

# 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

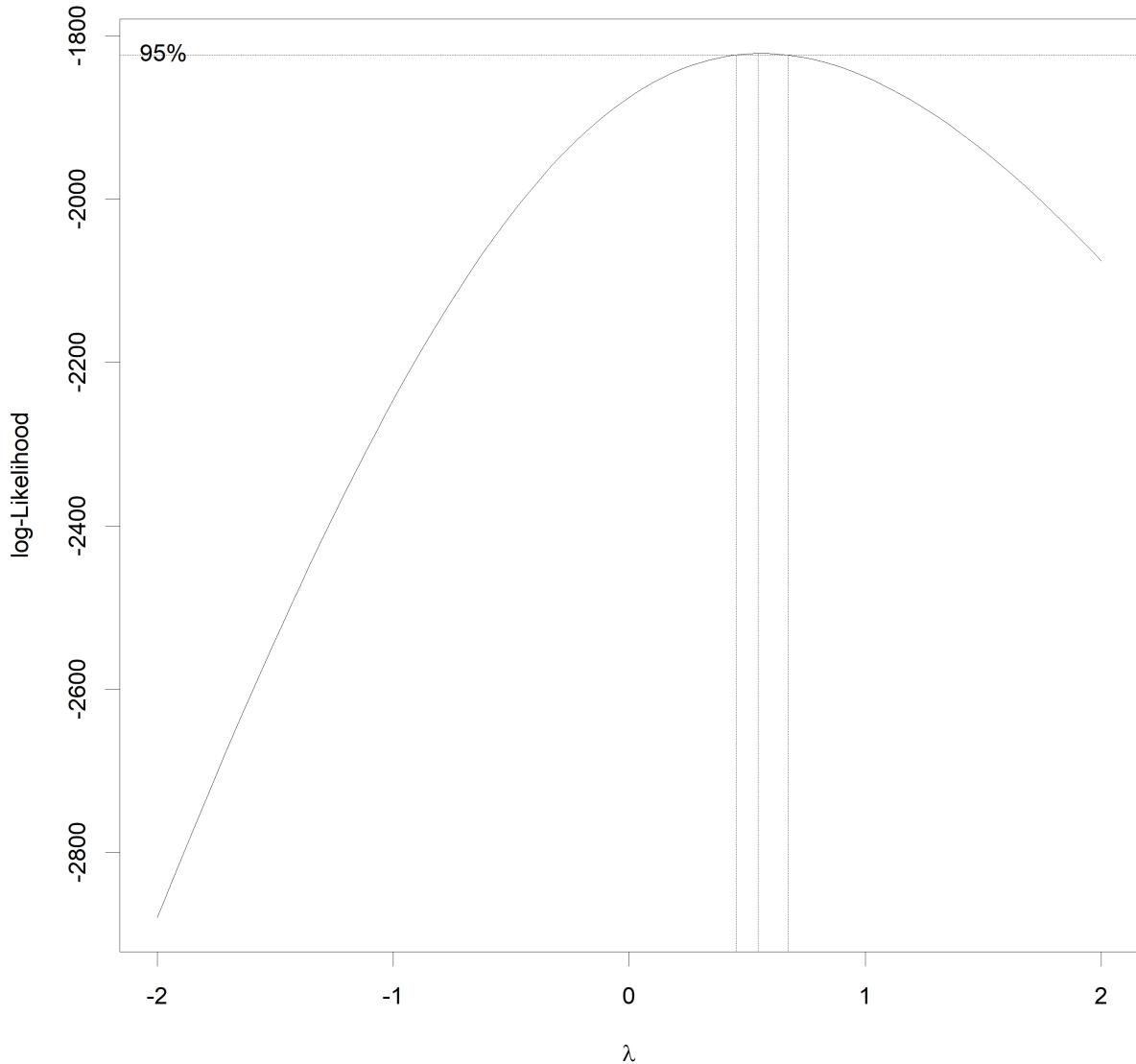
## Overall Model

```
##  
## 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
```

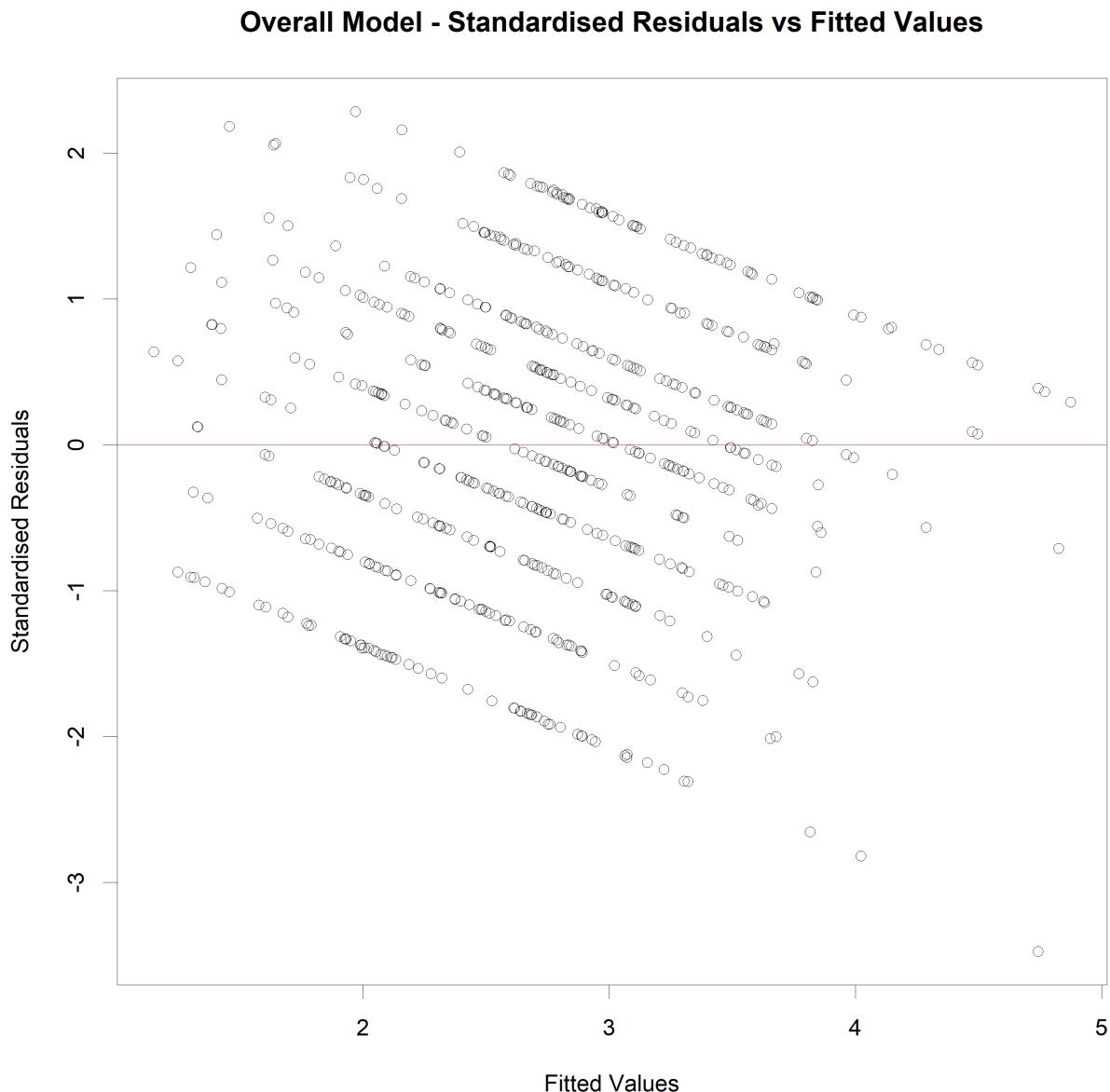
## Box-Cox Power Transformation

```
##  
## 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



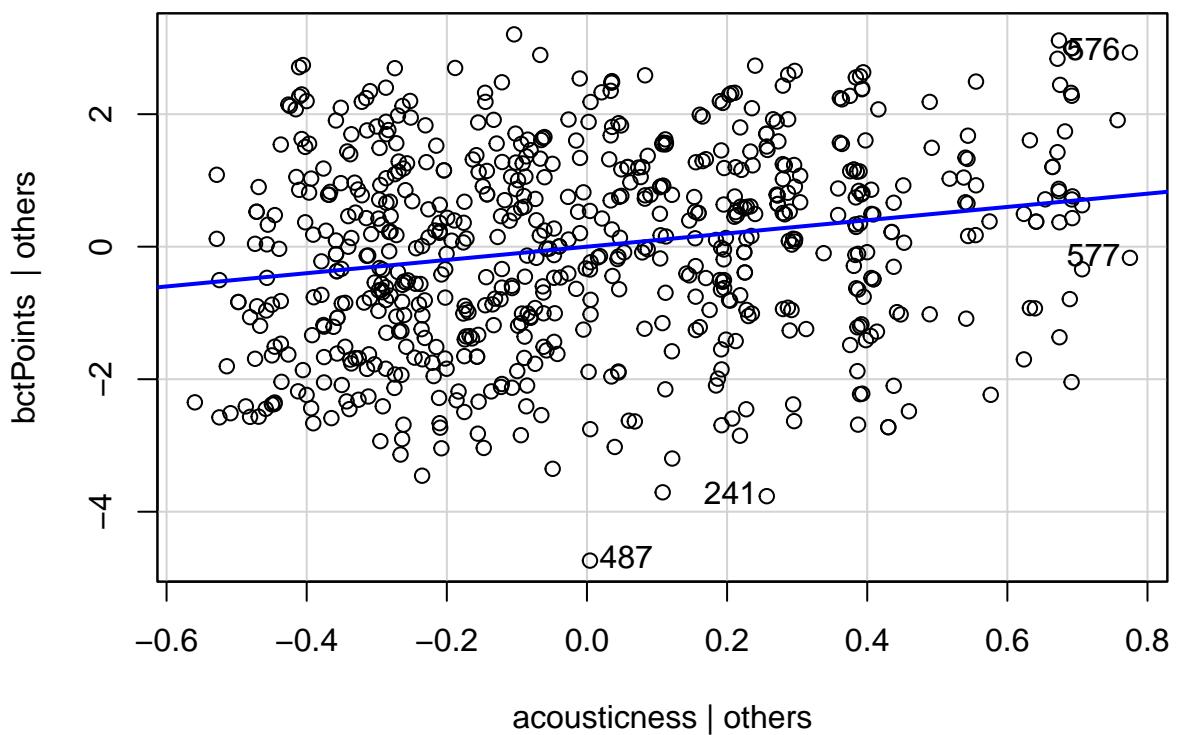
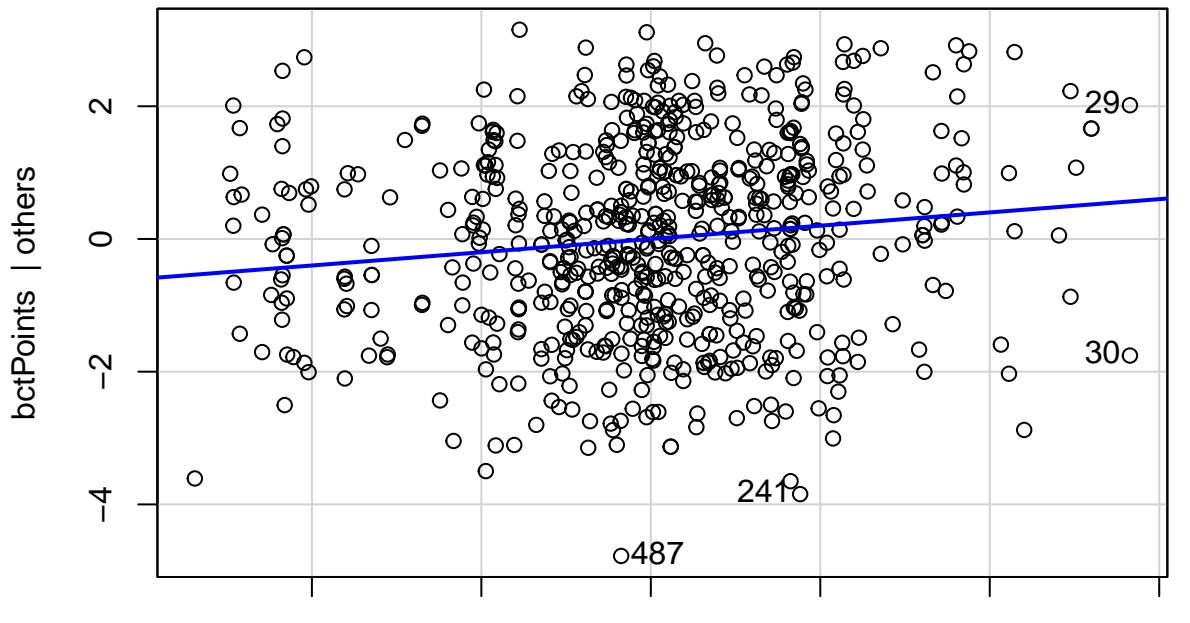
## Bonferroni Outlier Test

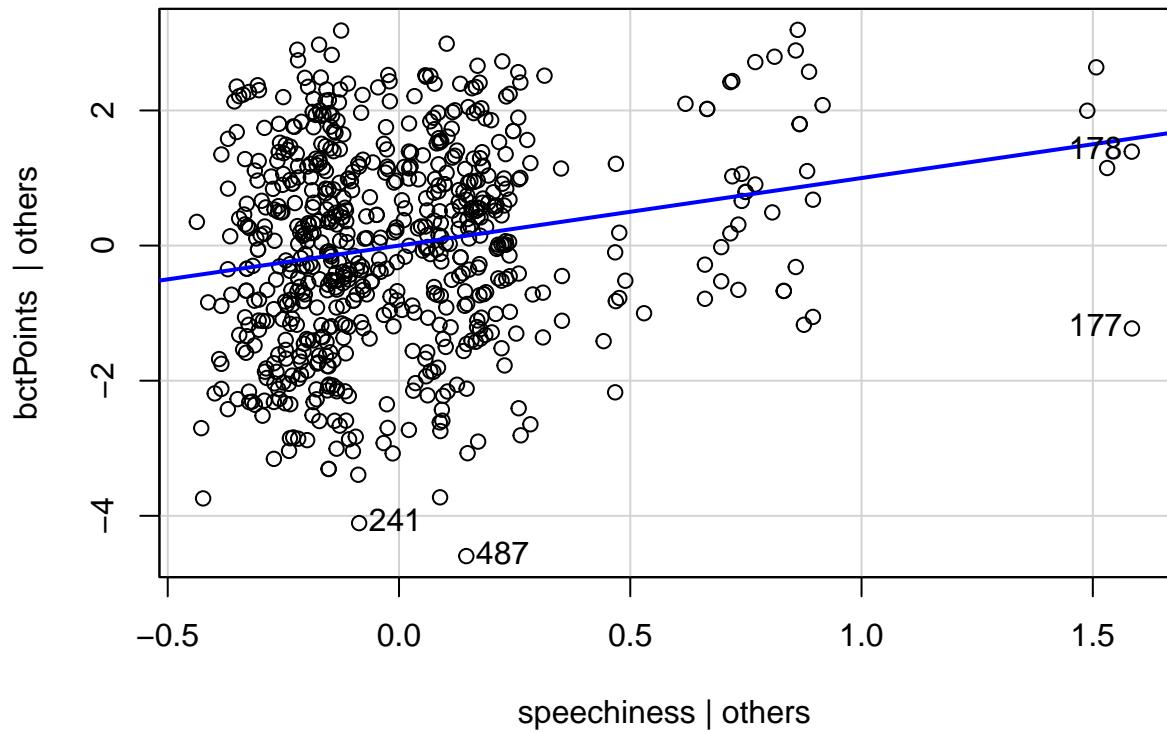
	rstudent	p	bonf.p	signif	cutoff
487	-3.473914	0.0005472	0.3600624	0	0.05

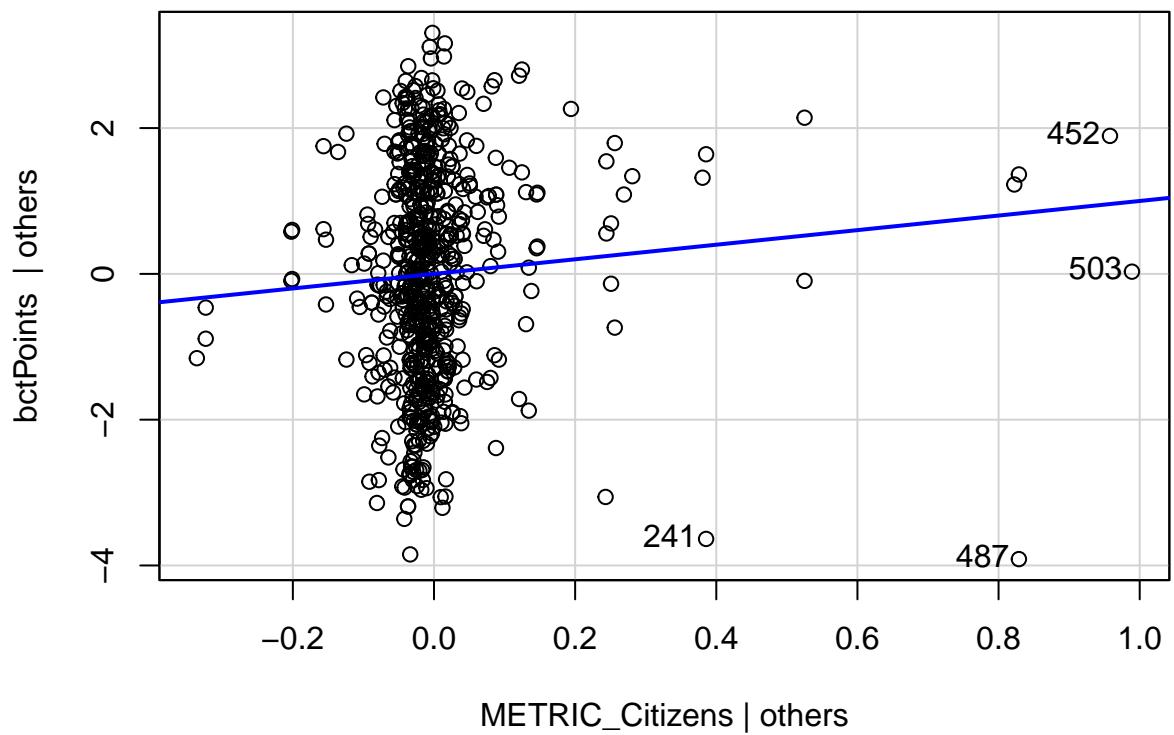
## Outlier Standardised Residuals

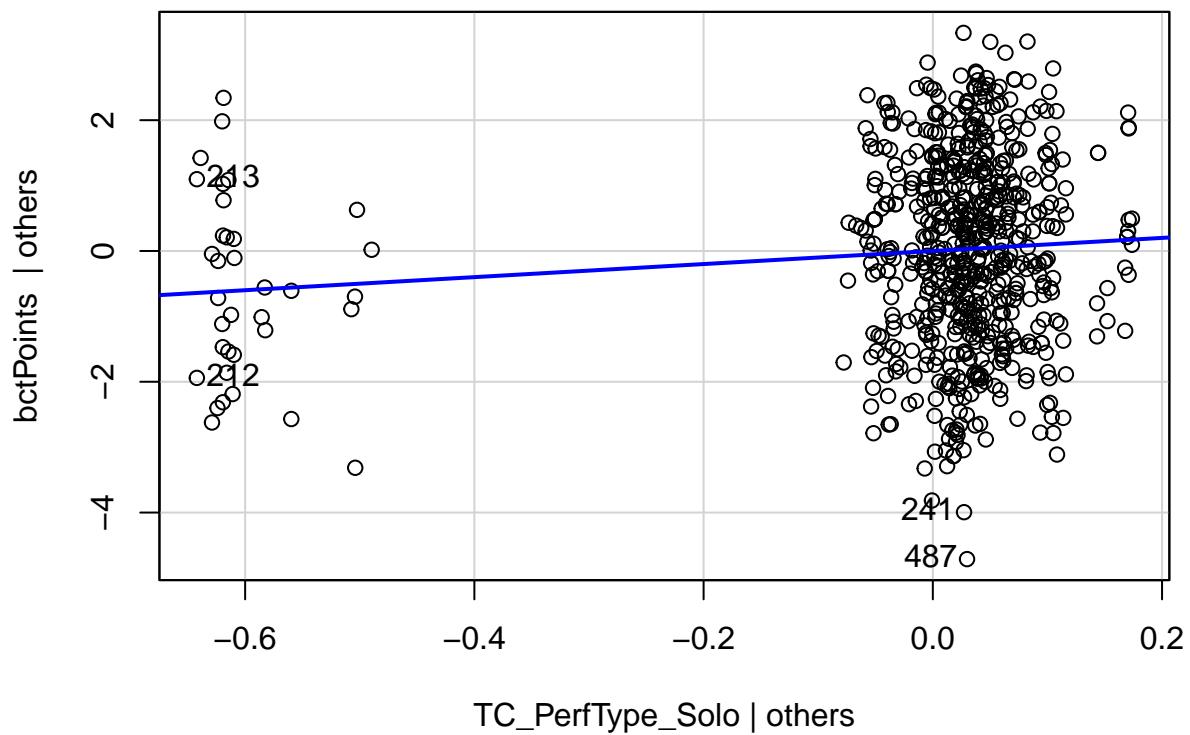
outlier_residuals
39
77
103
177
241
360

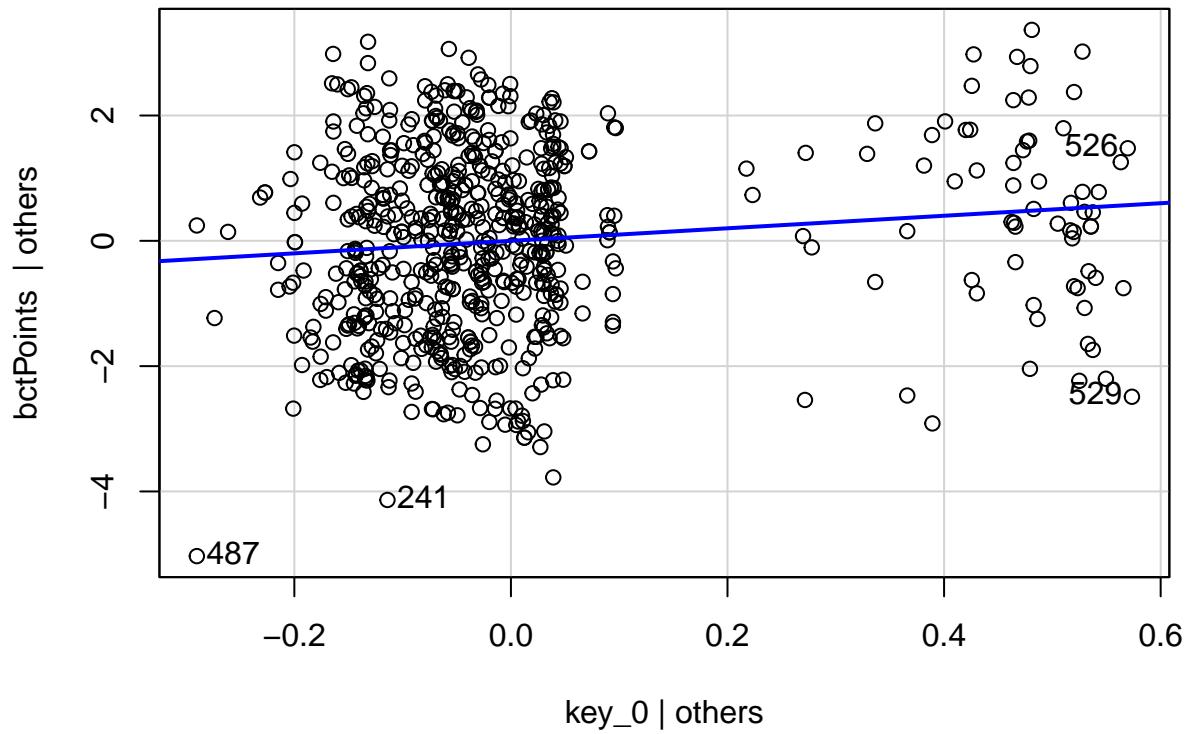
## Leverage Plots

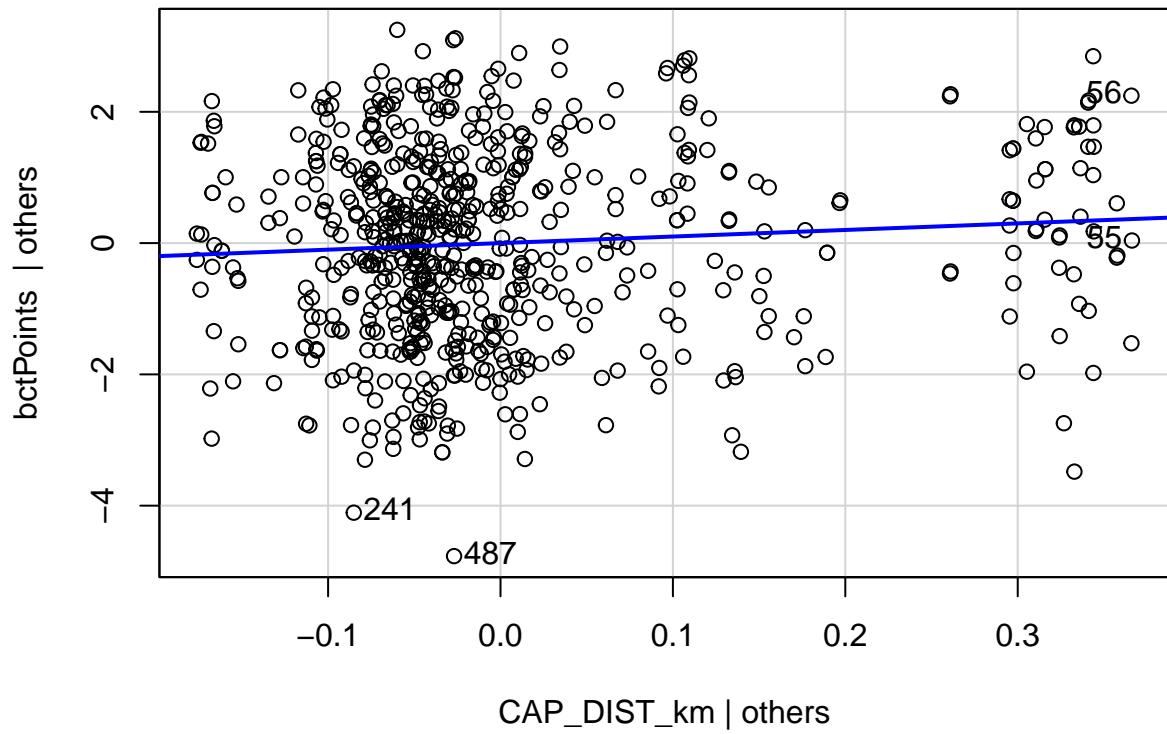


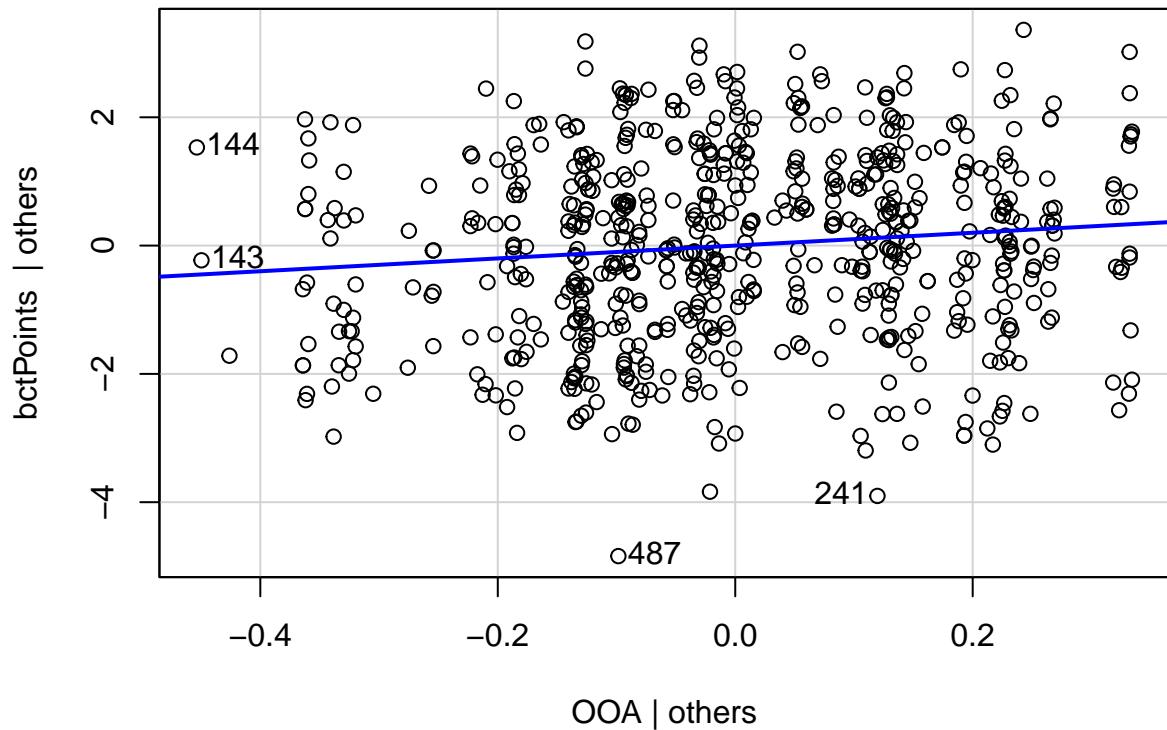


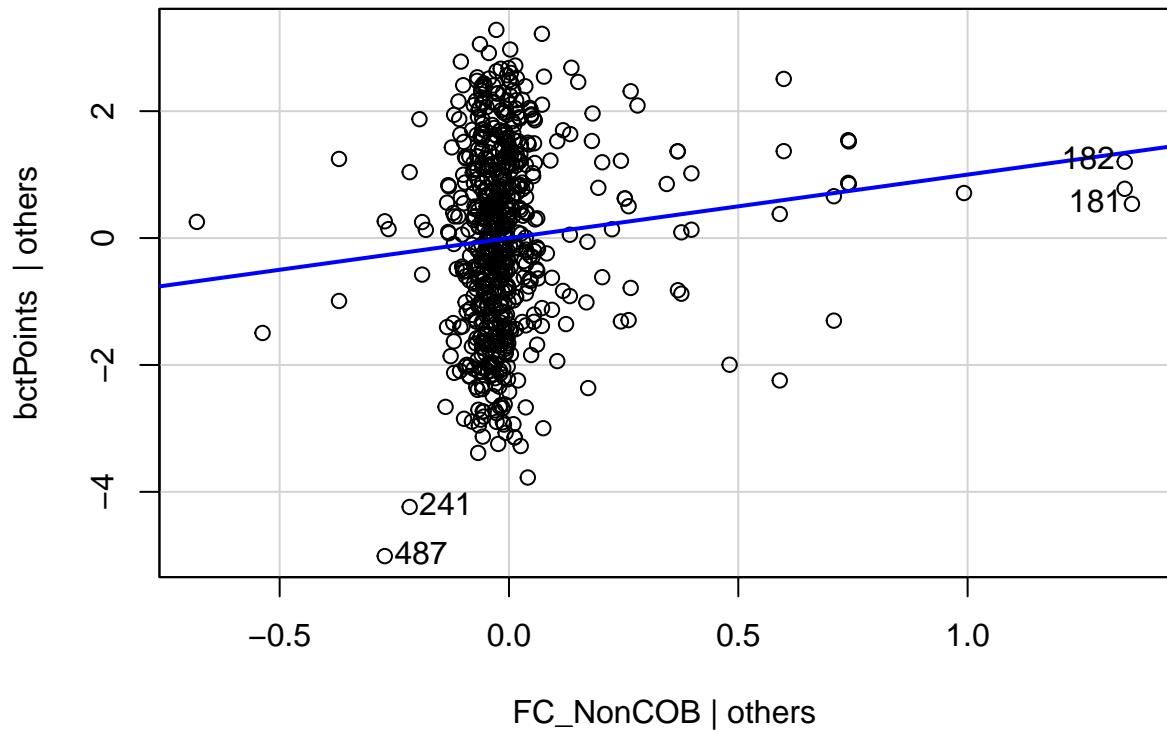




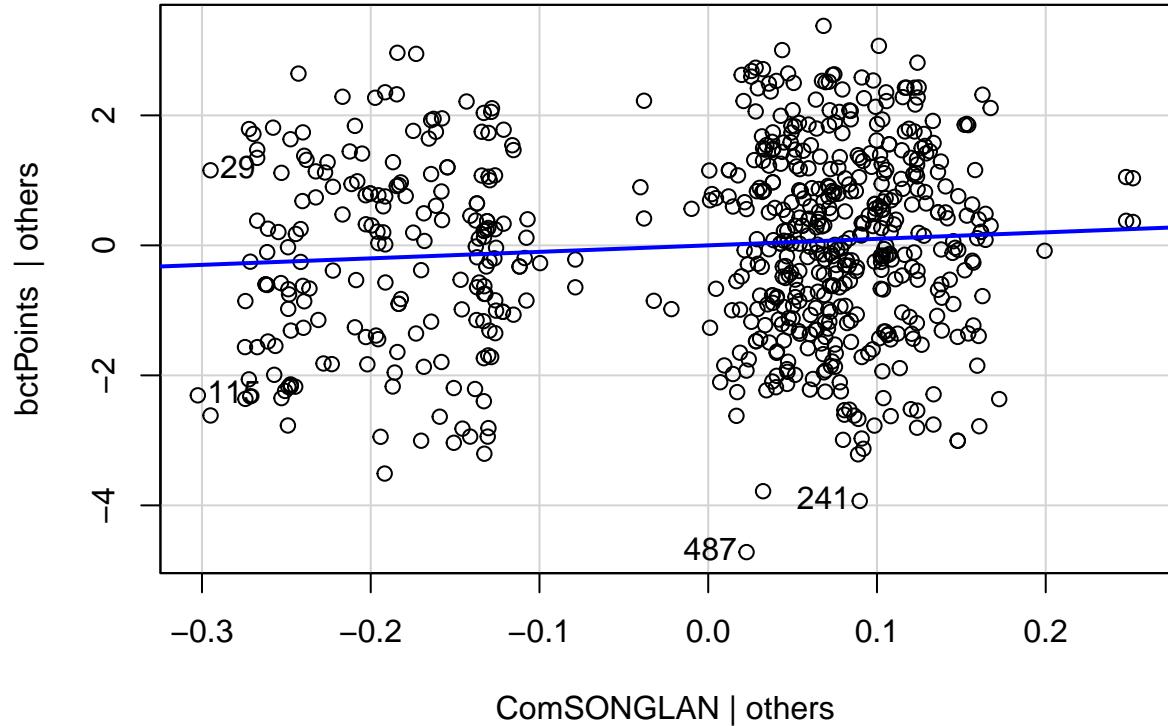




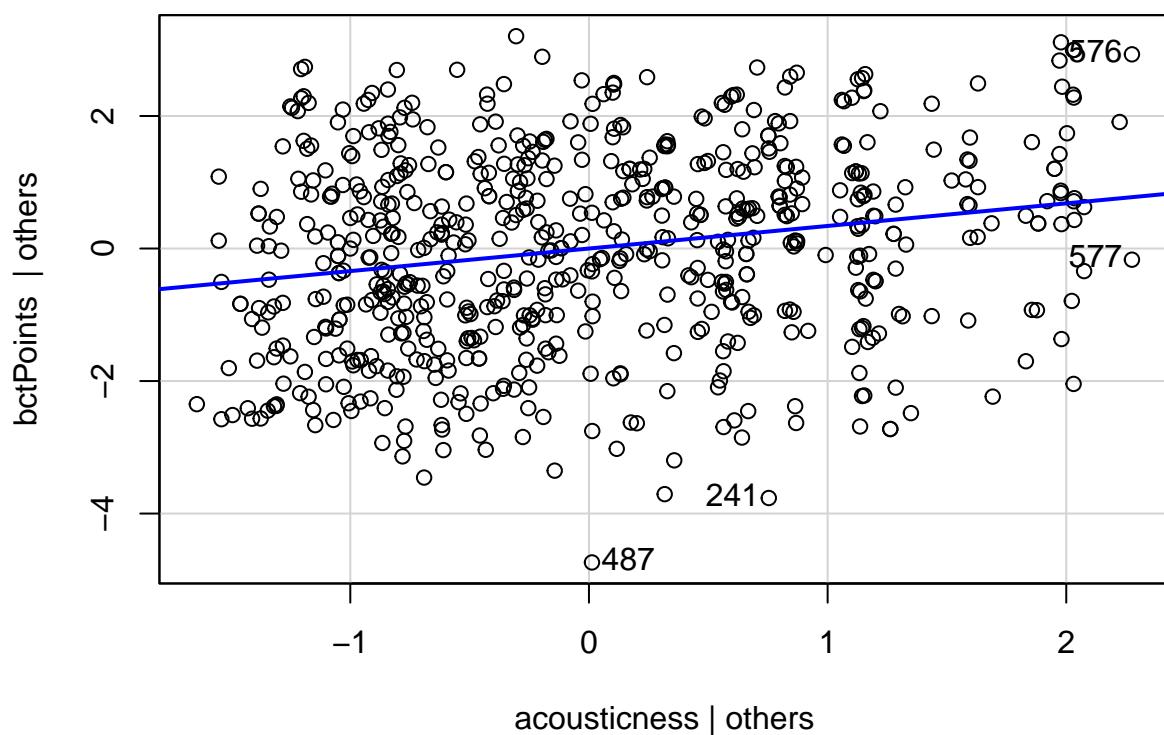
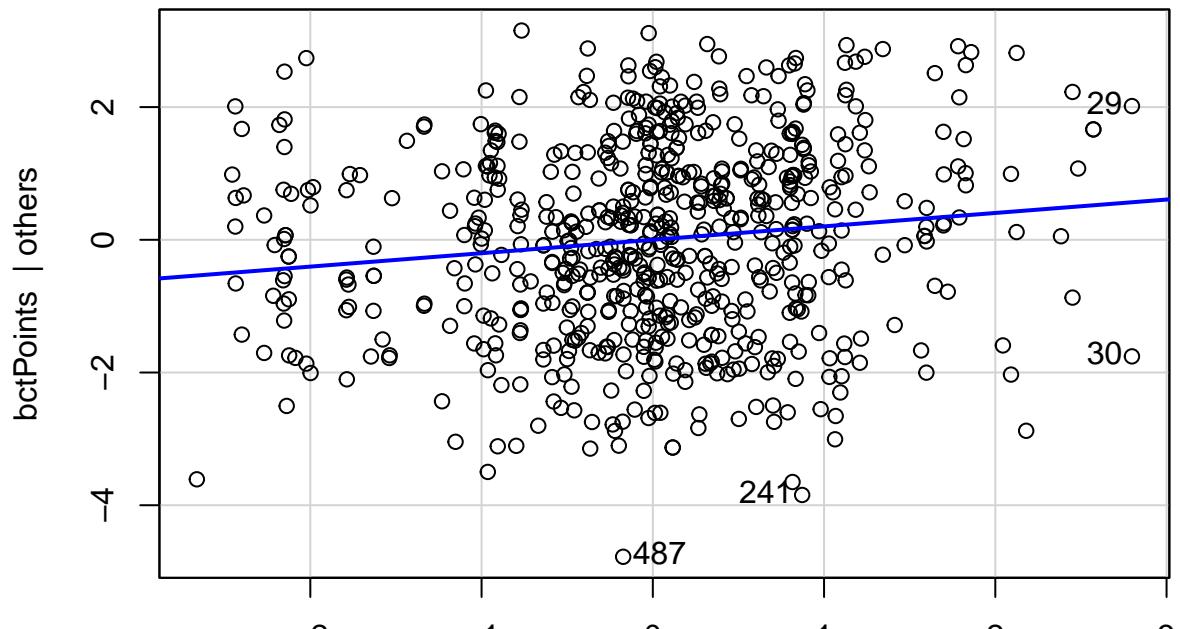


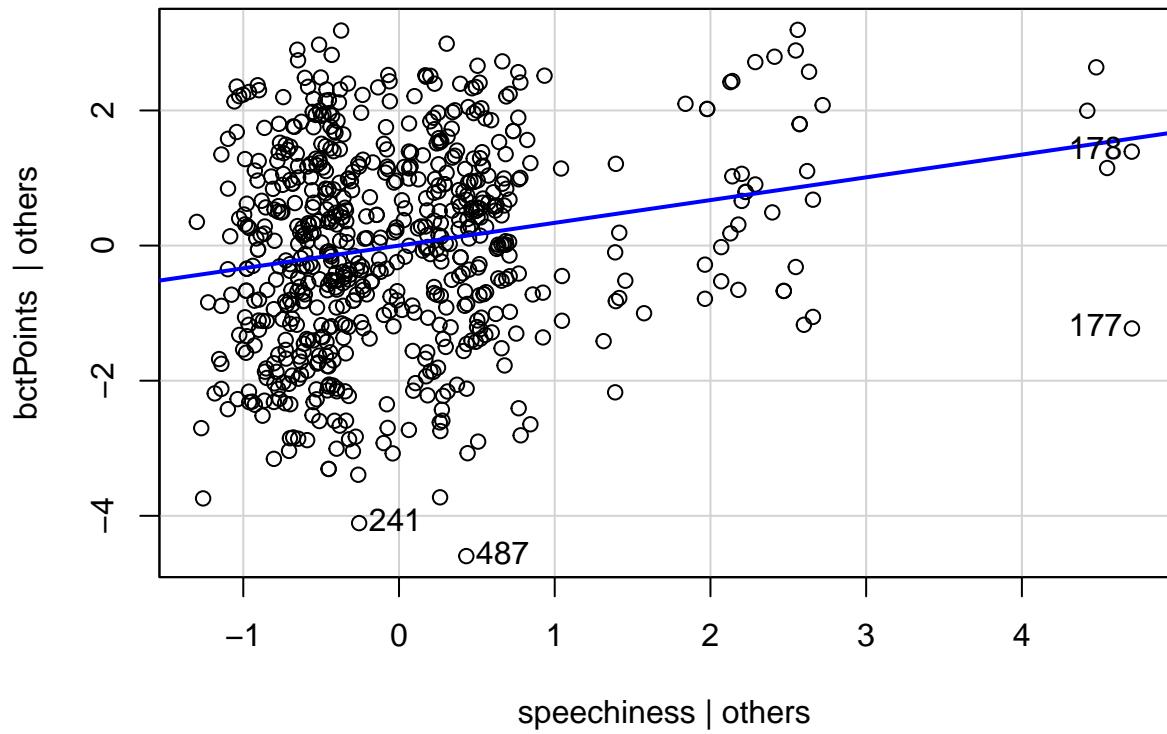


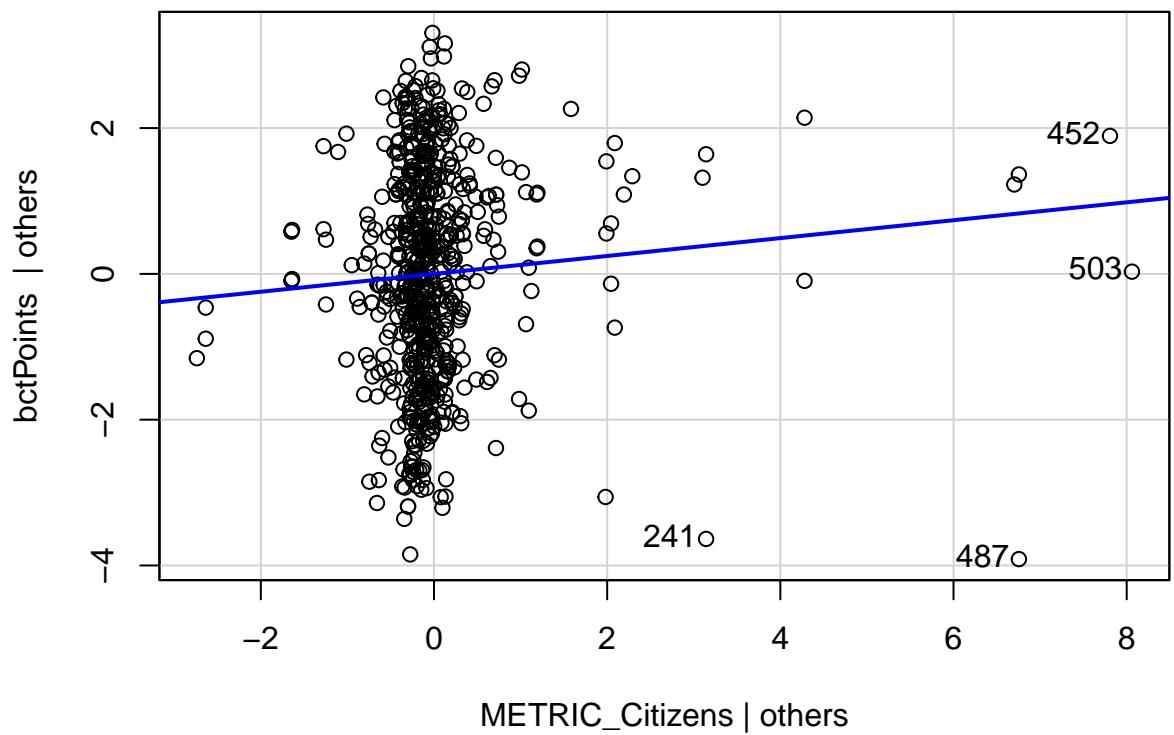
## Leverage Plots

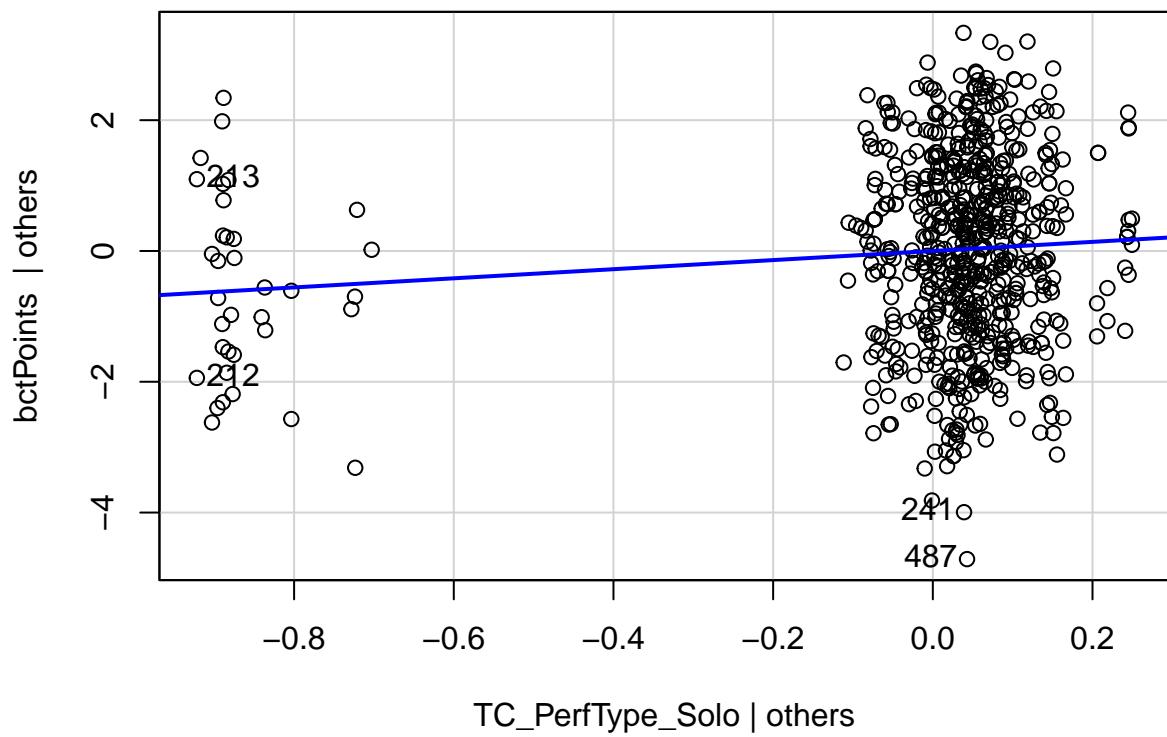


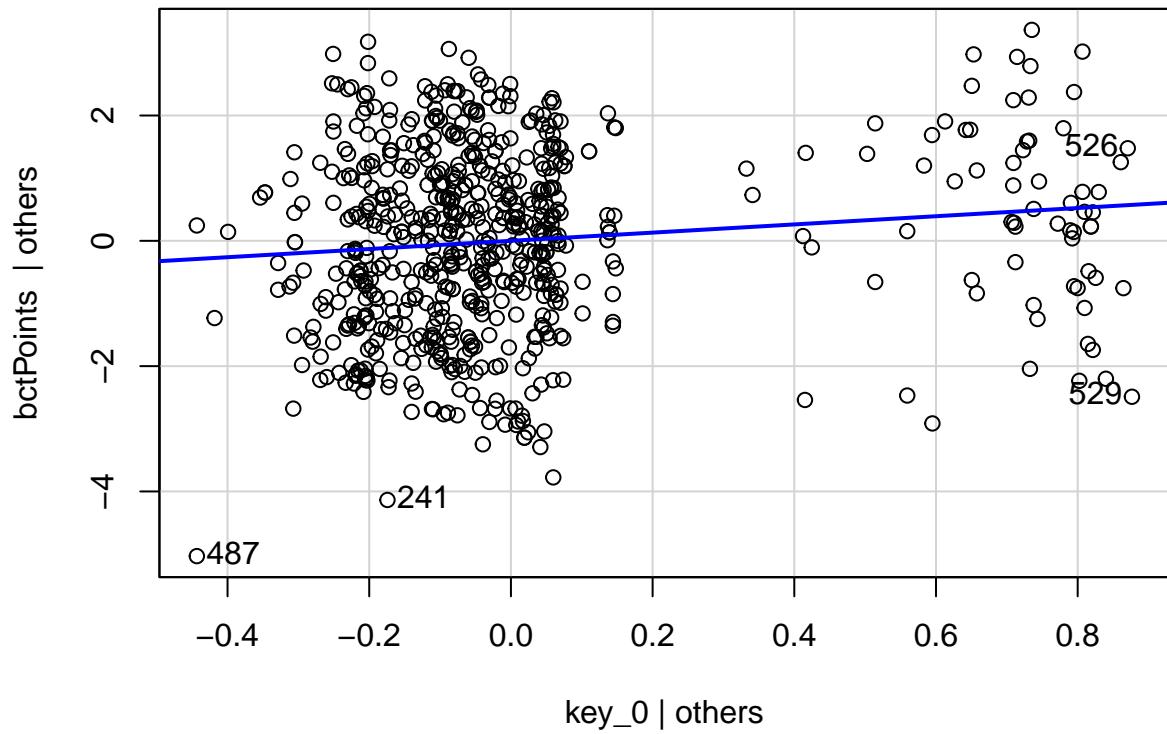
### Added-Variable Plots

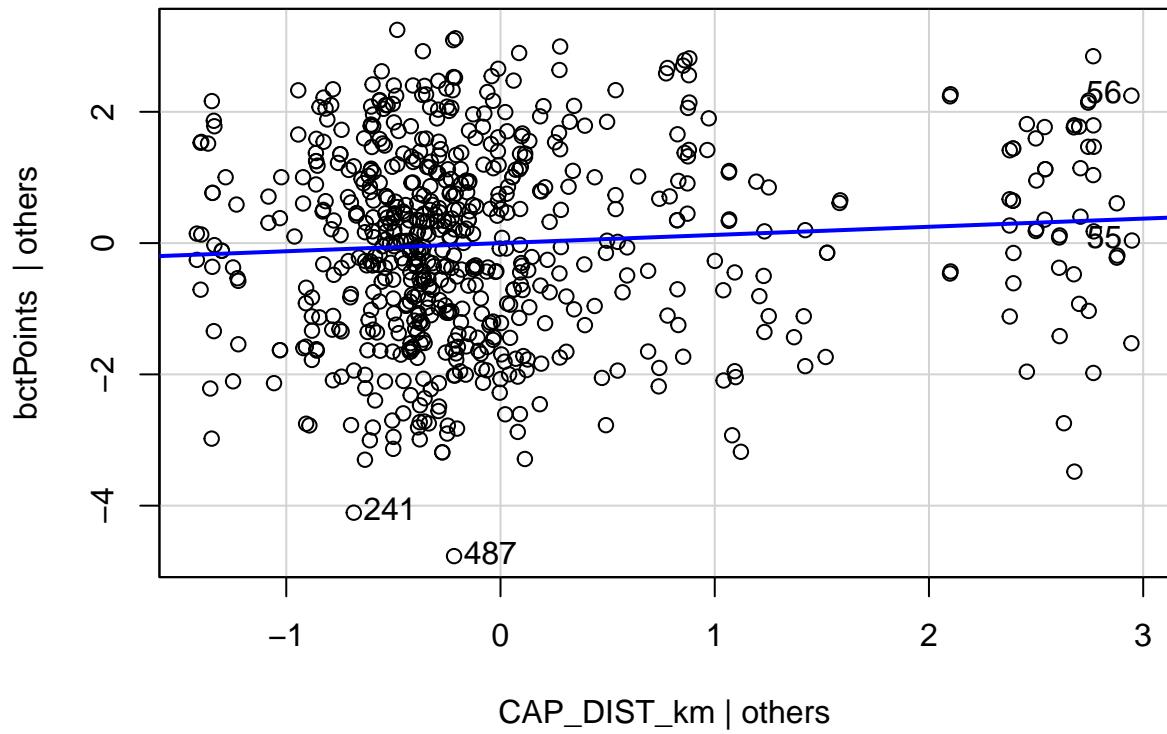


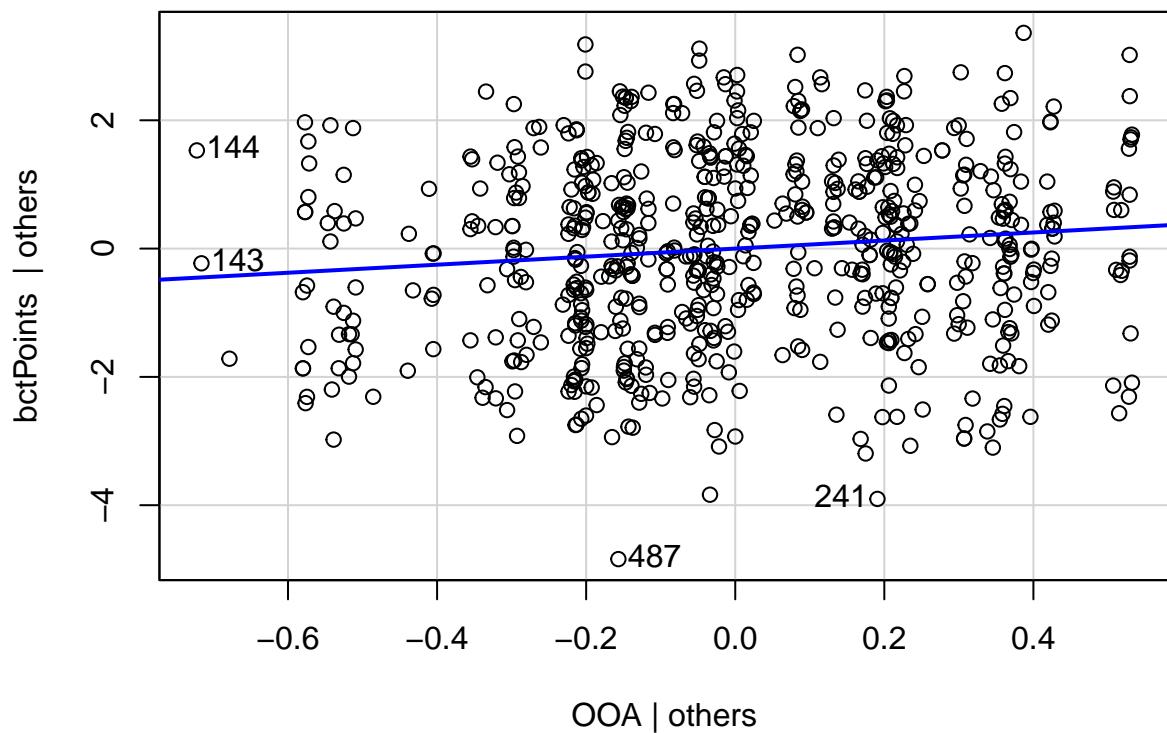


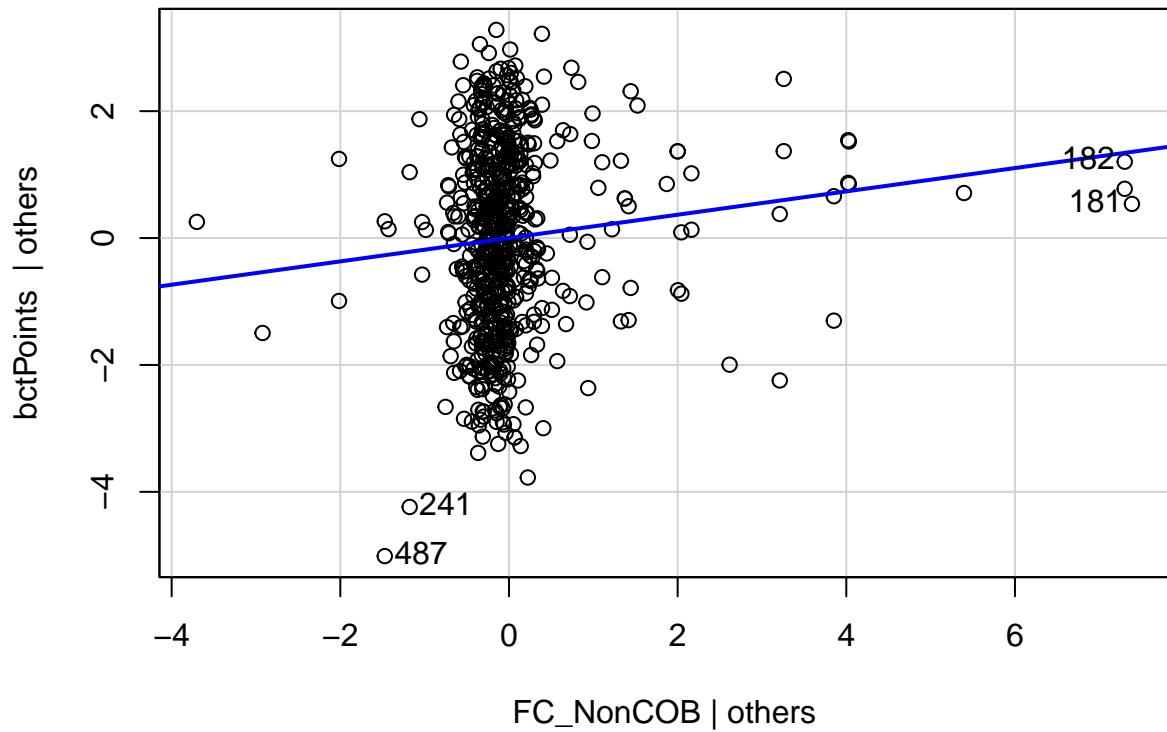




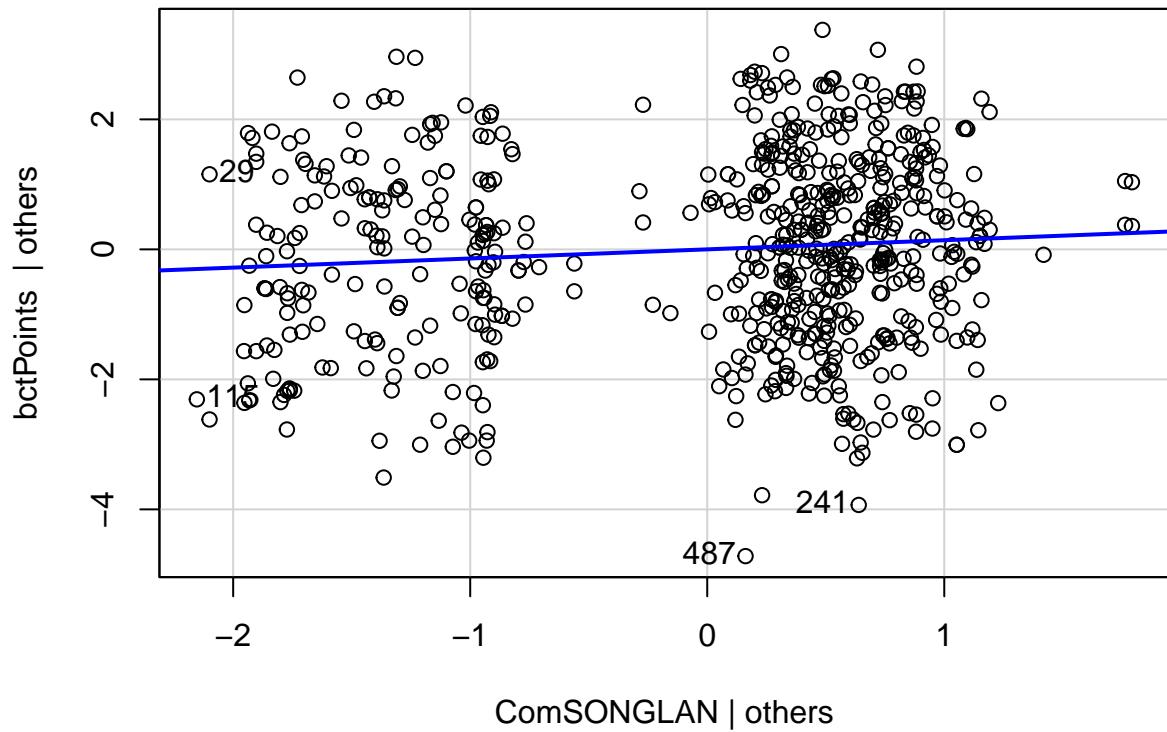




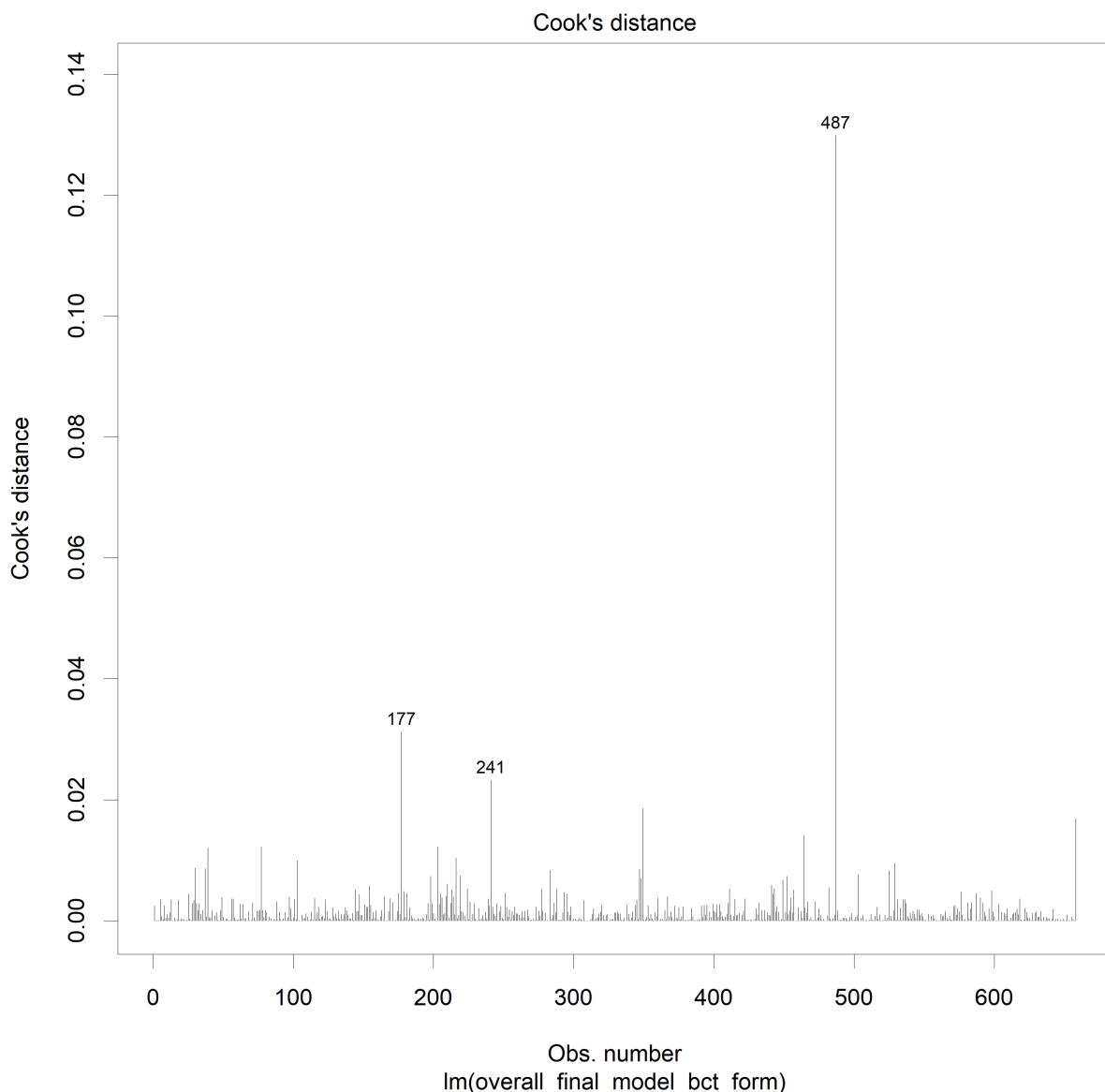




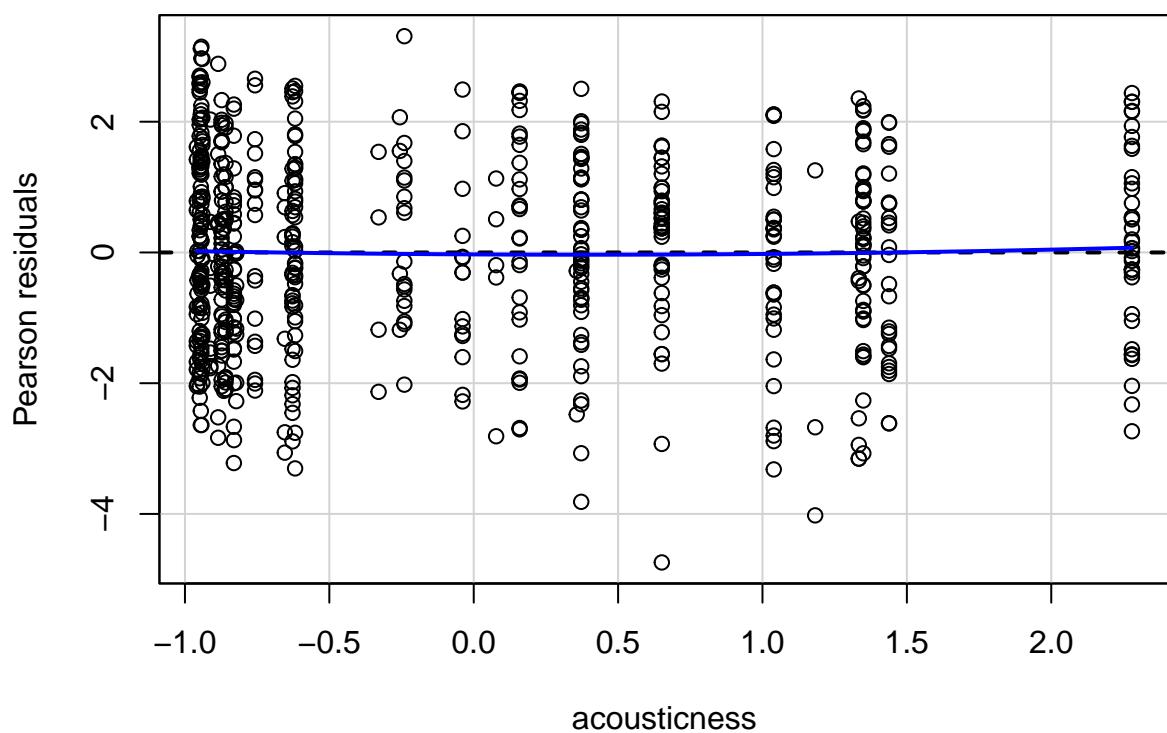
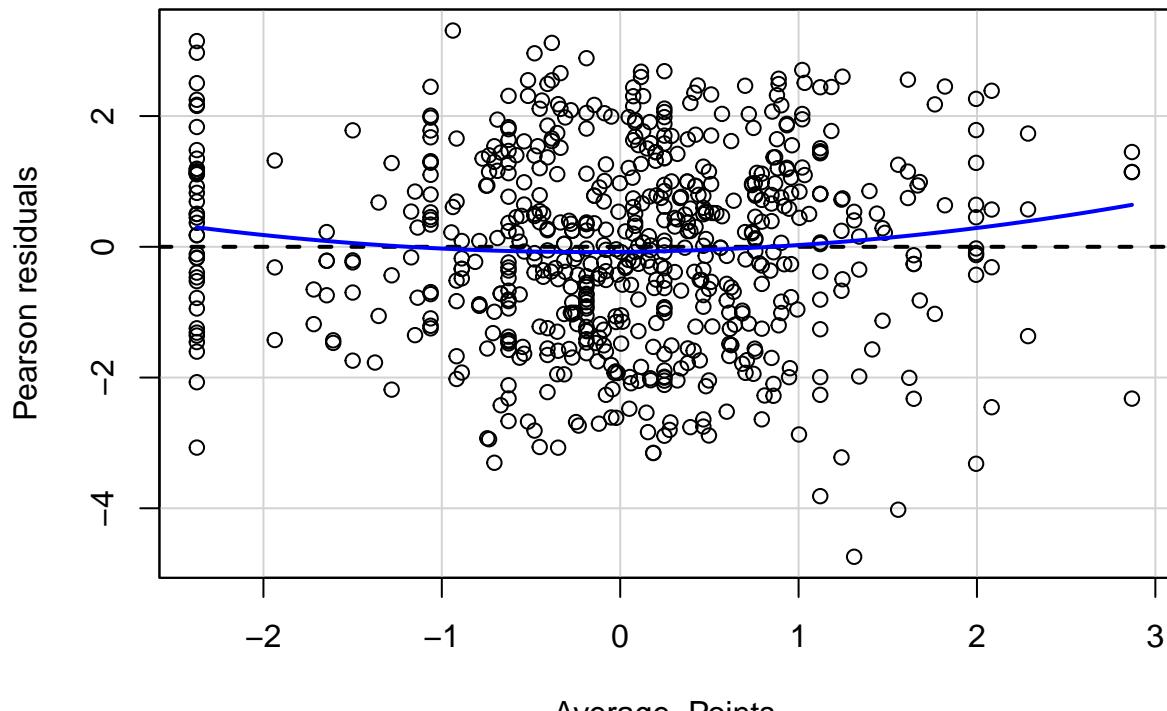
### Added-Variable Plots

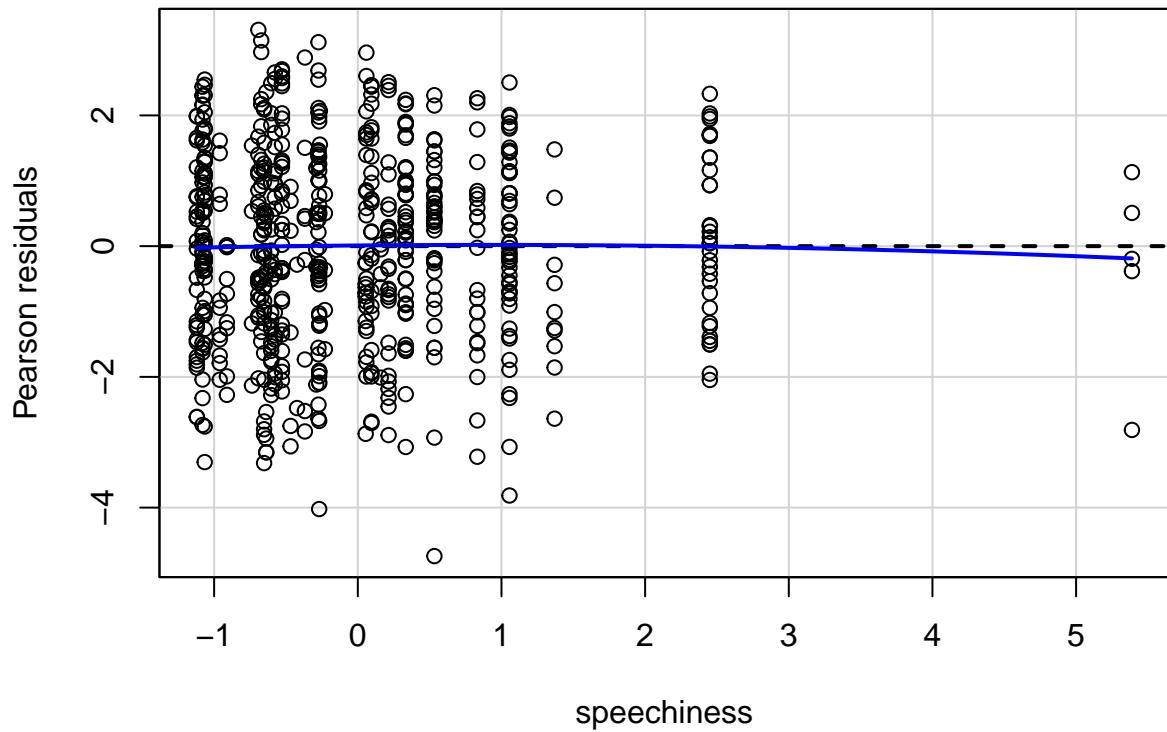


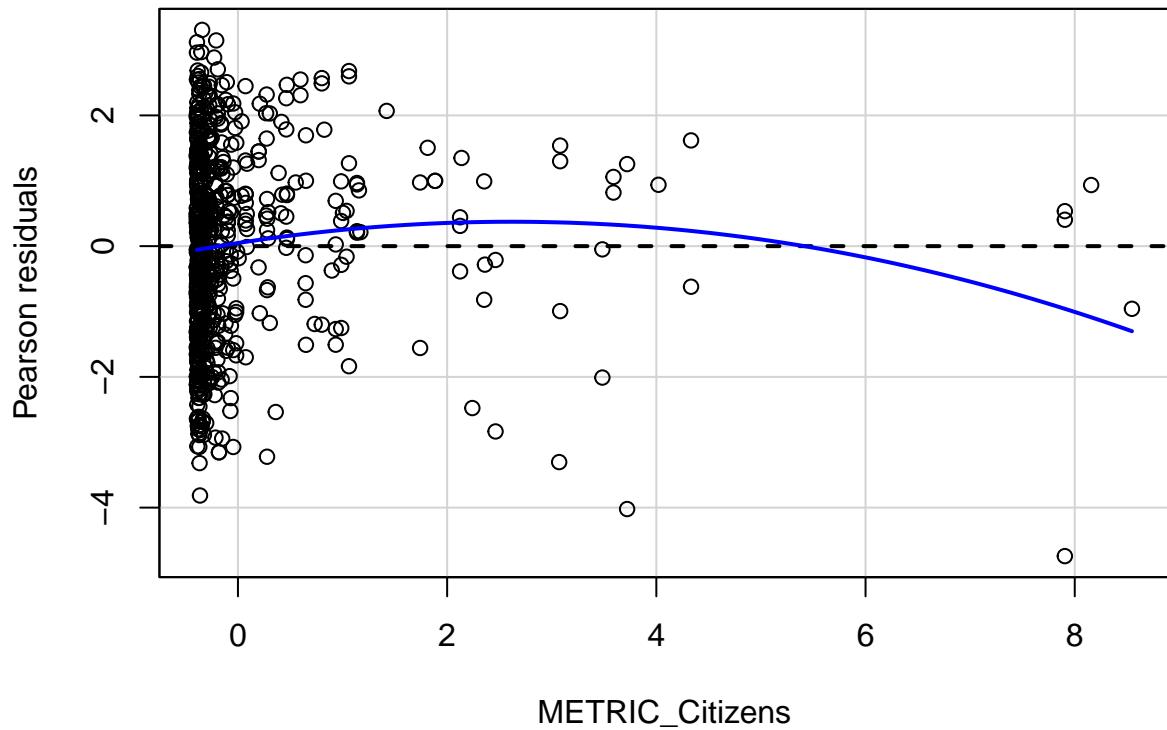
## Cooks Distance

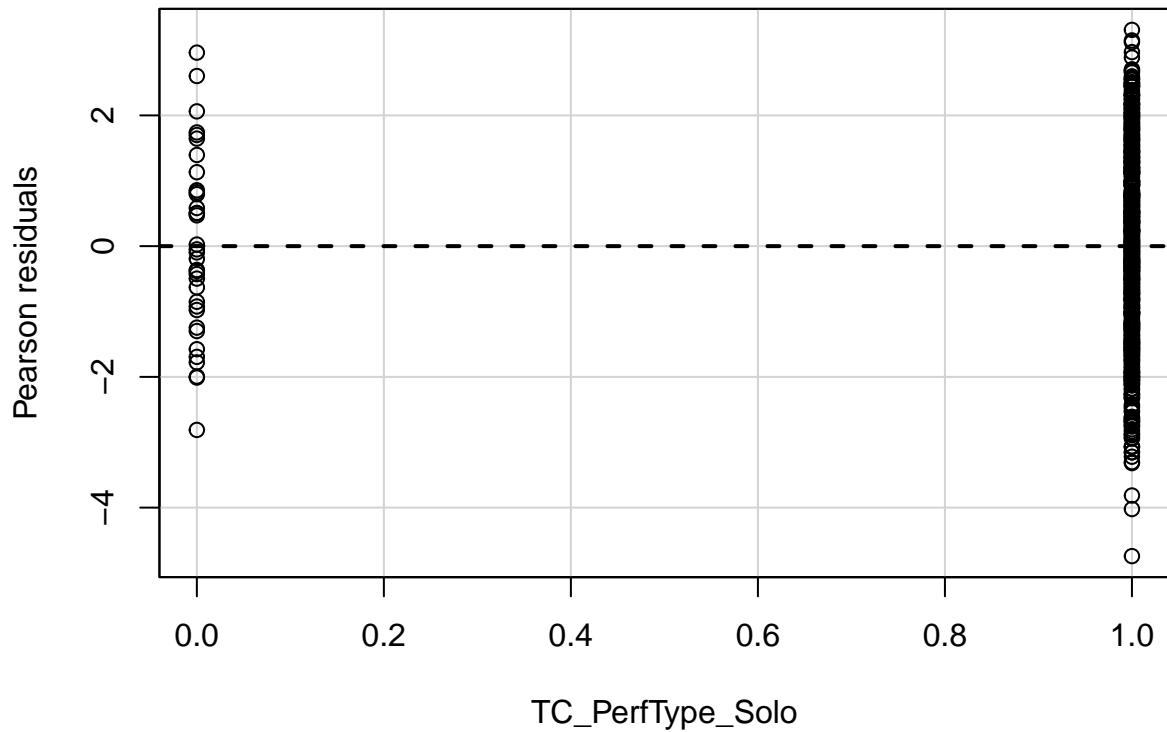


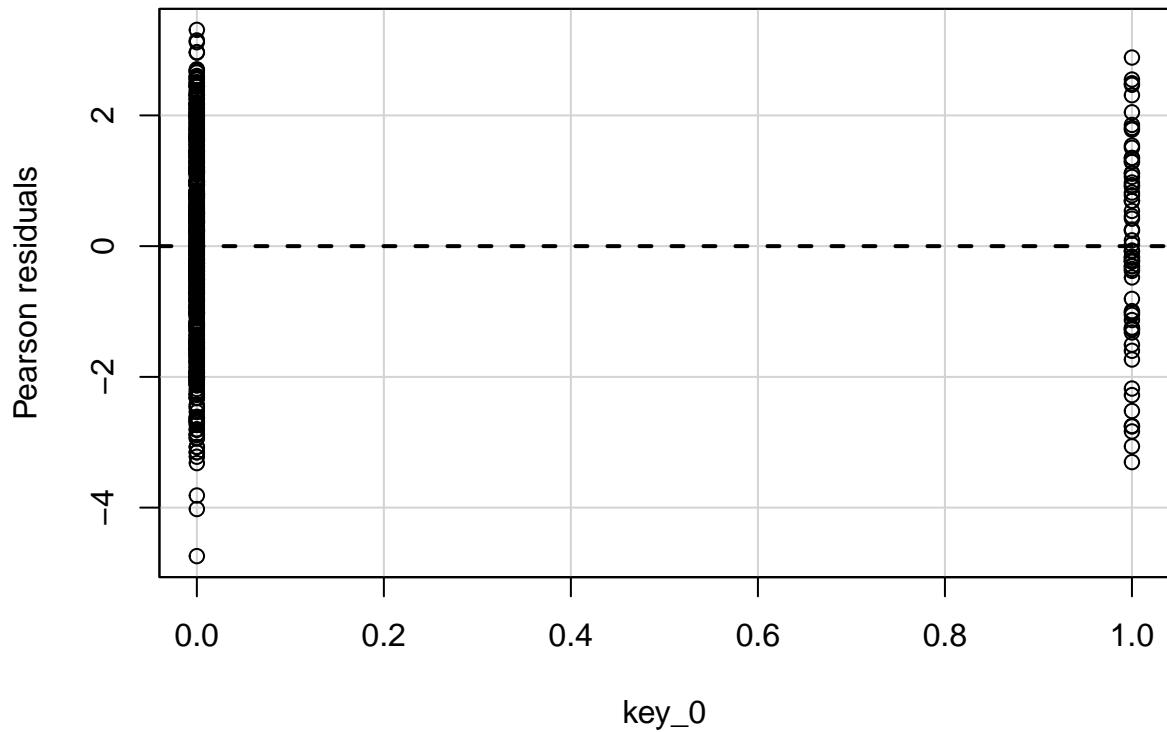
## Residual Plots

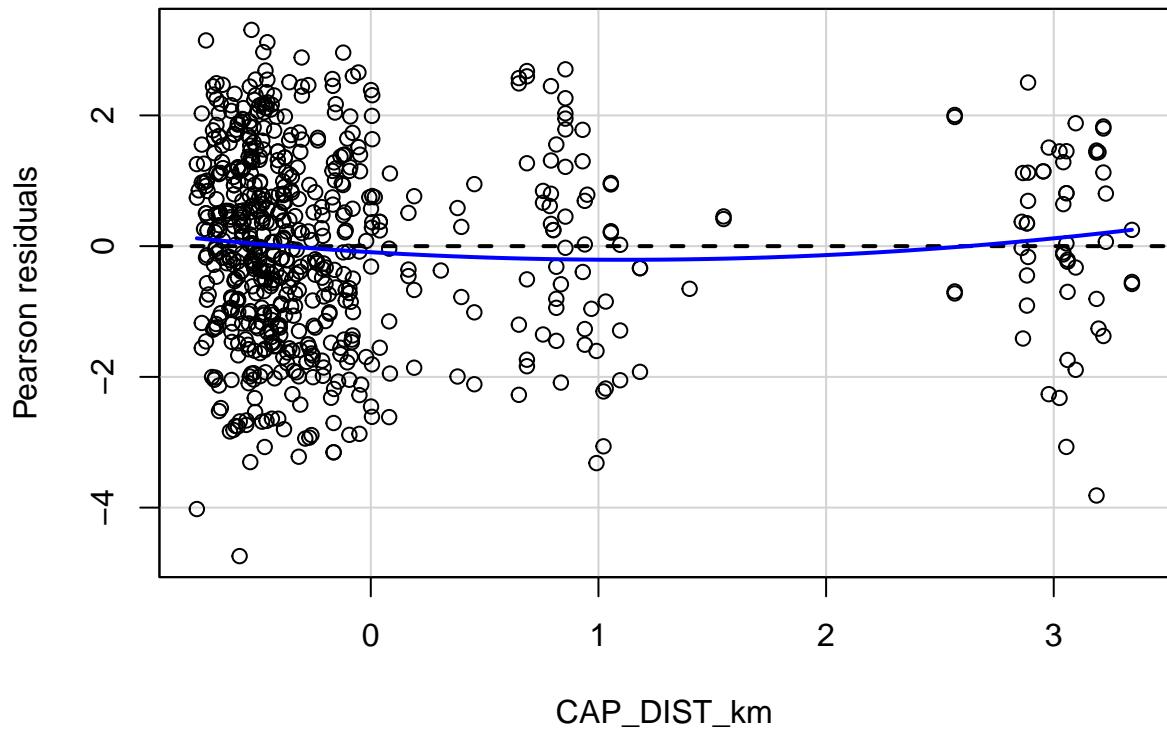


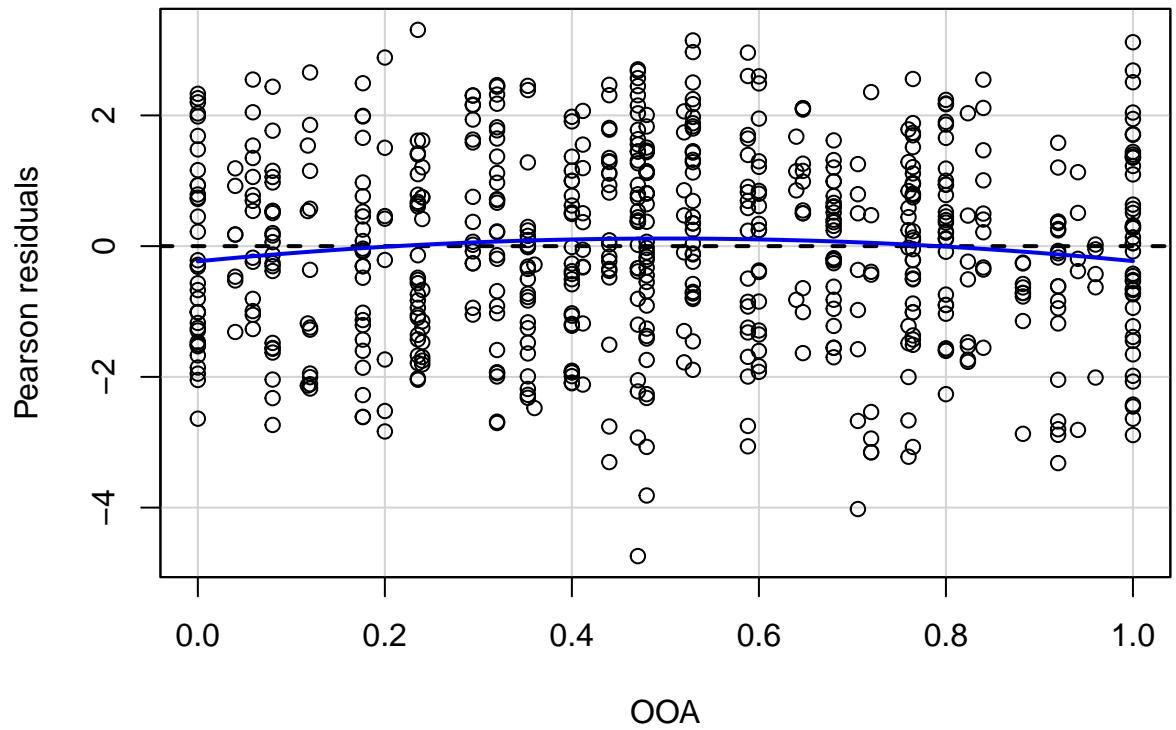


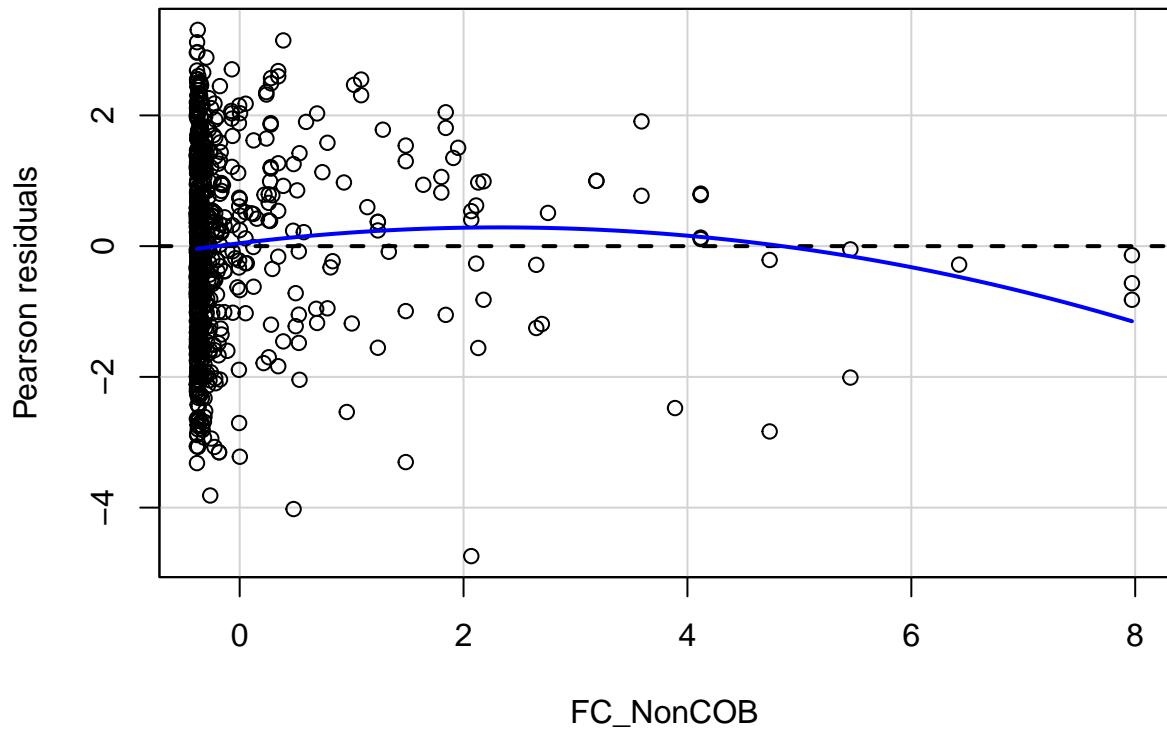


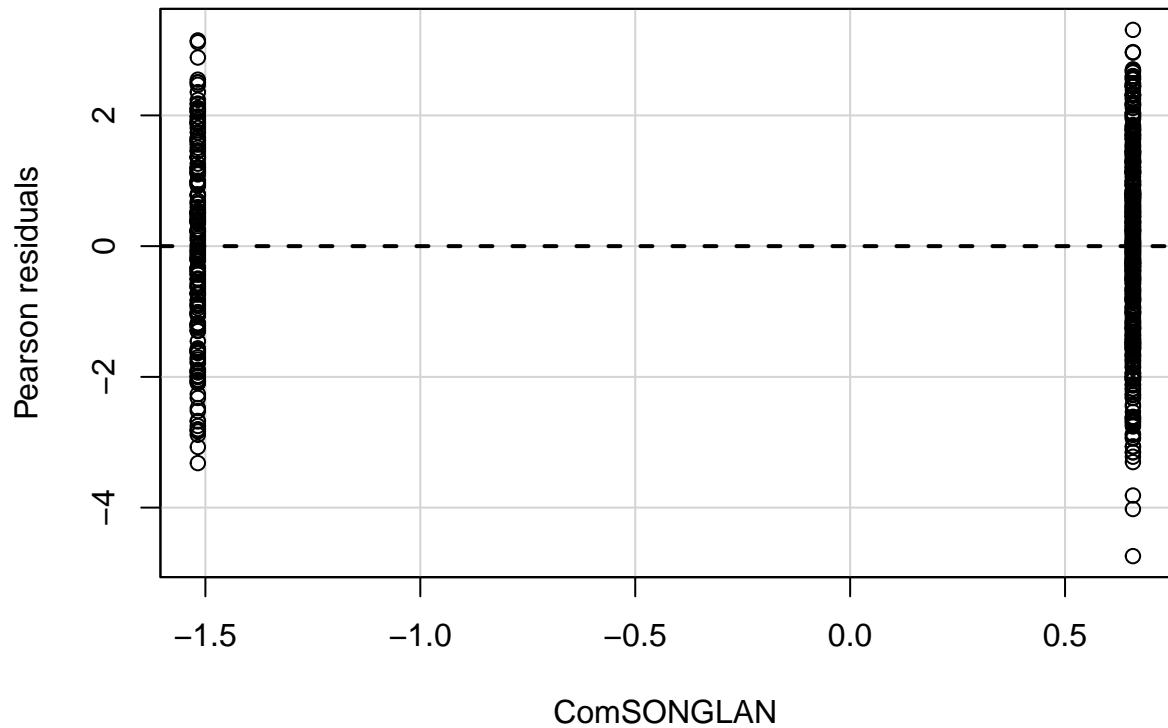


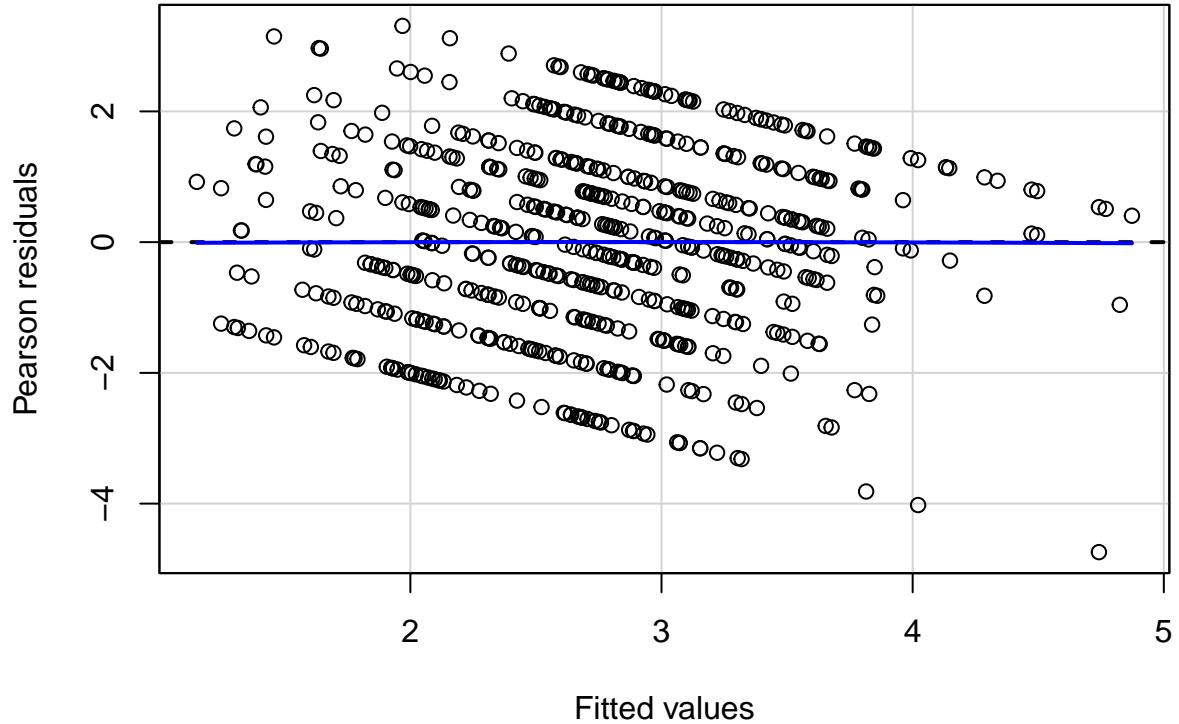












### Influence Plot

```

## 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

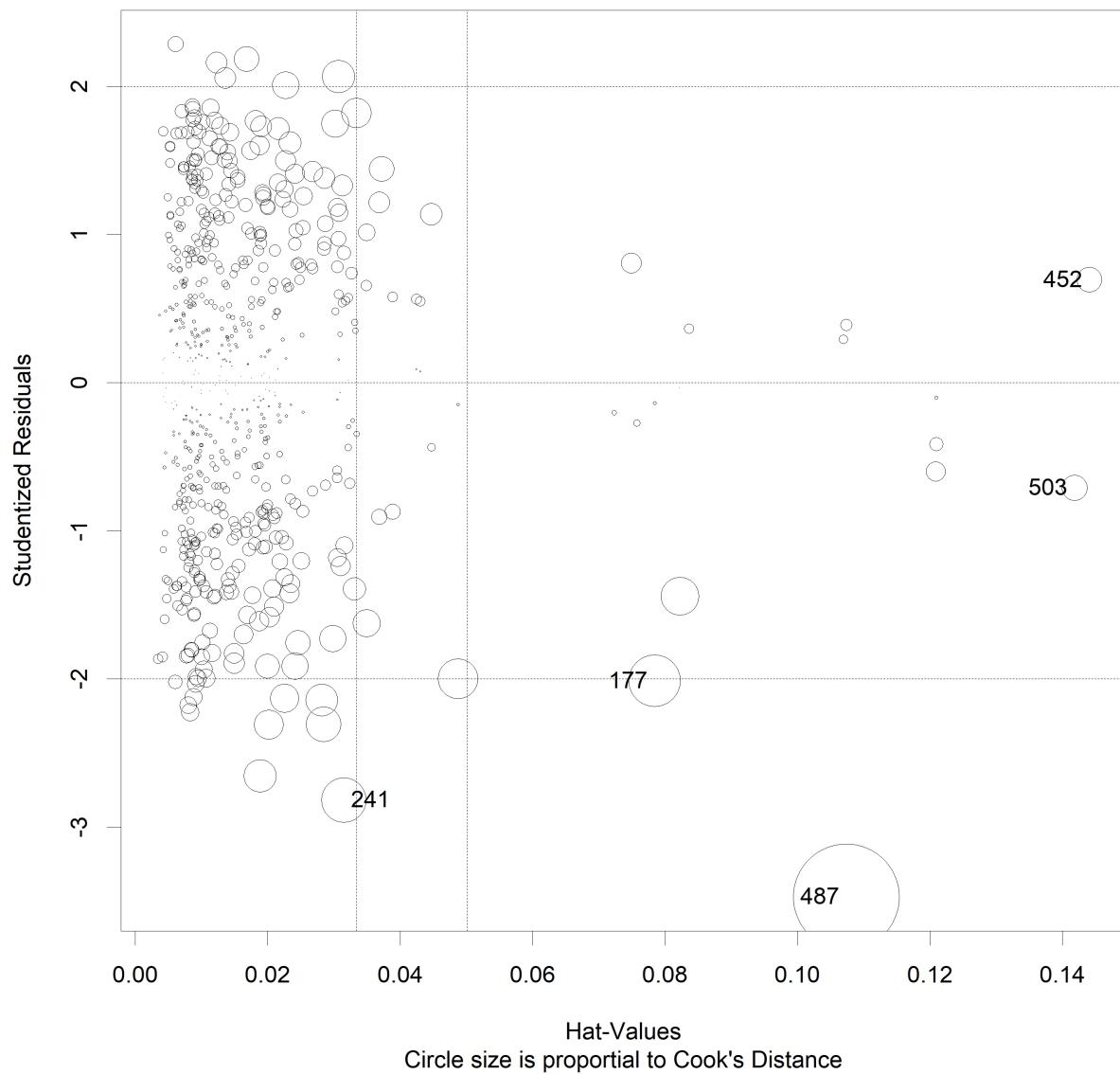
## Warning in box(...): "id.method" is not a graphical parameter

## 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



### Resdiaul Normality Tests

Normality Test

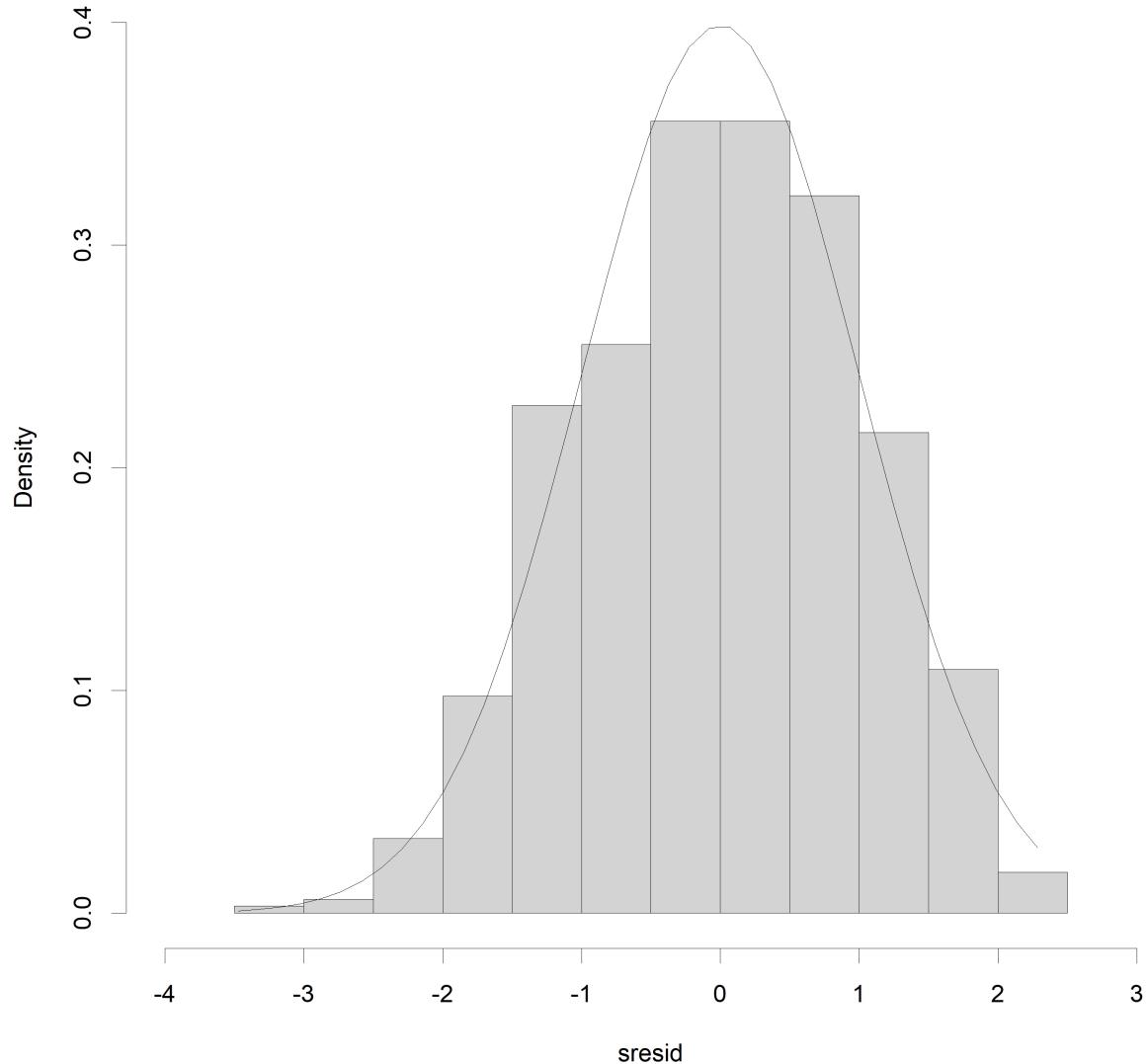
- Ho: The data is normally distributed
- Ha: the data is not normally distributed

NormTest	Stat	Pval
shapiro.test	0.99127	0.00063
ad.test	1.17303	0.00458

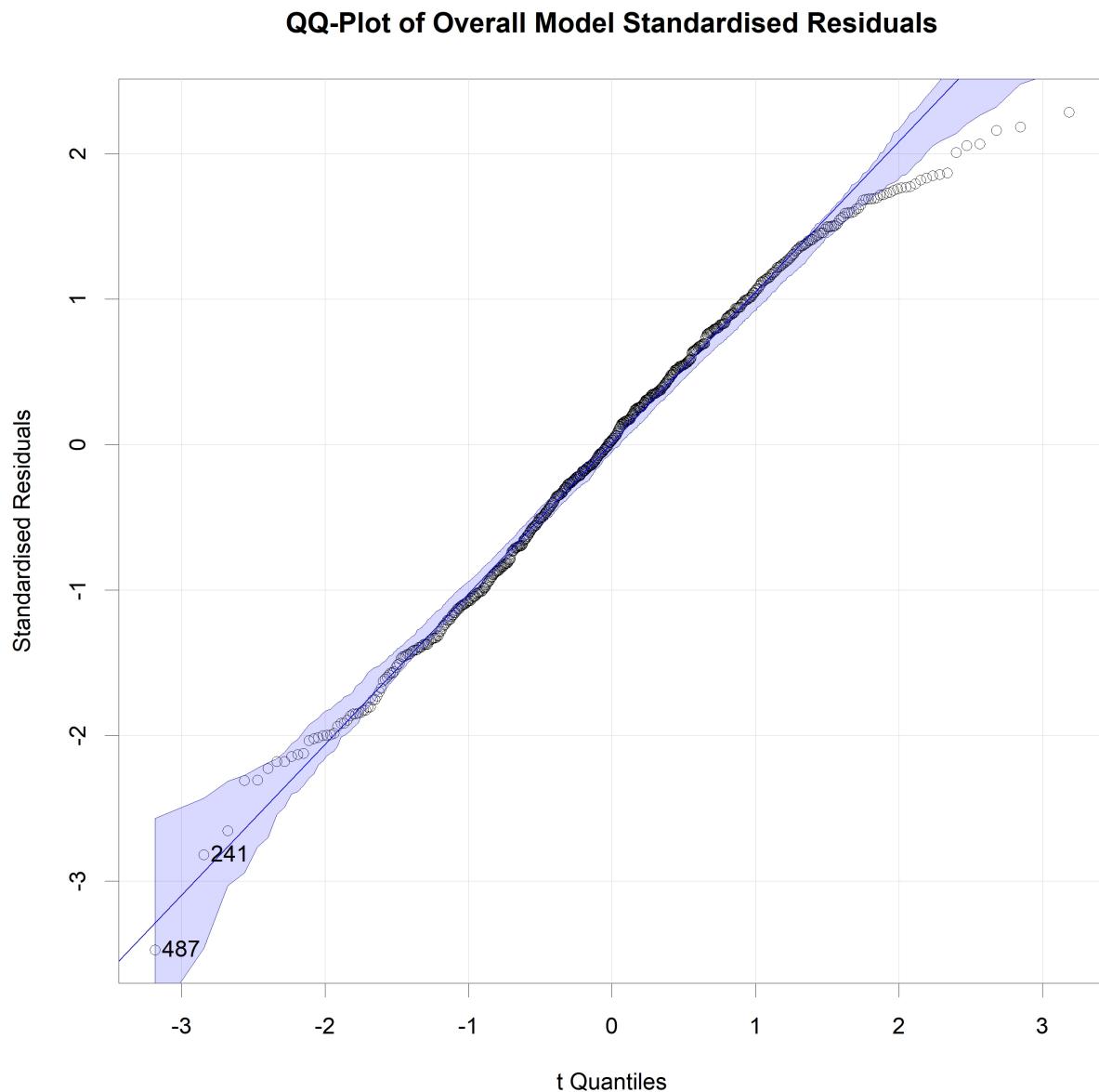
NormTest	Stat	Pval
cvm.test	0.16383	0.01564
lille.test	0.03283	0.08898
person.test	37.02432	0.04352
sf.test	0.99178	0.00149

### Residual Histogram

**Overall Model - Distribution of Standardised Residuals**



## Residual QQ-Plot



## Non-Constant Variance Test

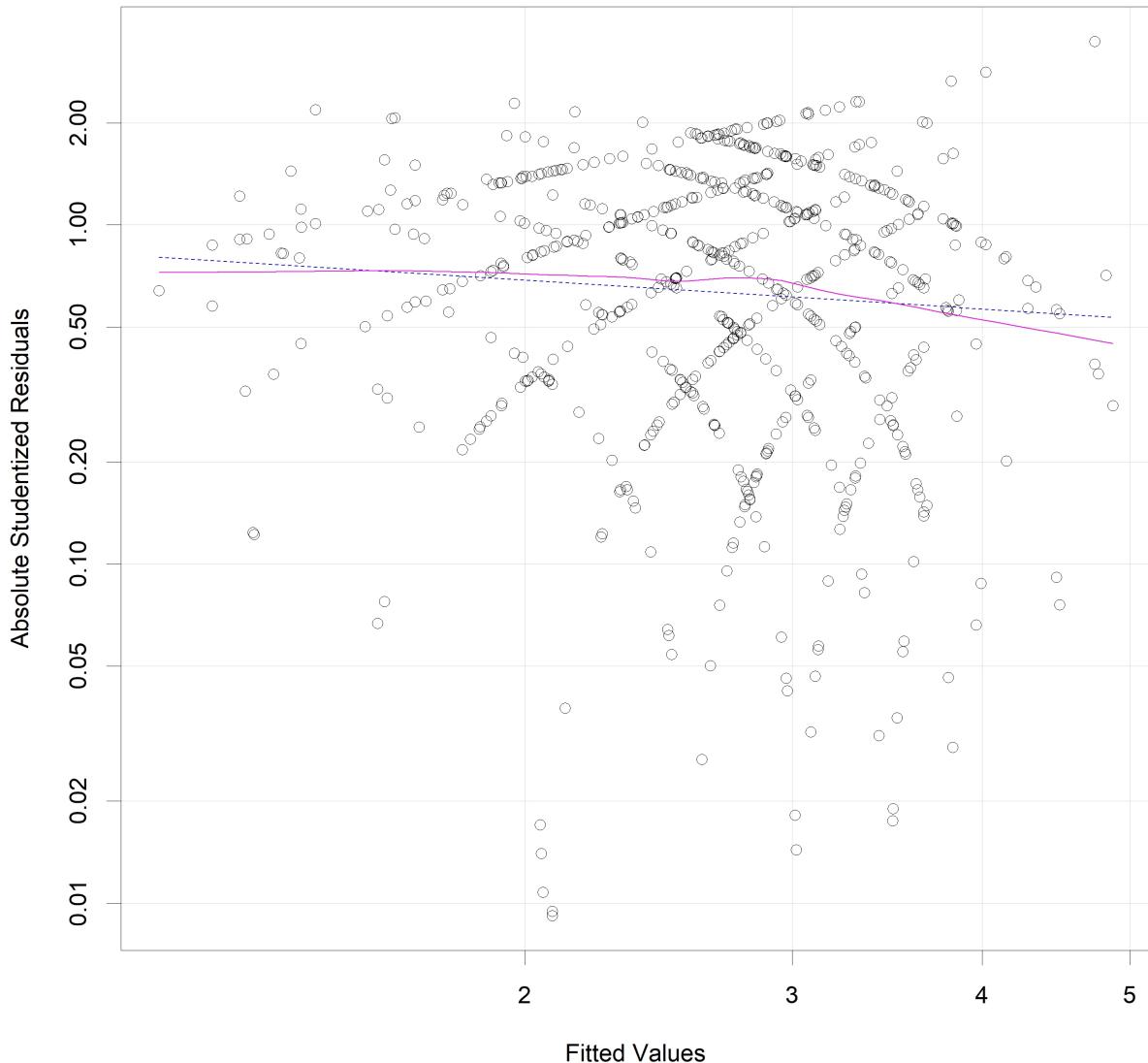
Non-Constant Error Variance Test

- $H_0$ : constant error variance
- $H_a$ : 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	$\text{sqrt(VIF)} > 2$
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
CAP_DIST_km	1.139690	0
OOA	1.188927	0
FC_NonCOB	1.344230	0
ComSONGLAN	1.150996	0

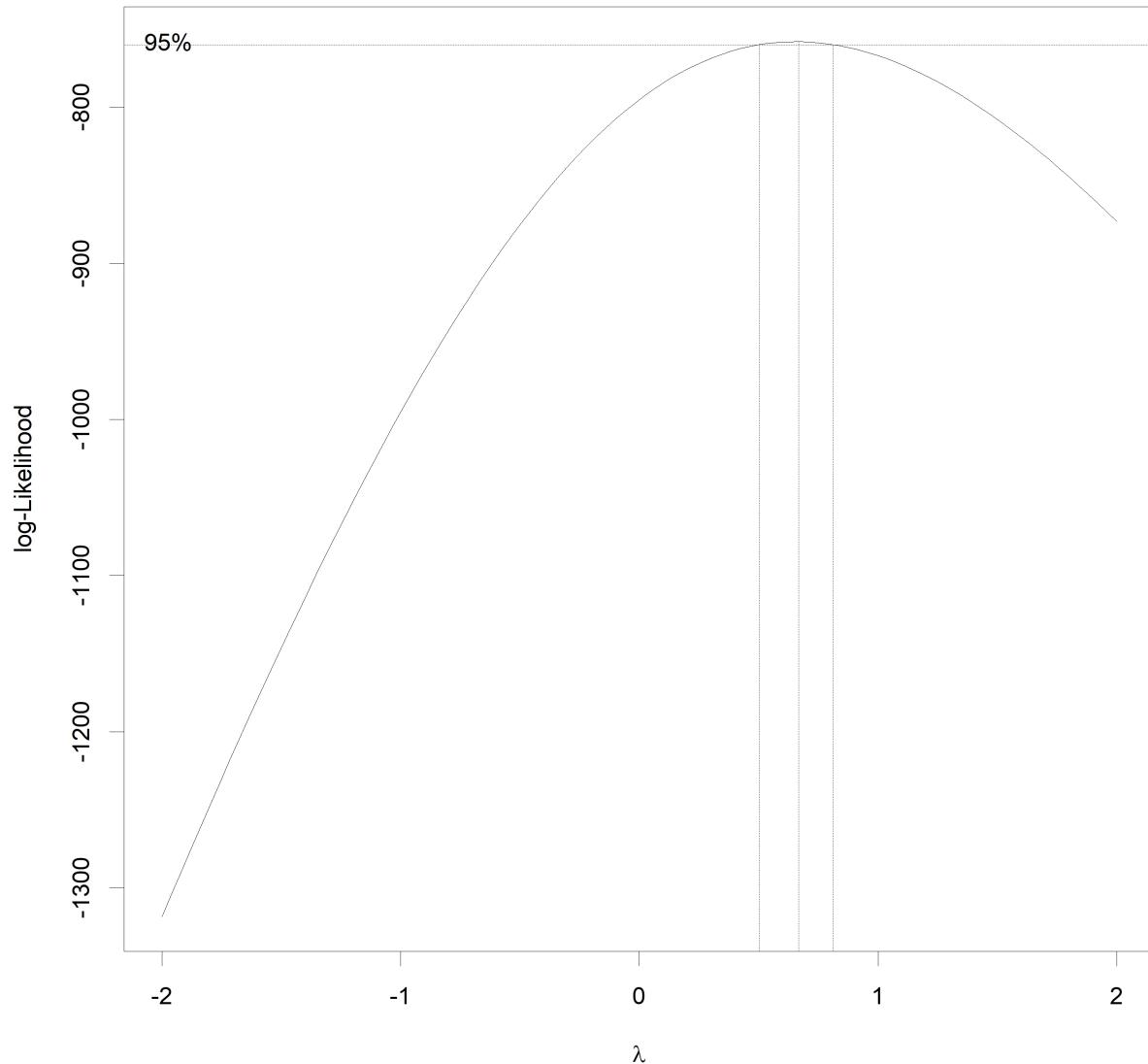
## Televote Model

```
##  
## 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
```

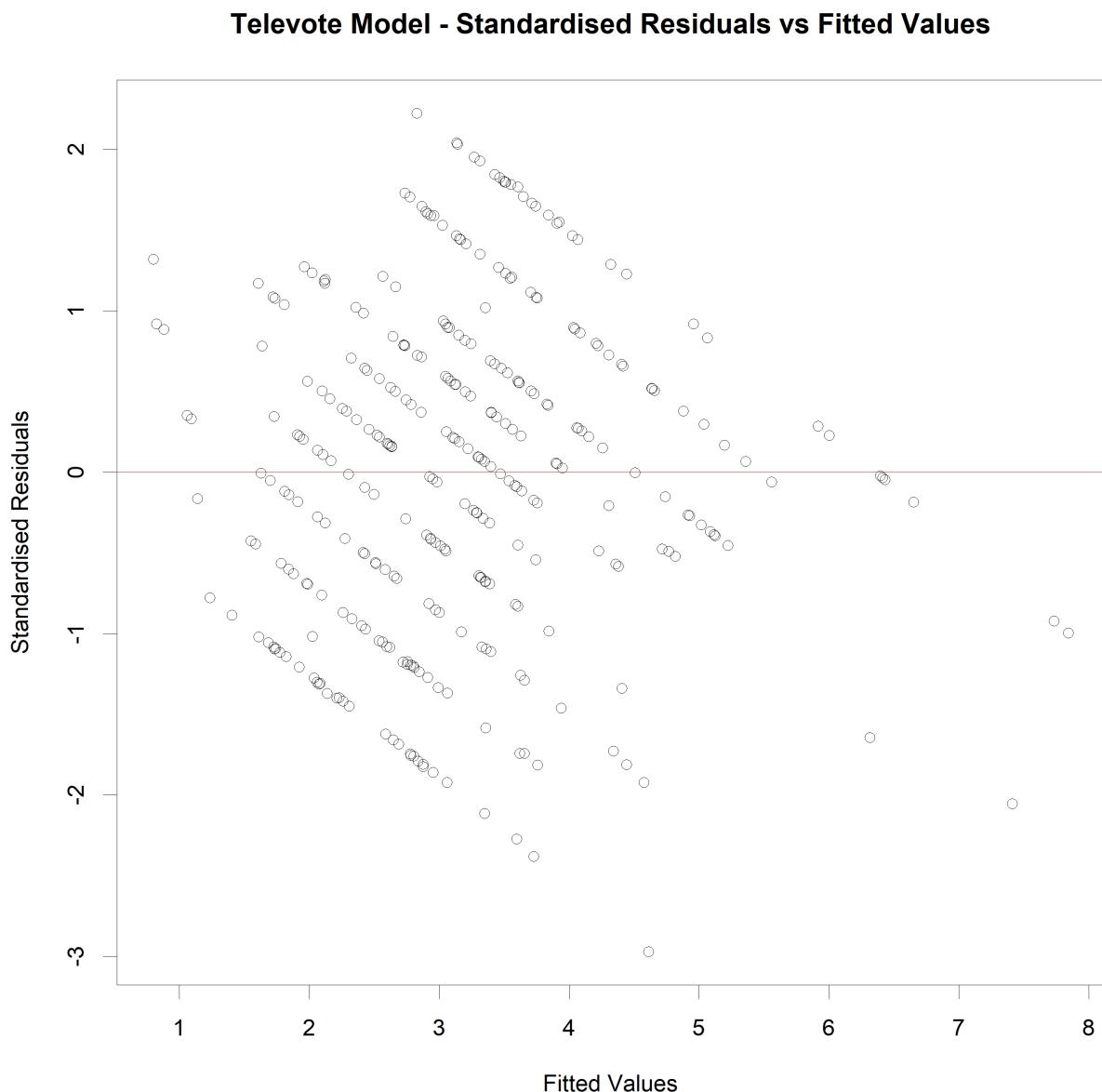
## Box-Cox Power Transformation

```
##  
## 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 **  
## acousticness 0.28053  0.09743  2.879 0.004257 **  
## FC_NonCitizens 0.35982  0.10241  3.514 0.000506 ***  
## VBlocs1_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
```



## Residual vs Fitted Values



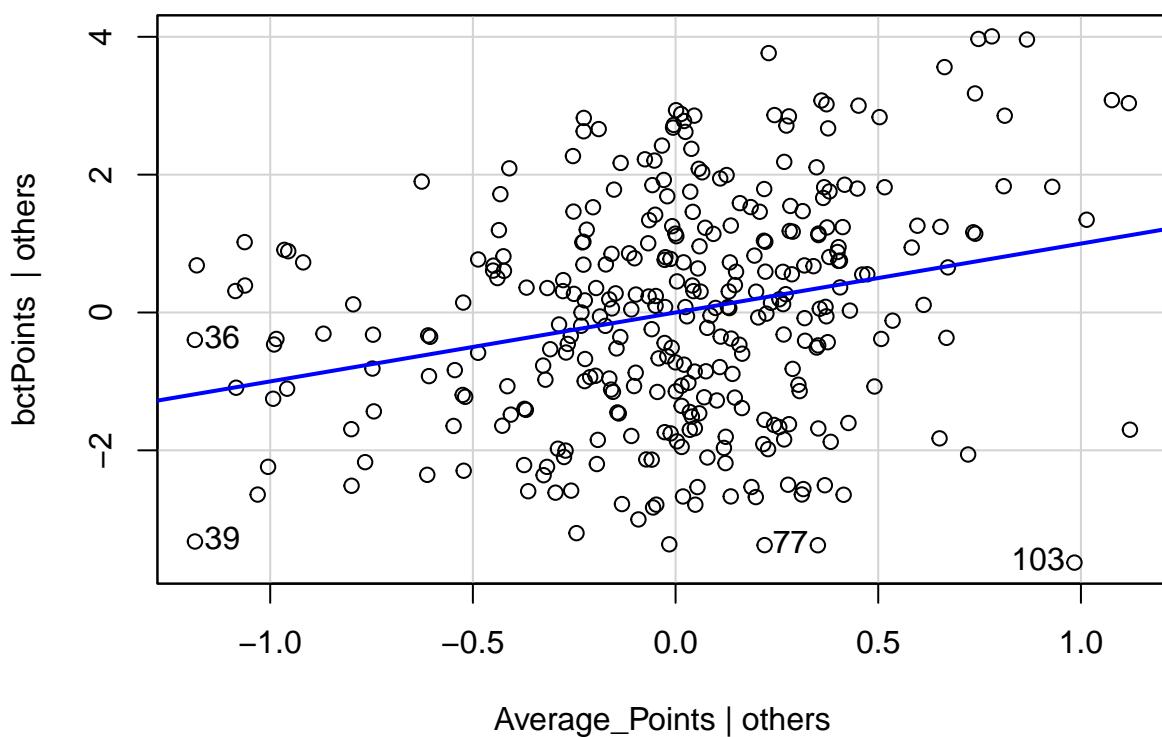
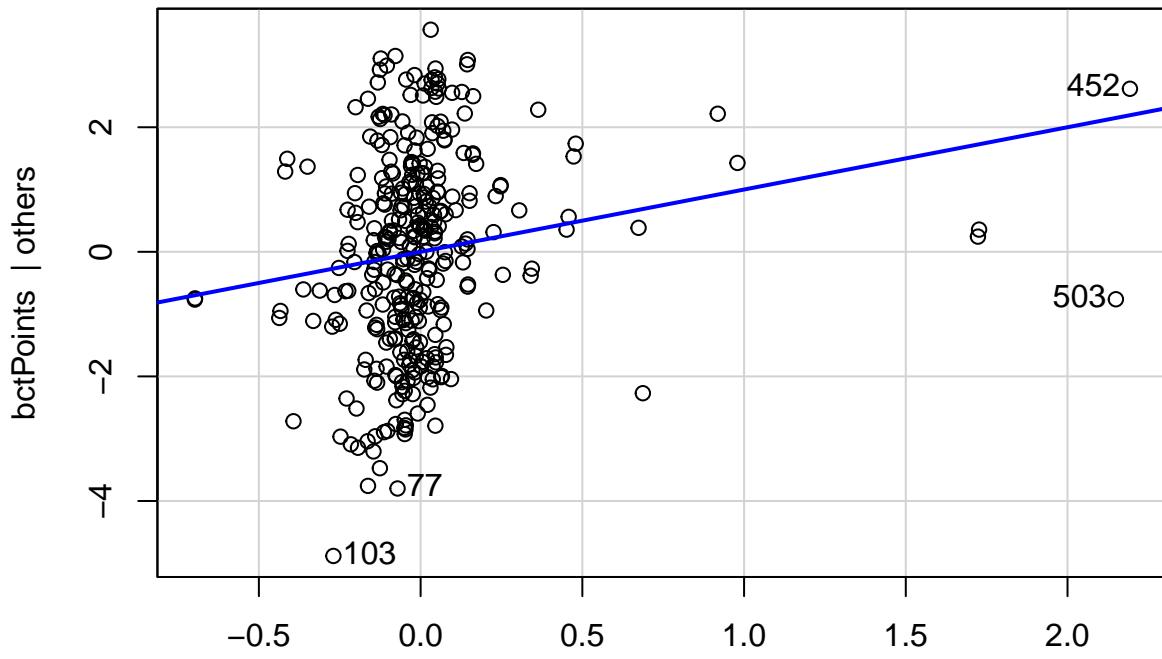
## Bonferroni Outlier Test

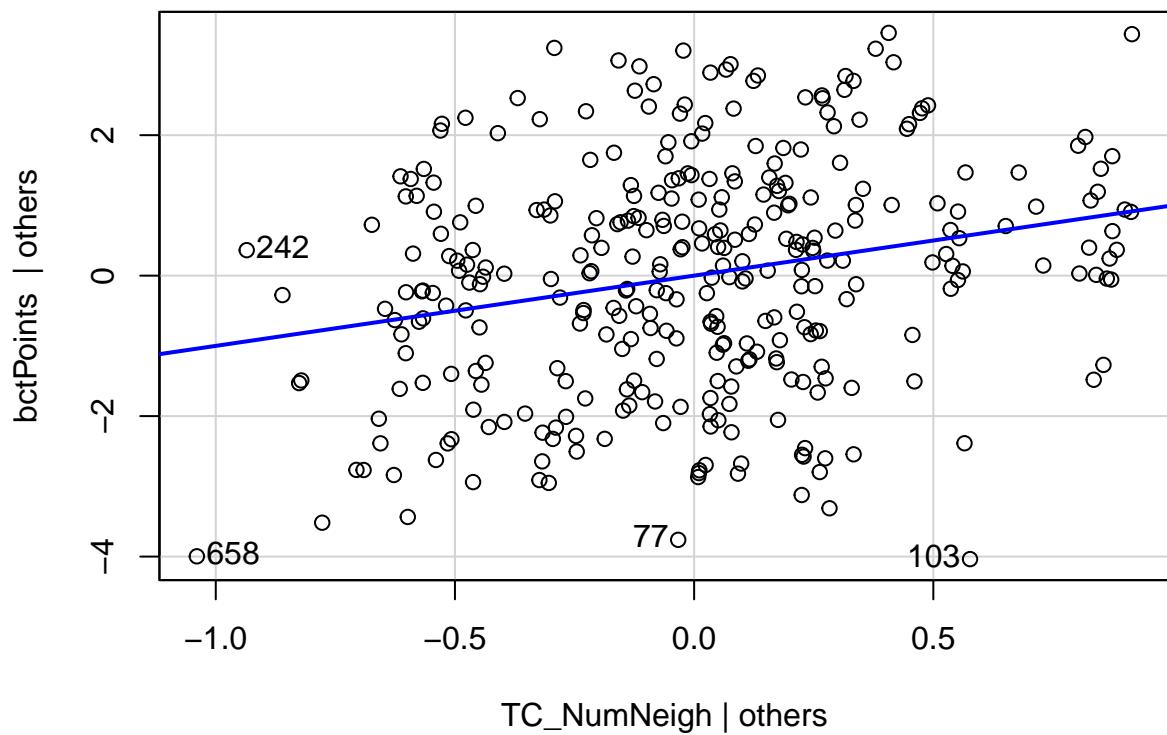
	rstudent	p	bonf.p	signif	cutoff
103	-2.970711	0.0031989	1.046038	0	0.05

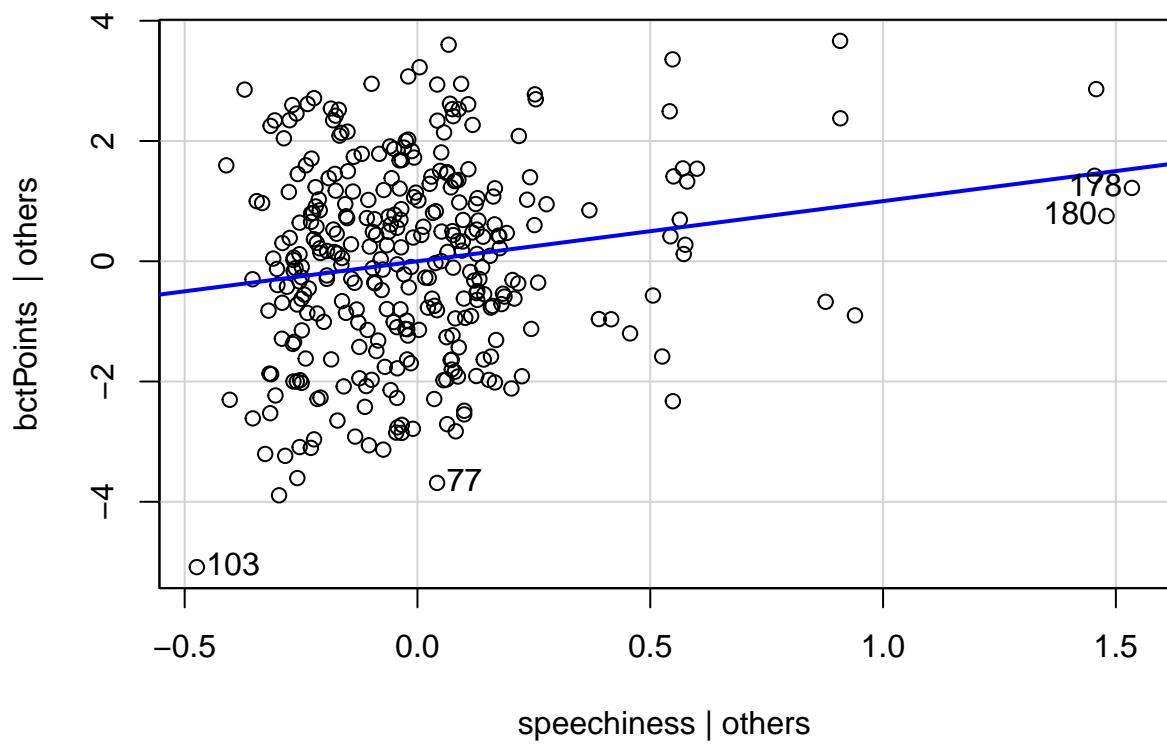
## Residual Outliers

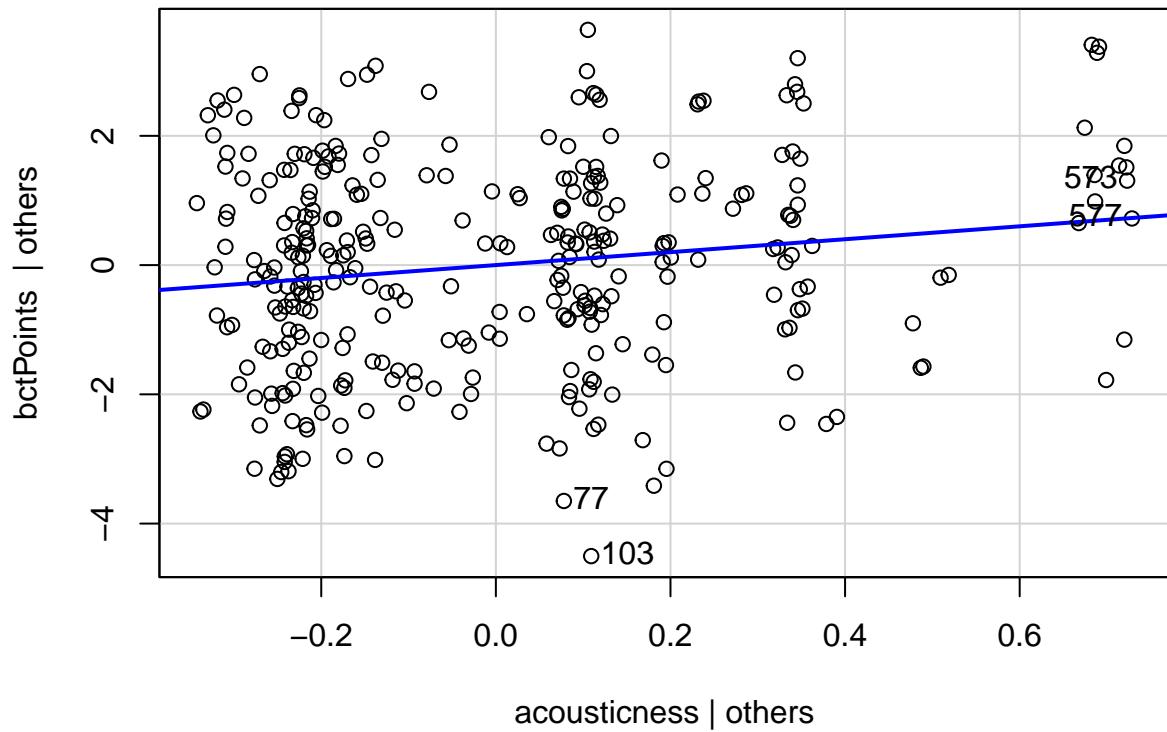
<u>outlier_residuals</u>
77
88
101
103
503

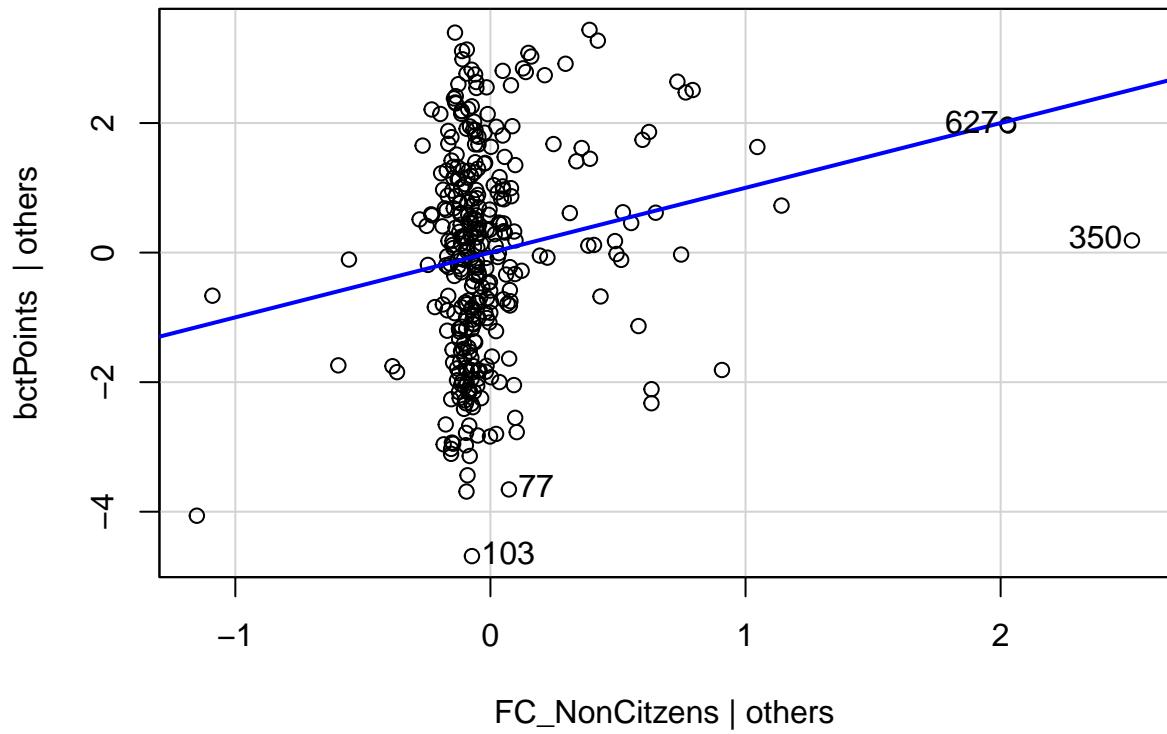
## Leverage Plots

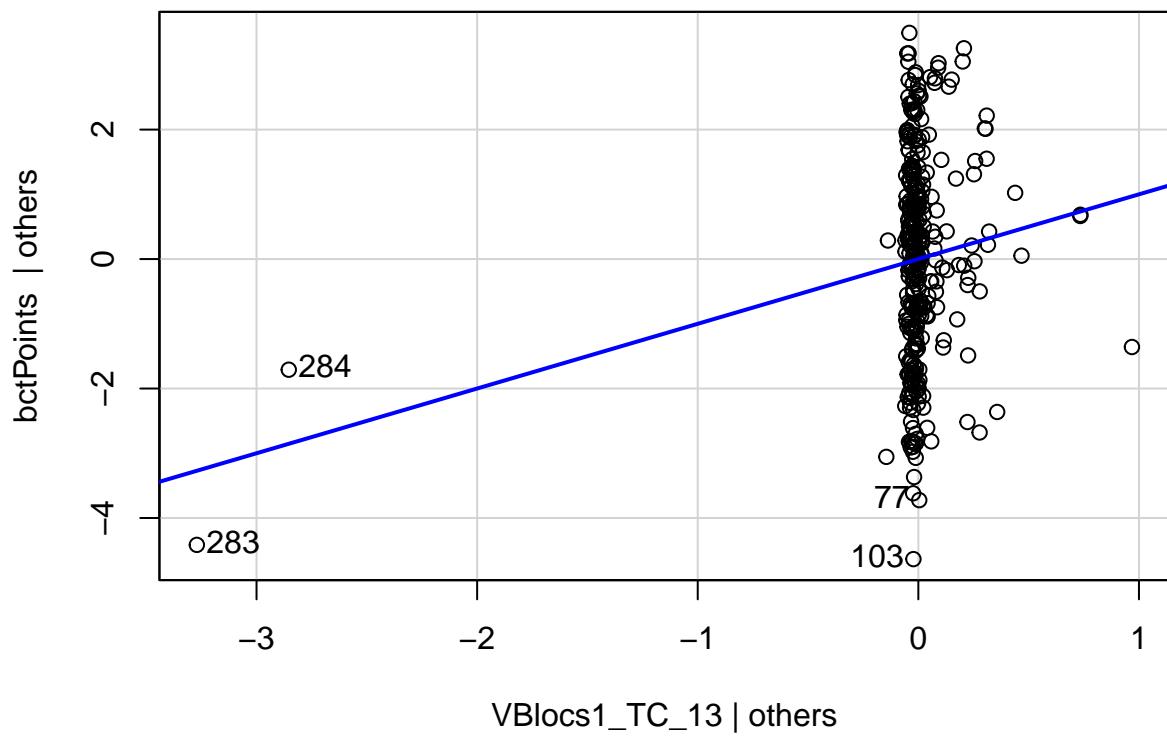


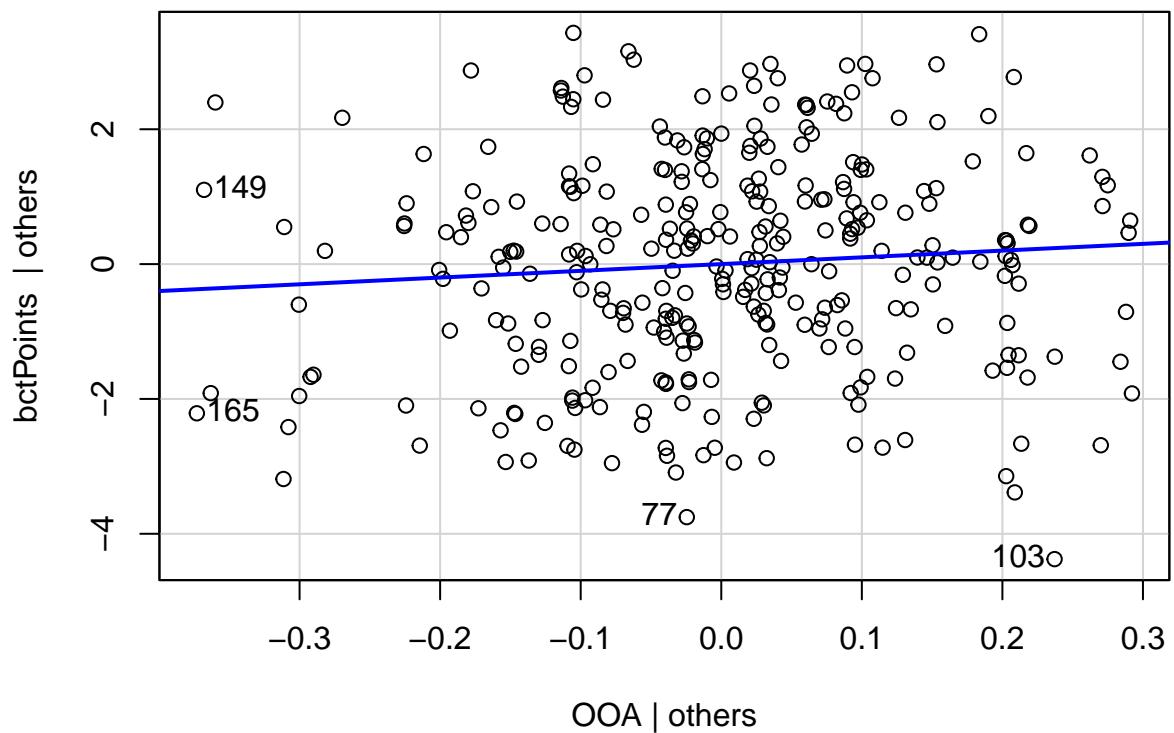




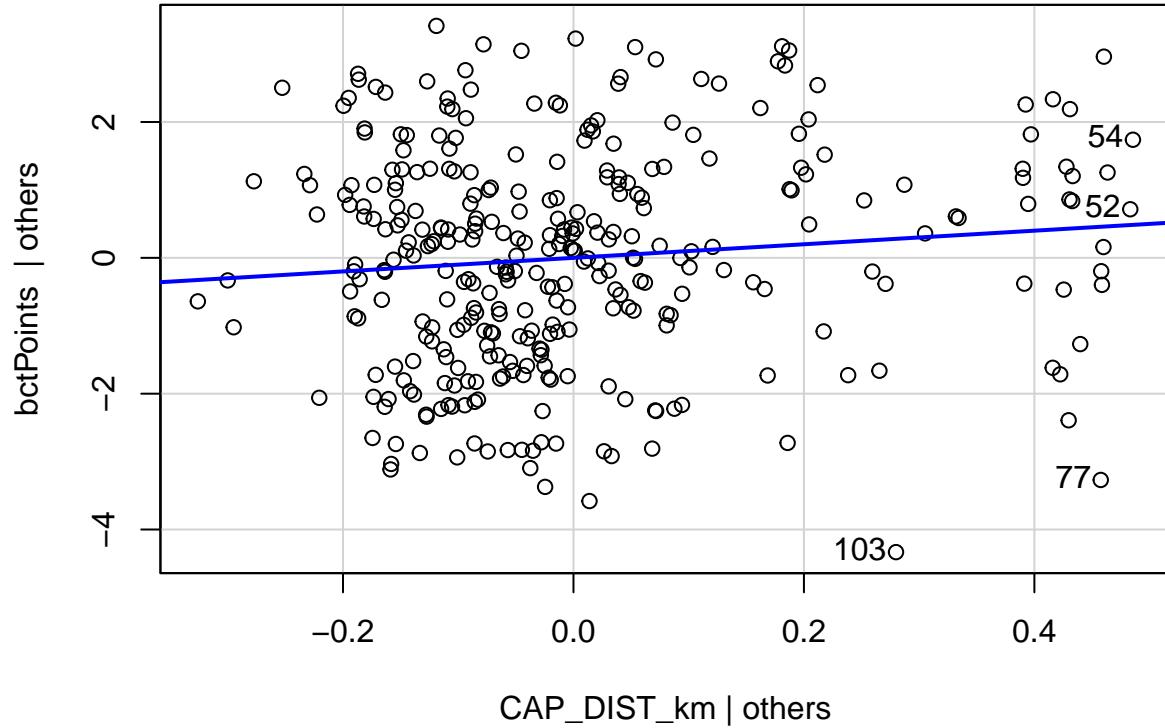




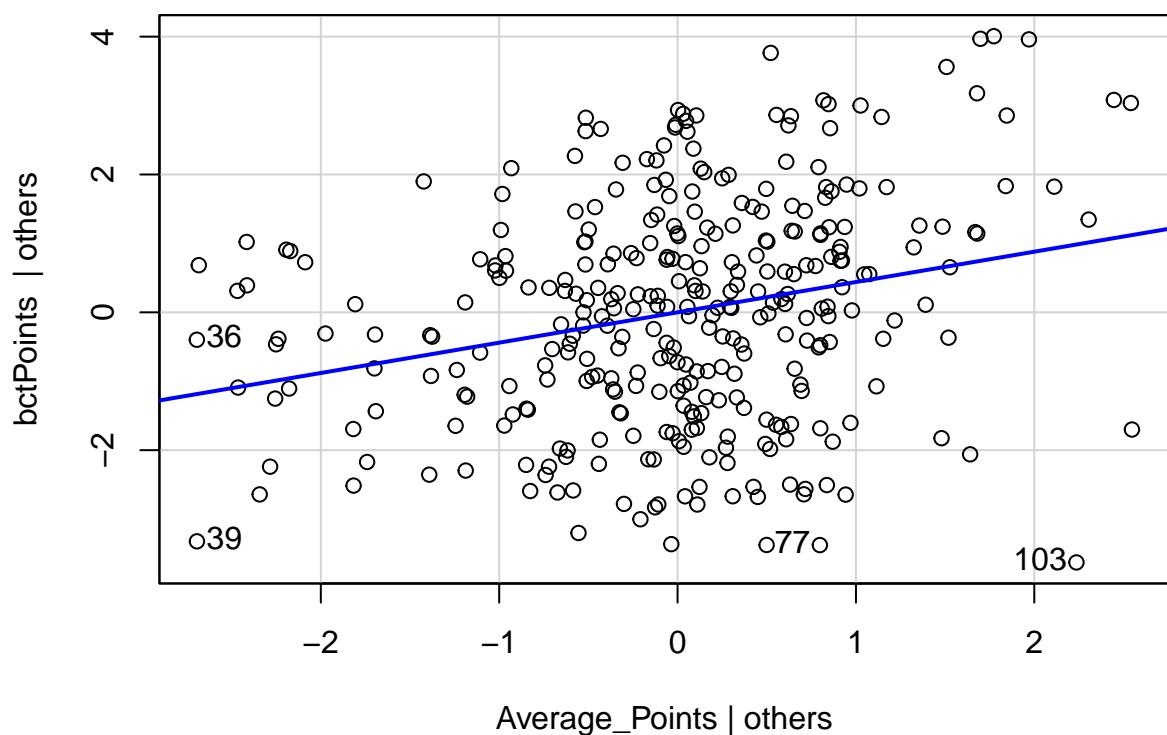
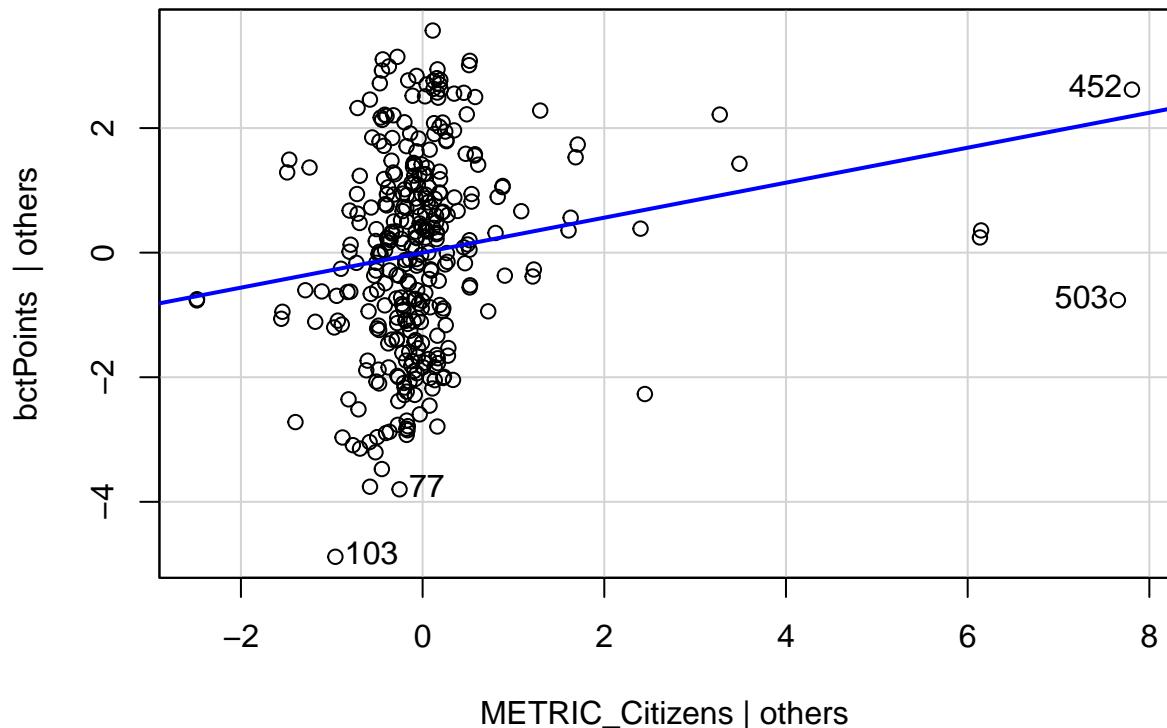


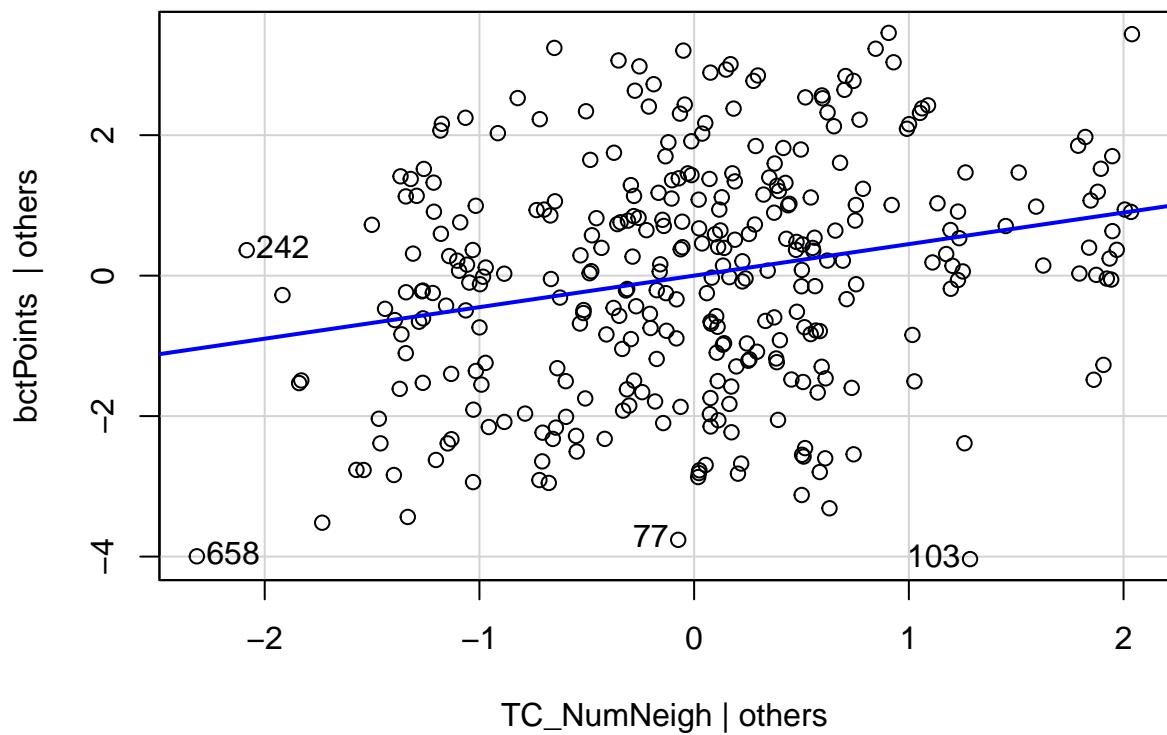


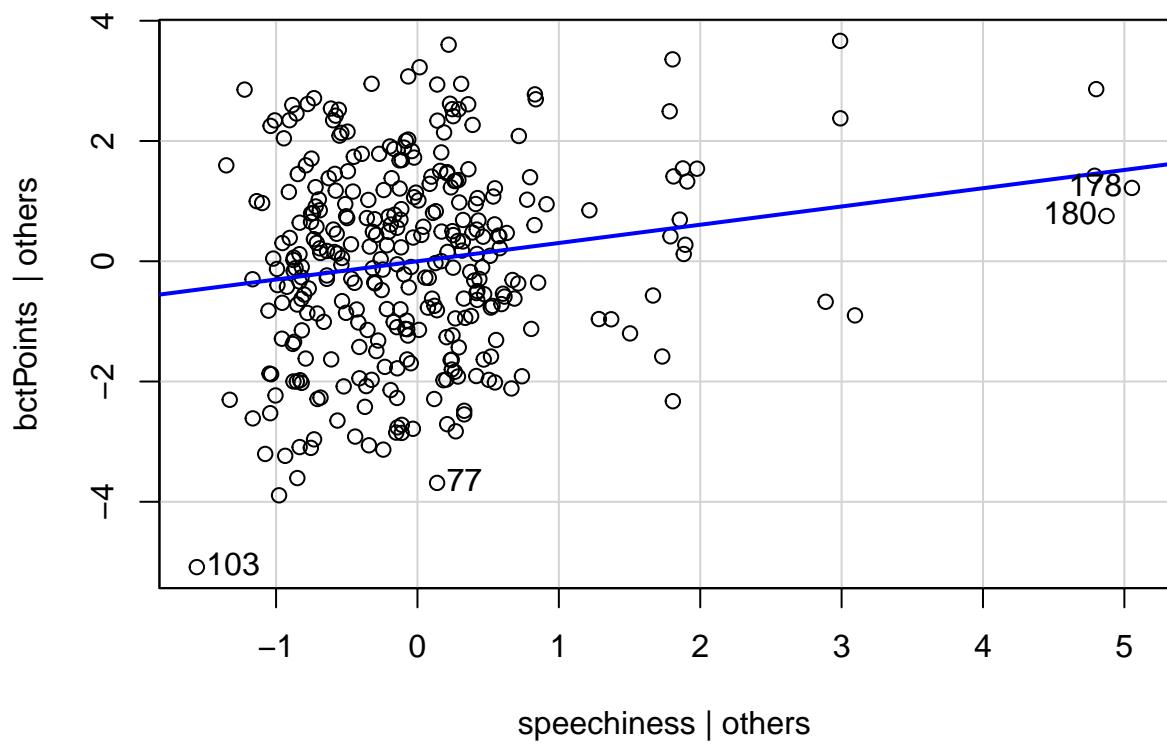
### Leverage Plots

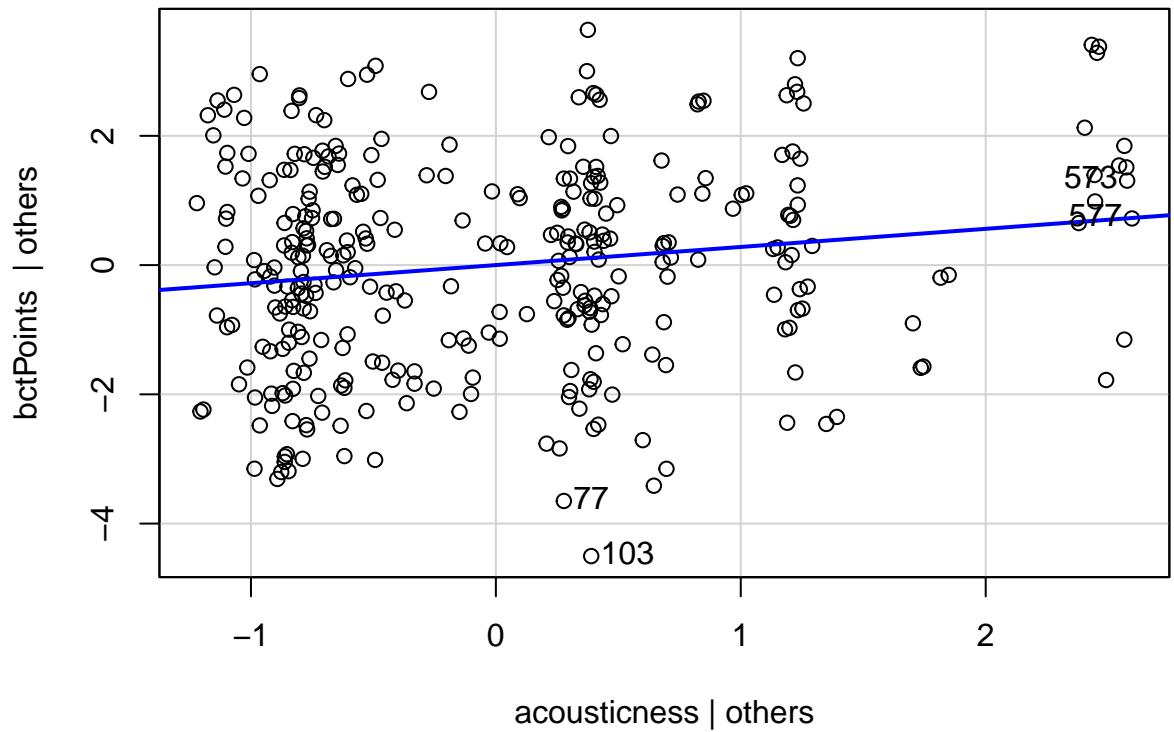


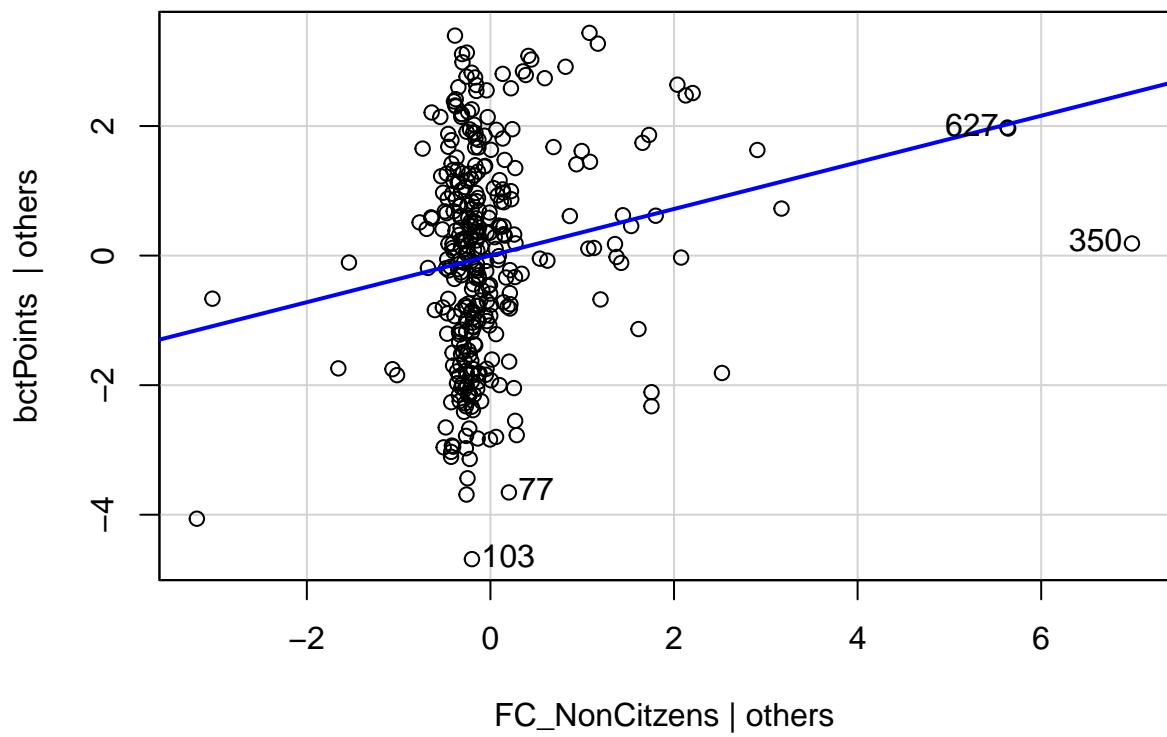
### Added Variable Plots

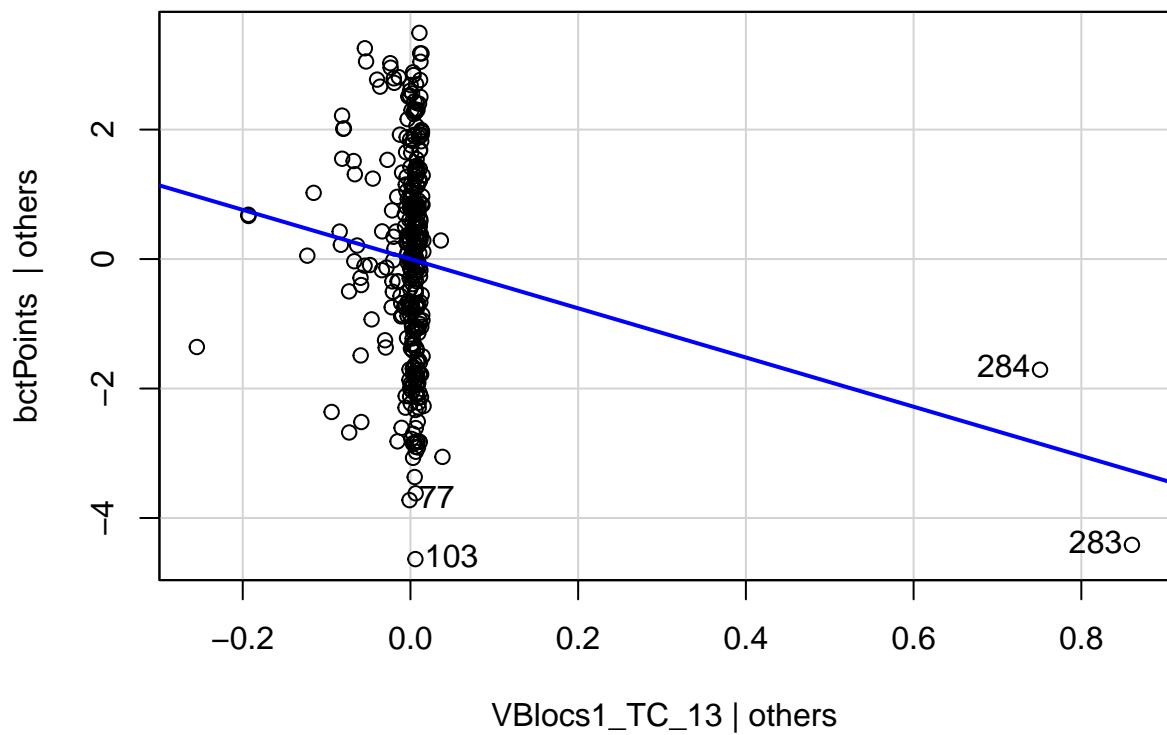


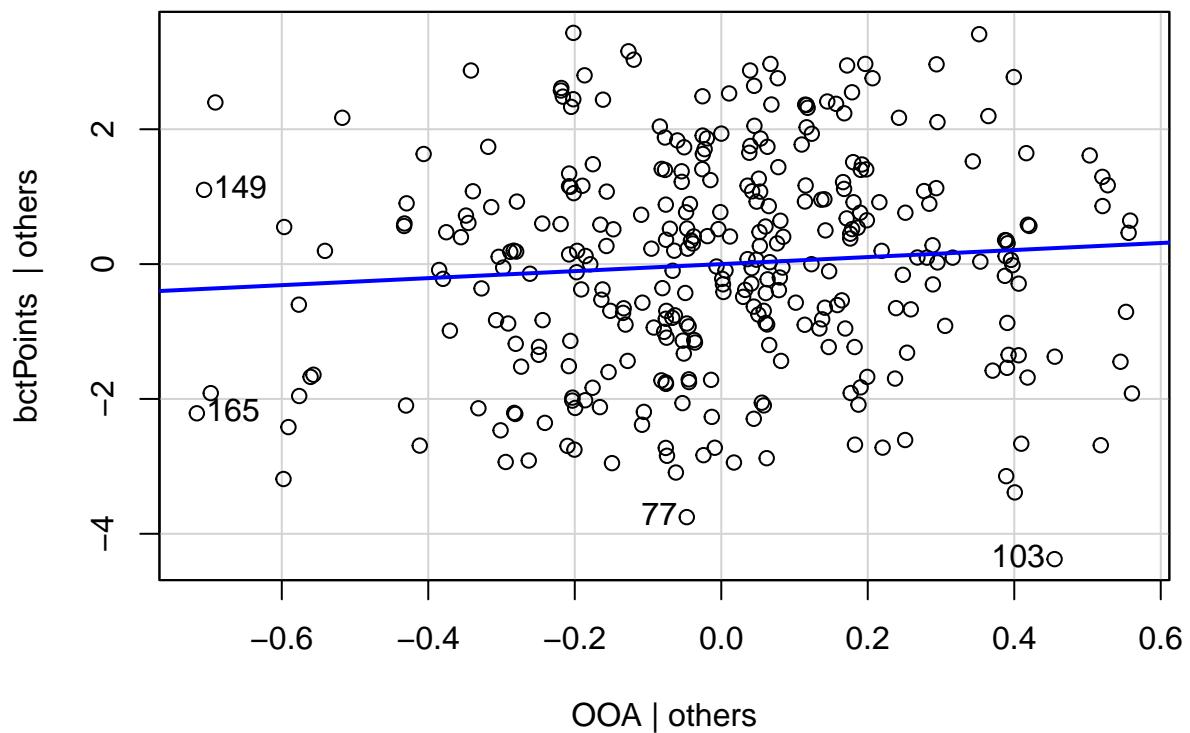




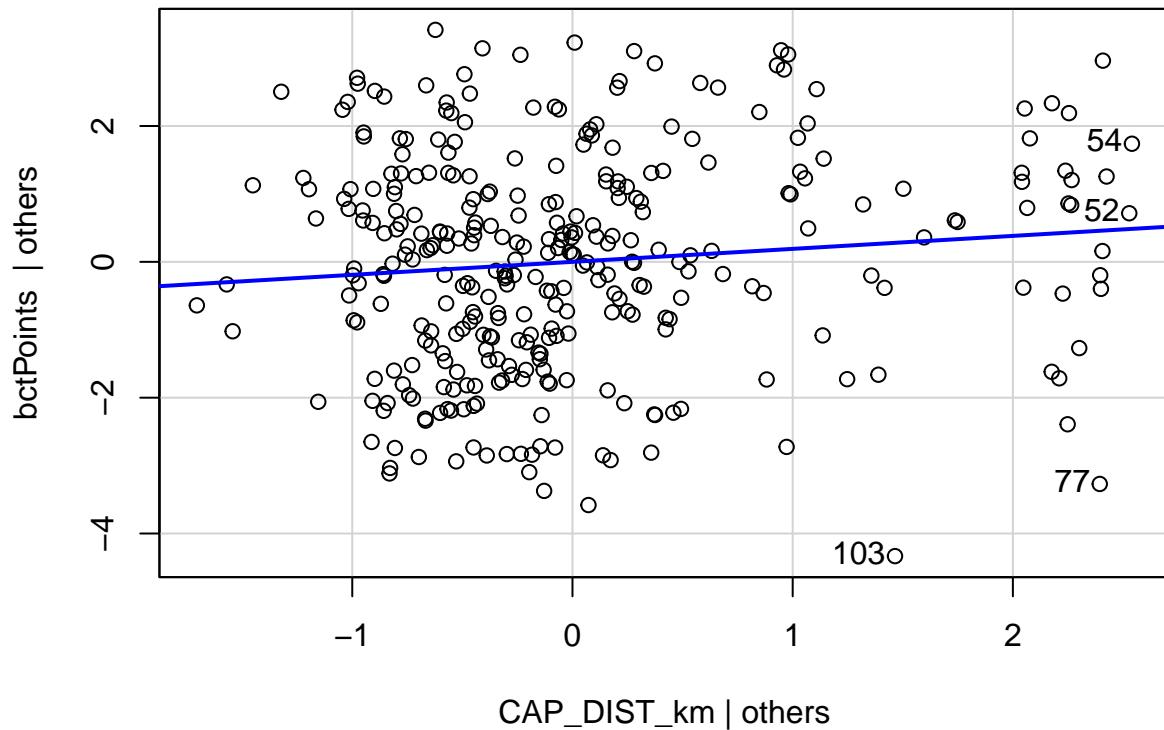




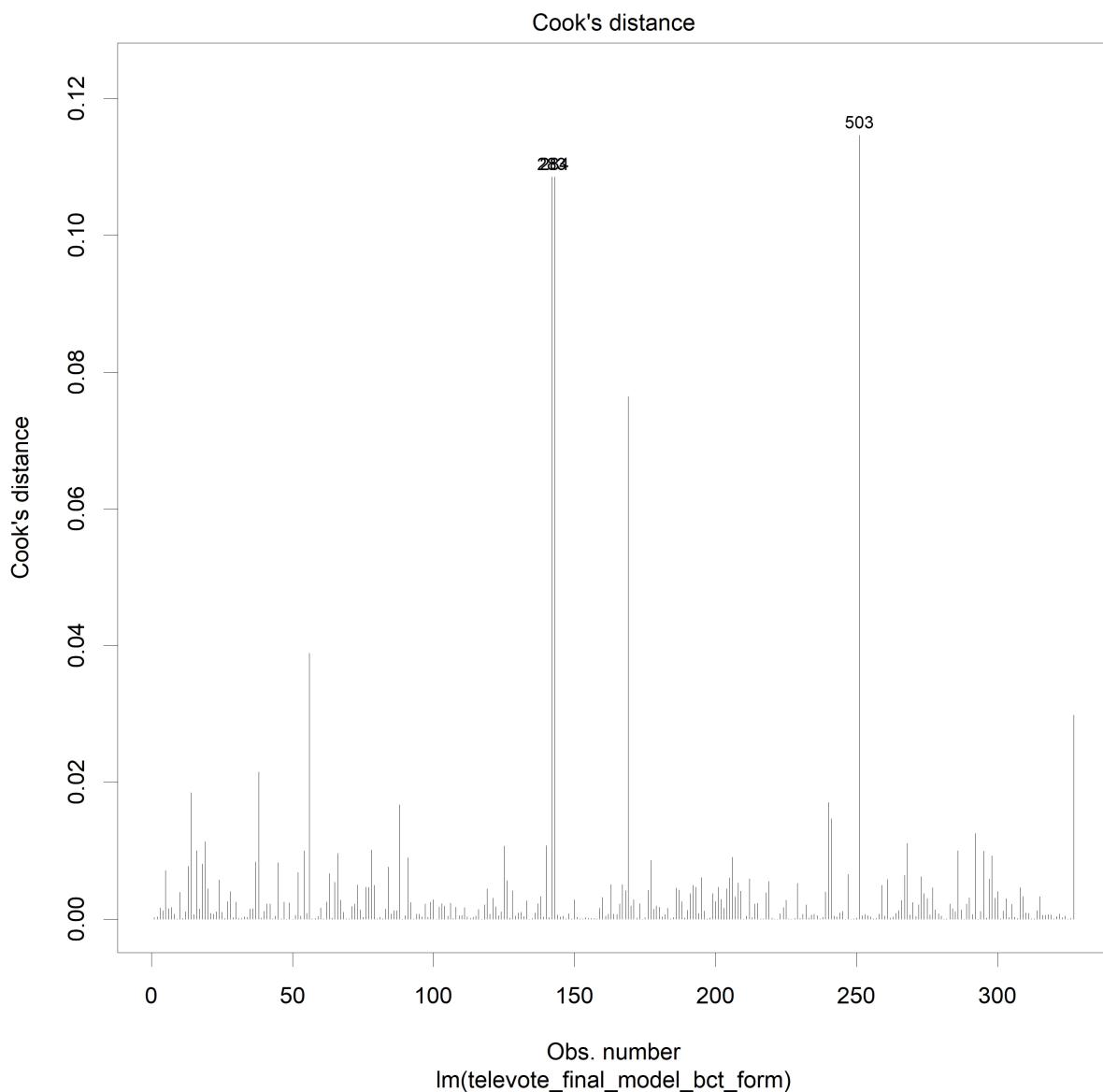




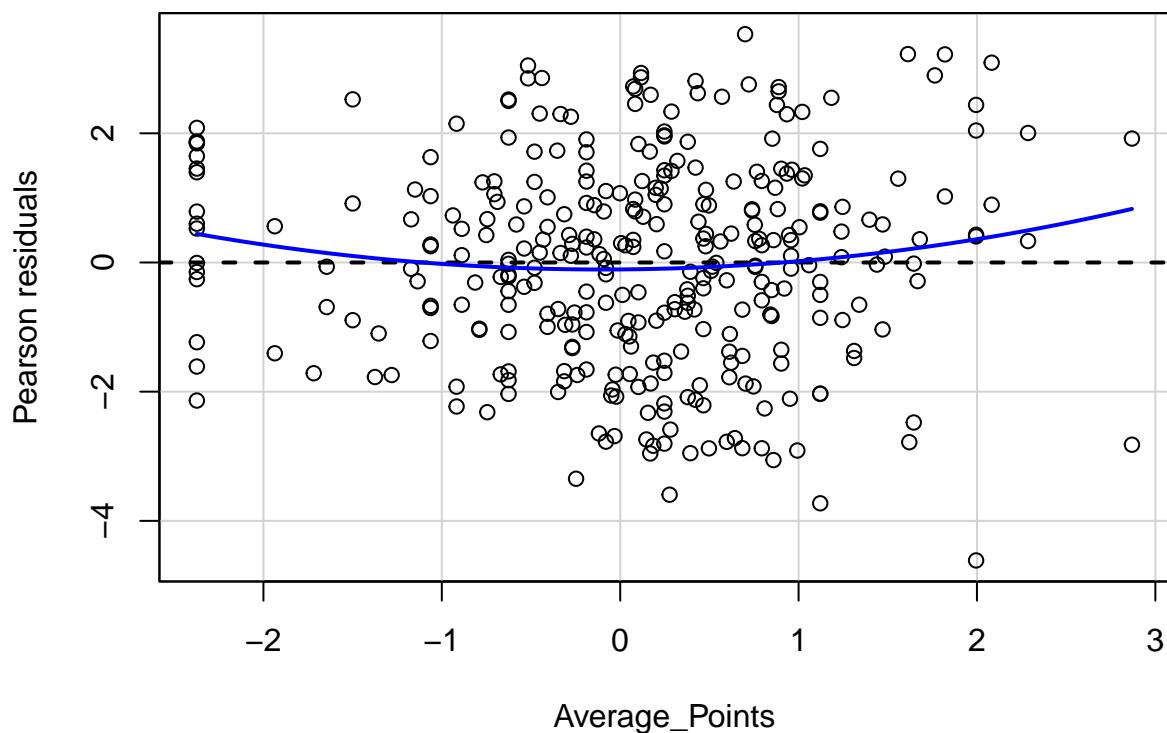
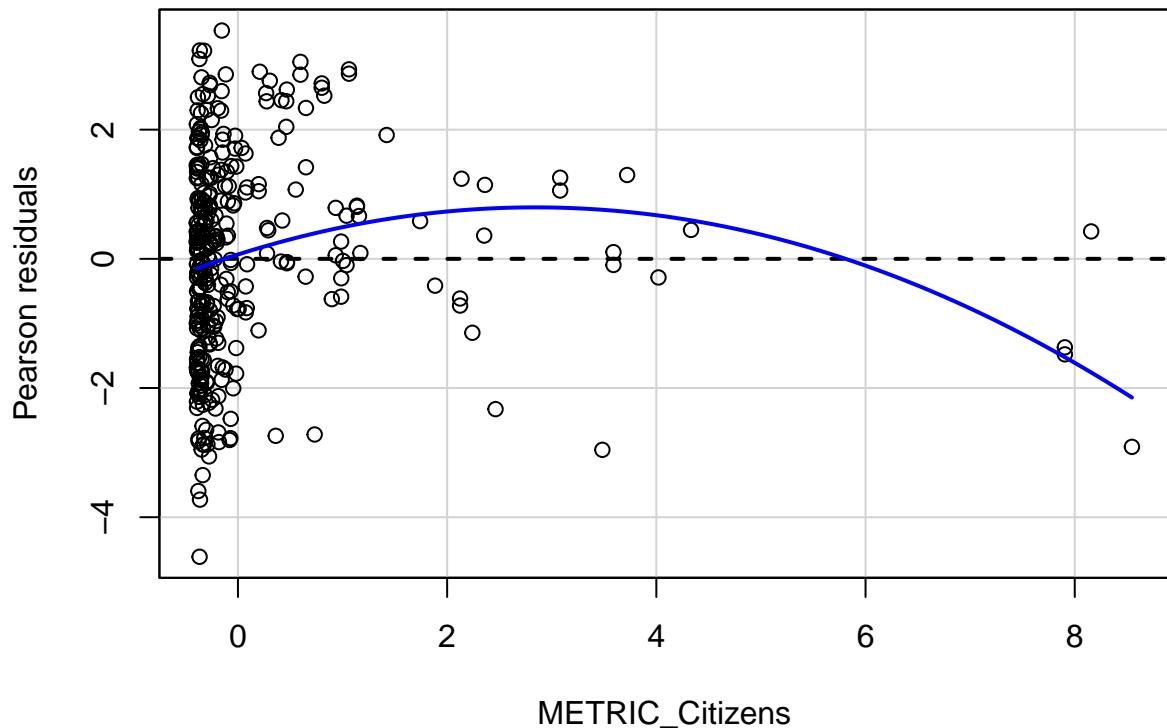
### Added-Variable Plots

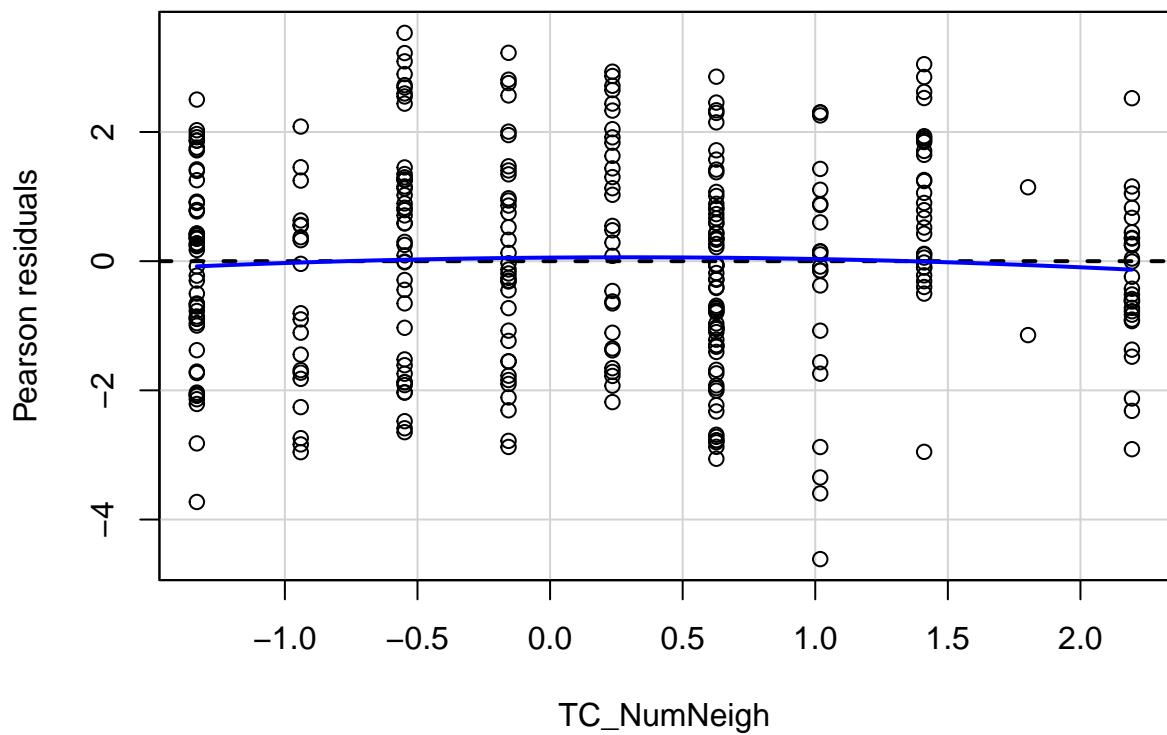


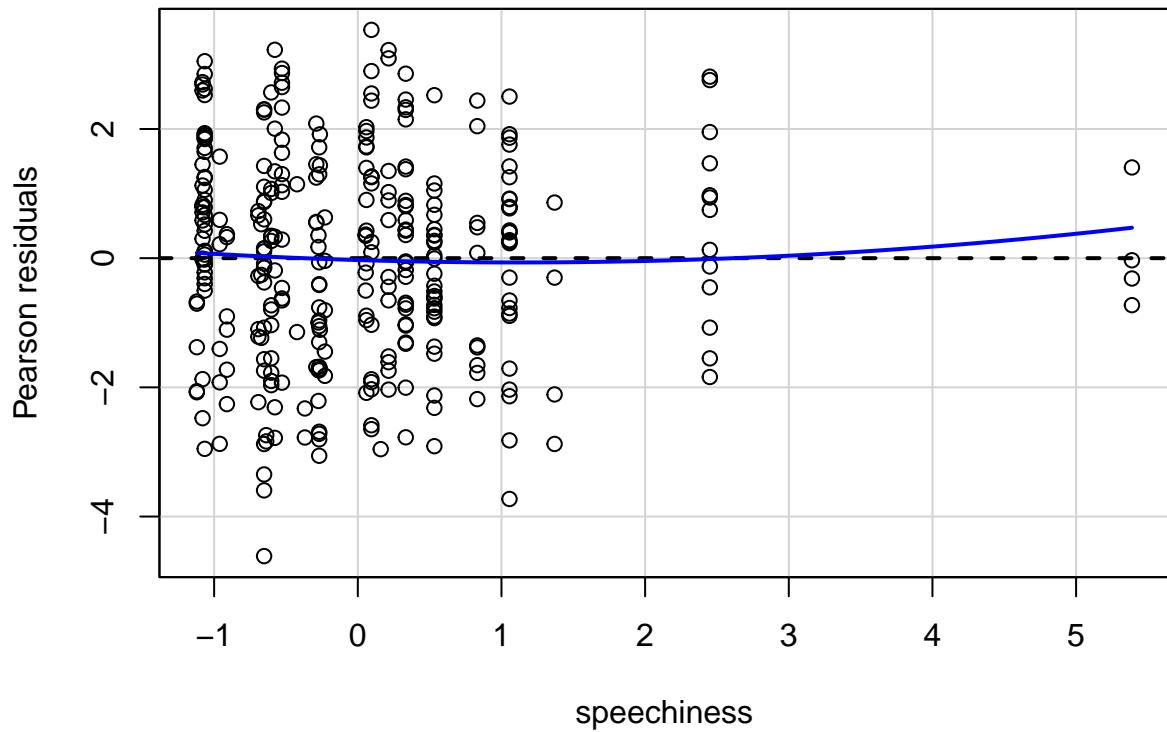
## Cooks Distance Plot

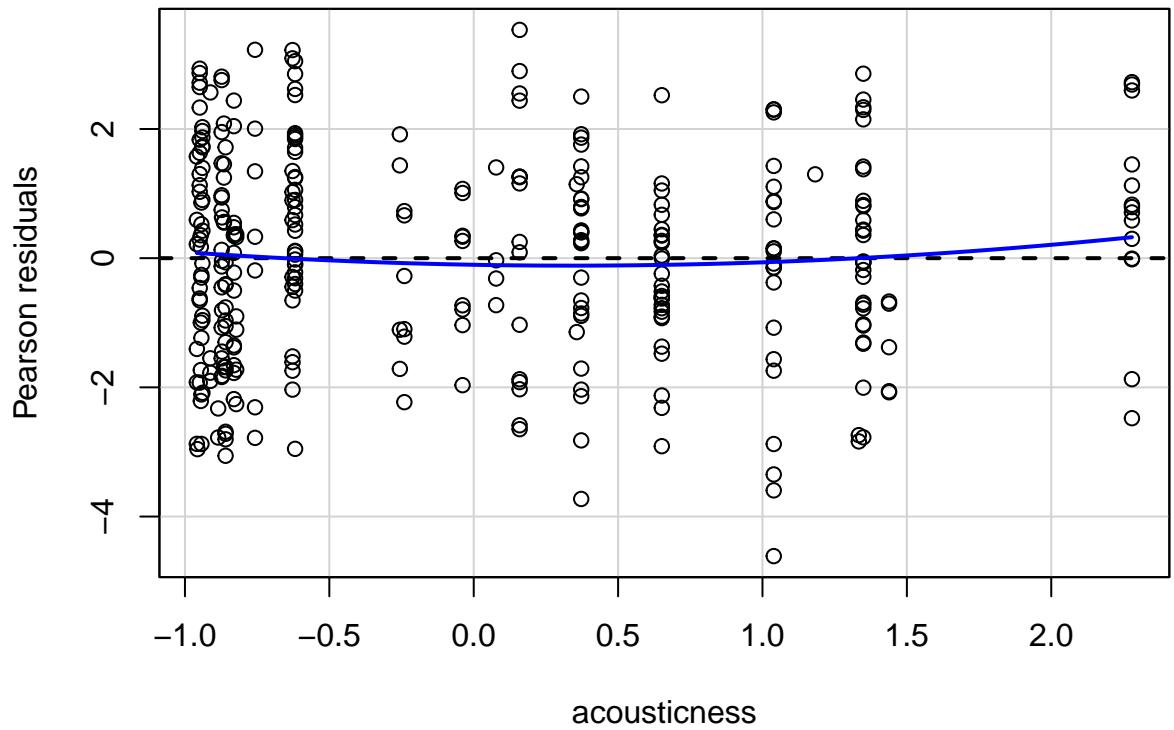


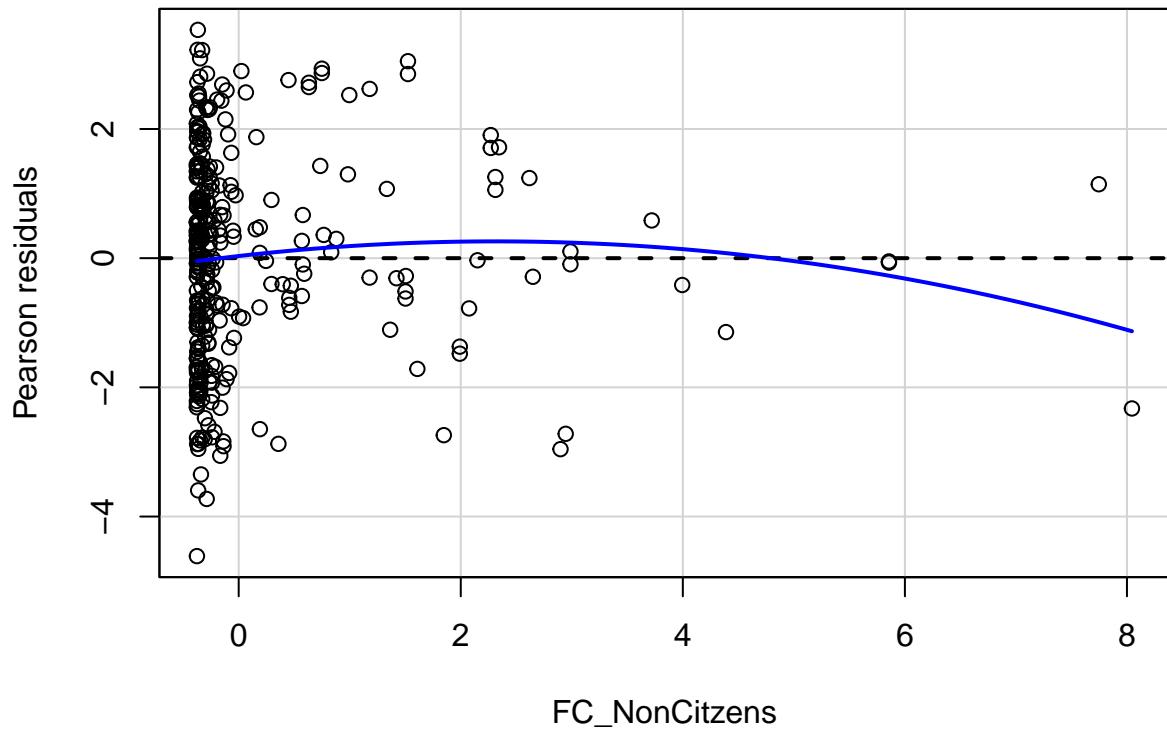
## Residual Plots

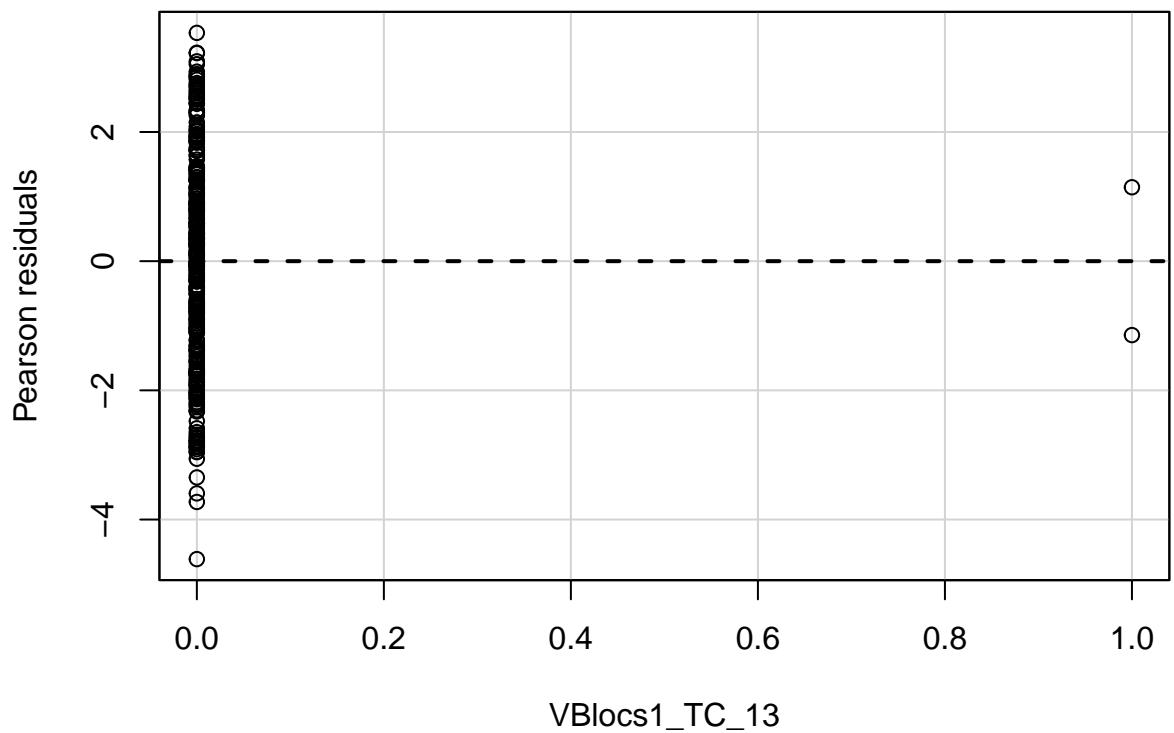


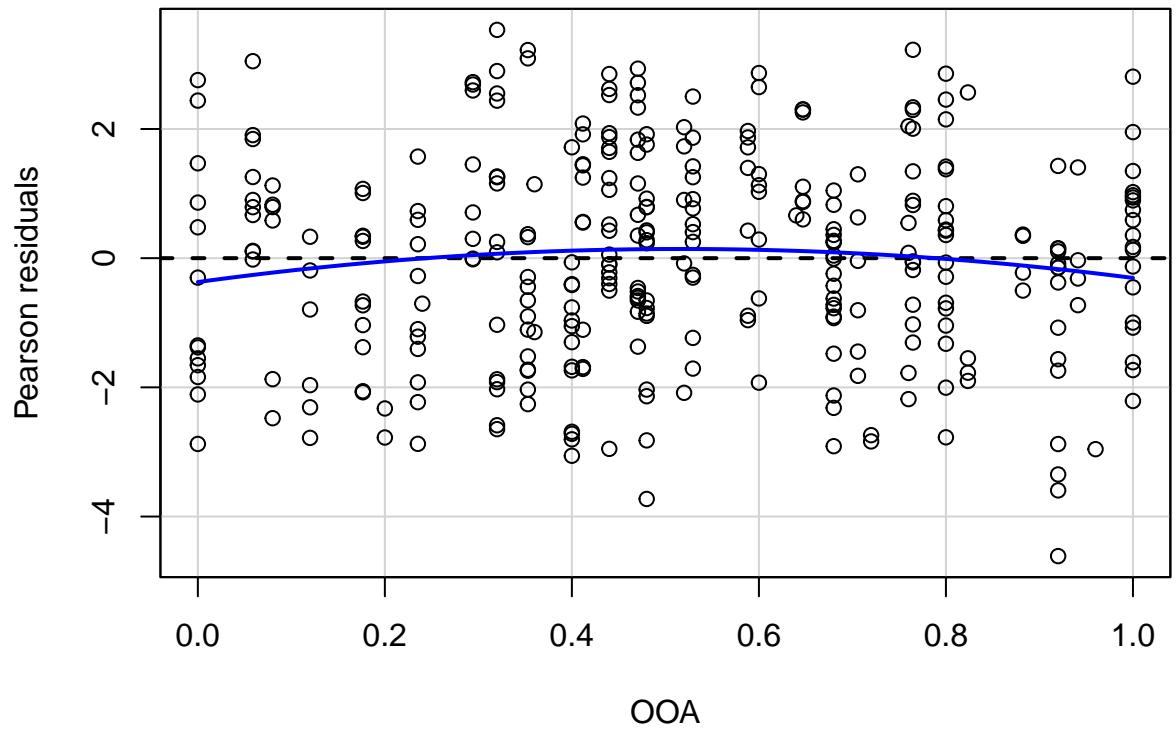


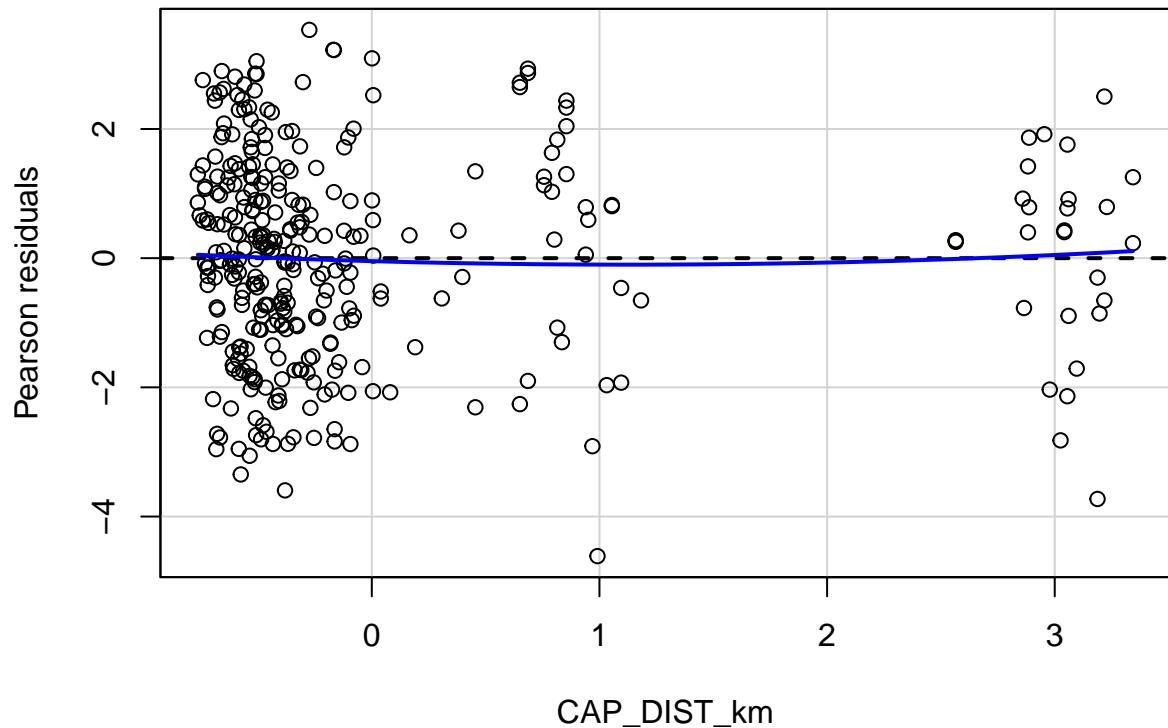


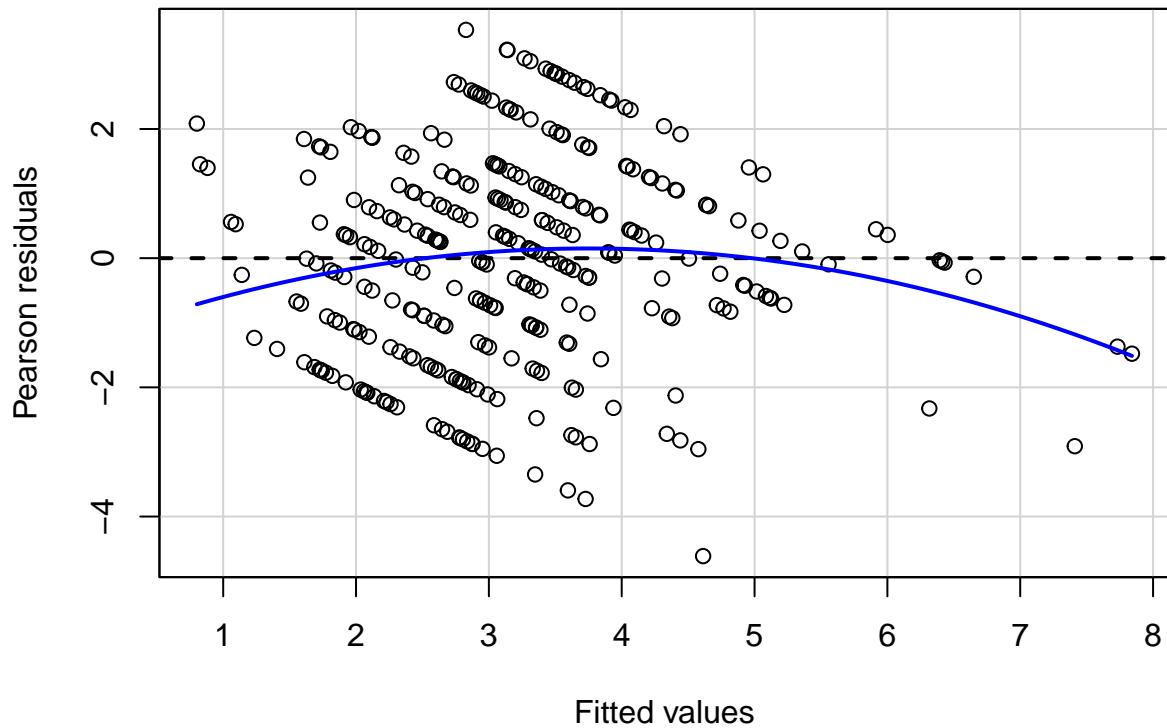












### Influence Plot

```

## 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

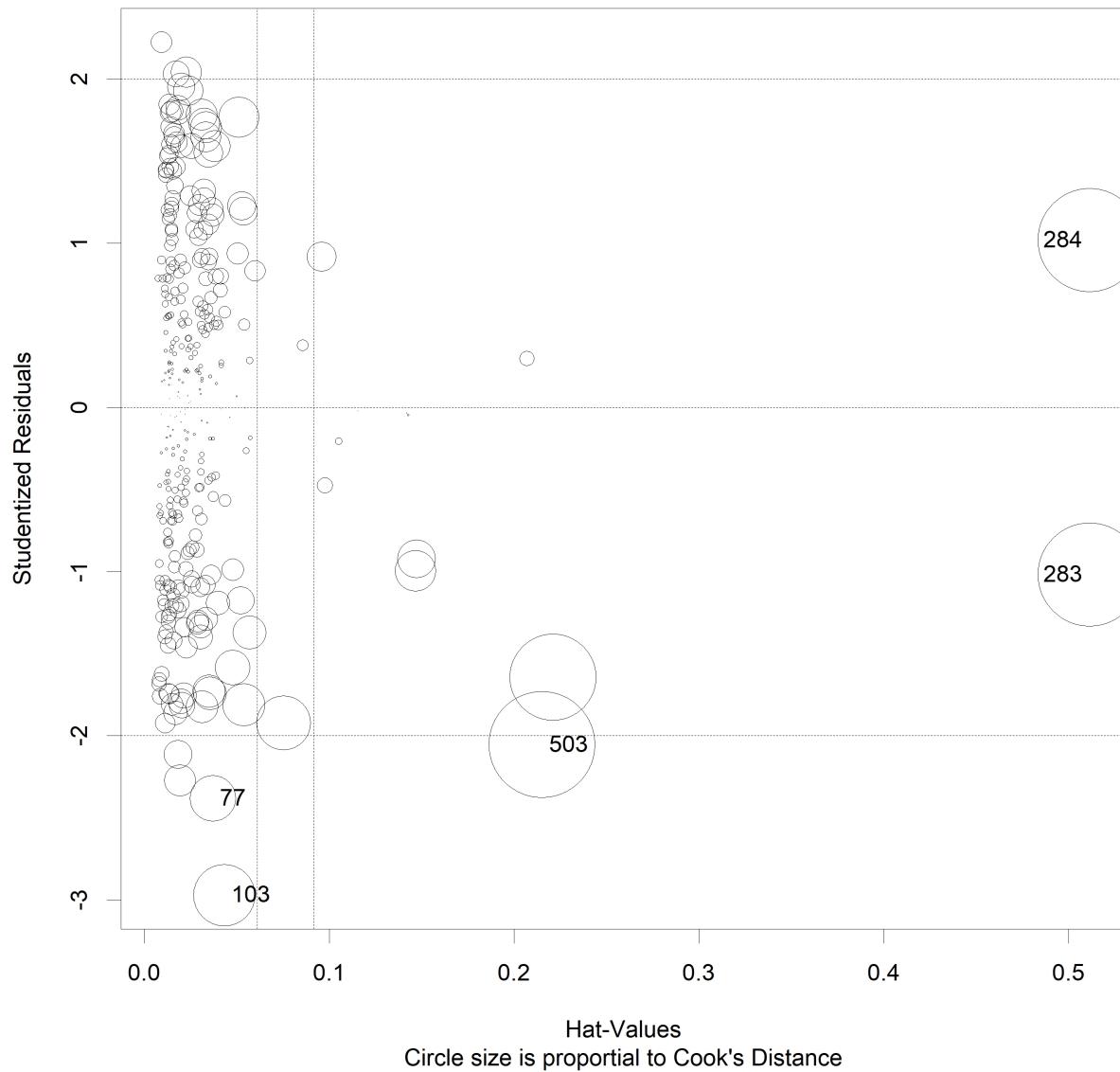
## Warning in box(...): "id.method" is not a graphical parameter

## 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 Tests

Normality Test

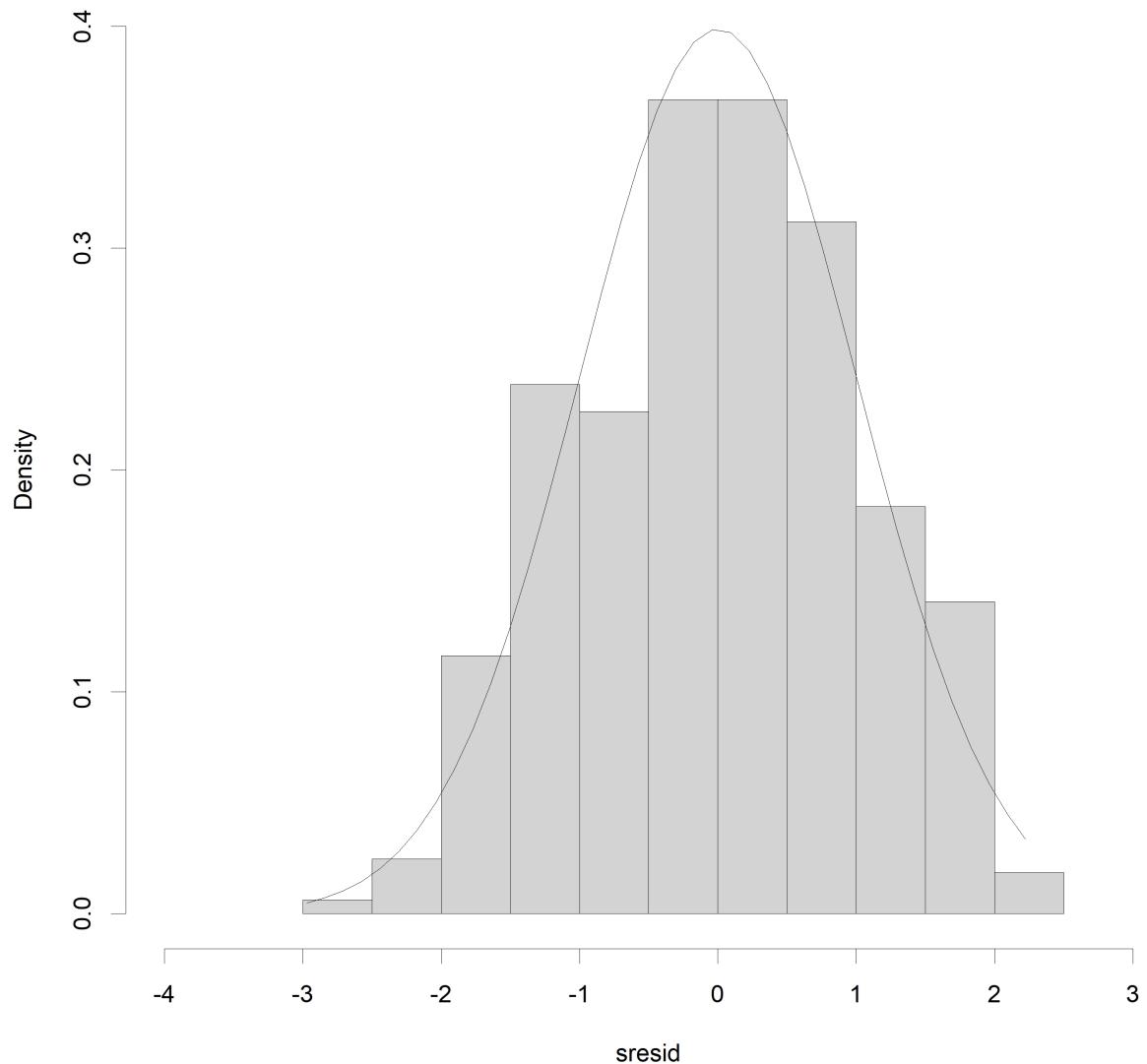
- Ho: The data is normally distributed
- Ha: the data is not normally distributed

NormTest	Stat	Pval
shapiro.test	0.99075	0.03758
ad.test	0.59623	0.11856

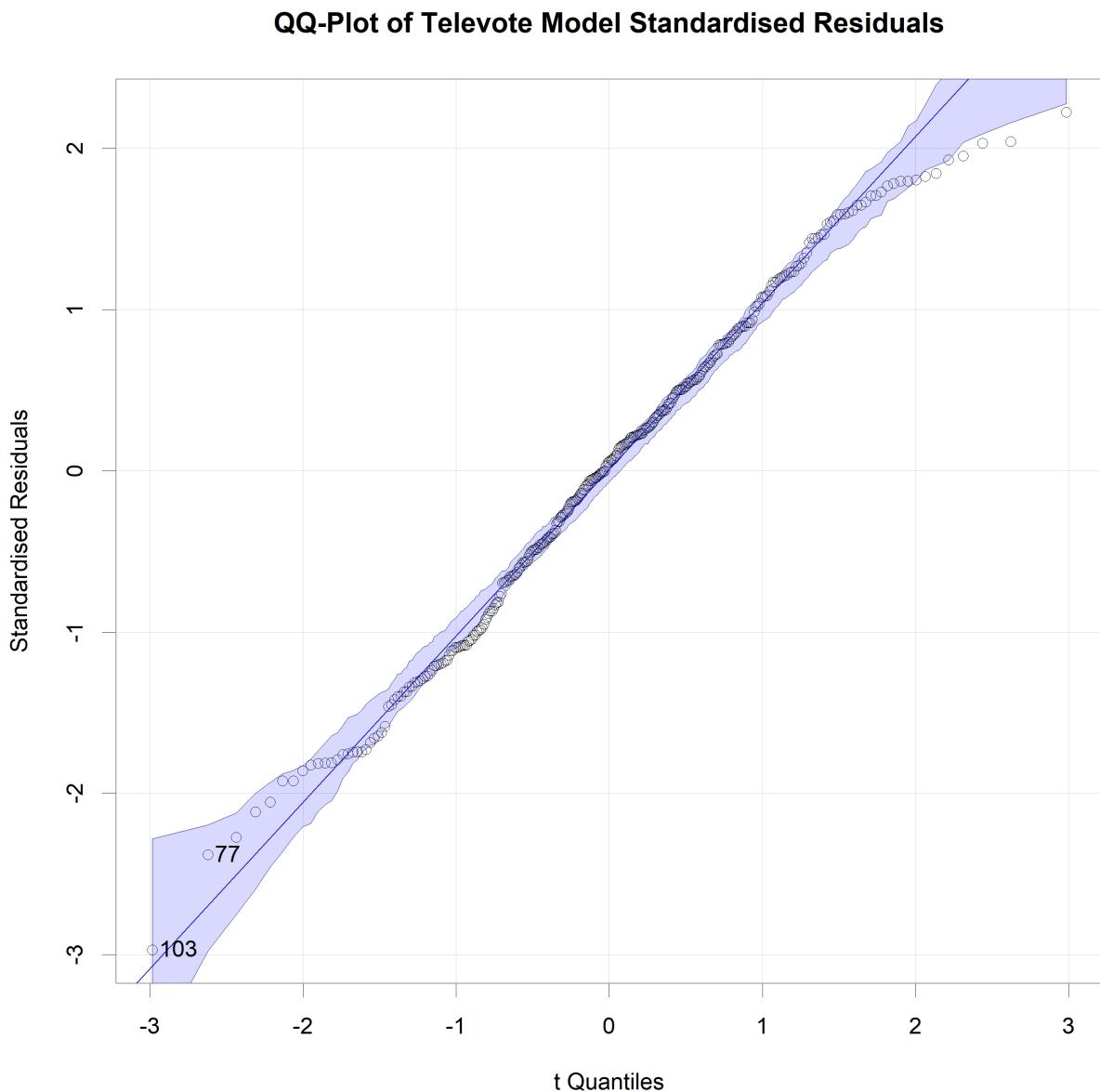
NormTest	Stat	Pval
cvm.test	0.07592	0.23336
lille.test	0.0381	0.29588
person.test	21.13761	0.27253
sf.test	0.99202	0.07153

### Residual Distribution

**Televote Model - Distribution of Standardised Residuals**



## Residual QQ-Plot



## Non-Constant Variance Test

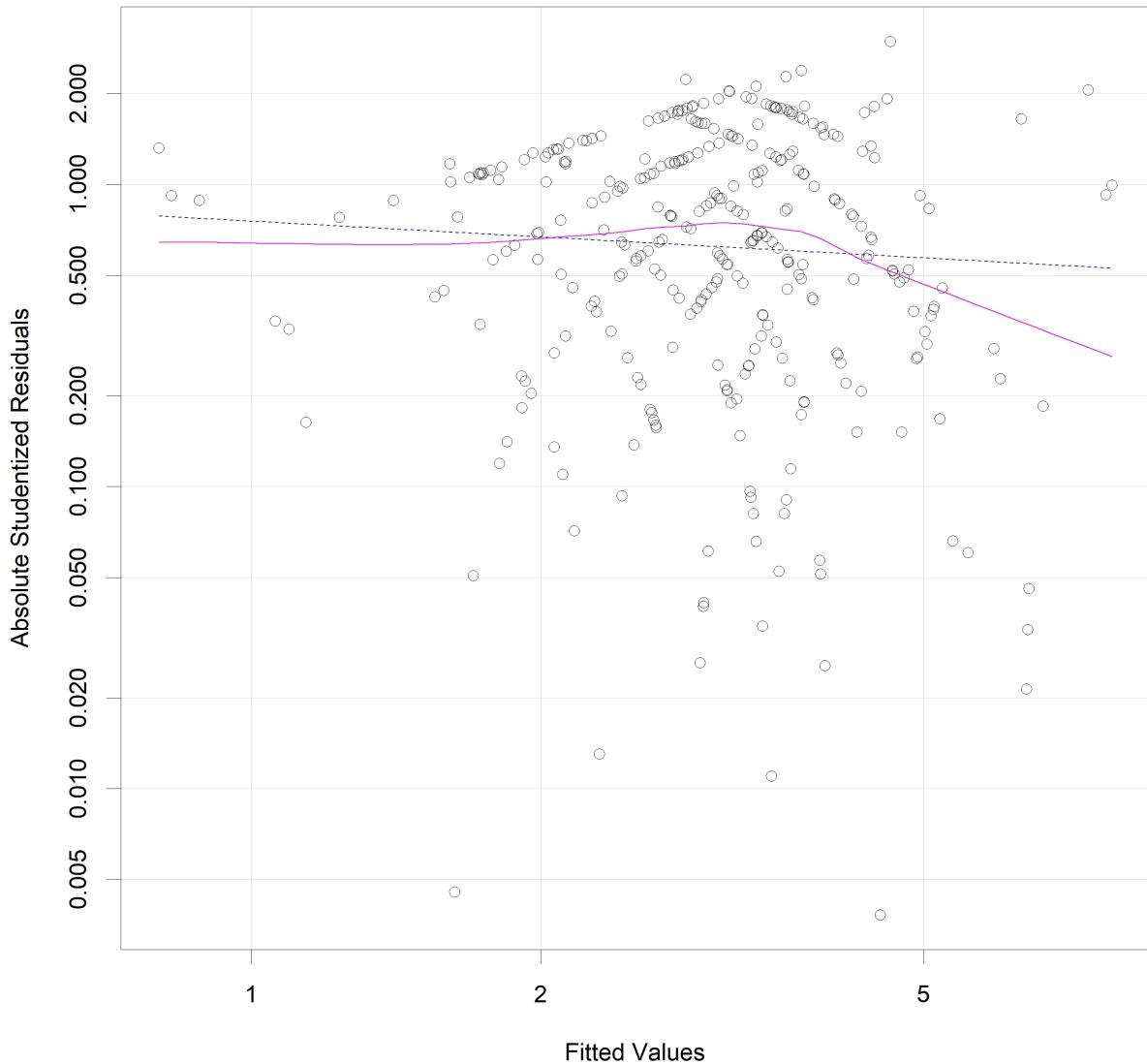
Non-Constant Error Variance Test

- $H_0$ : constant error variance
- $H_a$ : 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
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
```

## Power Transformation

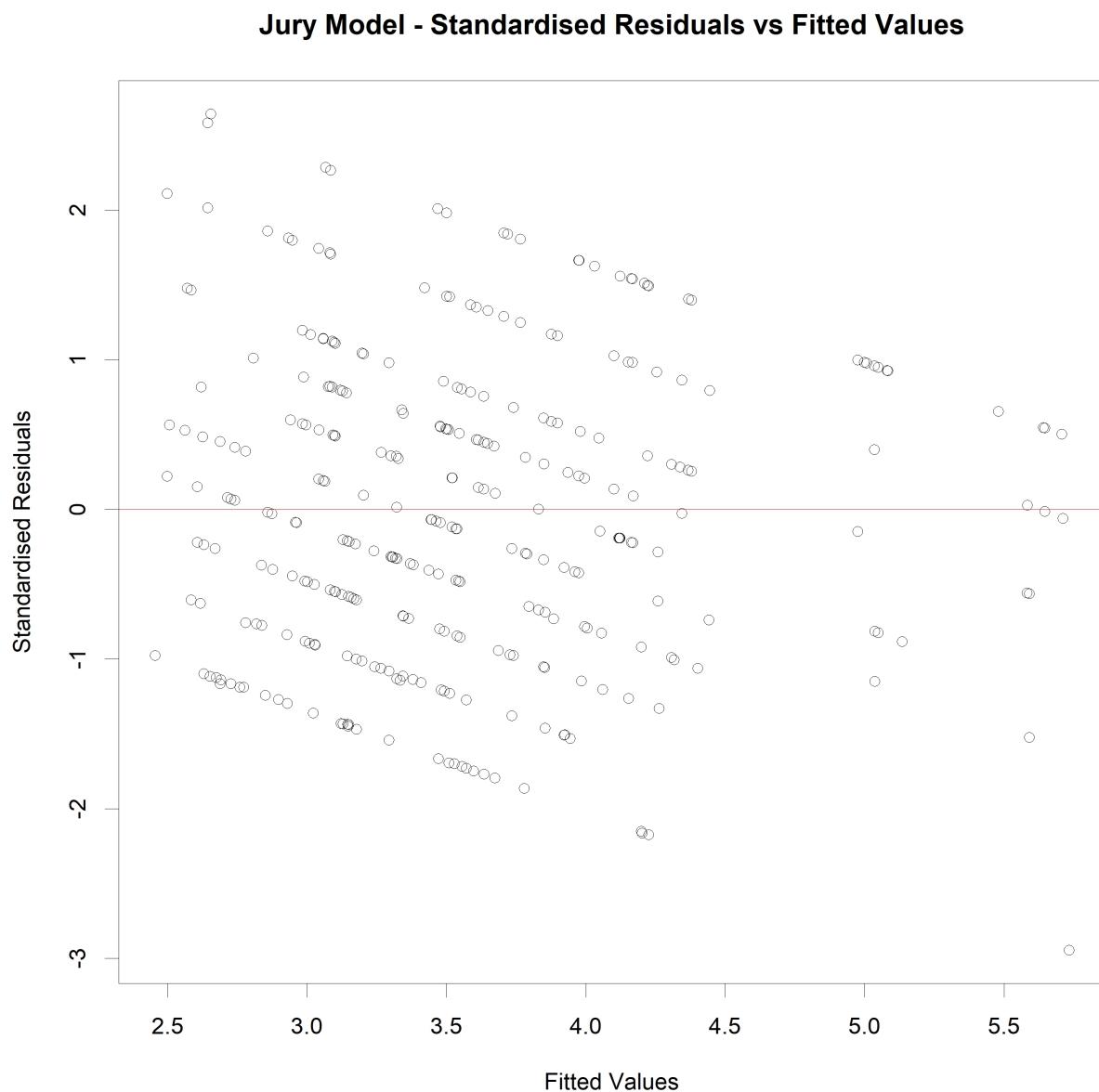
```
##  
## Call:  
## lm(formula = jury_final_model_pt_form, data = jury_data)  
##  
## Residuals:  
##      Min     1Q Median     3Q    Max  
## -4.051 -1.185 -0.045  1.071  3.804  
##  
## Coefficients:  
##                               Estimate Std. Error t value Pr(>|t|)  
## (Intercept)             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



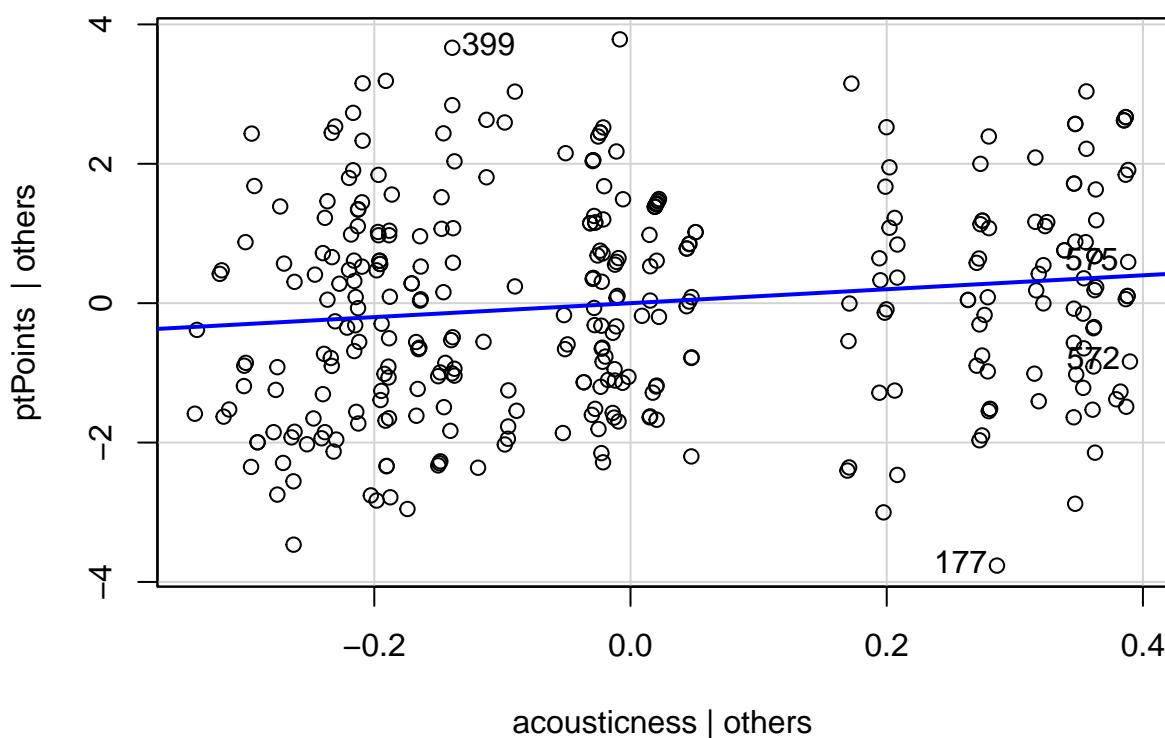
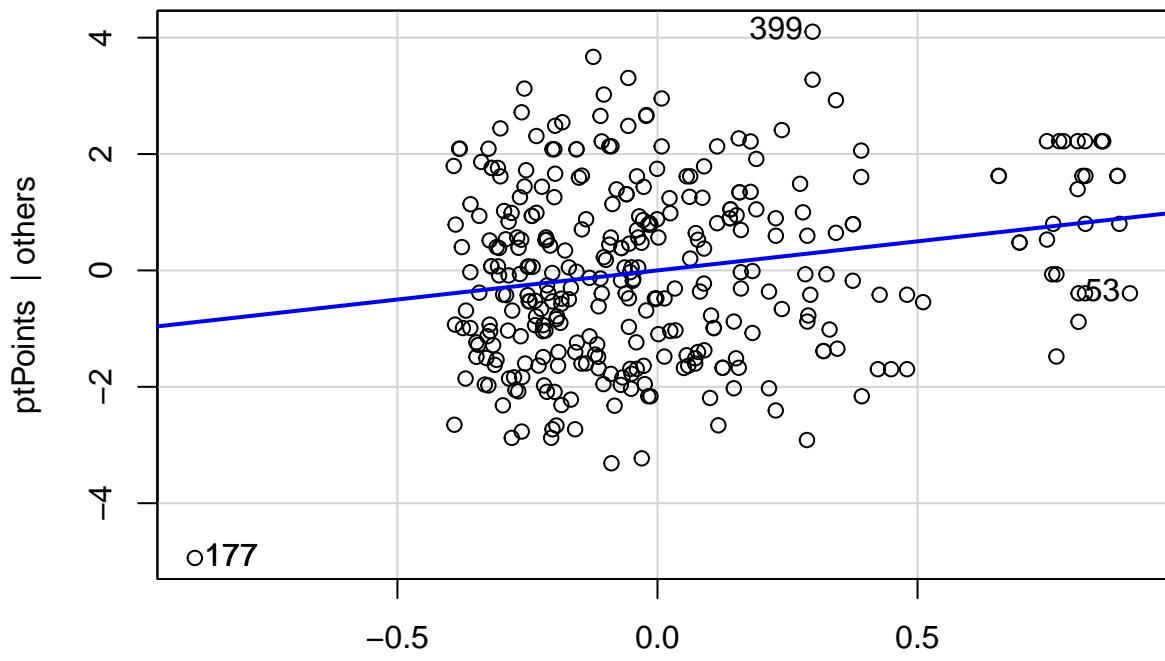
### Bonferroni Outlier Test

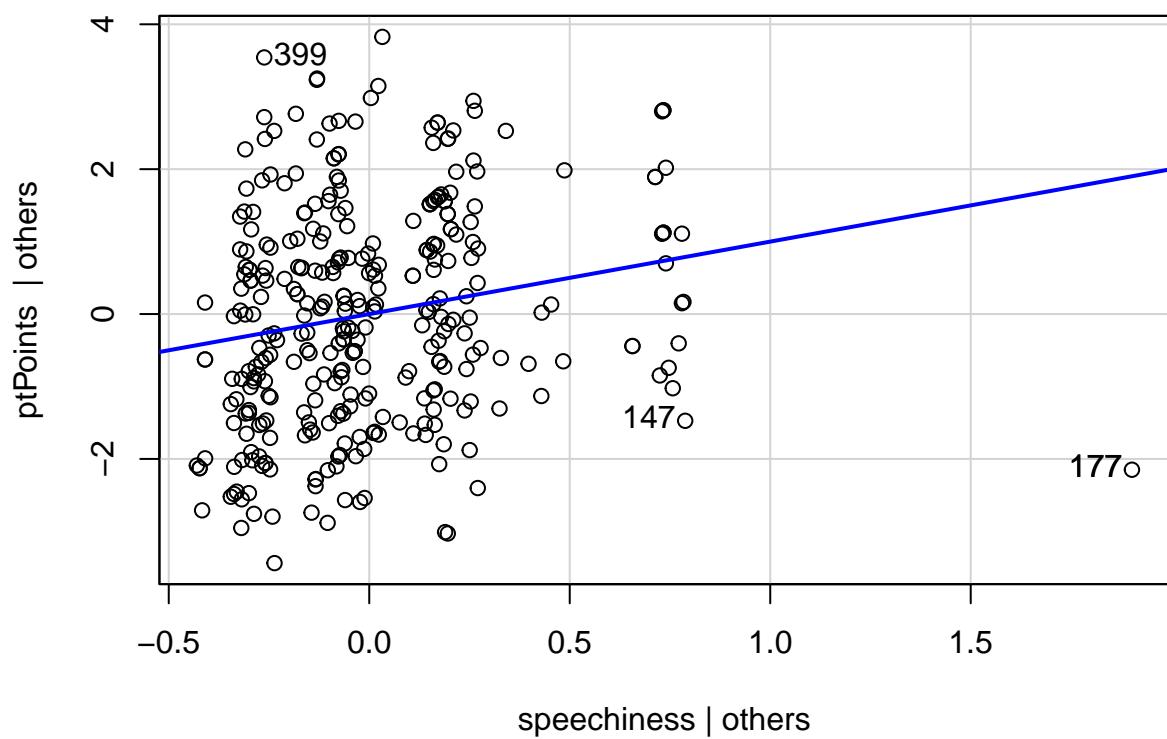
	rstudent	p	bonf.p	signif	cutoff
177	-2.945099	0.0034643	1.146697	0	0.05

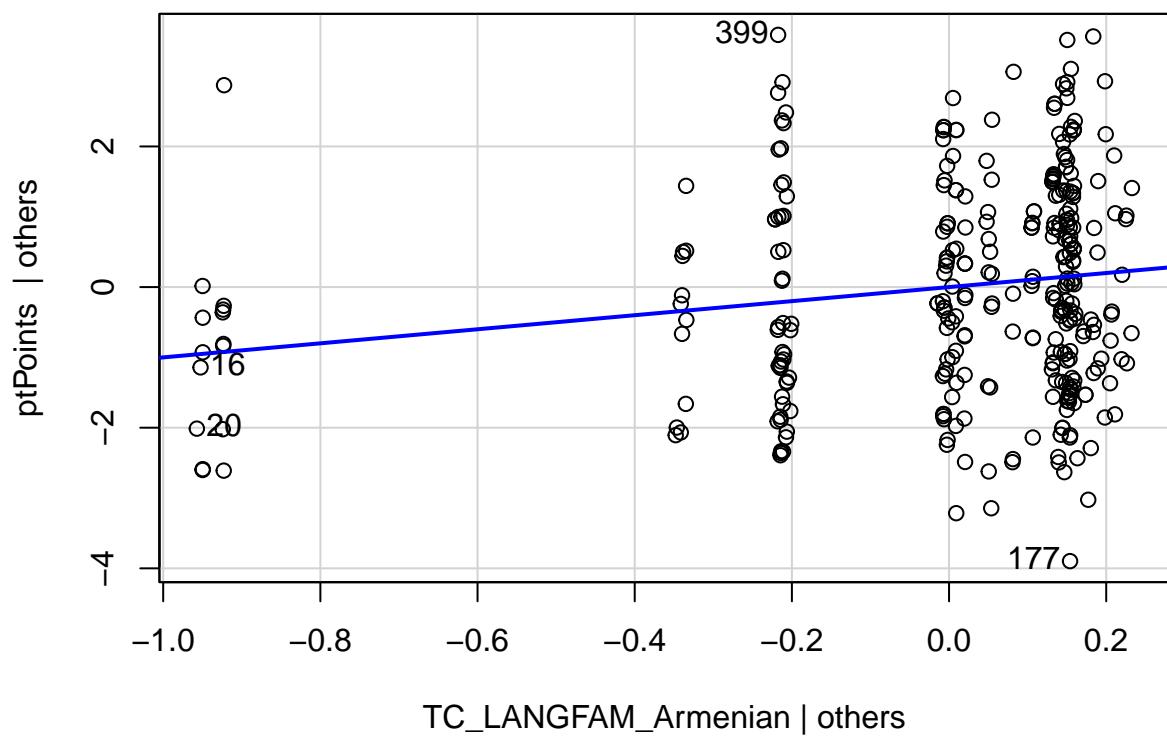
## Outlier Resdiauls

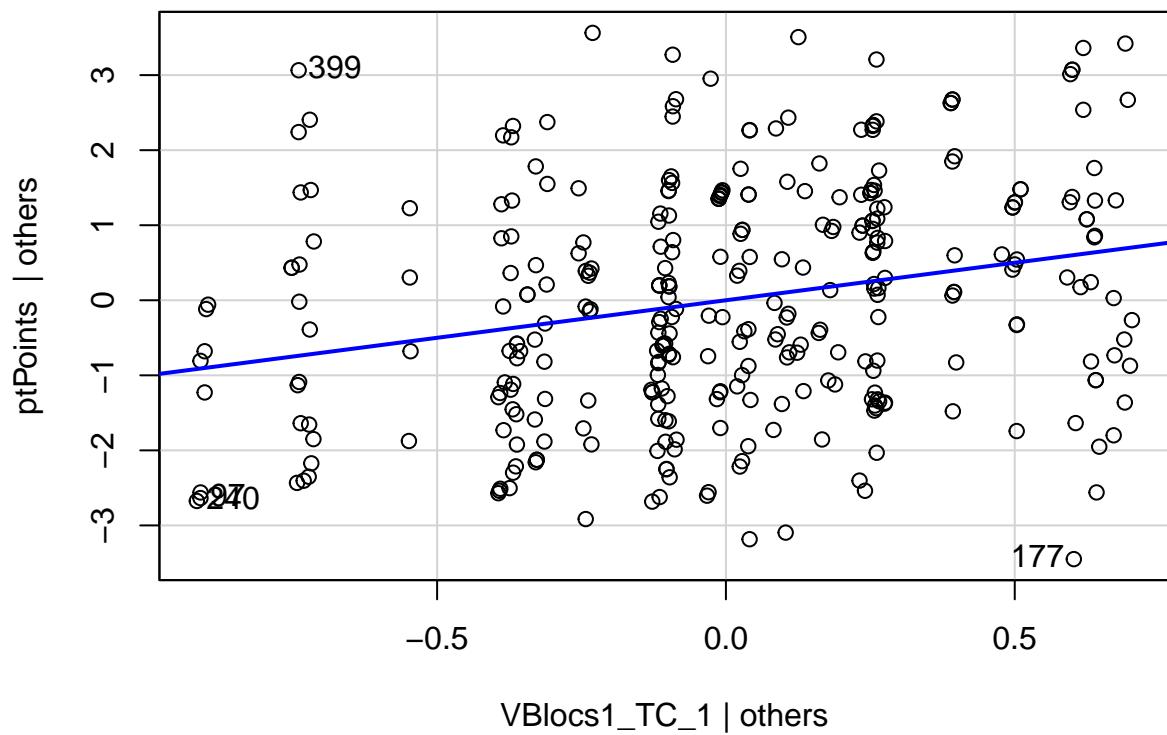
<u>outlier_residuals</u>
177
516
529
618

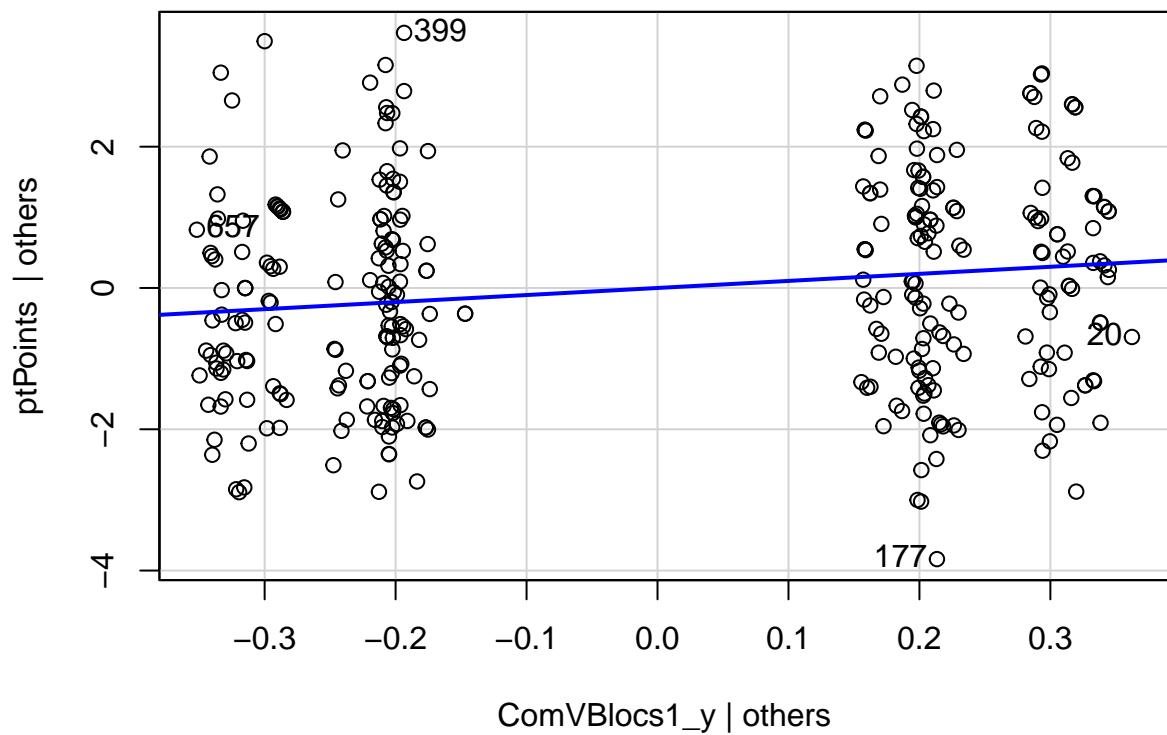
## Leverage Plots

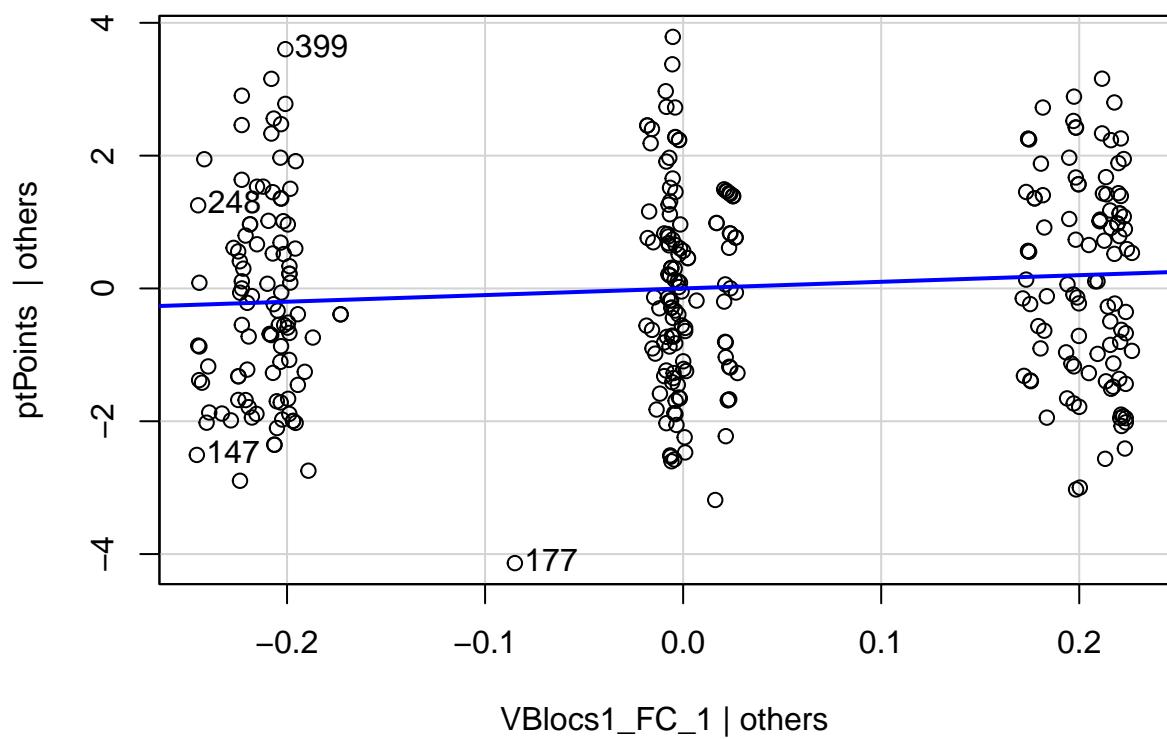




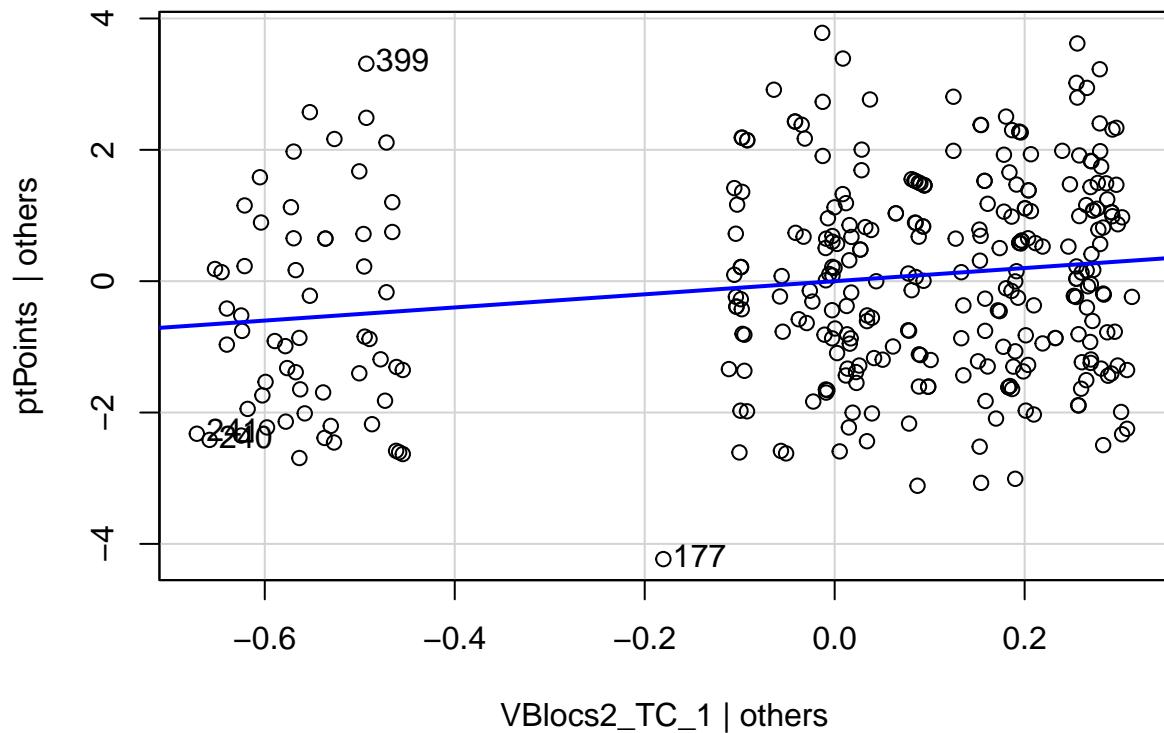




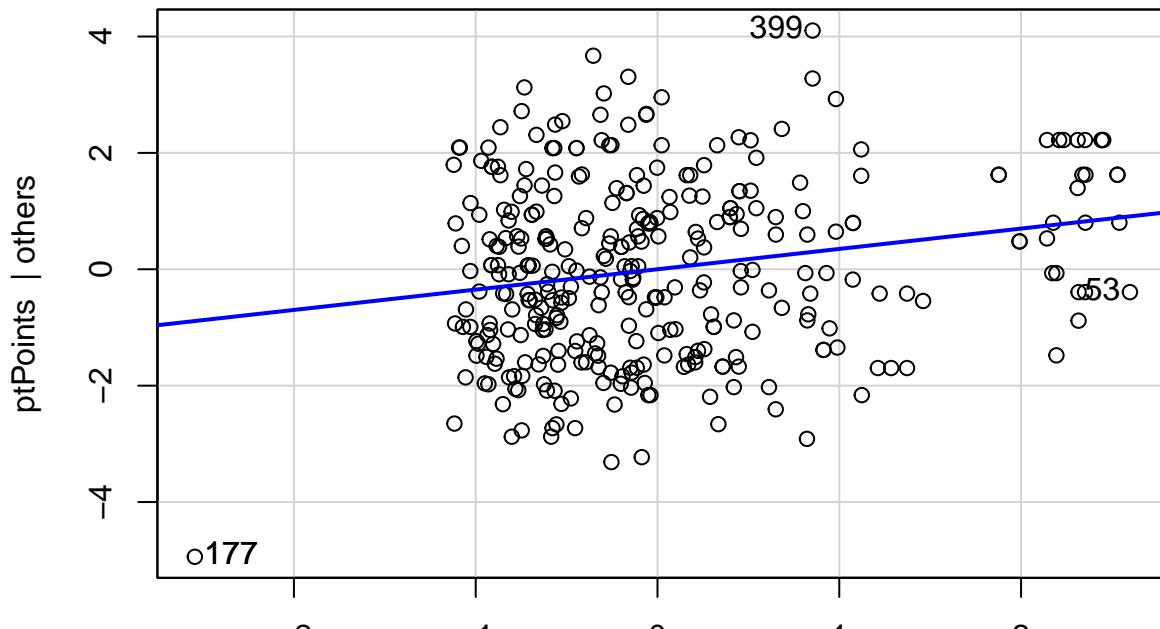




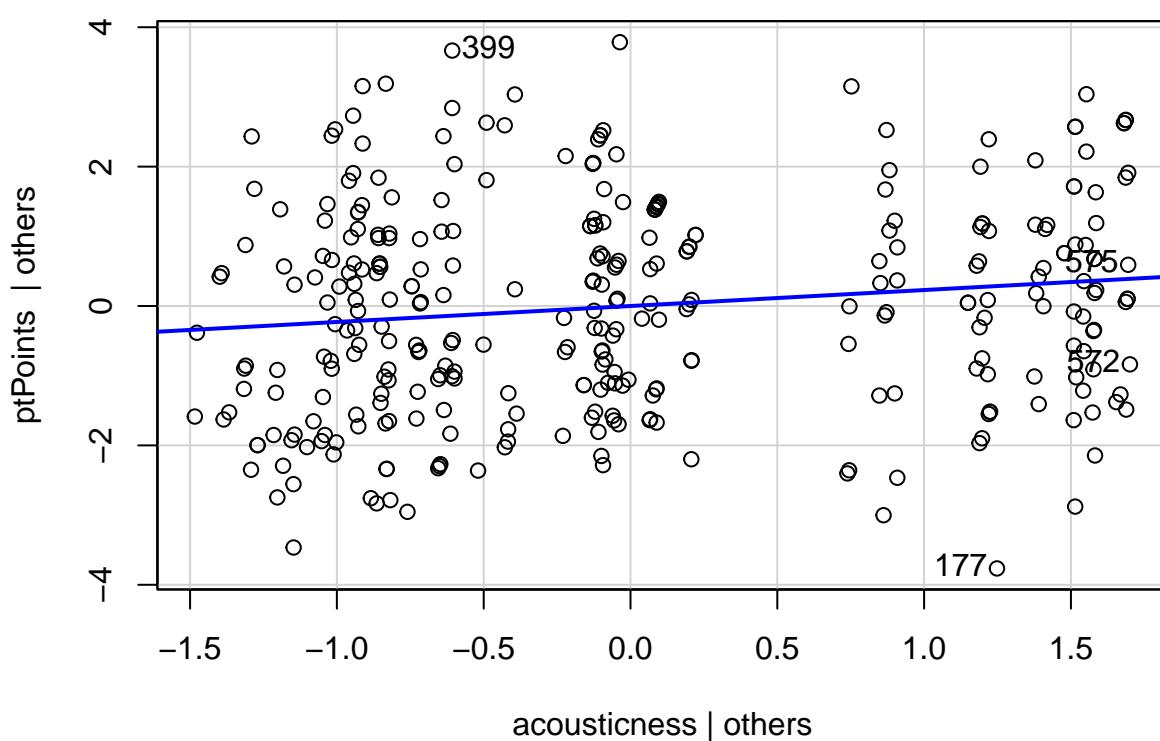
### Leverage Plots



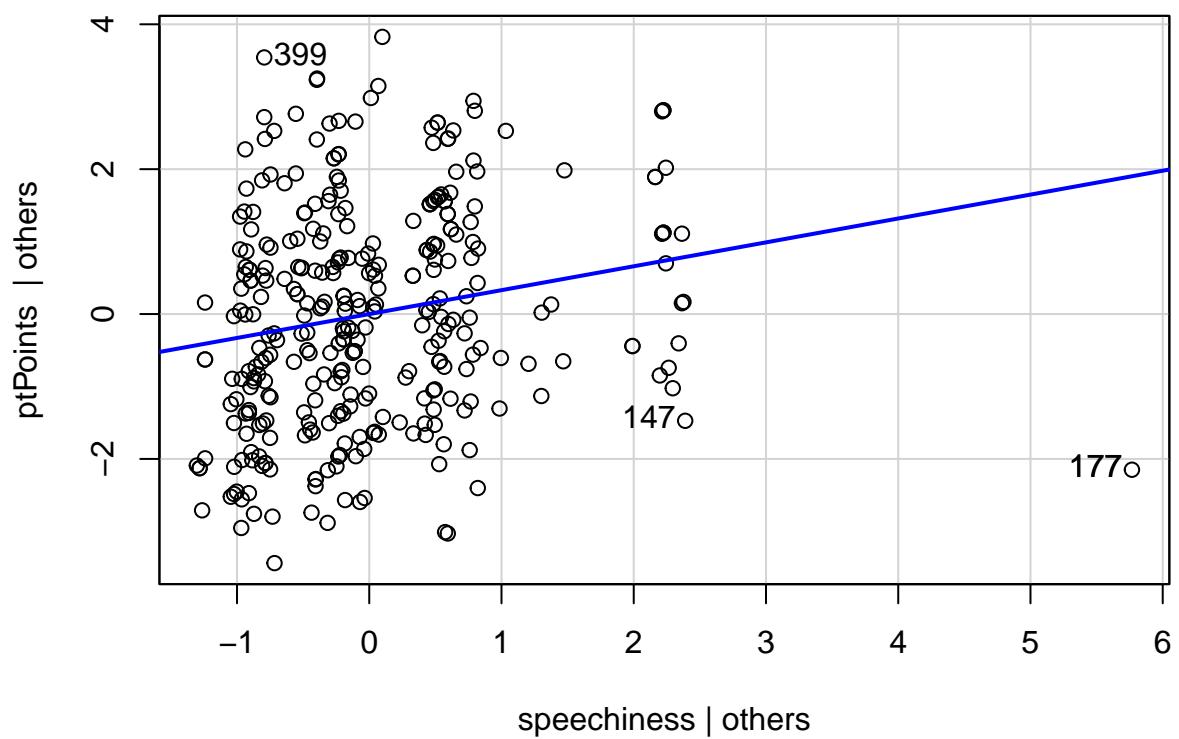
### Added VAriable Plots

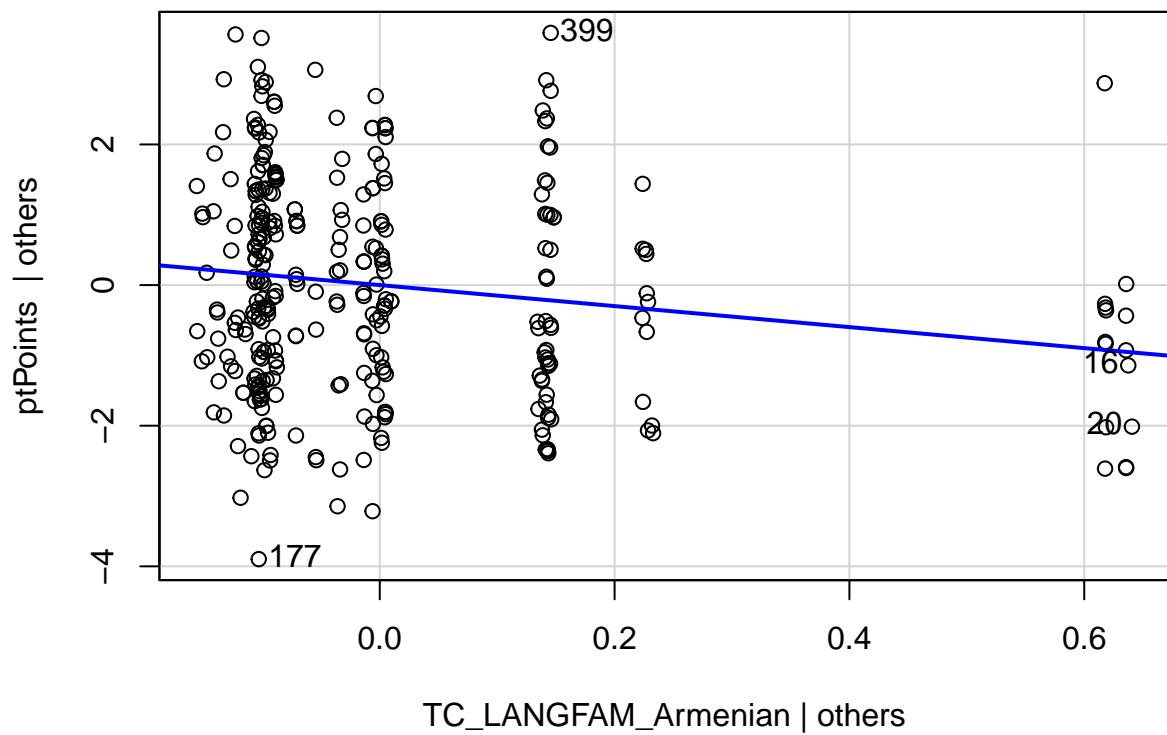


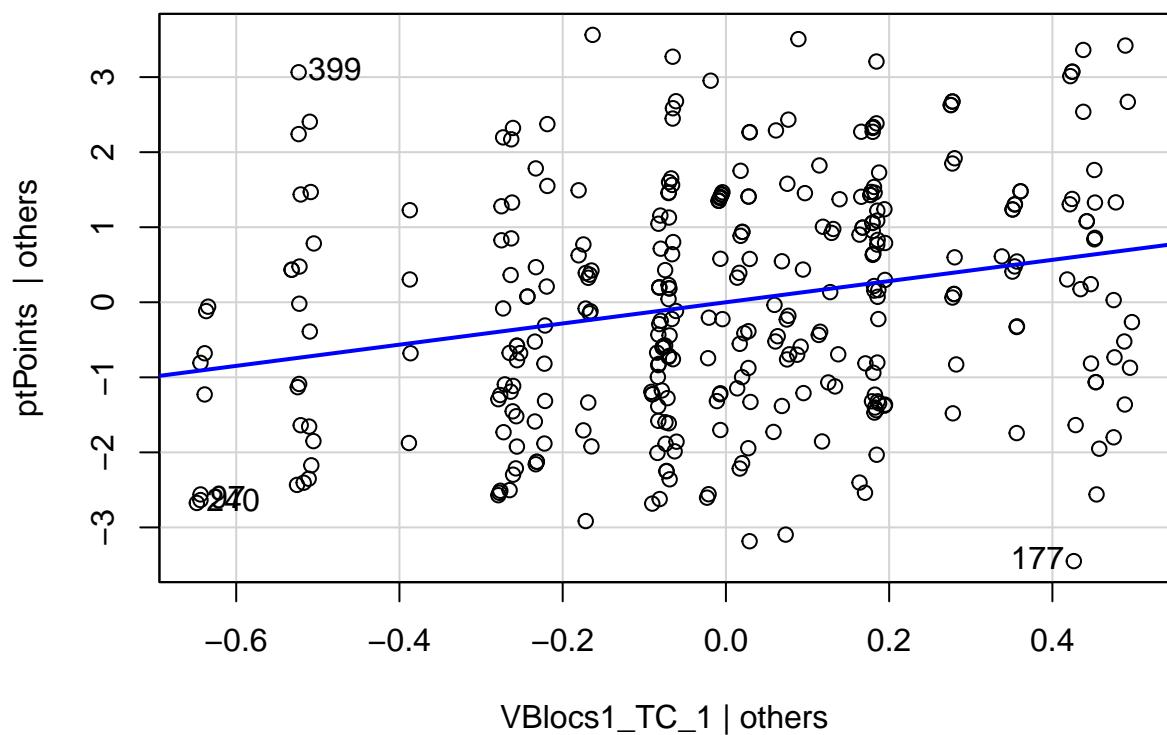
CAP\_DIST\_km | others

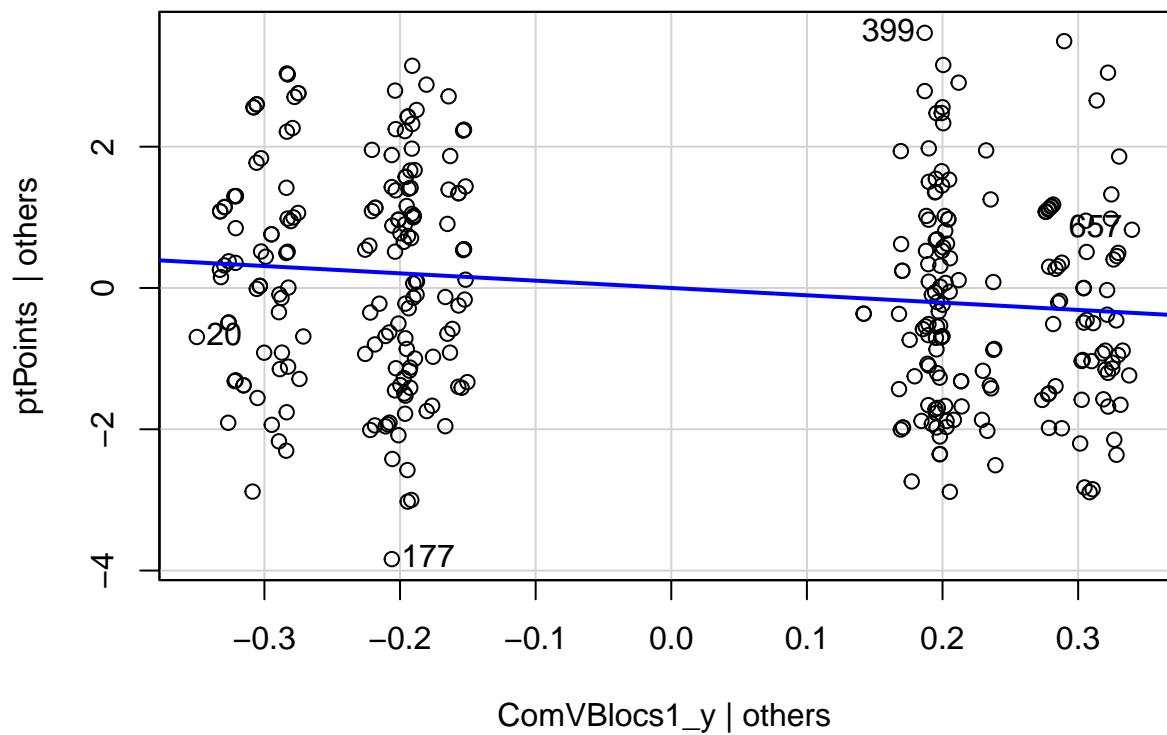


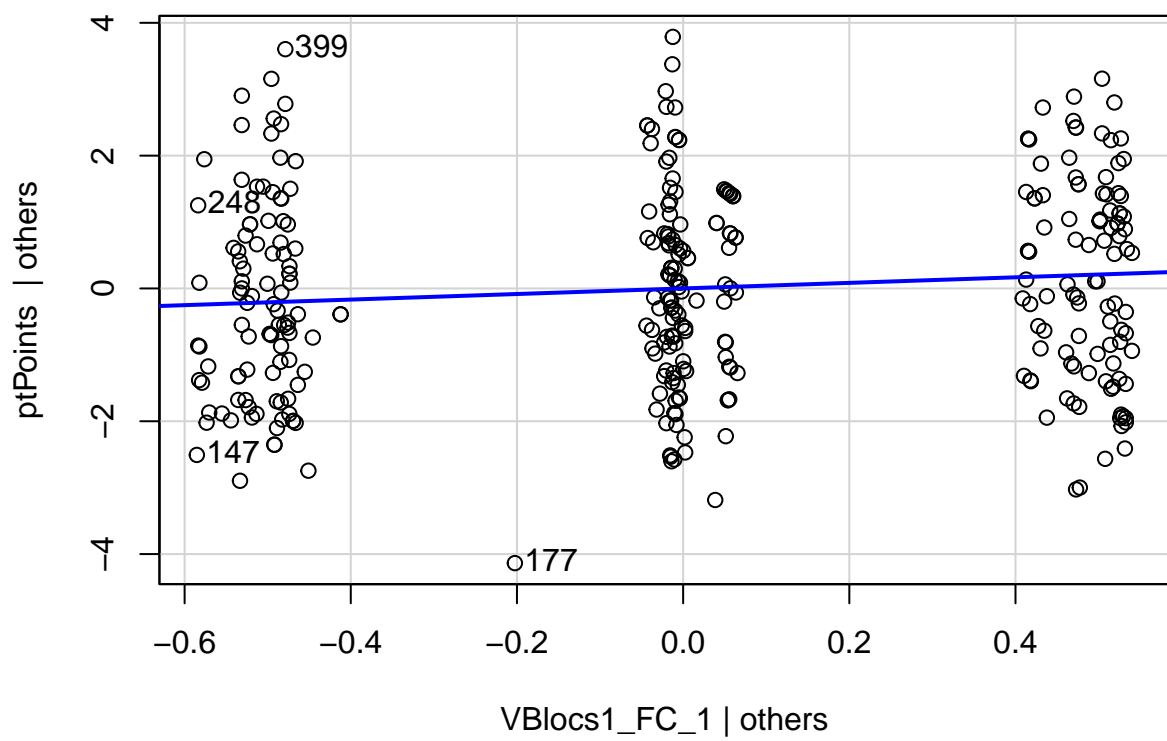
acousticness | others



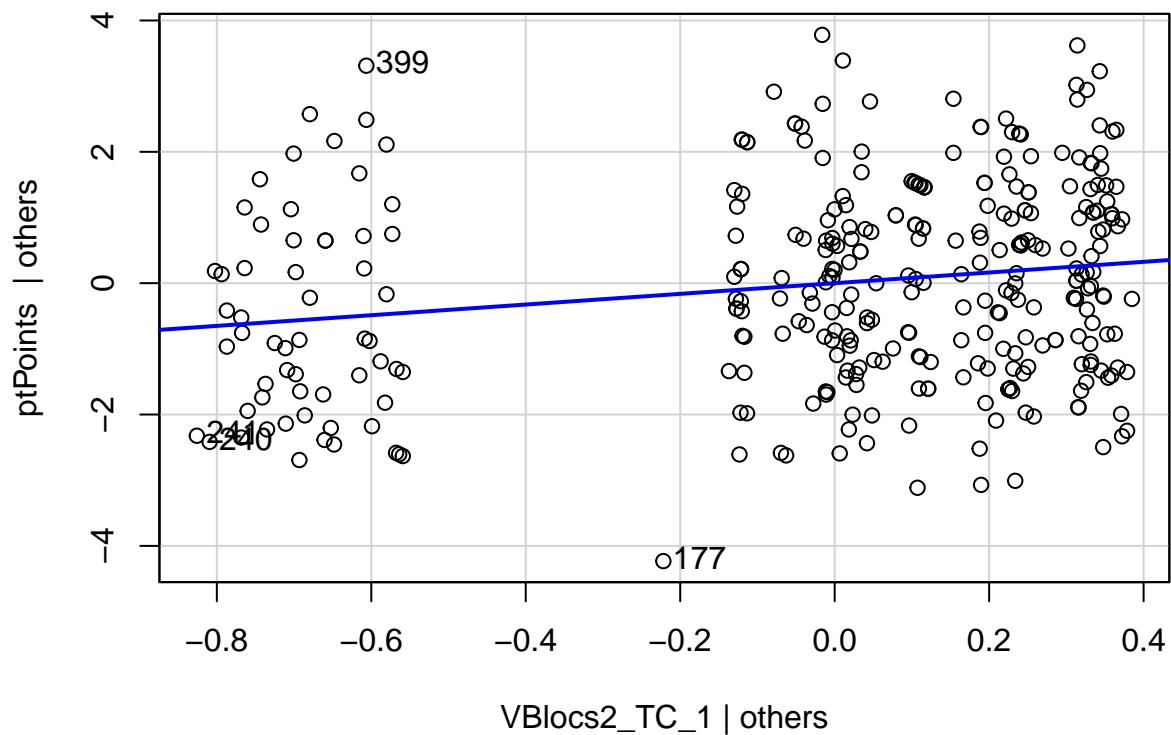




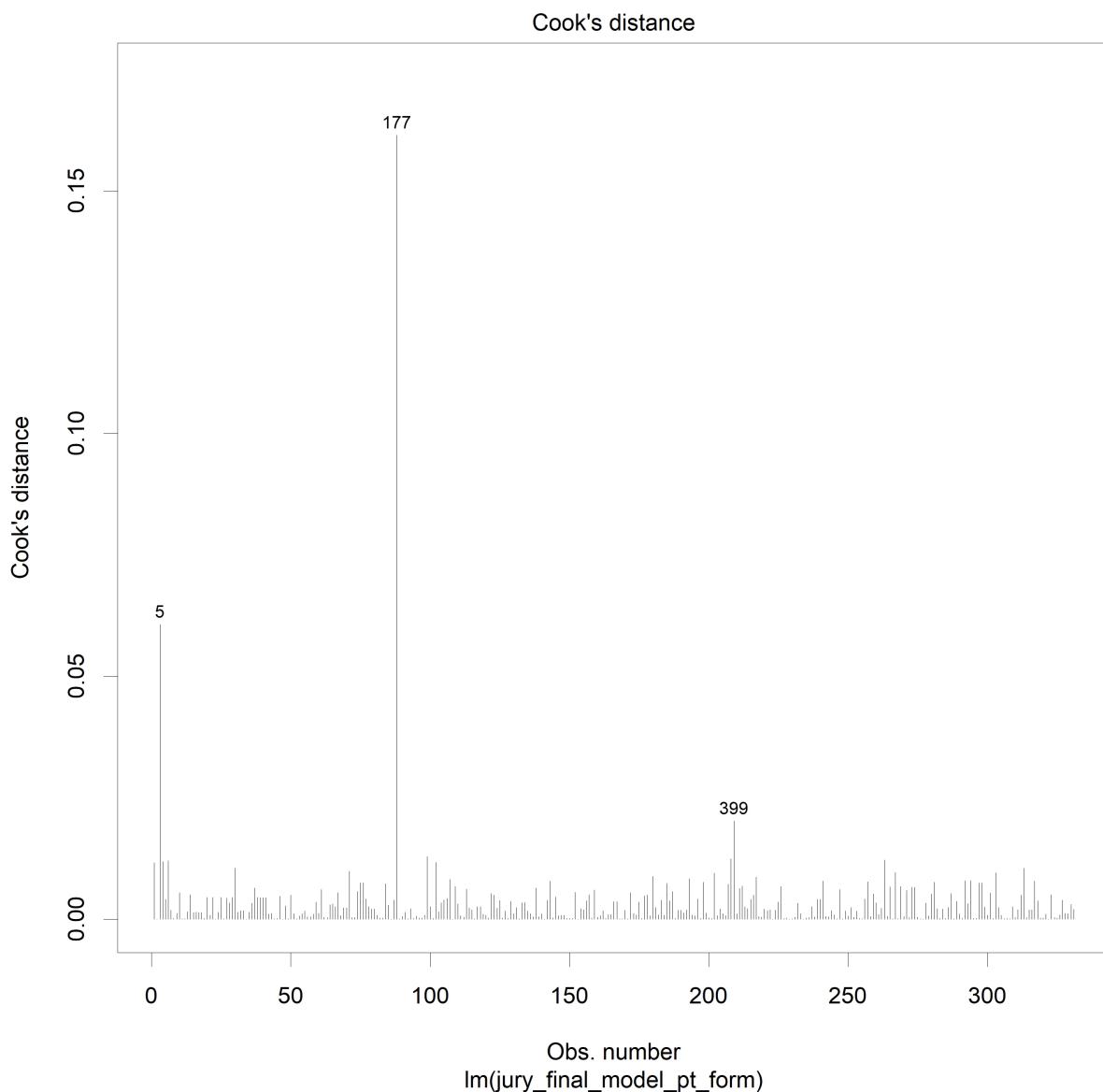




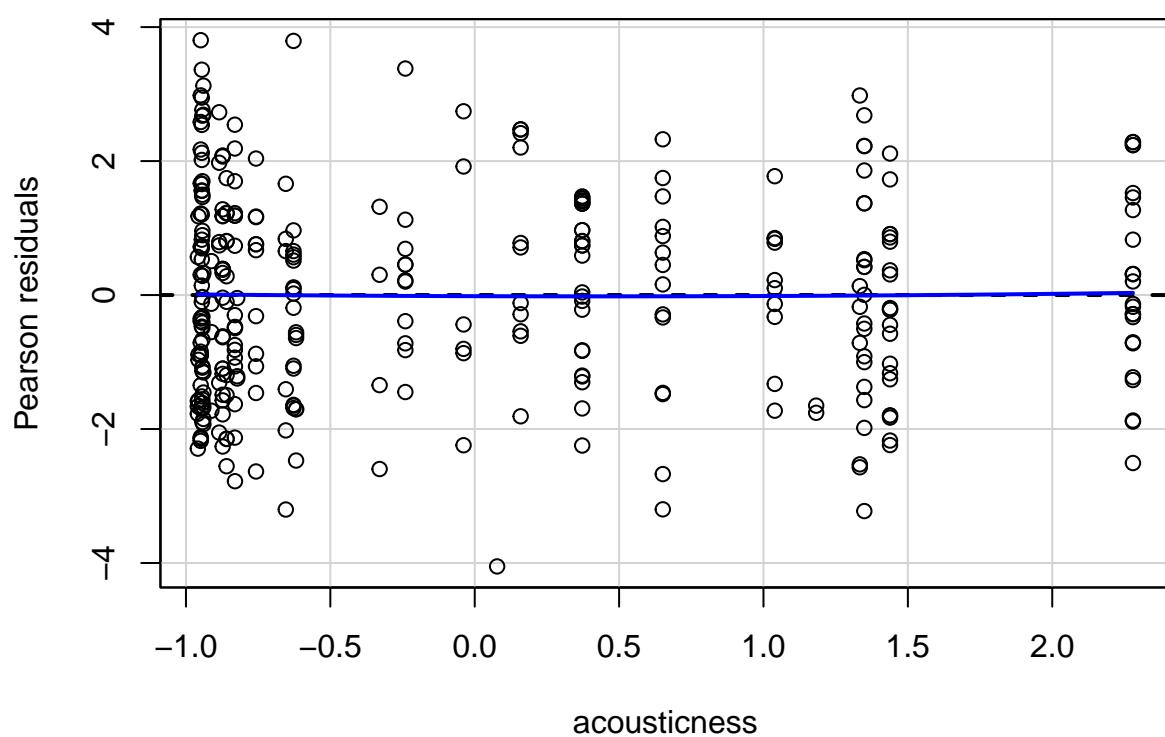
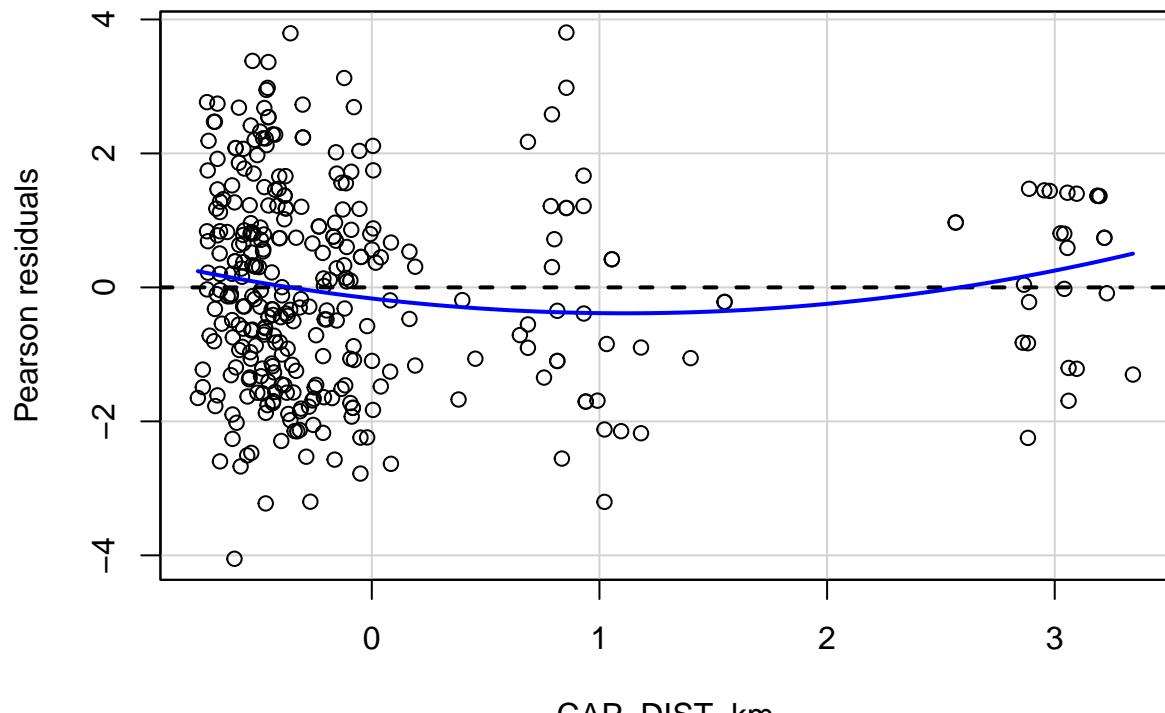
### Added-Variable Plots

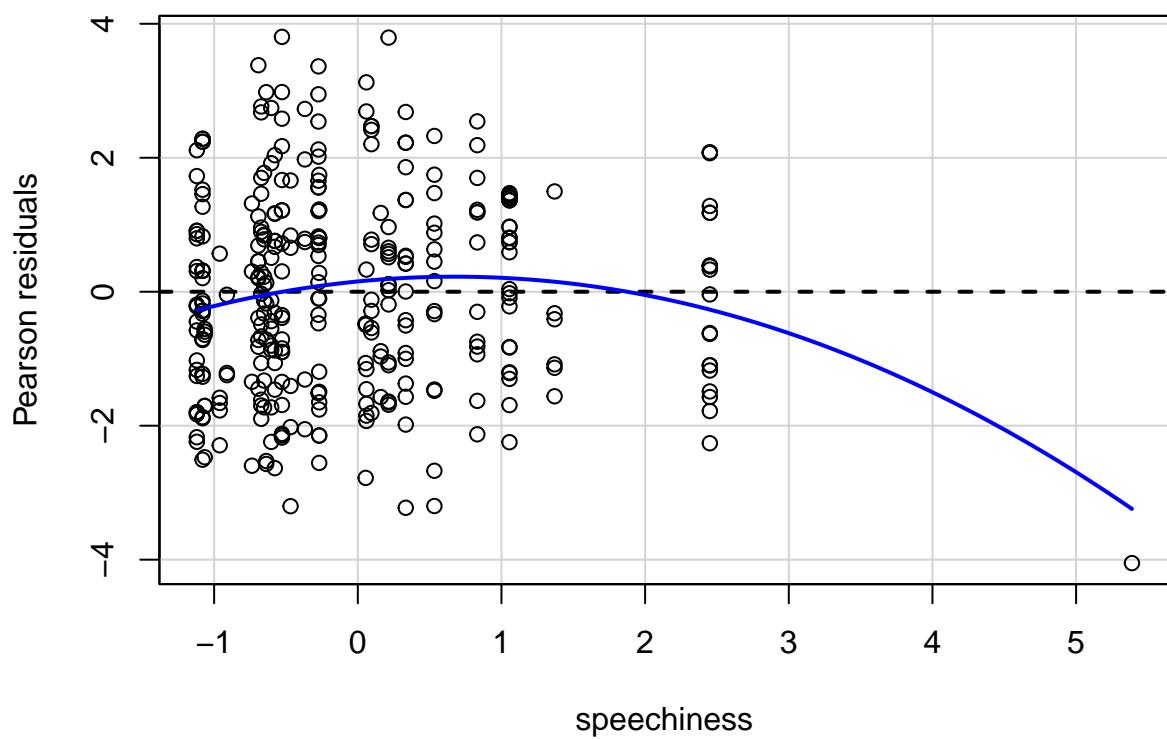


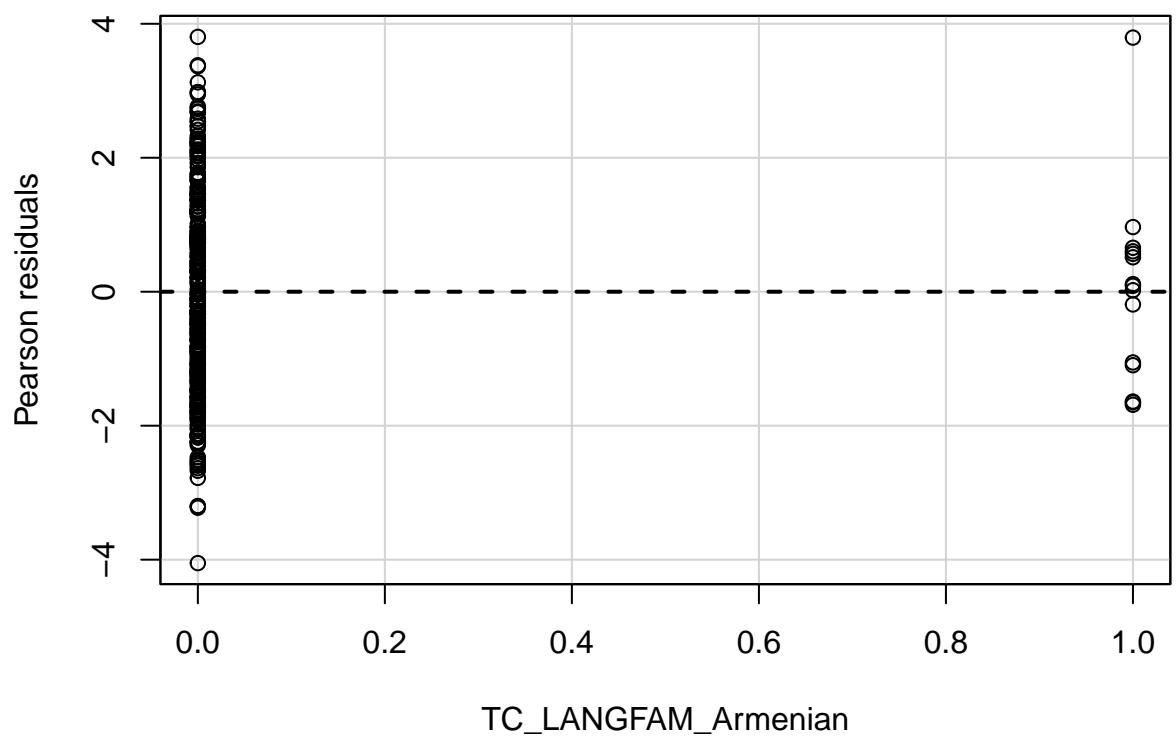
### Cooks Distance Plot

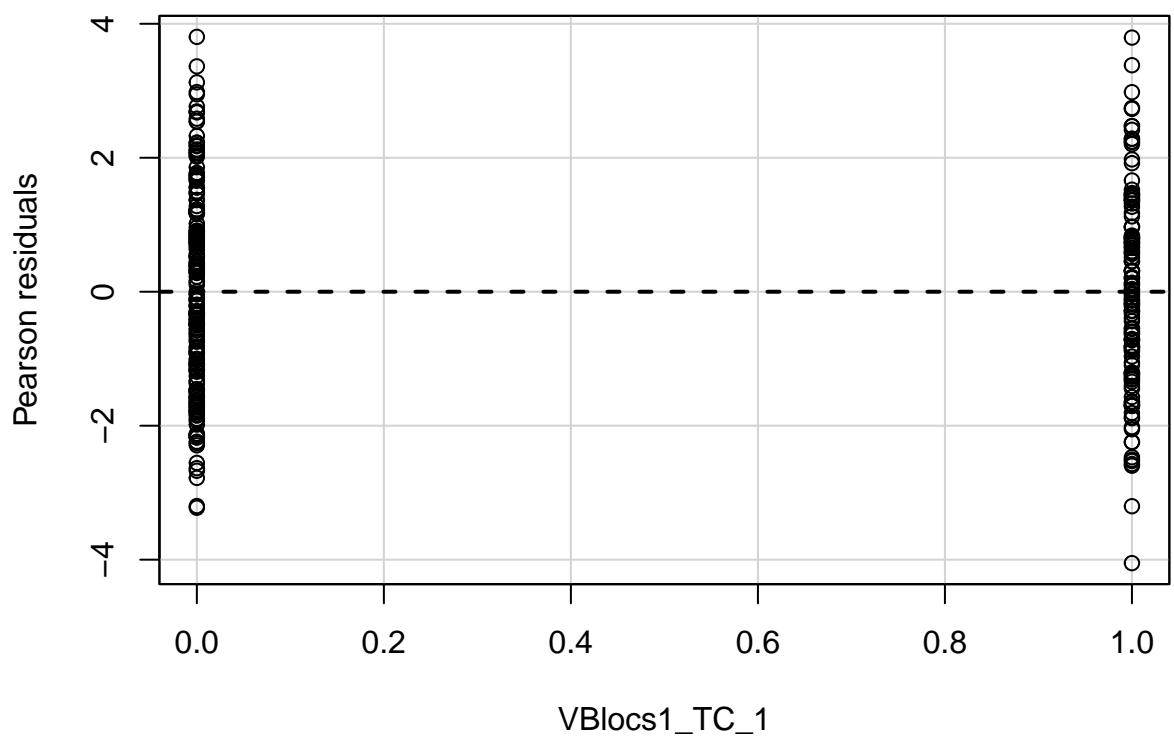


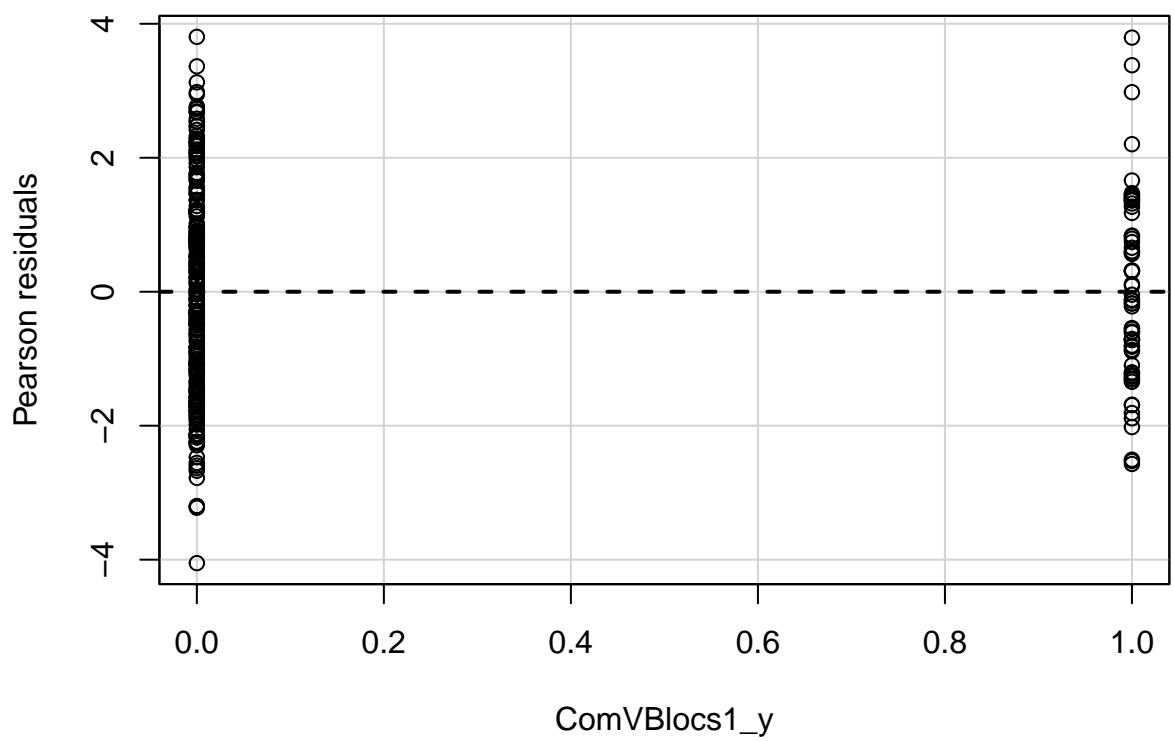
## Residual Plots

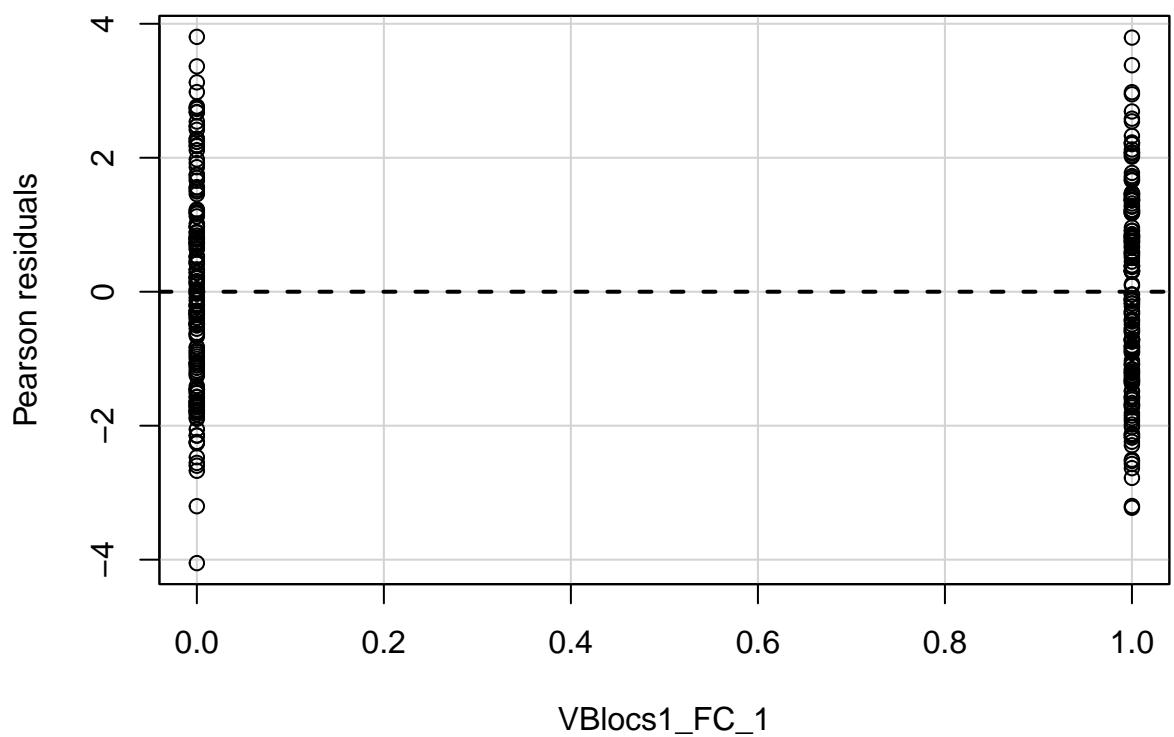


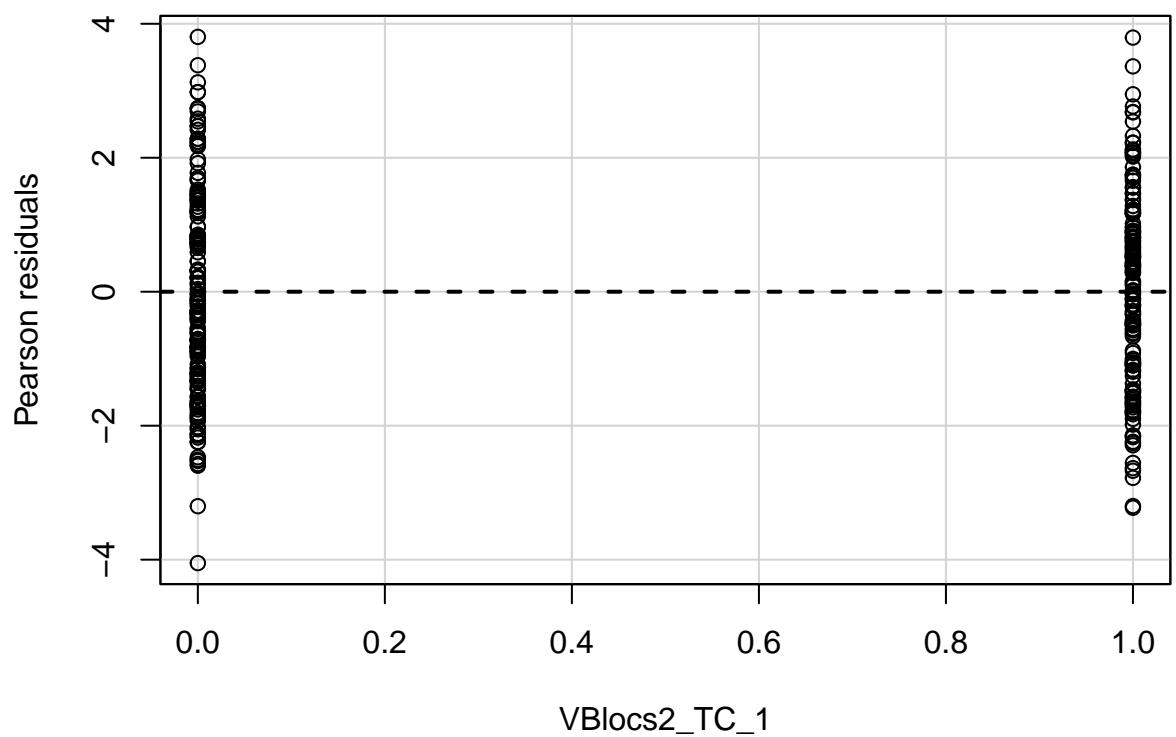


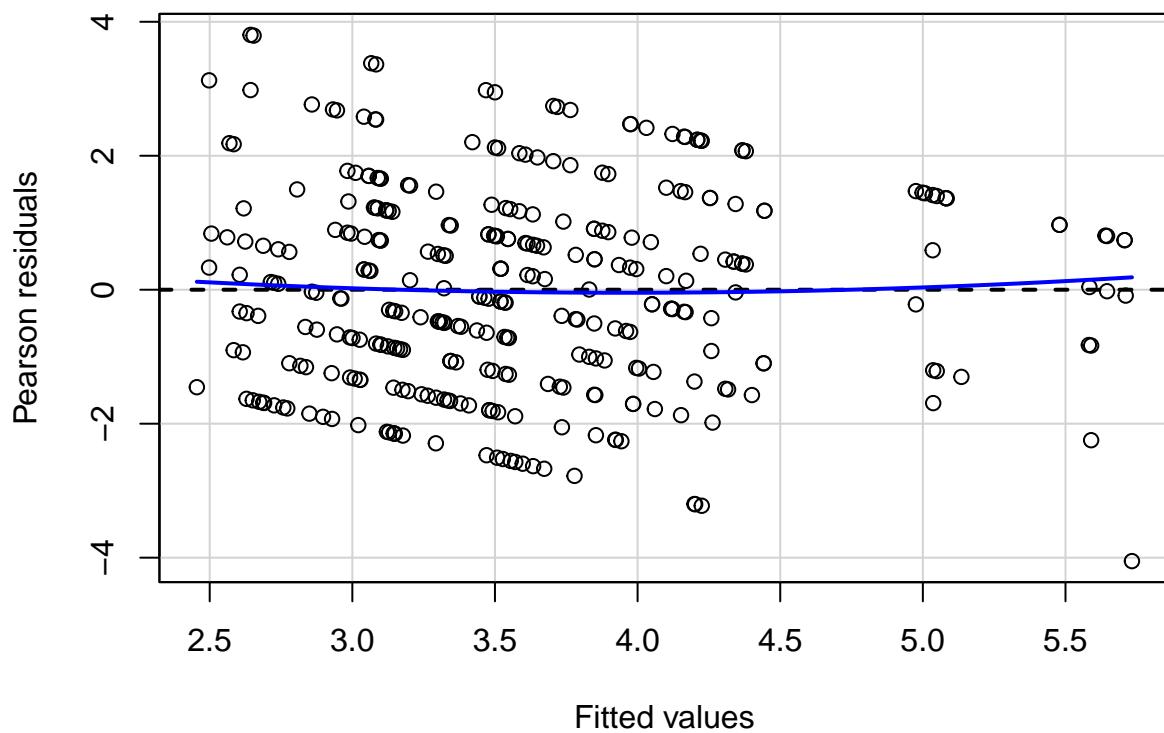












### Influence Plot

```

## 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

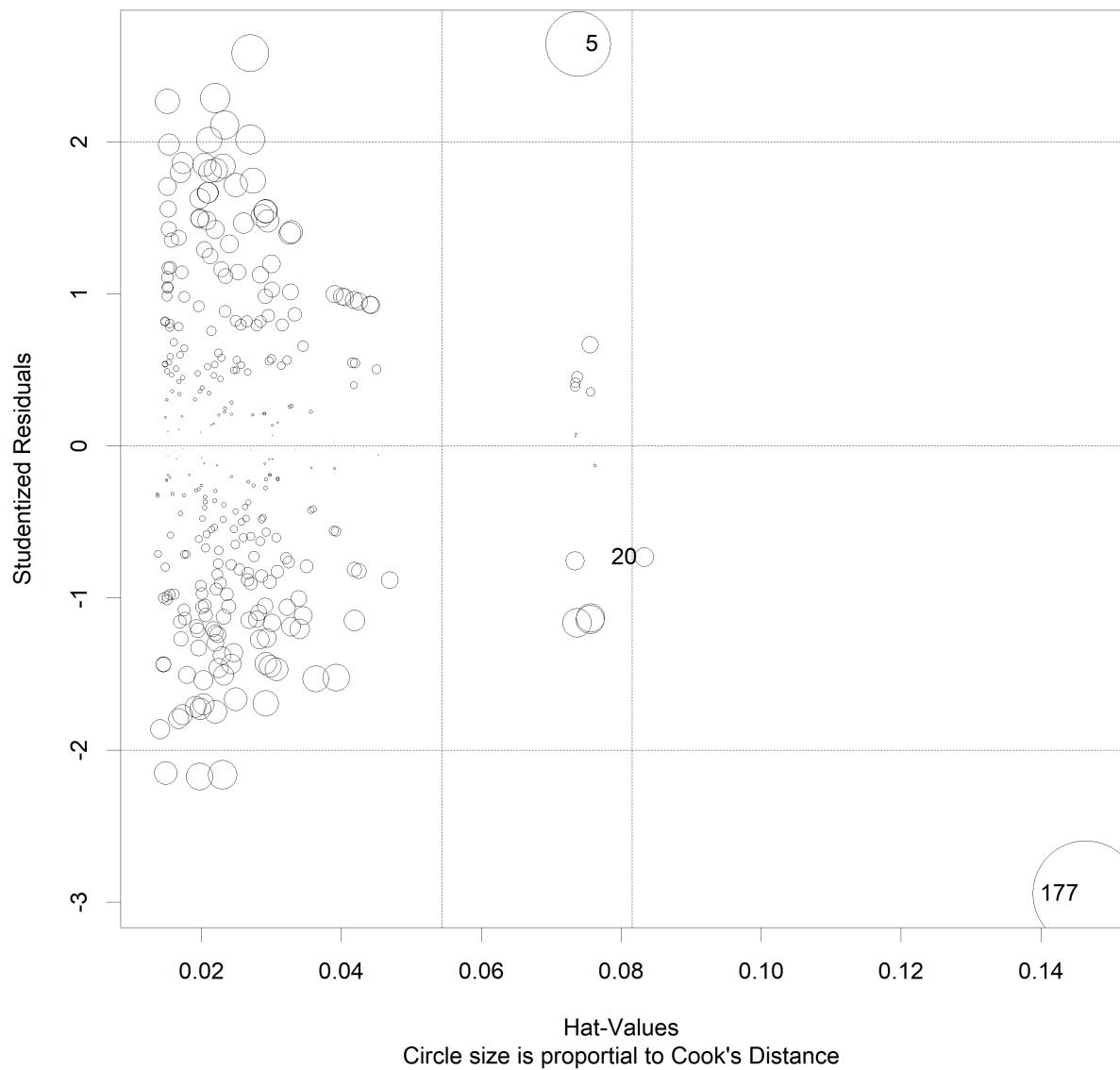
## Warning in box(...): "id.method" is not a graphical parameter

## 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 Tests

Normality Test

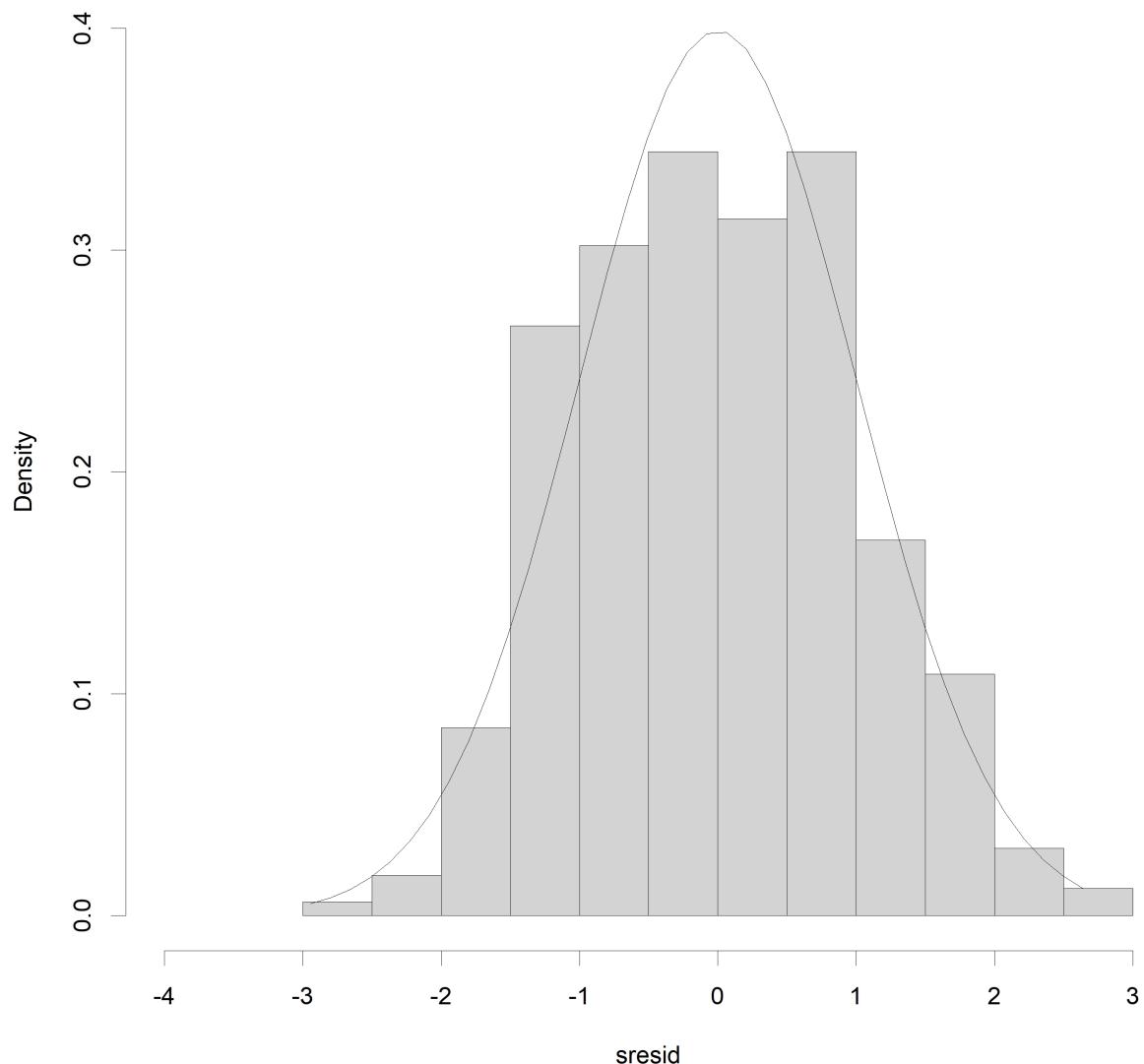
- Ho: The data is normally distributed
- Ha: the data is not normally distributed

NormTest	Stat	Pval
shapiro.test	0.99153	0.05511
ad.test	0.89016	0.02271

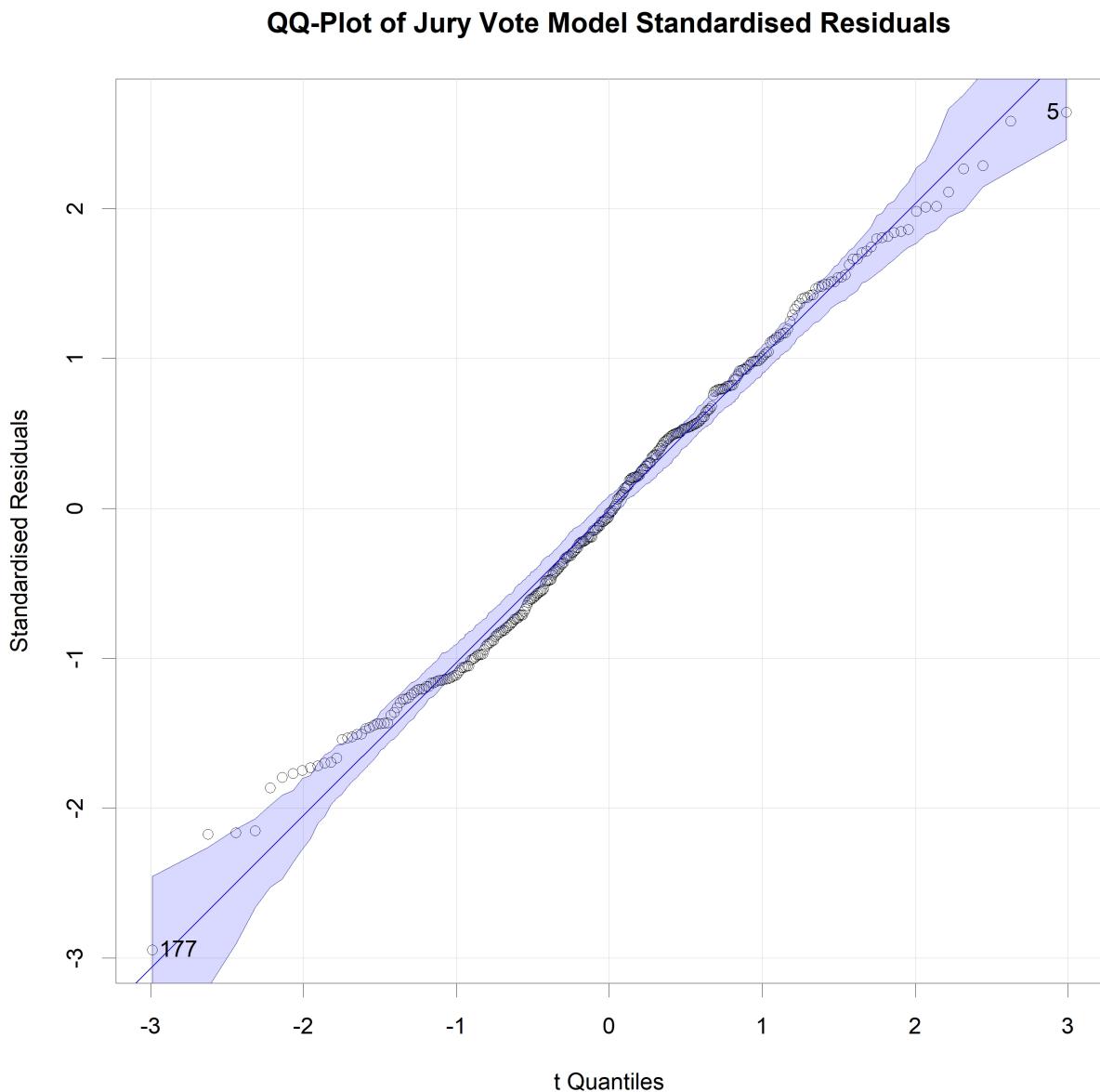
NormTest	Stat	Pval
cvm.test	0.13742	0.03478
lille.test	0.0473	0.0716
person.test	30.56798	0.03228
sf.test	0.99221	0.07562

## Residual Plots

### Jury Model - Distribution of Standardised Residuals



## Residual QQ-Plot



## Non-Constant Variance Test

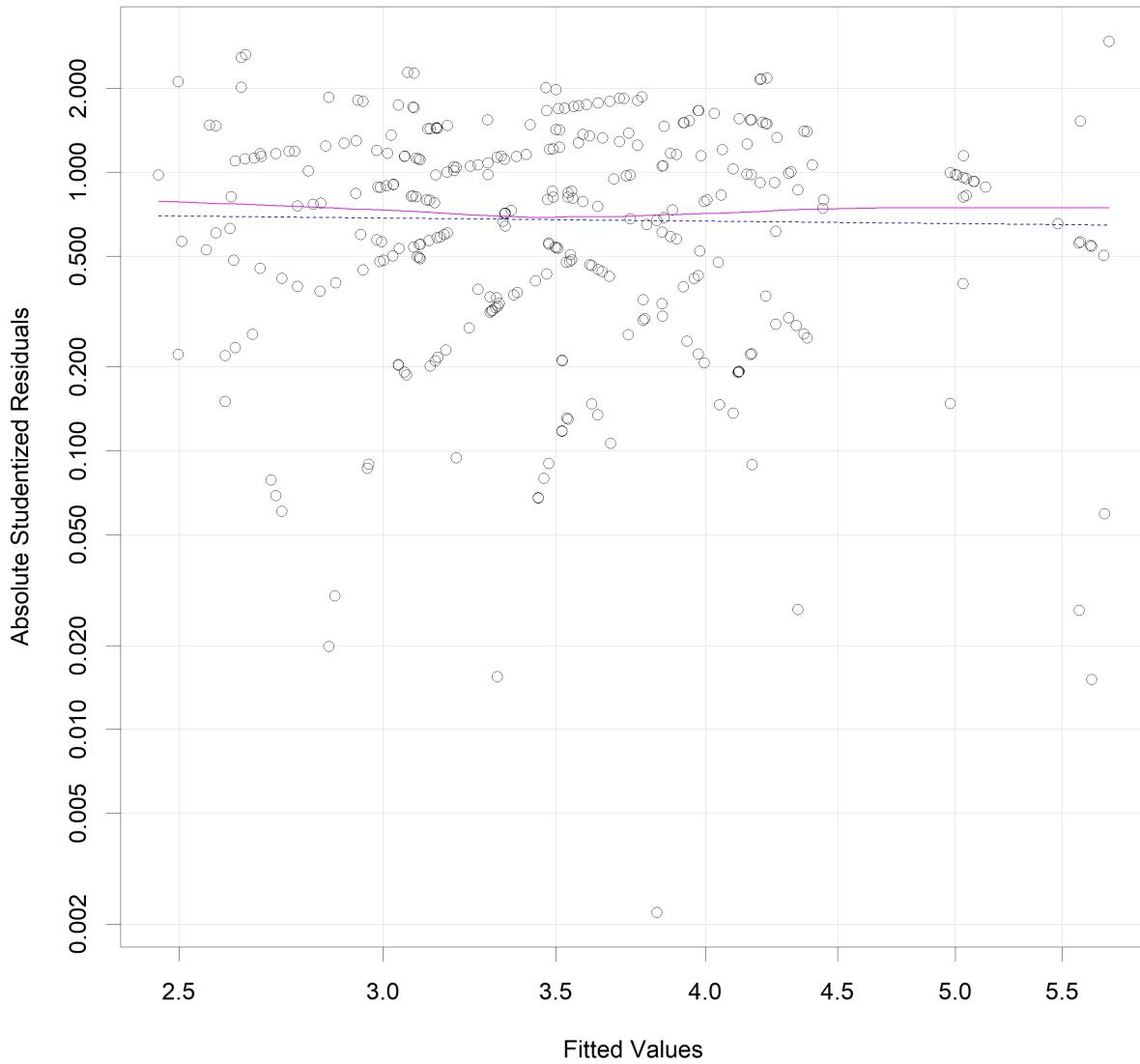
### Non-Constant Error Variance Test

- $H_0$ : constant error variance
- $H_a$ : 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 Influation 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
VBlocs1_FC_1	1.654895	0
VBlocs2_TC_1	2.067919	0