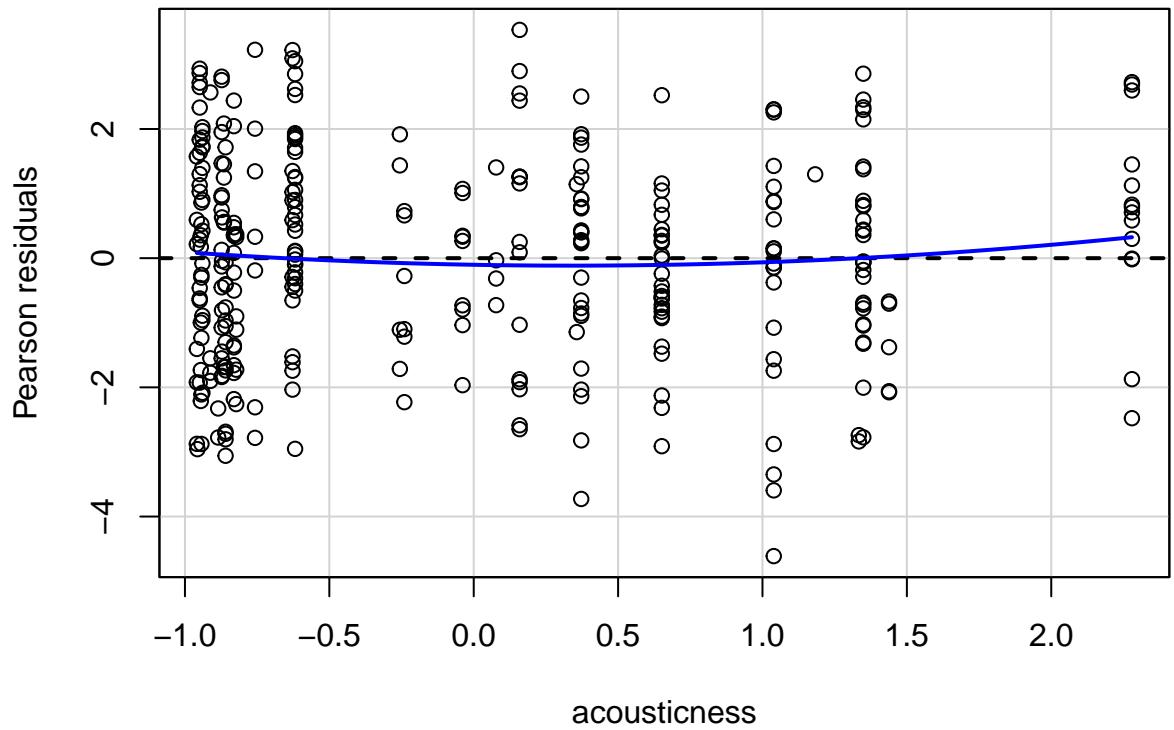


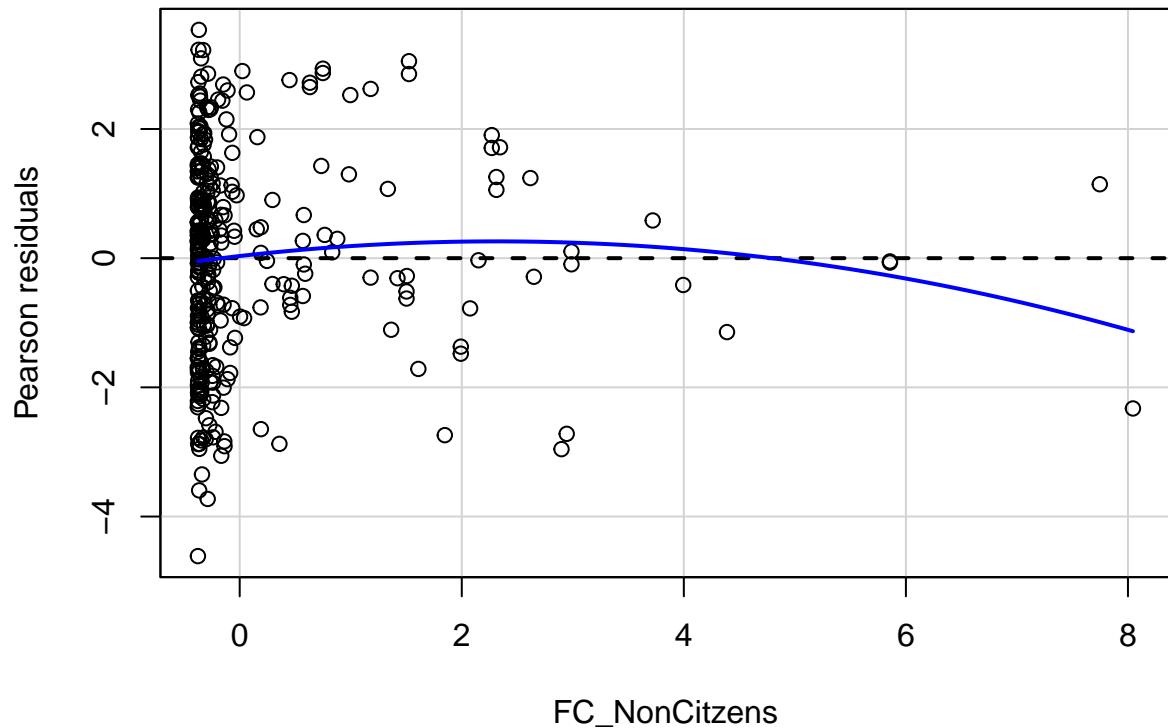
Residual Plots

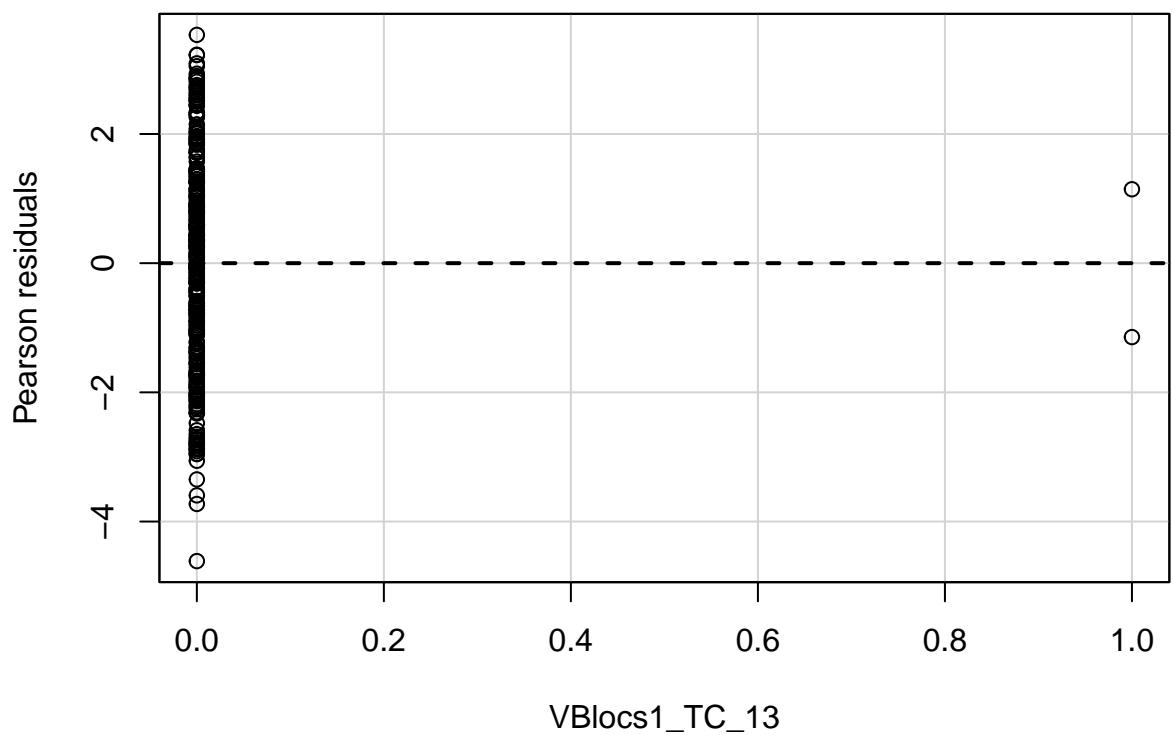


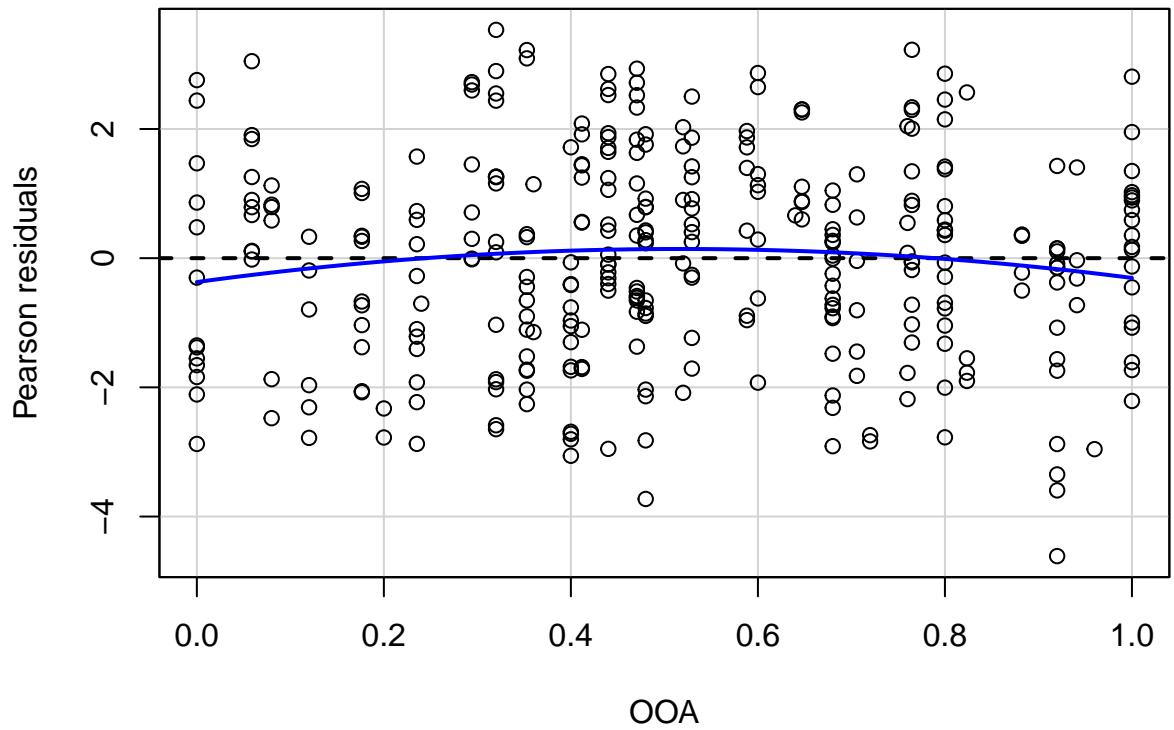


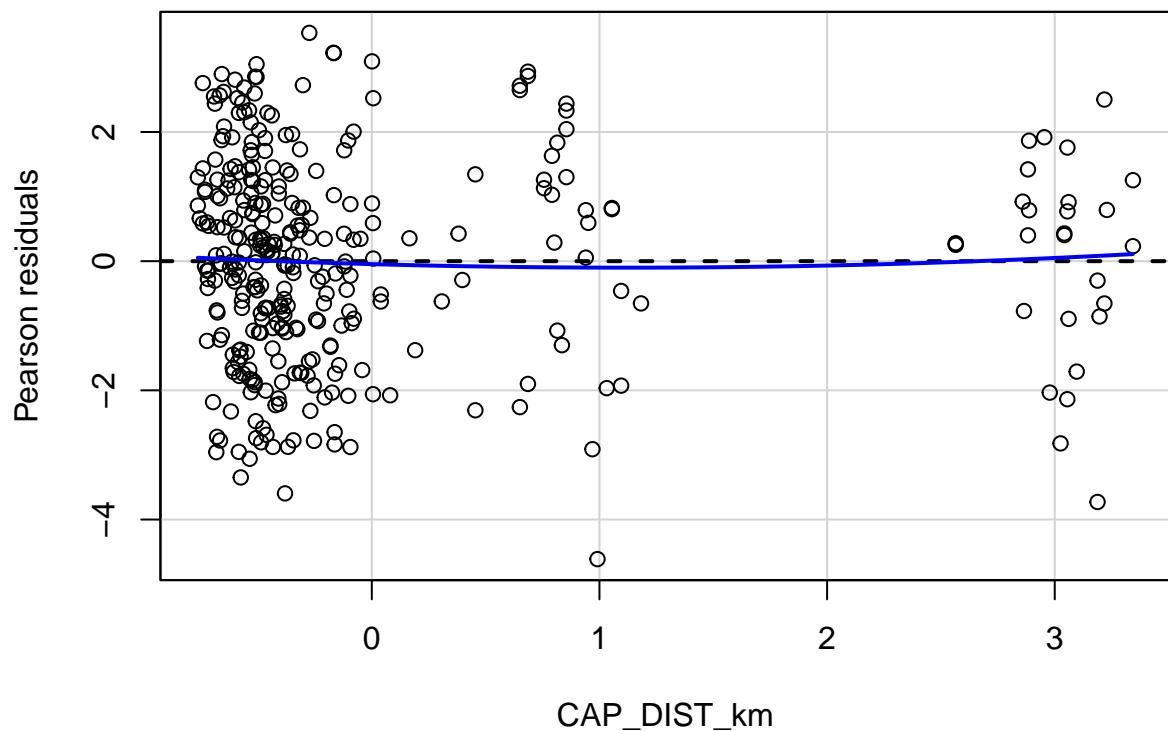


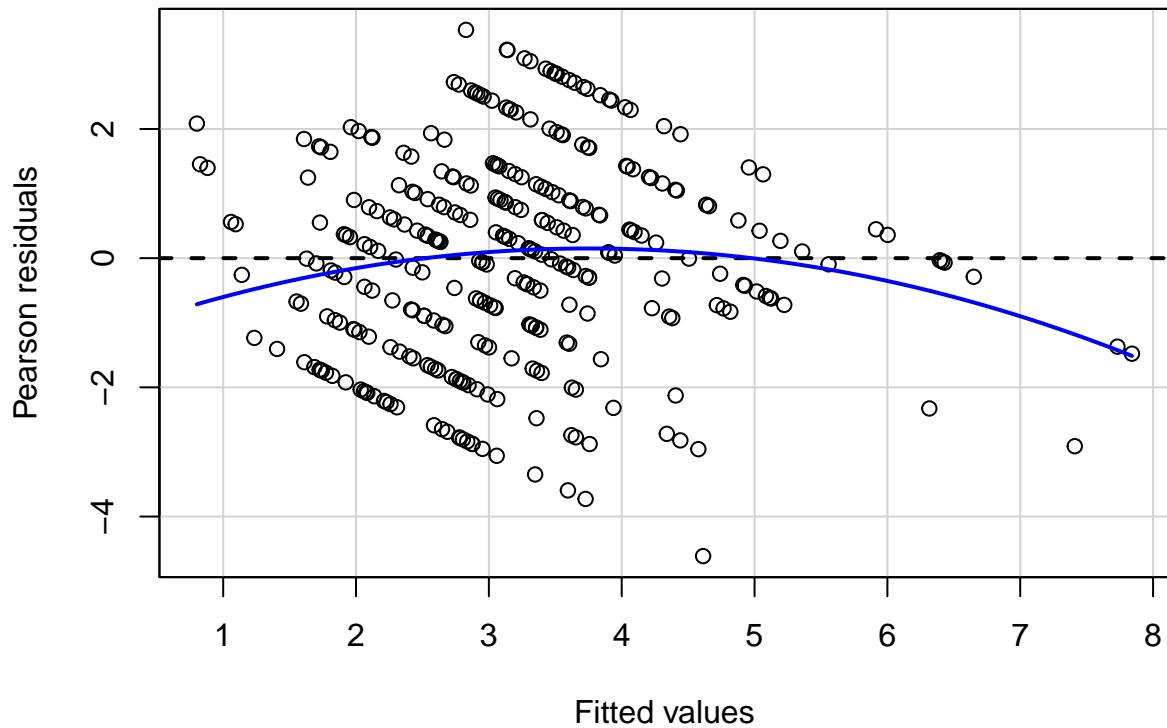












Influence Plot

```
## Warning in plot.window(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy, type, ...): "id.method" is not a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

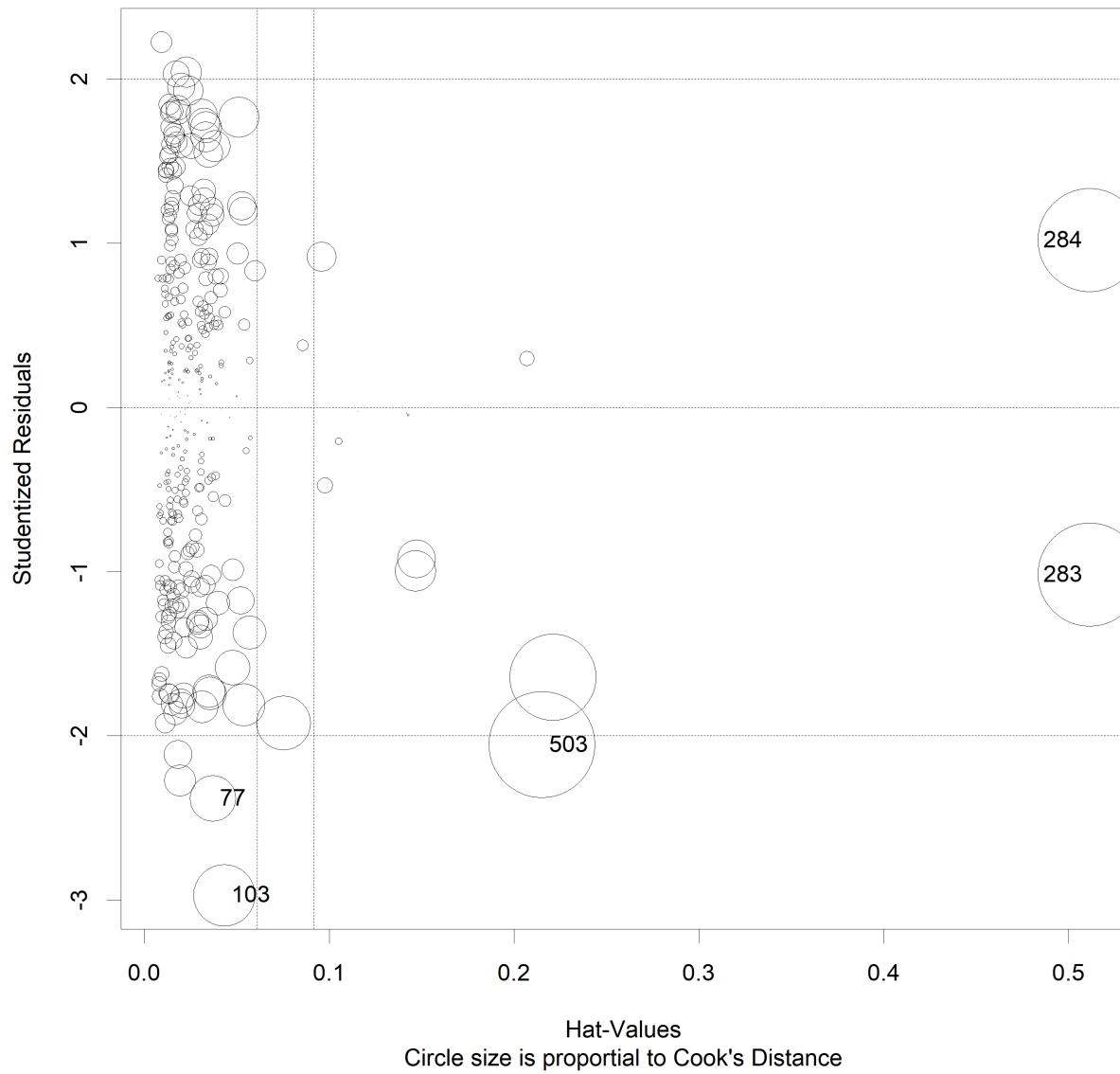
## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

## Warning in box(...): "id.method" is not a graphical parameter

## Warning in title(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "id.method" is not a
## graphical parameter
```

Televote Model - Influence Plot



Normality Assumption

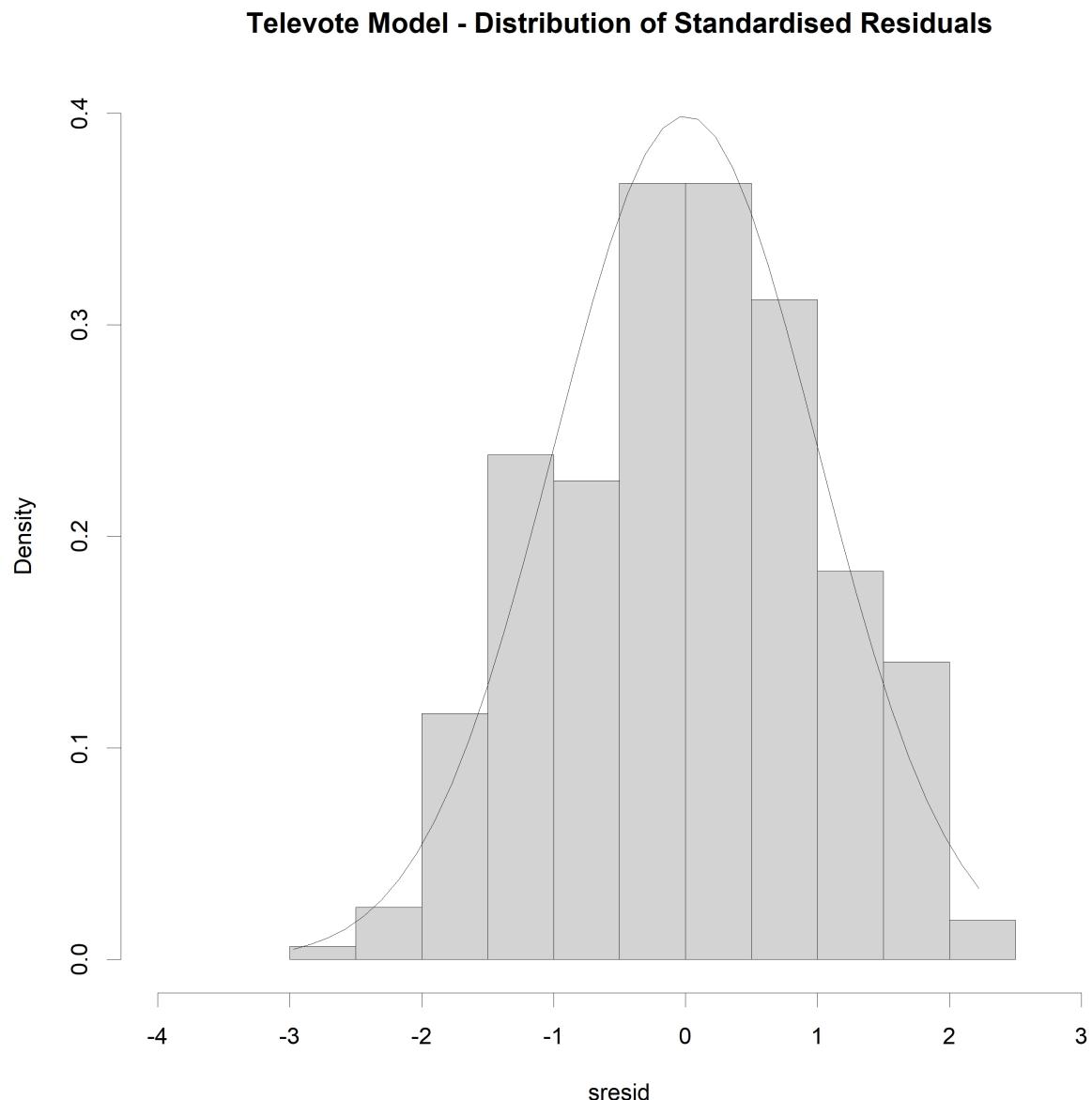
Normality Tests

Normality Test

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

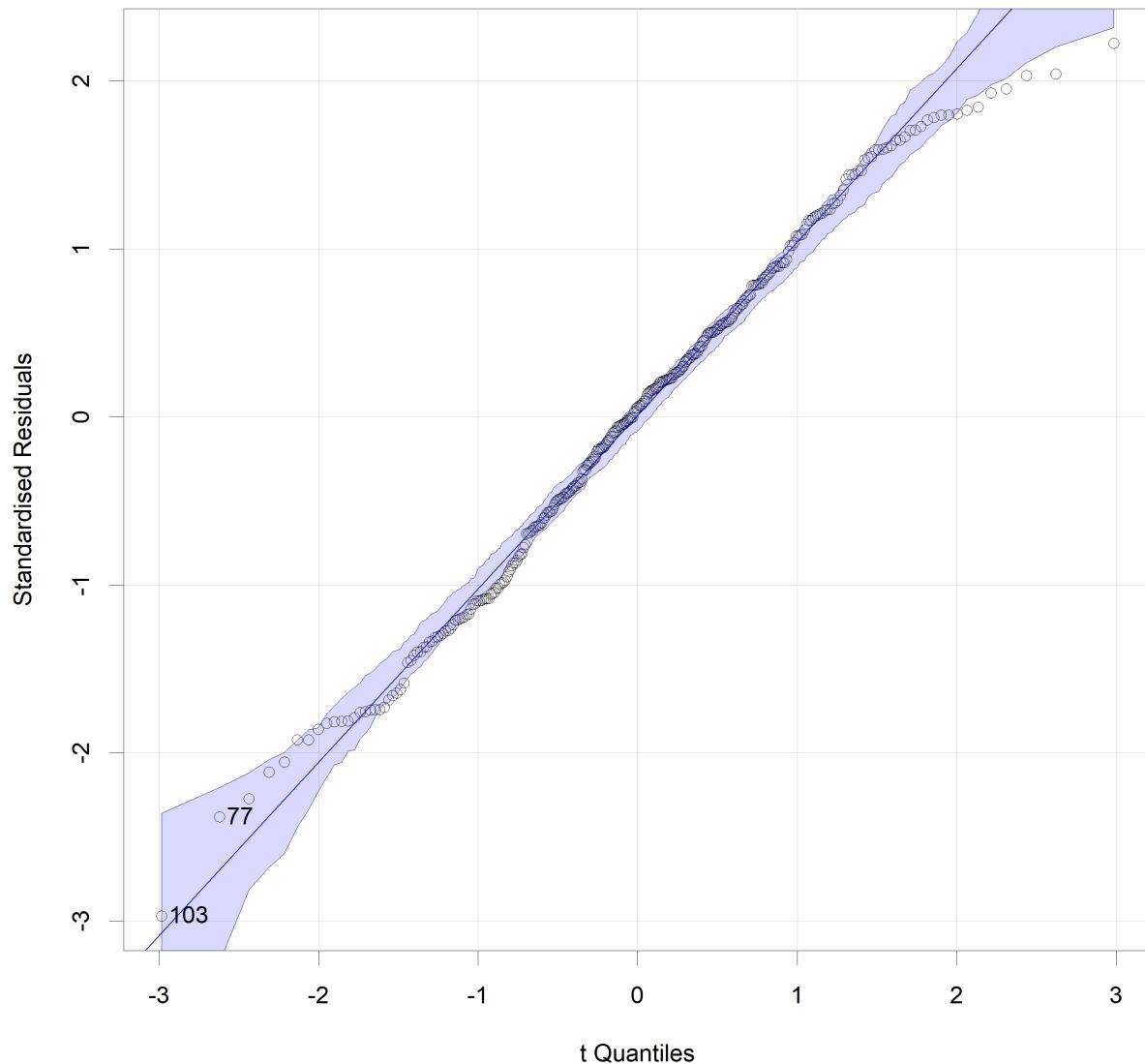
NormTest	Stat	Pval
shapiro.test	0.99075	0.03758
ad.test	0.59623	0.11856
cvm.test	0.07592	0.23336
lille.test	0.0381	0.29588
person.test	21.13761	0.27253
sf.test	0.99202	0.07153

Residual Histogram



Residual QQ-Plot

QQ-Plot of Televote Model Standardised Residuals



Constant Variance Assumption

Non-Constant Variance Test

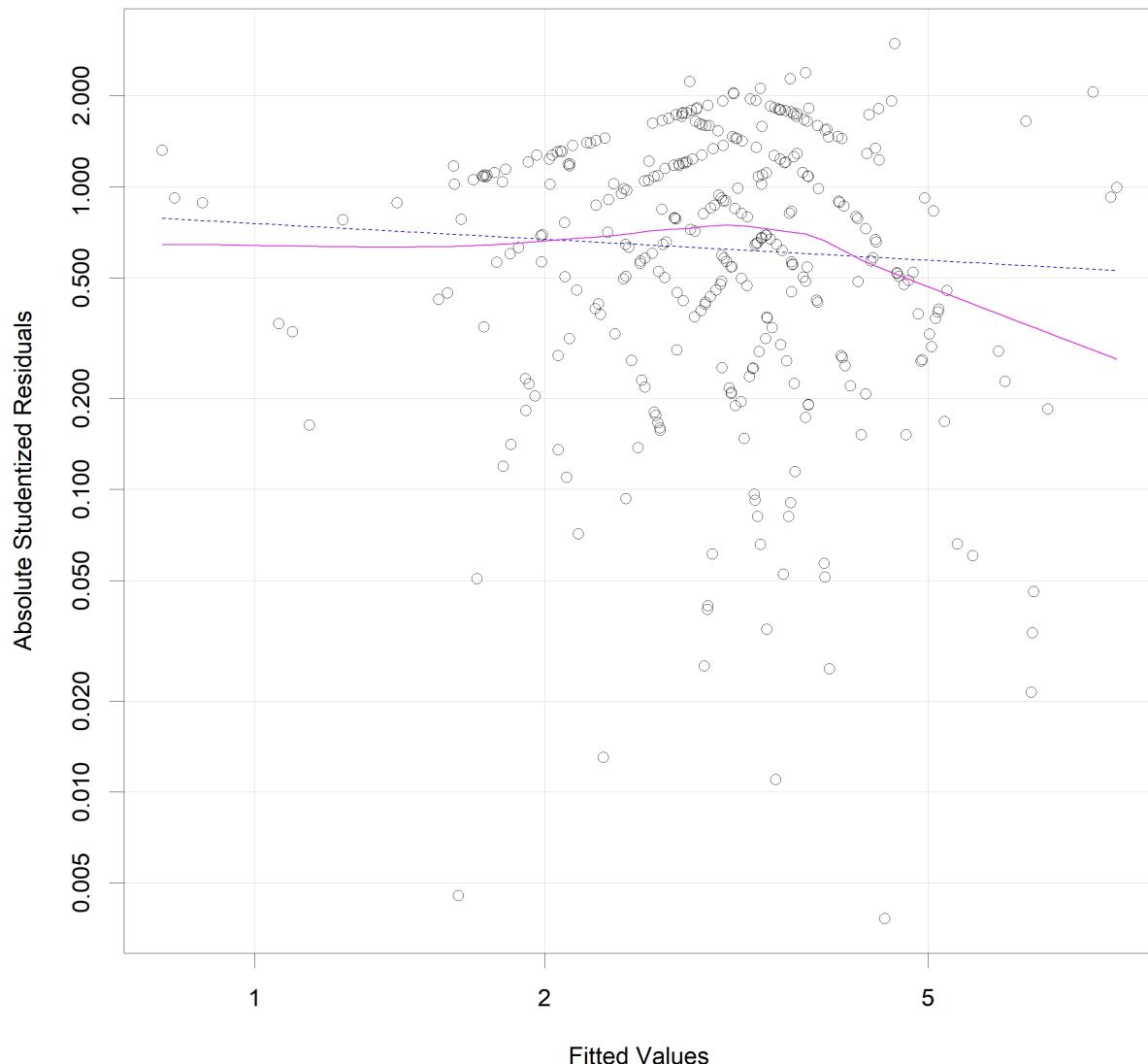
Non-Constant Error Variance Test

- 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
```

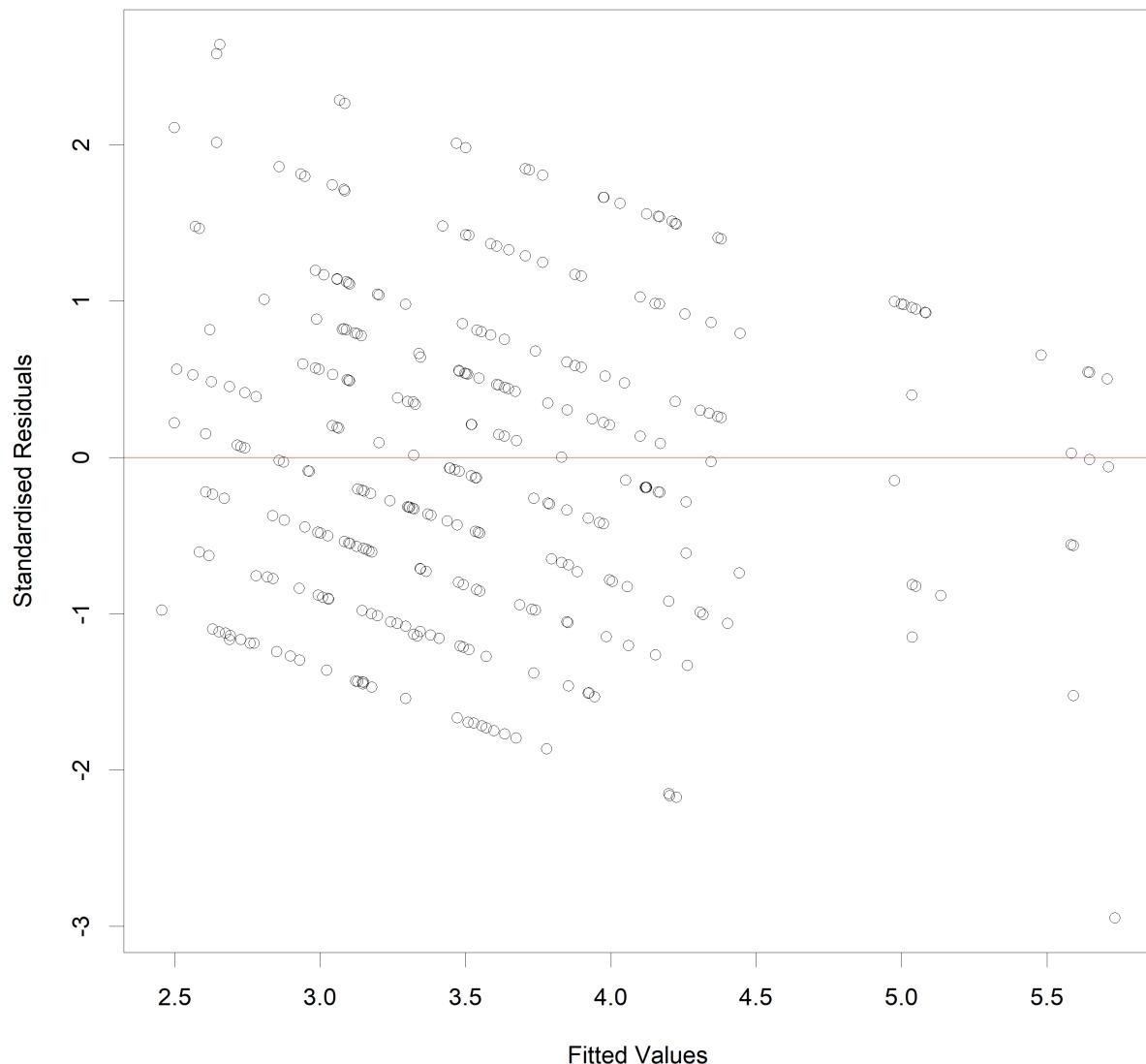
Response Variable Transformation

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

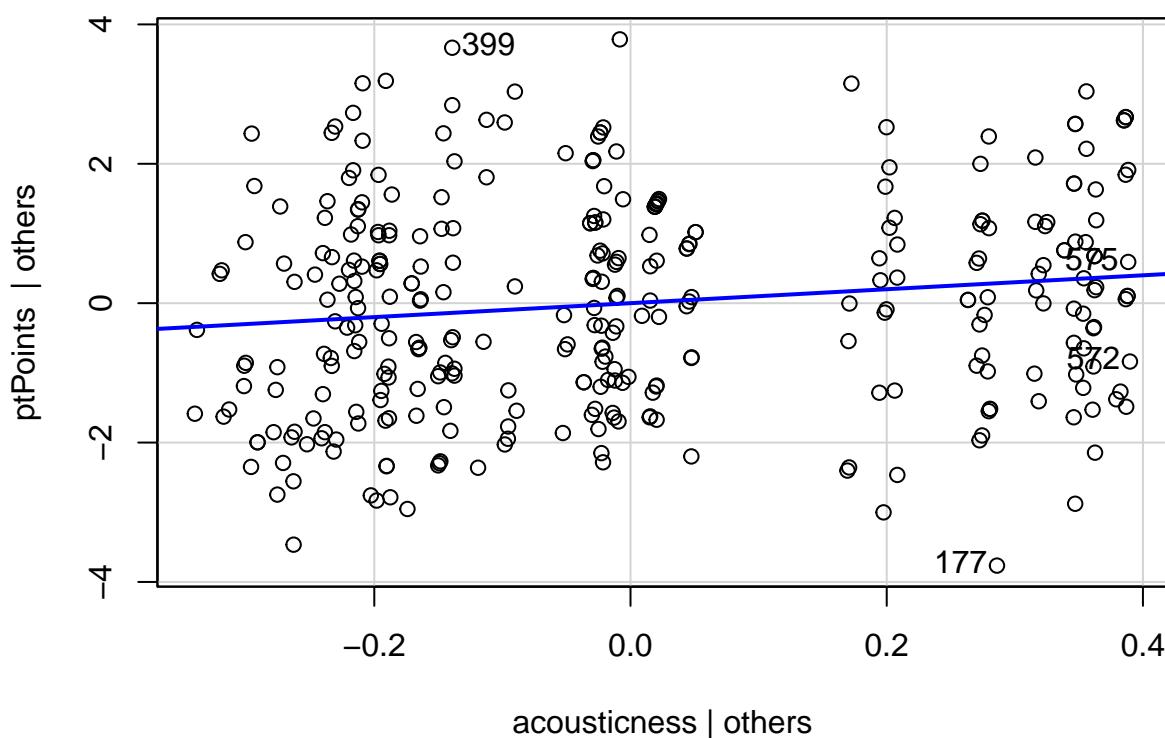
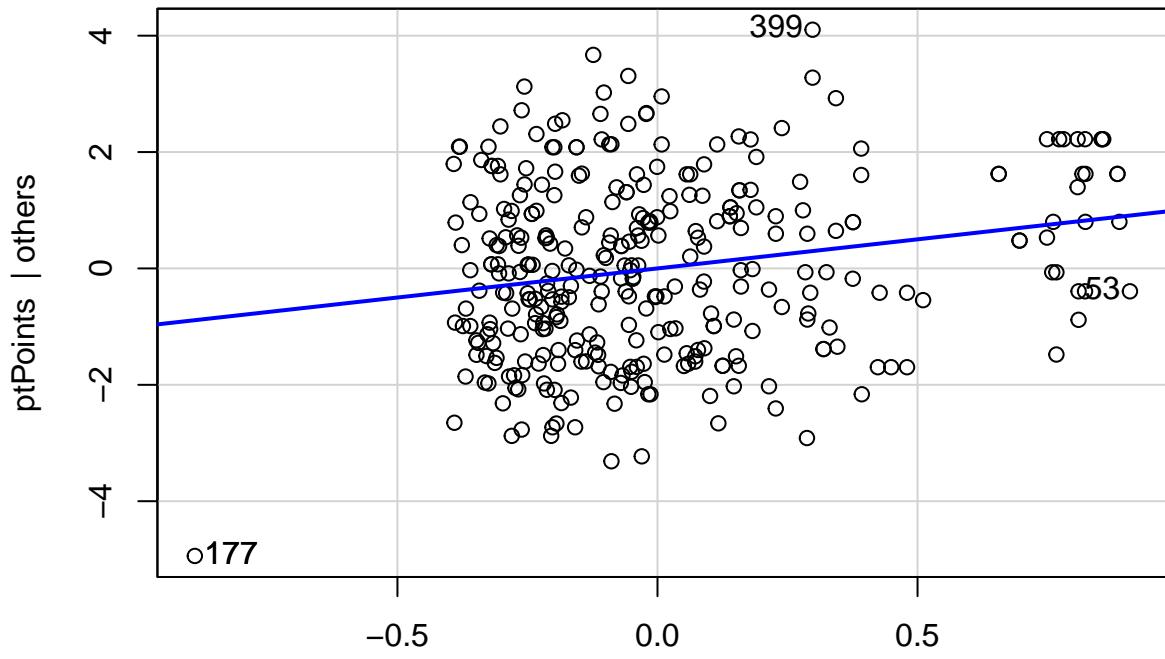
Bonferroni Outlier Test

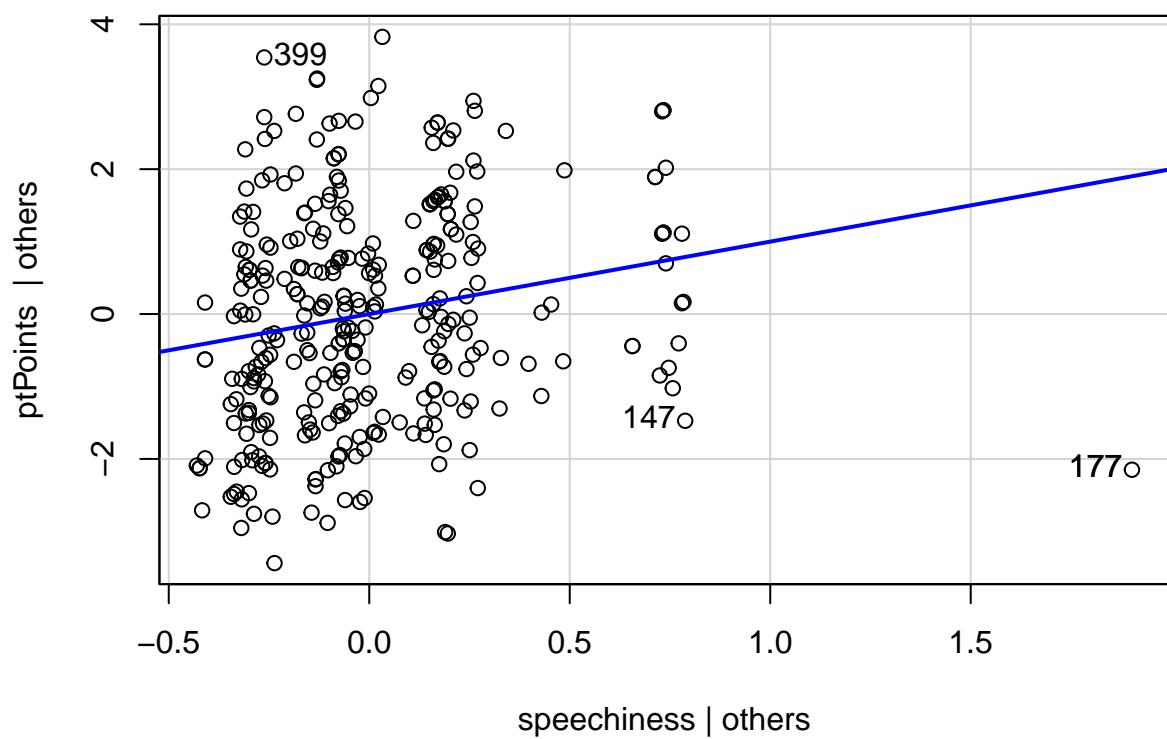
	rstudent	p	bonf.p	signif	cutoff
177	-2.945099	0.0034643	1.146697	0	0.05

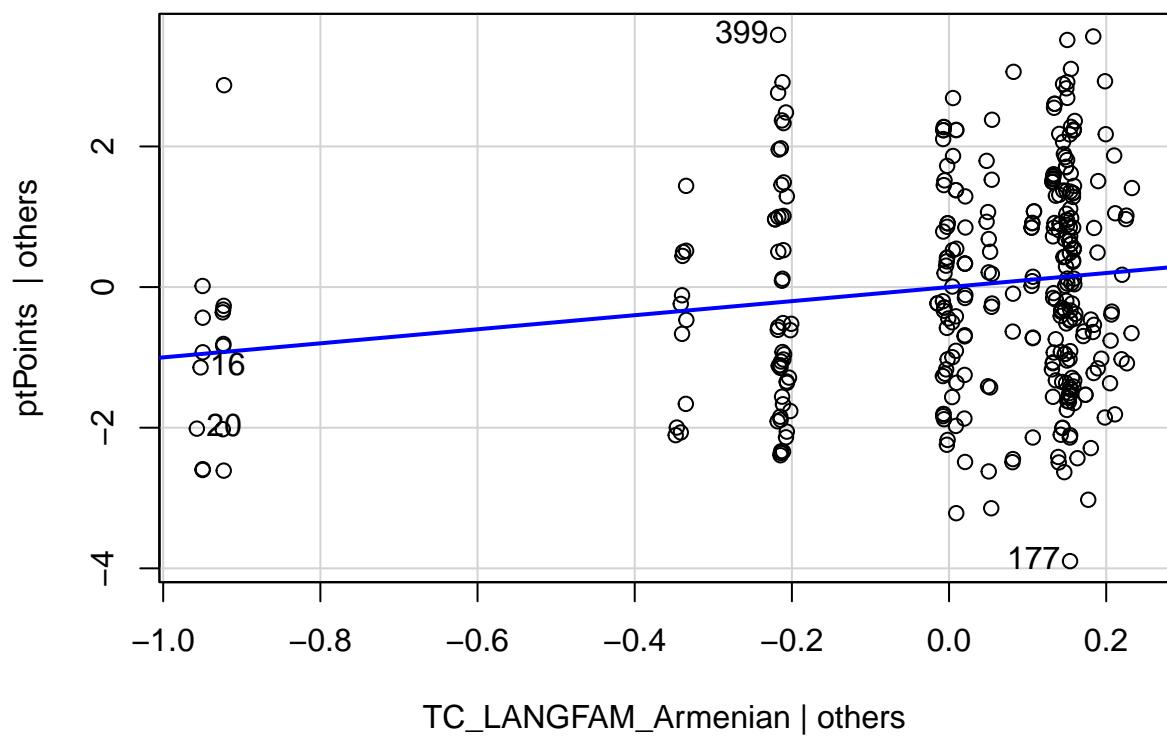
Outlier Residuals

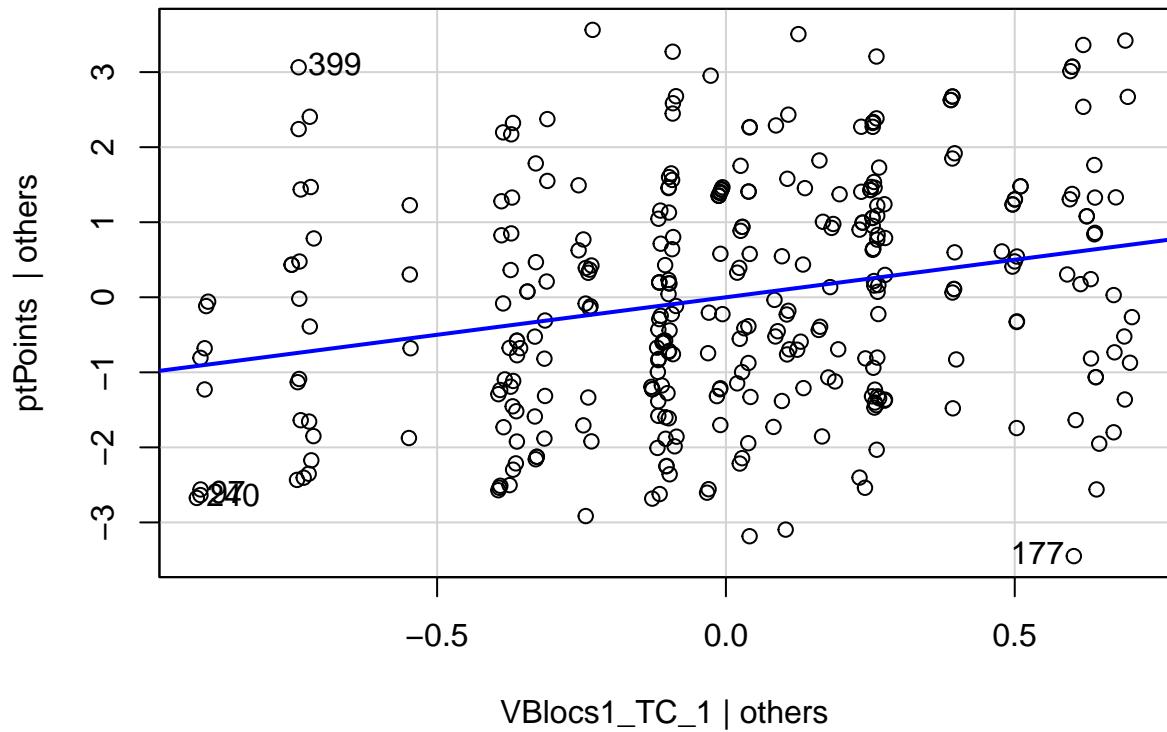
outlier_residuals
177
516
529
618

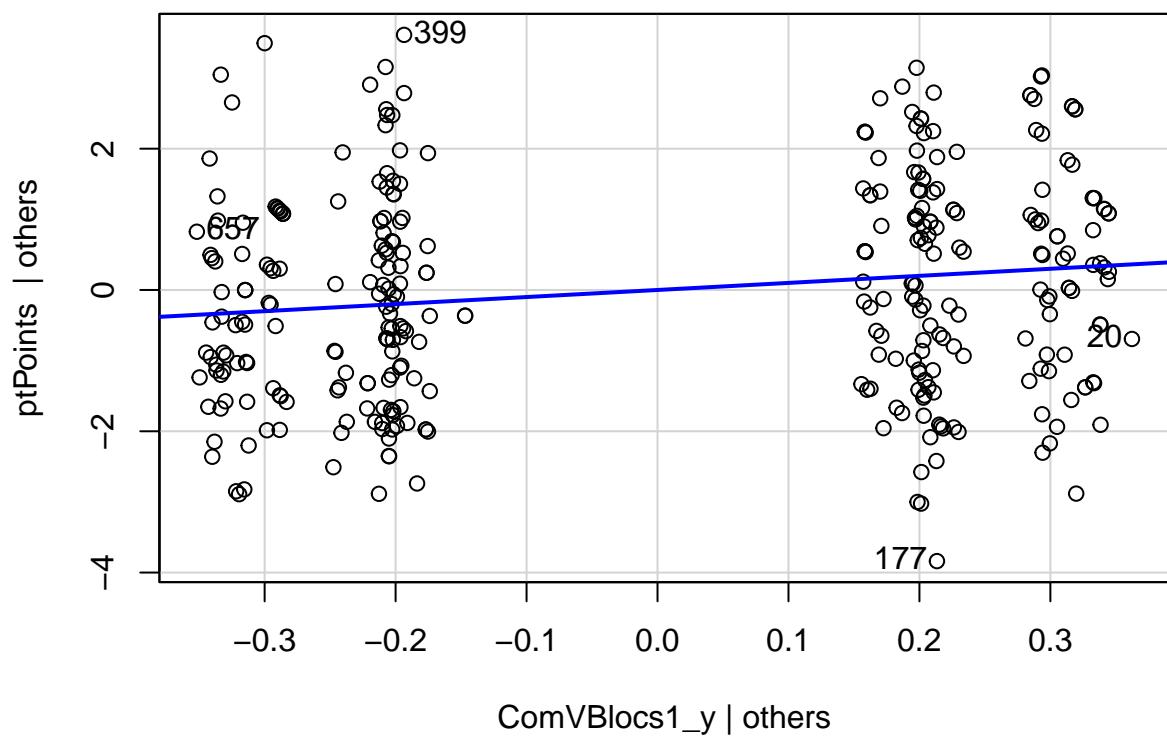
Leverage Plots

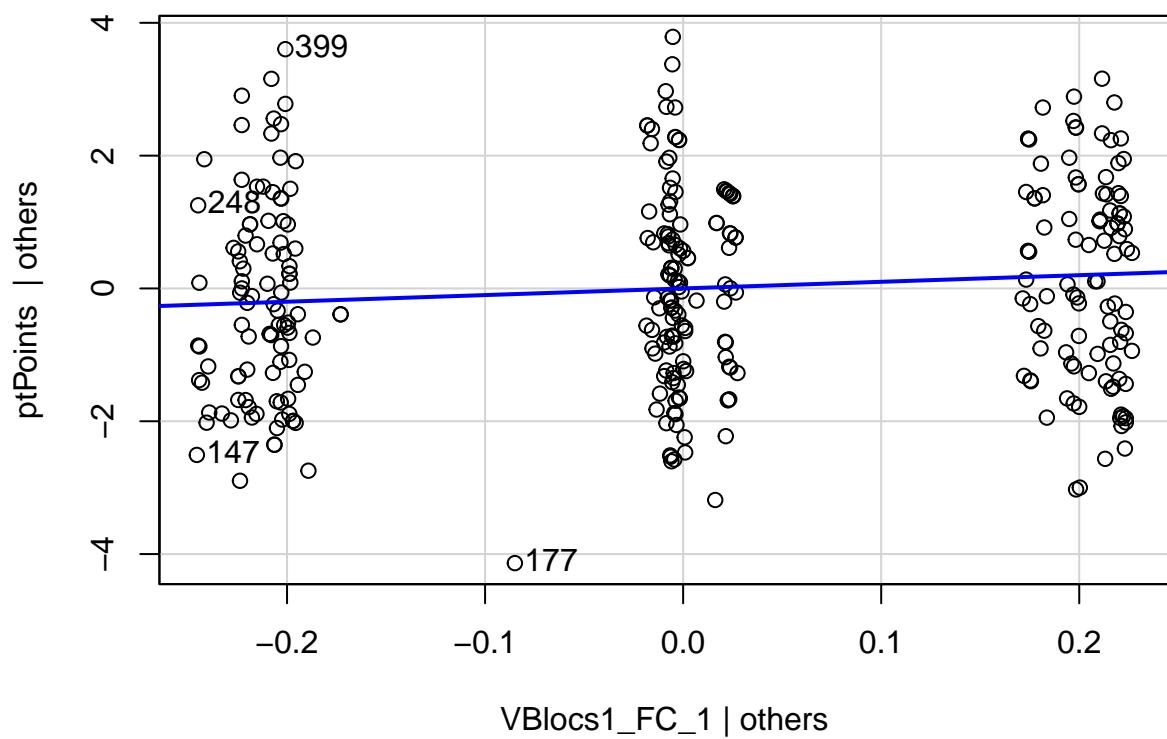




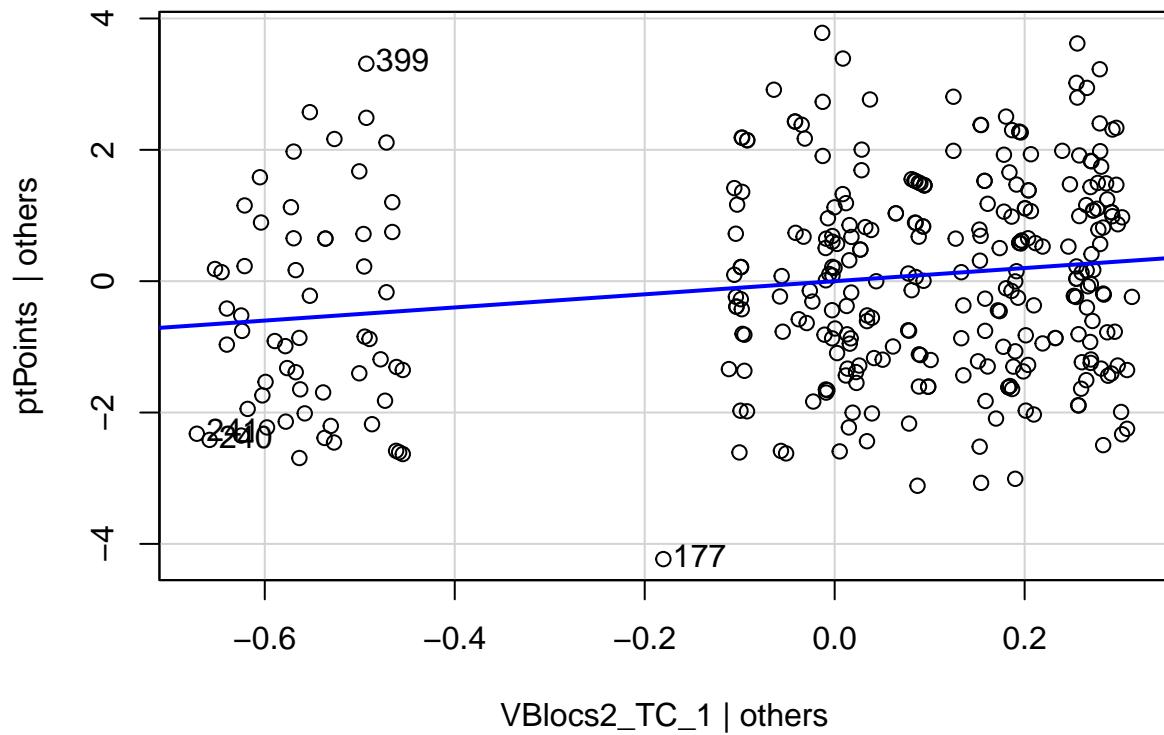




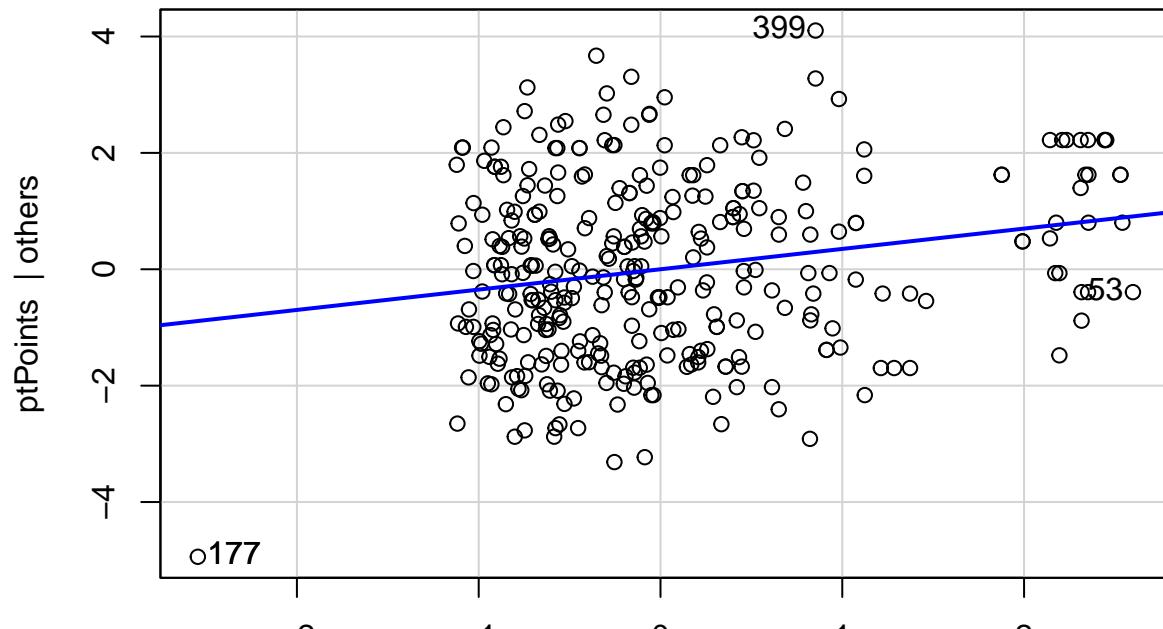




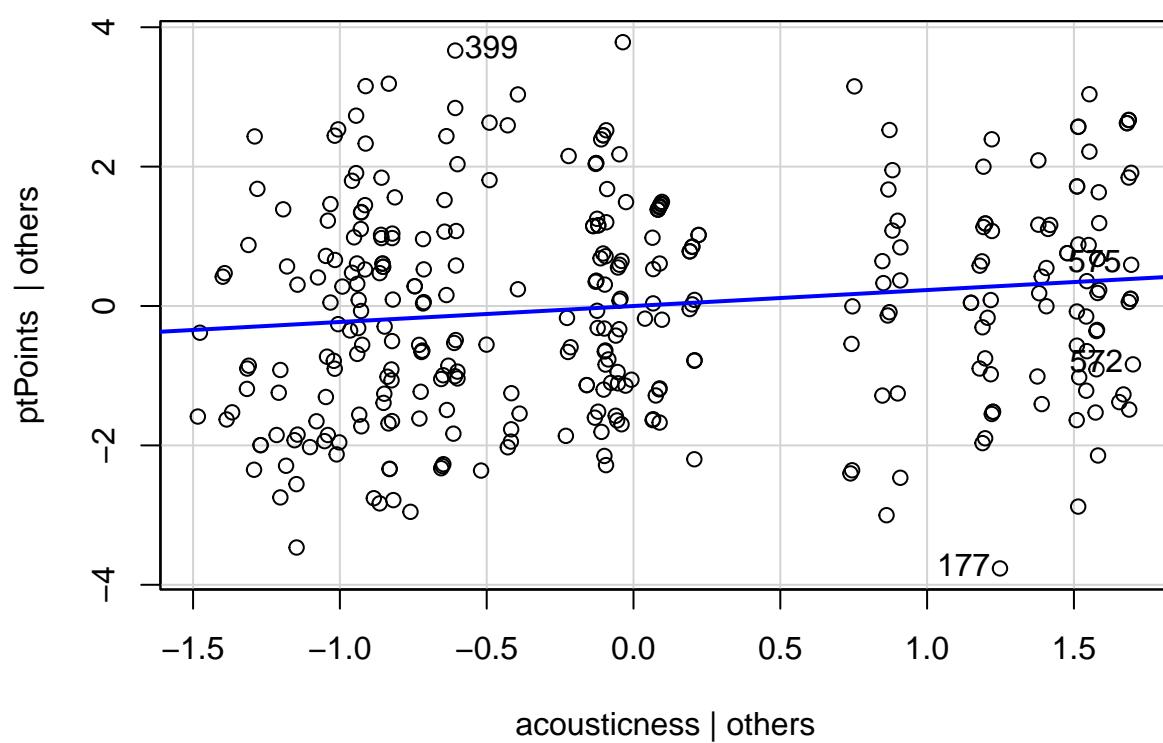
Leverage Plots



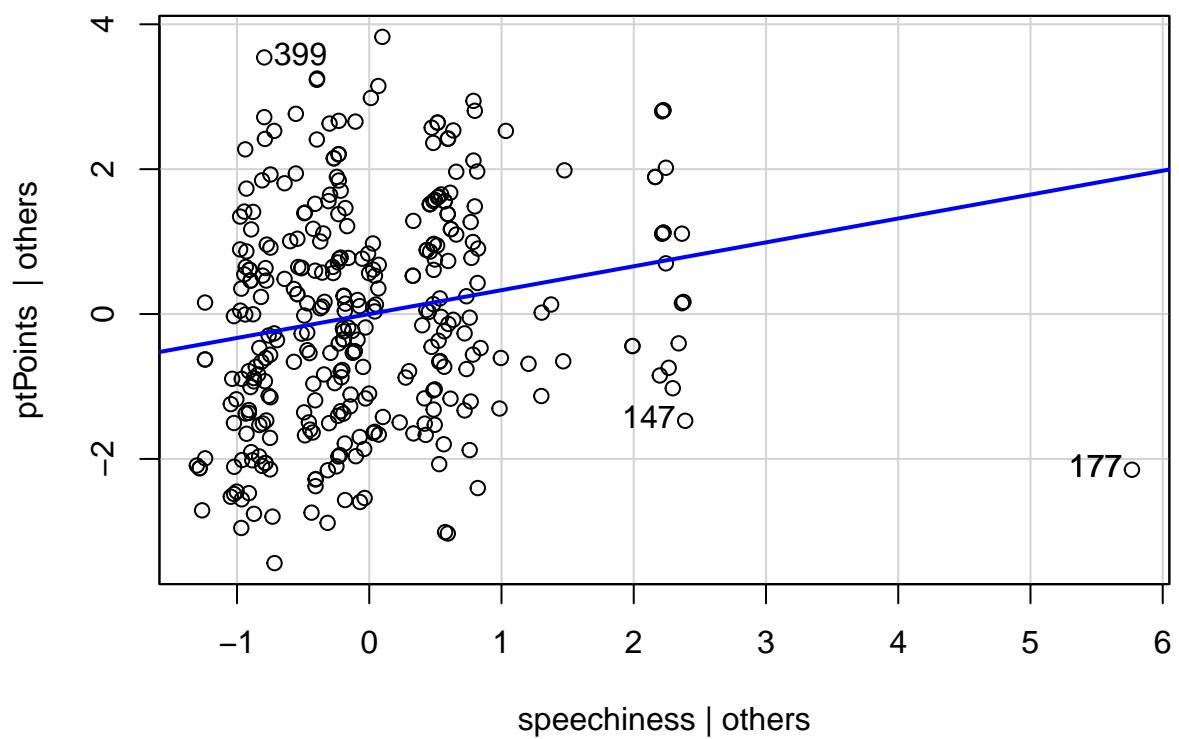
Added Variable Plots

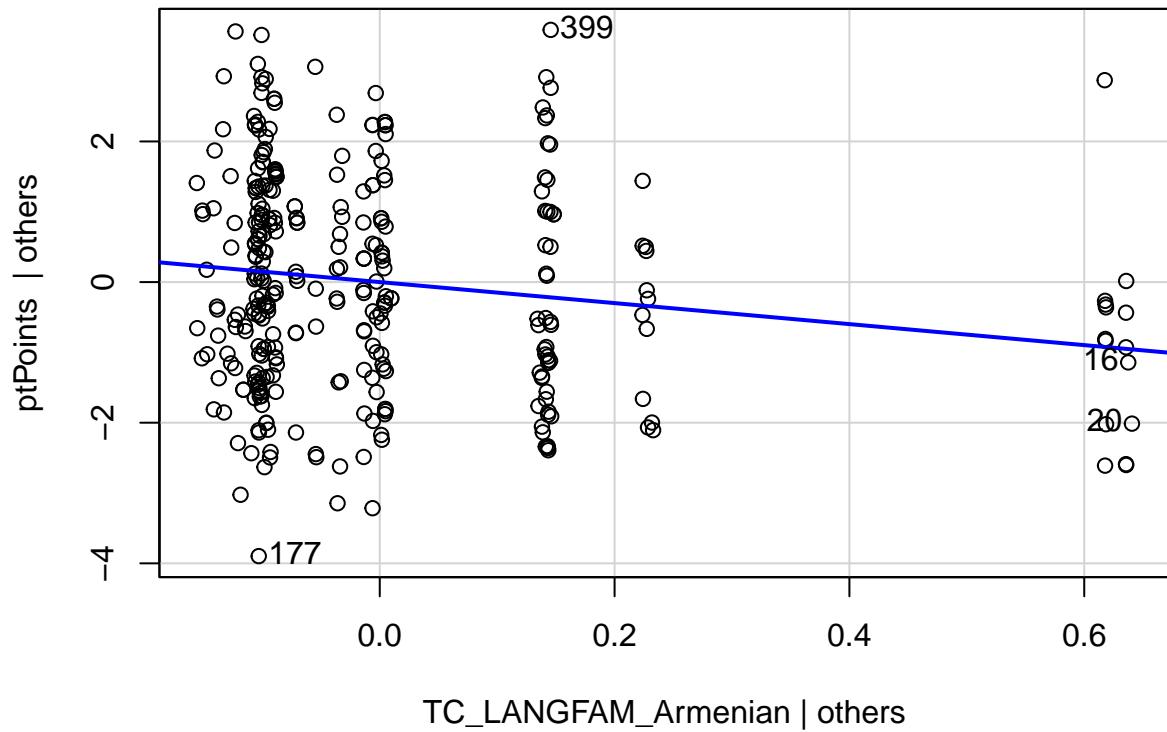


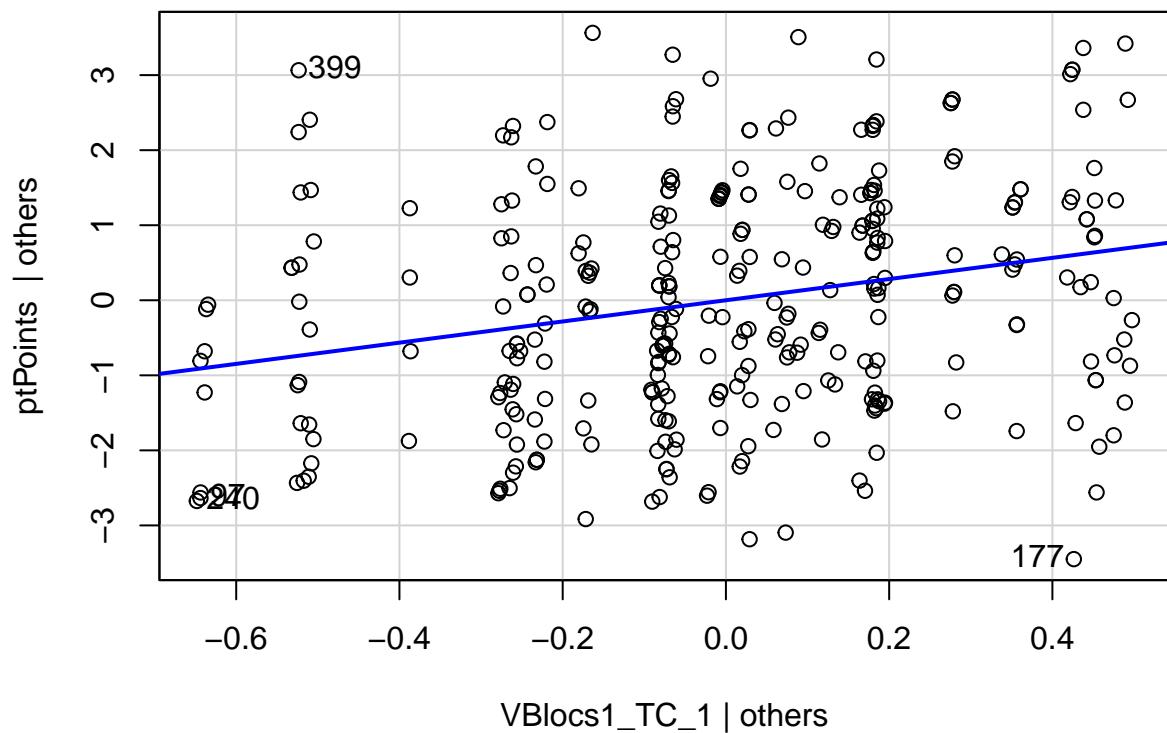
CAP_DIST_km | others

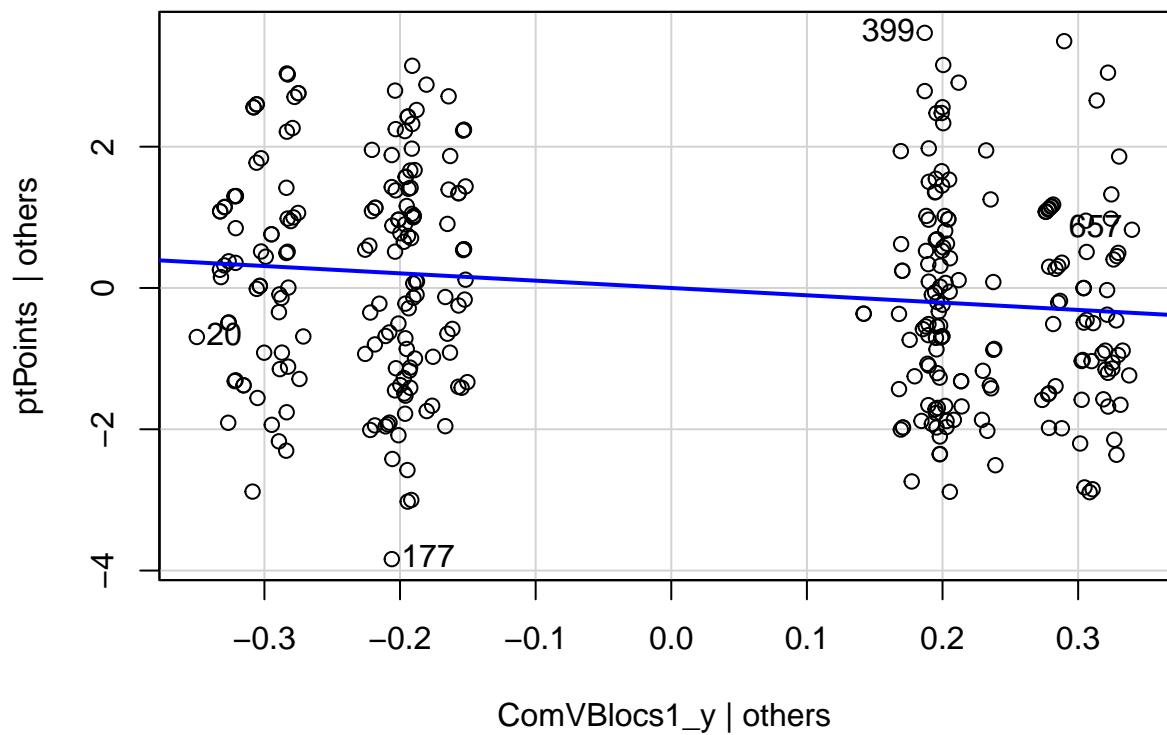


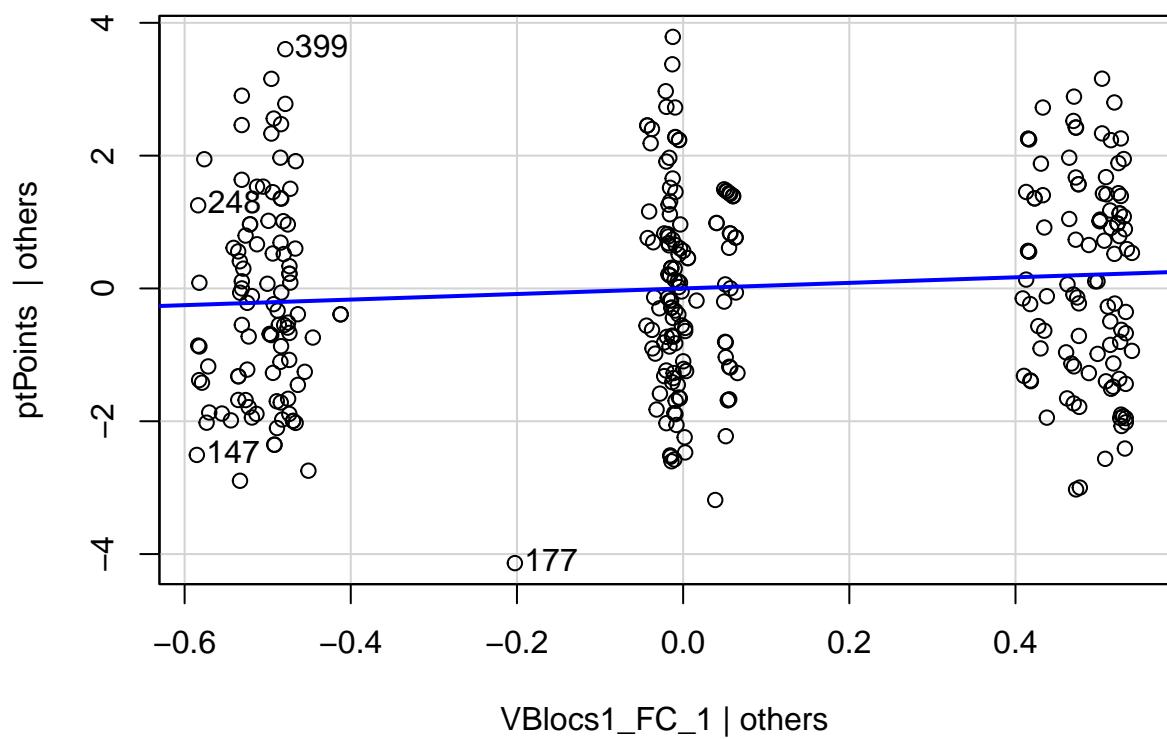
acousticness | others



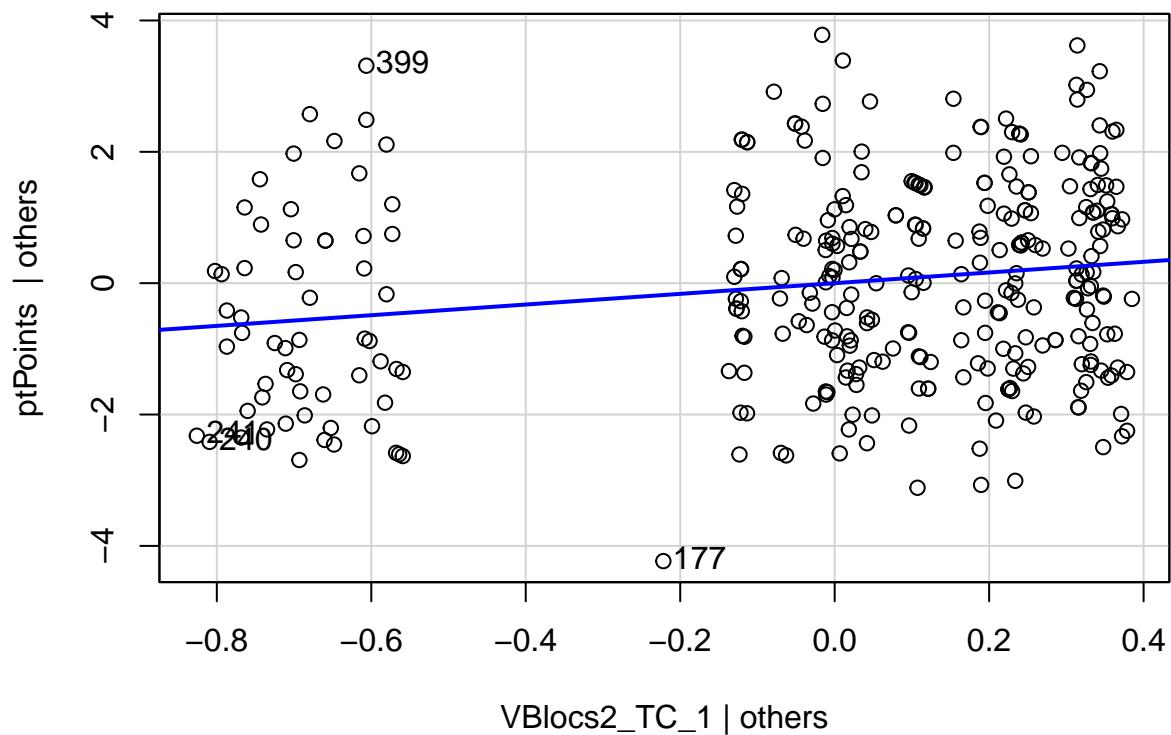




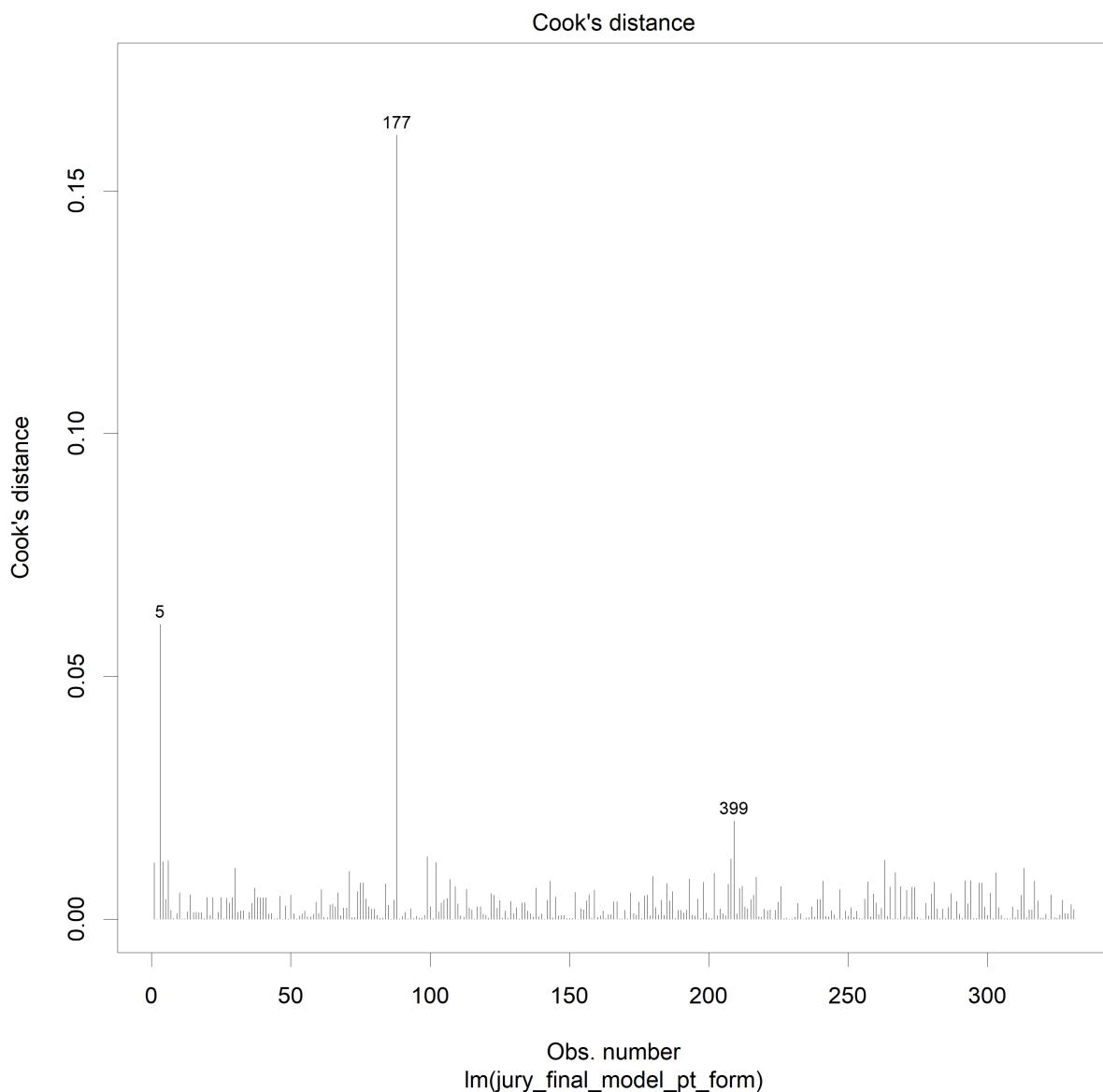




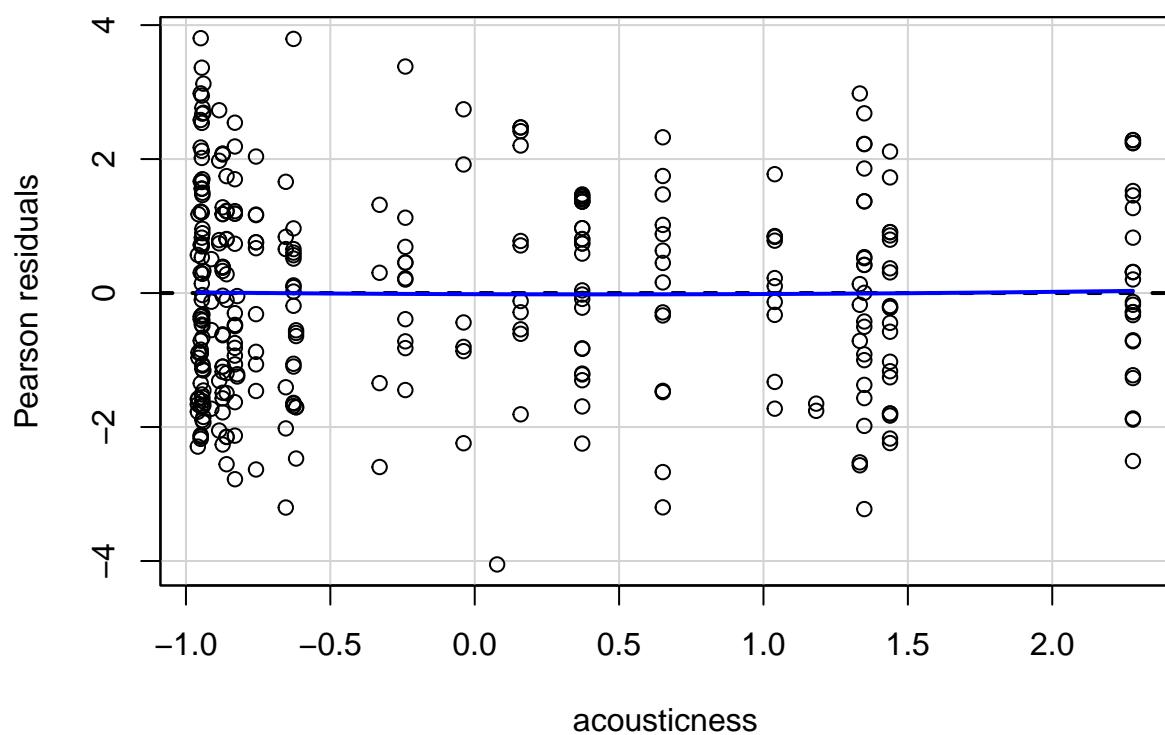
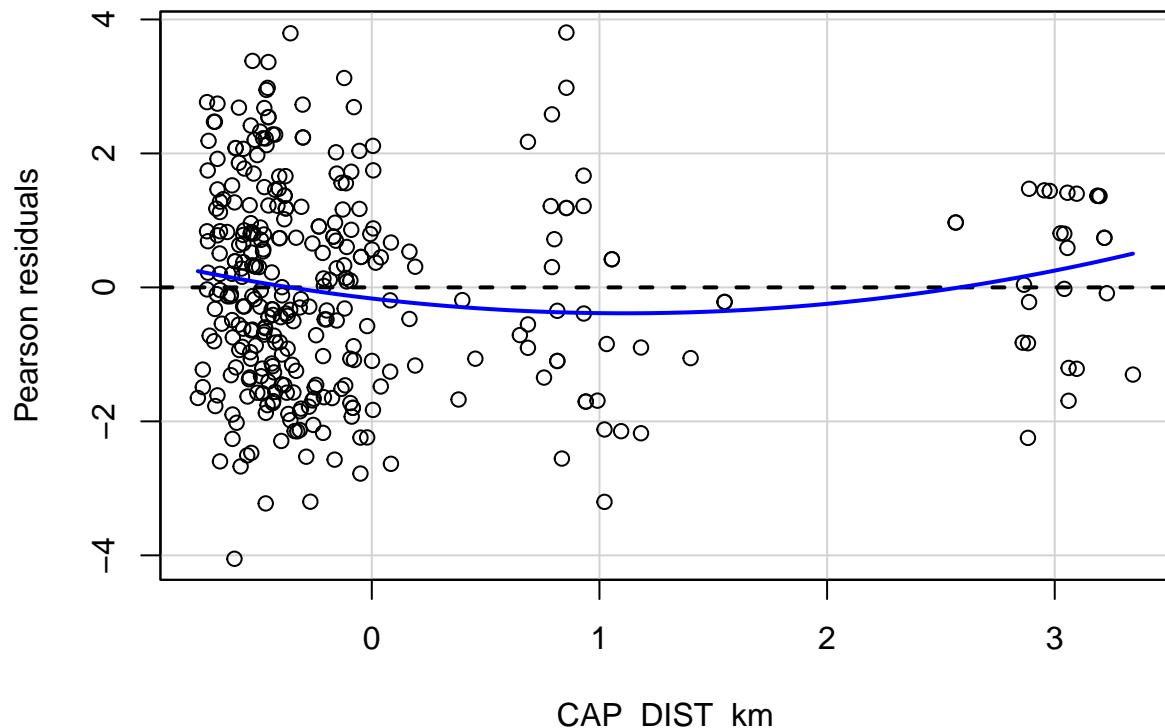
Added-Variable Plots

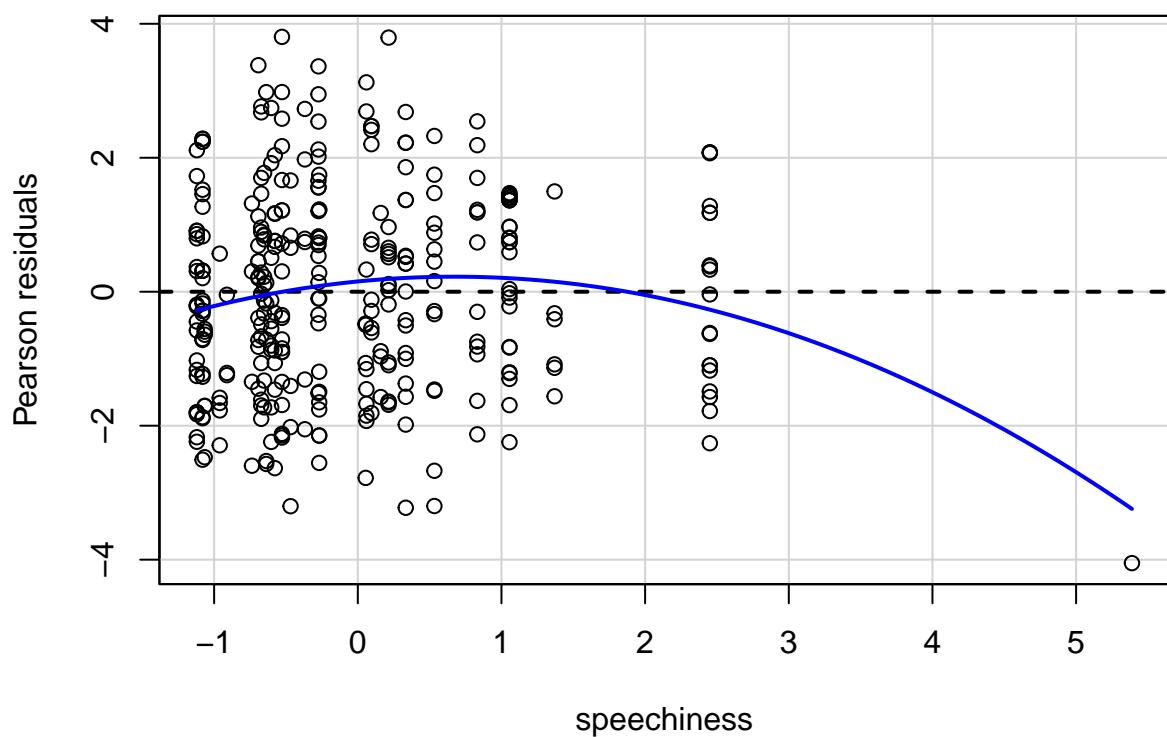


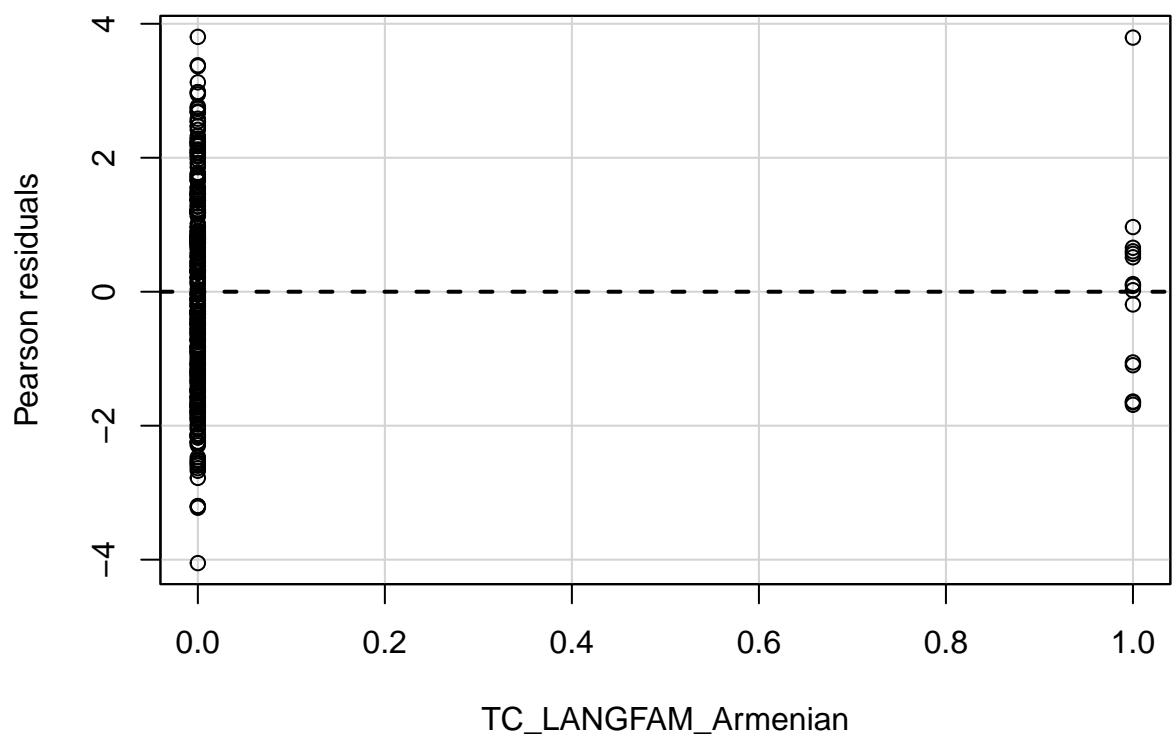
Cooks Distance Plot

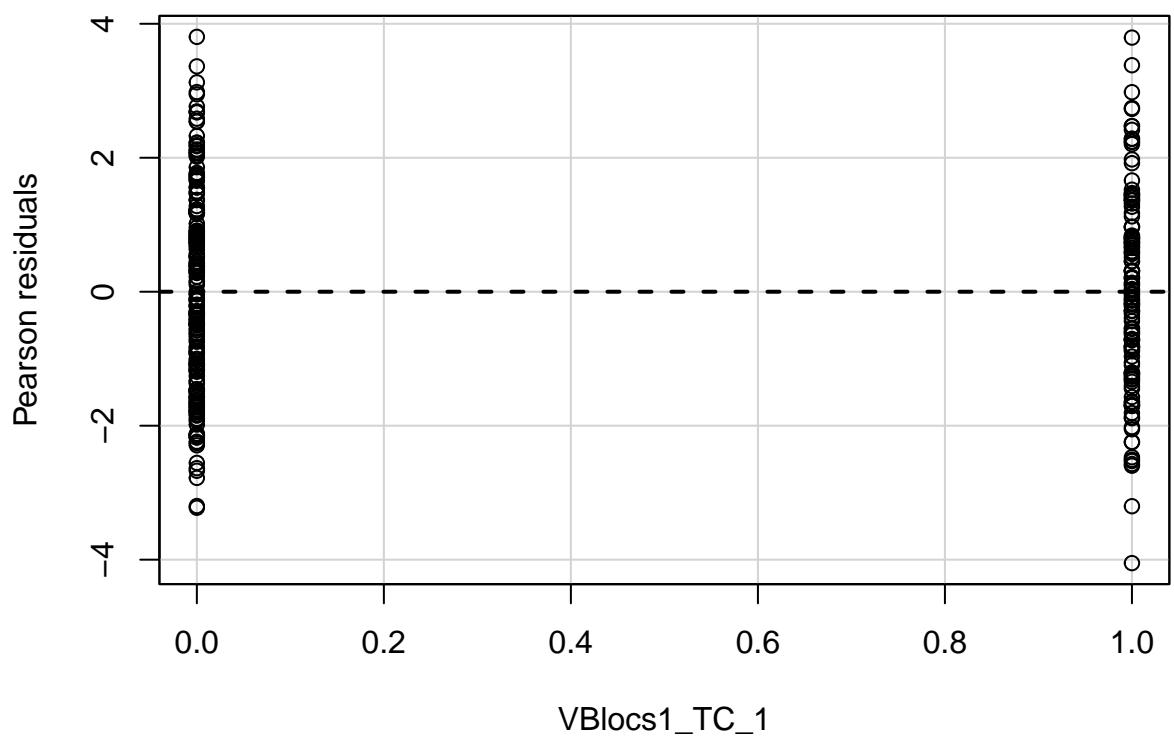


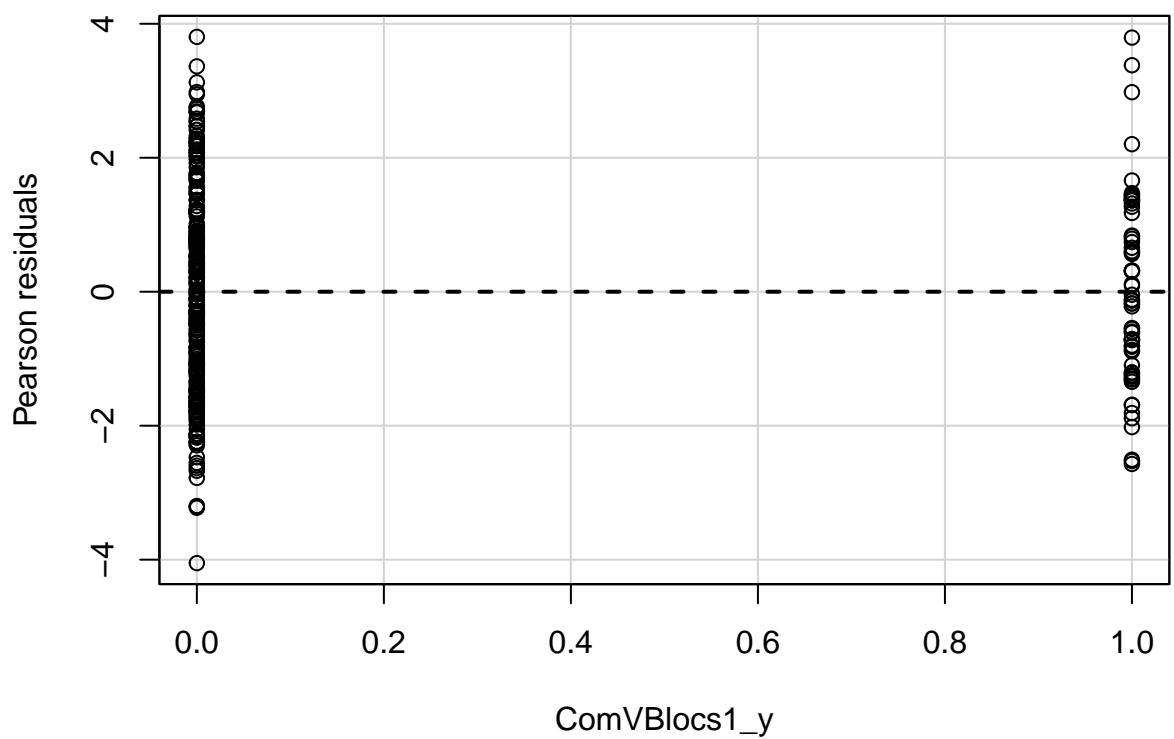
Residual Plots

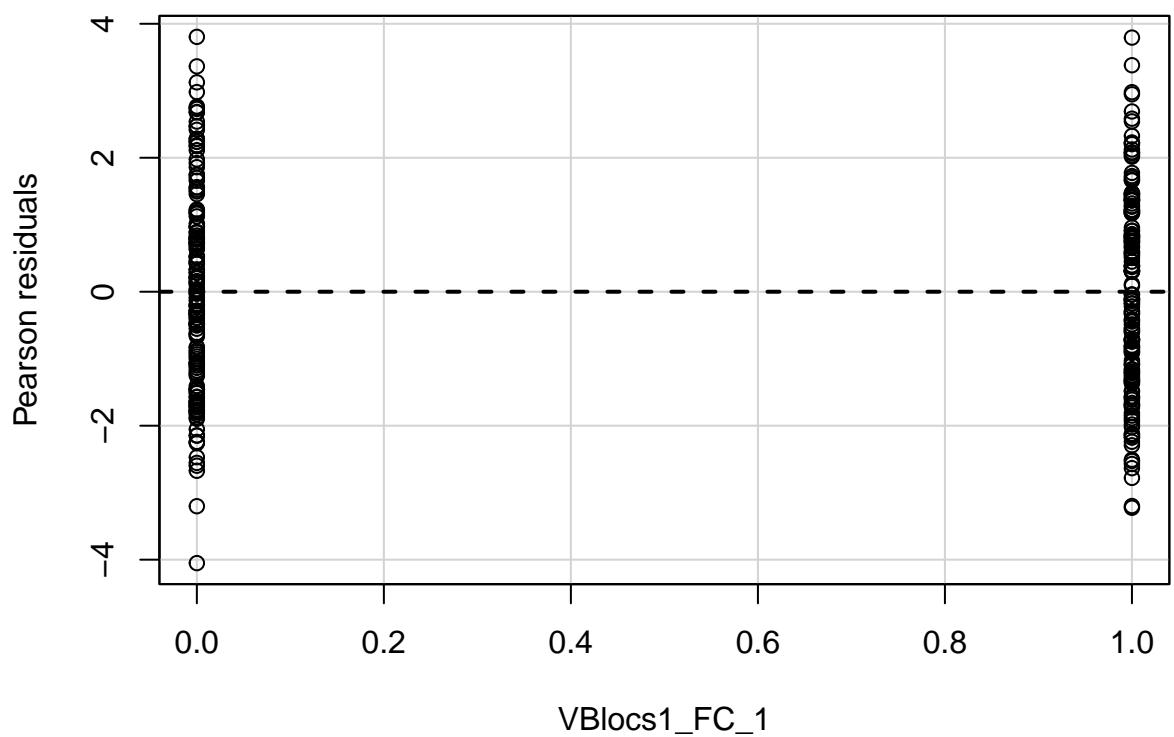


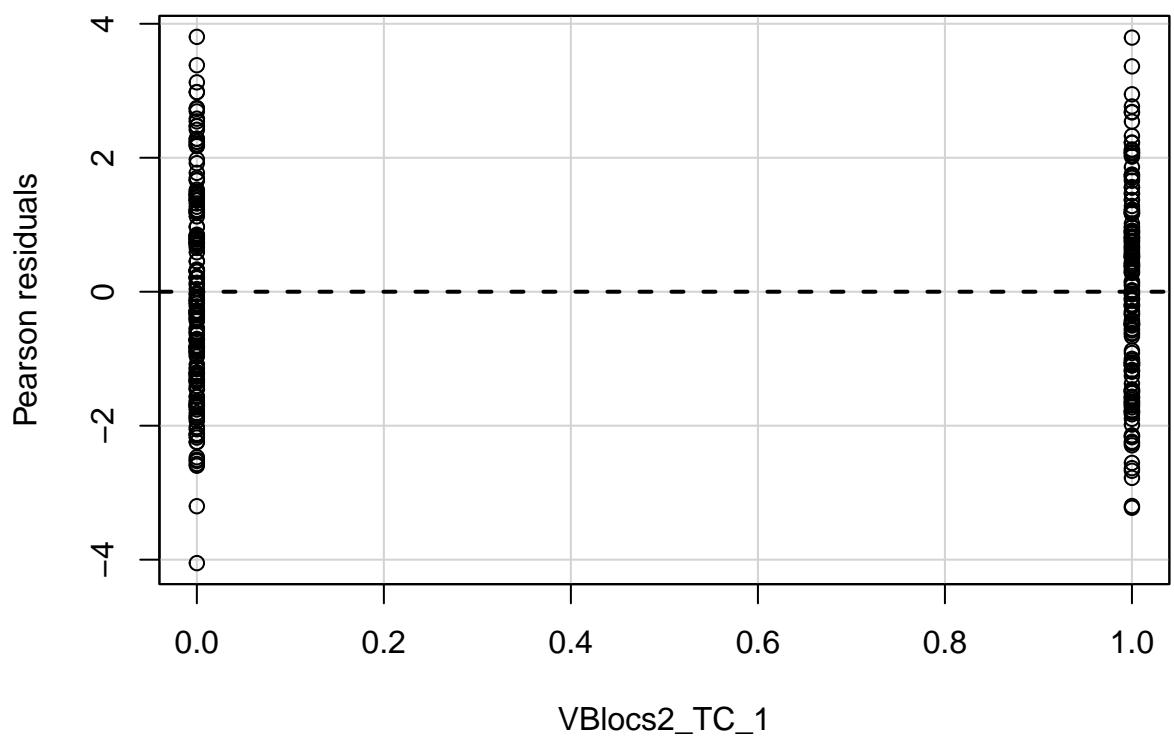


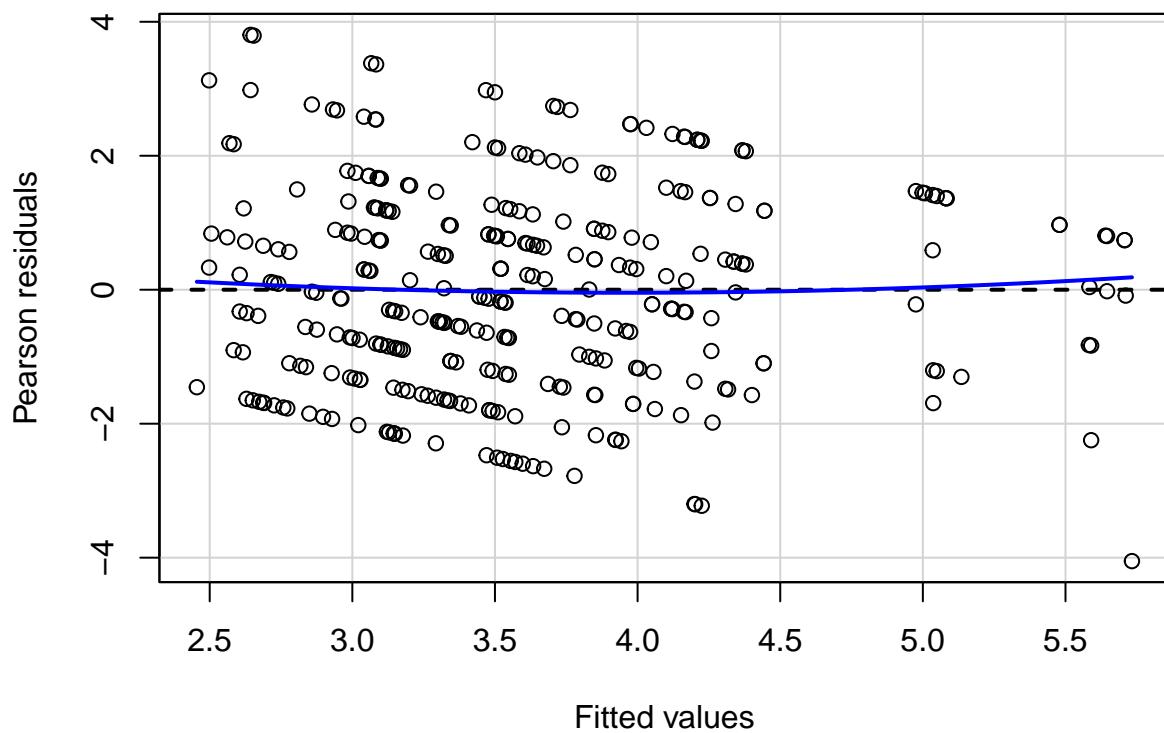












Influence Plot

```

## Warning in plot.window(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy, type, ...): "id.method" is not a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not
## a graphical parameter

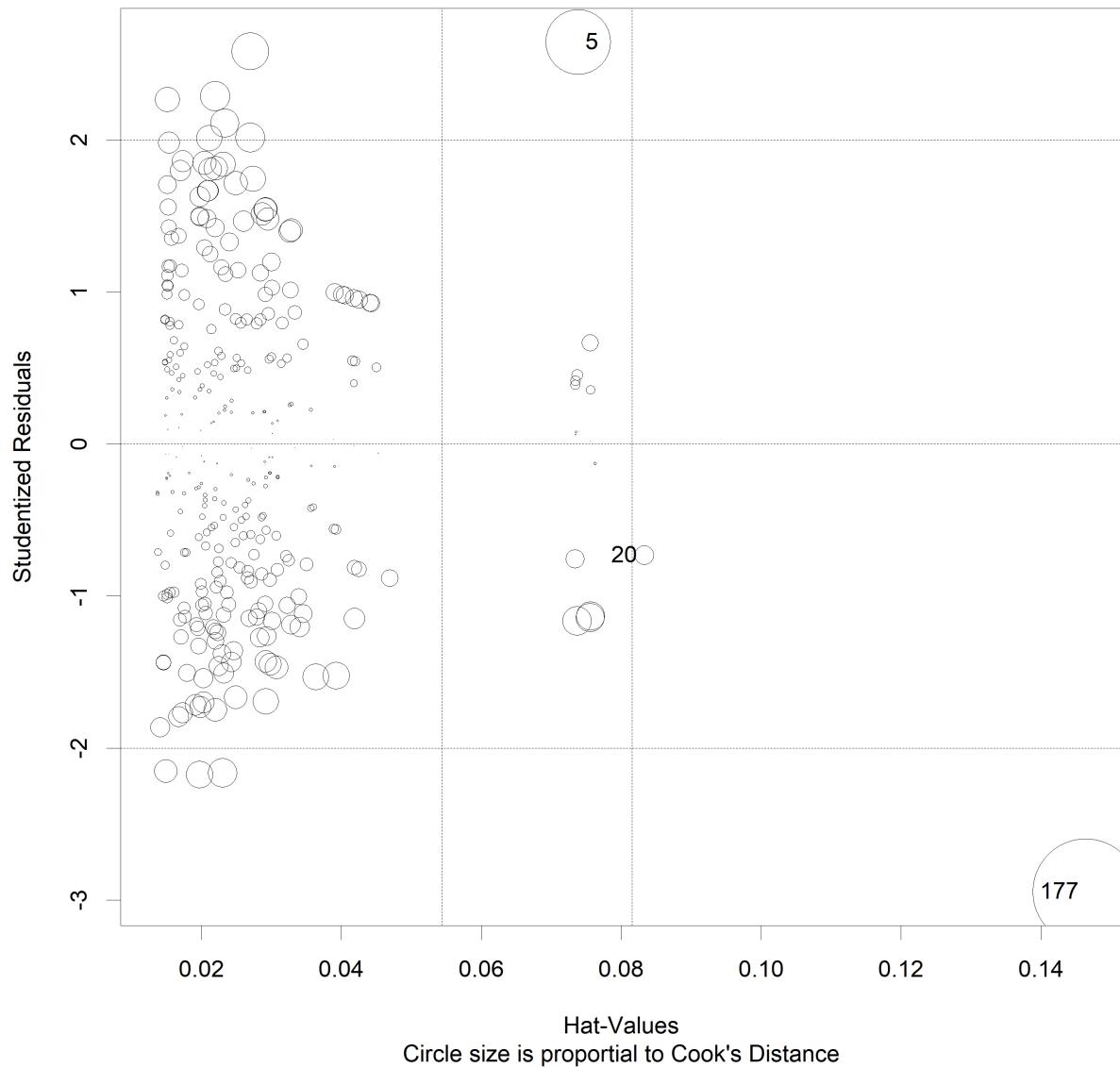
## Warning in box(...): "id.method" is not a graphical parameter

## Warning in title(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "id.method" is not a
## graphical parameter

```

Jury Model - Influence Plot



Normality Assumption

Normality Tests

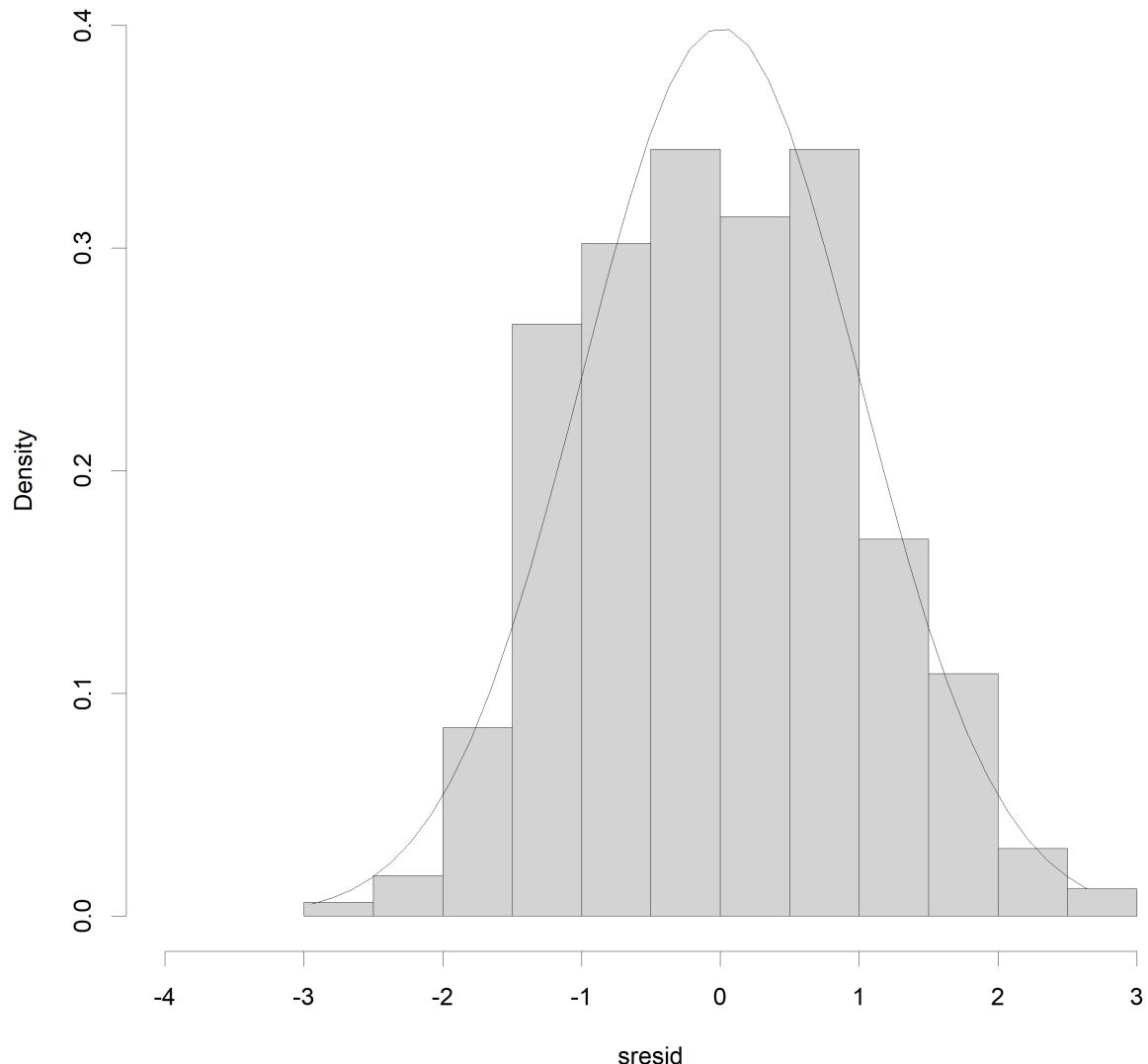
Normality Test

- 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

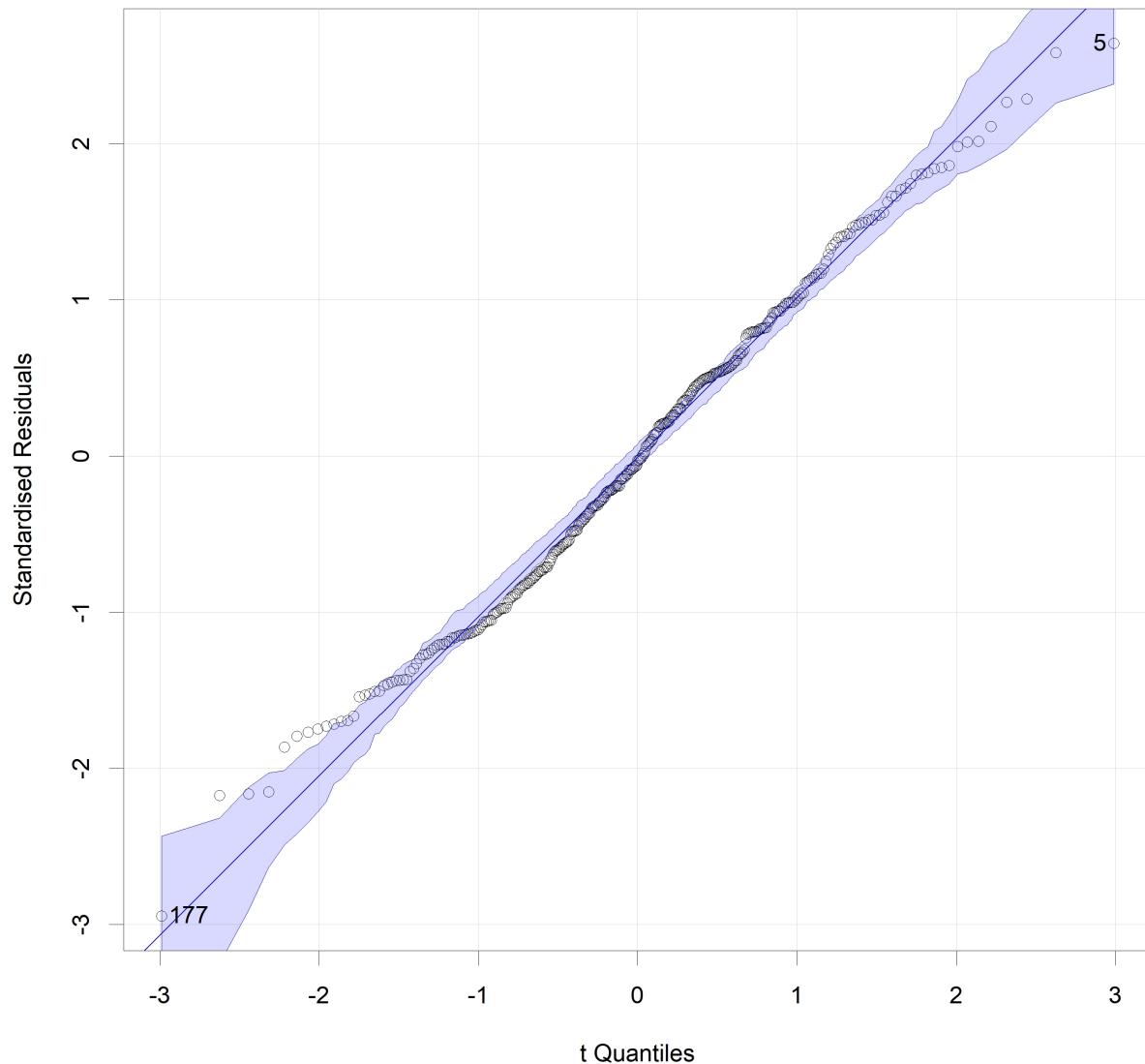
Residual Histogram

Jury Model - Distribution of Standardised Residuals



Residual QQ-Plot

QQ-Plot of Jury Vote Model Standardised Residuals



Constant Variance Assumption

Non-Constant Variance Test

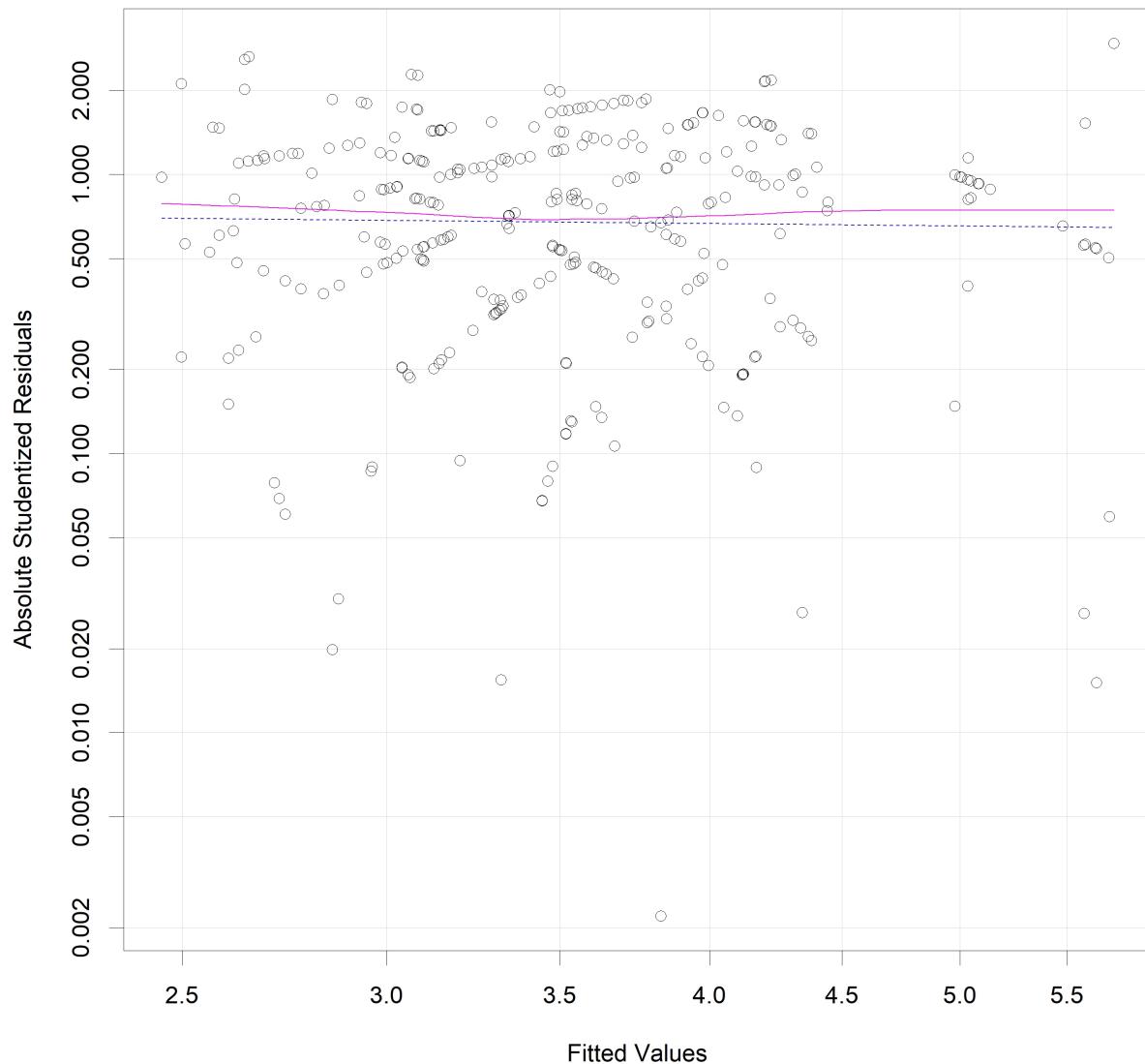
Non-Constant Error Variance Test

- 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