Methods for the Association between Segregation and Health in the Northeastern and Southeastern Brazilian metropolitan regions and medium size cities

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Overview

- Introduction
- Material
- Model structure
- Modeling strategy
- Results
- Discussion

Introduction

Main hypothesis: Income segregation mediates the relationship between income, together with **income inequality**, and health outcomes, e.g. total mortality;

Data: Outcome is SMR (base = Brazil). Covariates are average income, income inequality indicators, and segregation indexes;

Level of analysis: Municipalities / Metropolitan Regions of the Southeast and Northeast.

Material

- Data on income come from Census 2000 **sample** $\Rightarrow$ 10% of households, representative at the level of **conglomerate** (a set of census tracks);
- Households selected in the sample $\Rightarrow$ **all income** received by everyone in the household;
- **Average** income at the conglomerate level.

Material

- Study units (**super units**) are municipalities or great metropolitan regions (MR), e.g. Rio de Janeiro´s MR consists of more than 10 municipalities, some **rather large**;
- Each **conglomerate** is a subunit within a superunit $\Rightarrow$ income levels are representative of conglomerates;
- Levels of income are **averaged** or added up over conglomerates to the level of superunits.

Model structure

- Multiple linear regression with **weights** proportional to the observation (municipality or metropolitan region) population size;
- **Counts** of deaths are very large, so no need to Poisson or similar assumptions;
- Special care with **outliers**;
- Perhaps, great metropolitan regions should have been **split** into separate municipalities.

Model structure

Problem regarding **choice** of study units:

(i) If units are **municipalities**, clusters would be formed for those within great metropolitan regions;

(ii) If units consist of a **mix** of municipalities and metropolitan regions, one could think of a mix of two populations, from which samples of unequal sizes are extracted.

Modeling strategy

- Examine **visually** relationships between outcome and covariates;
- Problem $\Rightarrow$ study units vary in population size (**bubble** plot and similar techniques);
- Examine normality of the data, using **Box-Cox** transformations;
- Theoretical model is clear, however there are **several** ways to regard it with variables at hand.

Modeling strategy

- 1st step (**all in**) ⇒ fit full model;
- 2nd step (**avoid redundancy**) ⇒ select variables out, according to the VIF (Variance Inflation Factor) up to a given tolerance (mean VIF <10);
- 3rd step (**keeping statistical significance**) ⇒ select variables out because they are not significant;
- 4th step (**avoid inconsistency**) ⇒ select variables out according to lack of plausibility.

Modeling strategy

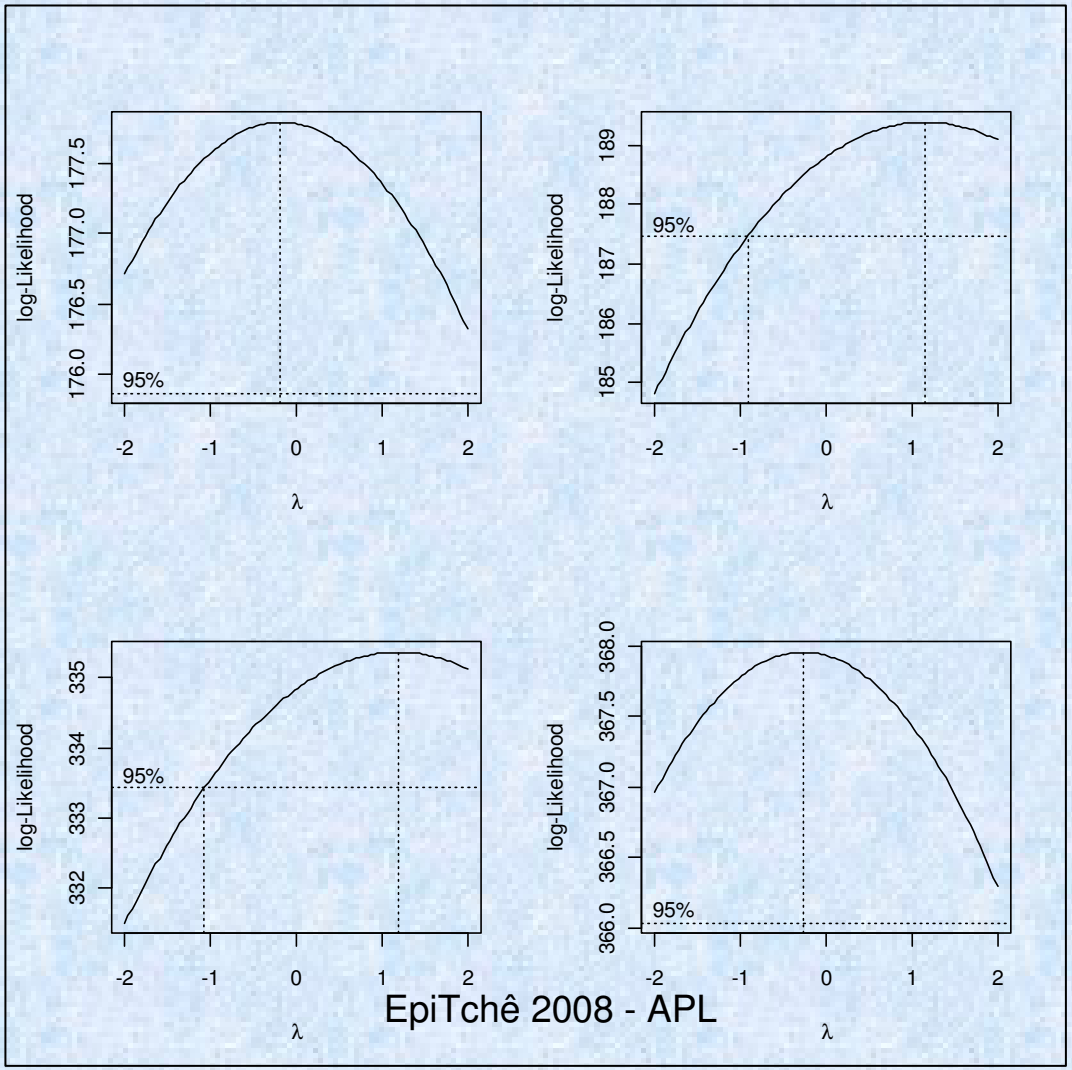
- Residual dagnostics focusing on **leverage** and influential values (outliers);
- After going for a model, reexamine normality of the data using **Box-Cox** transformations;
- Refit model if necessary;
- Different conclusions? Different significance levels?
- Magnitude and interpretation of effect are of importance?

Results

Four models were fitted:

- Men in Northeast $\Rightarrow$ log transformartion;
- Women in Northeast $\Rightarrow$ no transformation;
- Men in Southeast $\Rightarrow$ no transformation / inverse transformation;
- Women in Southeast $\Rightarrow$ log transformartion / no transformation.

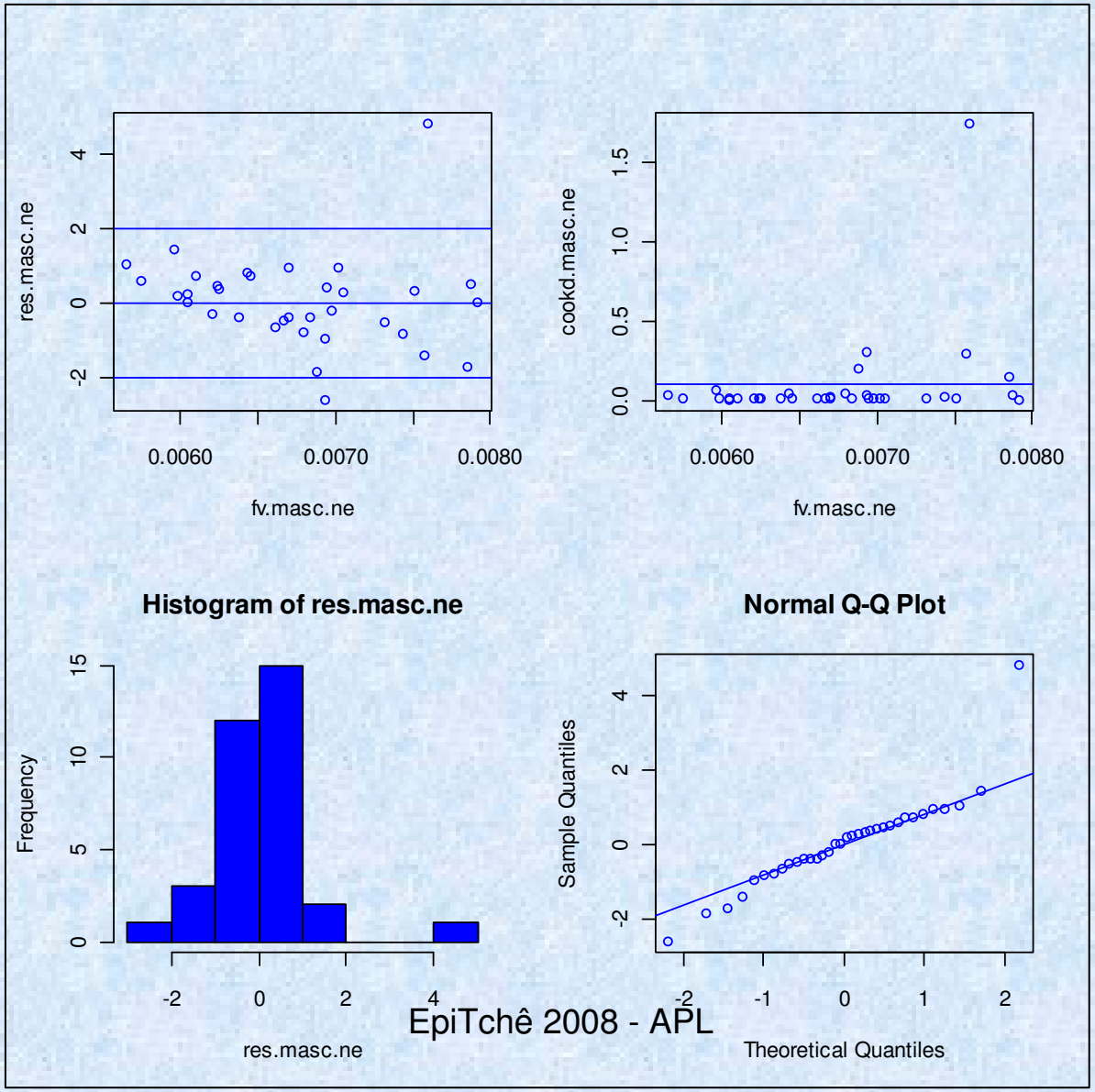
Transformations for the dependent variable (univariate): Box-Cox statistics



Model for men in the Northeast

```
Call:
lm(formula = smr_m2 ~ rendamd + perc_10r + r_40p, weights = pop_3a_m)

Residuals:
     Min       1Q   Median       3Q      Max
-1.60023 -0.39031  0.05993  0.39552  2.18855

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.416e-02  3.731e-03   3.797 0.000665 ***
rendamd     -1.710e-06  3.729e-06  -0.458 0.649899
perc_10r    -2.852e-04  1.018e-04  -2.801 0.008822 **
r_40p        2.677e-04  8.434e-05   3.174 0.003463 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.7409 on 30 degrees of freedom
Multiple R-squared: 0.342,      Adjusted R-squared: 0.2761
F-statistic: 5.196 on 3 and 30 DF,  p-value: 0.005201
```

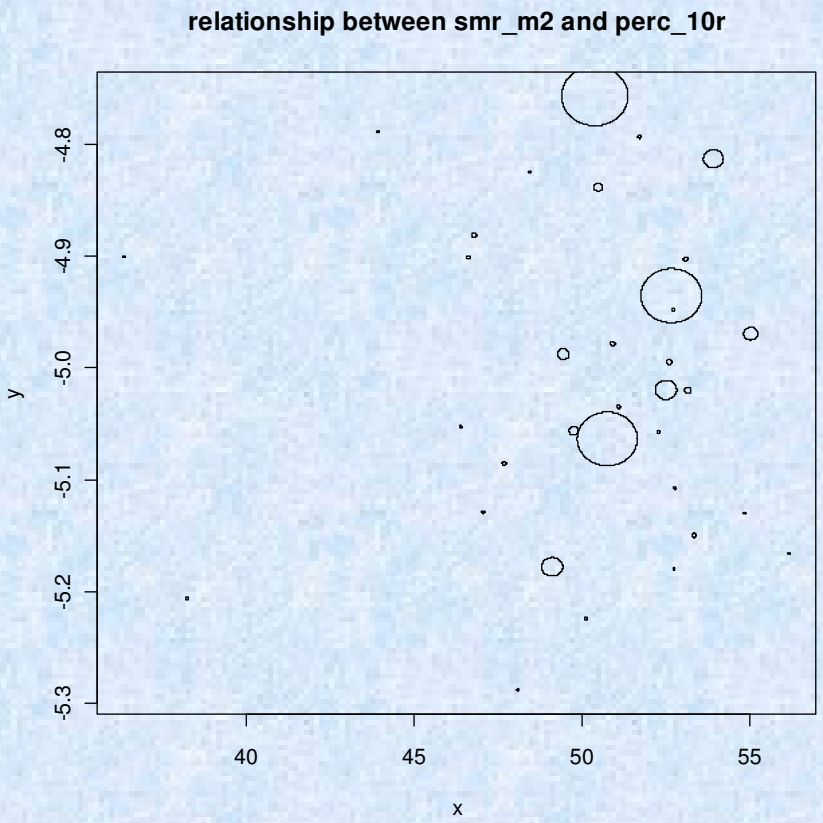
Residual diagnostics, all observations

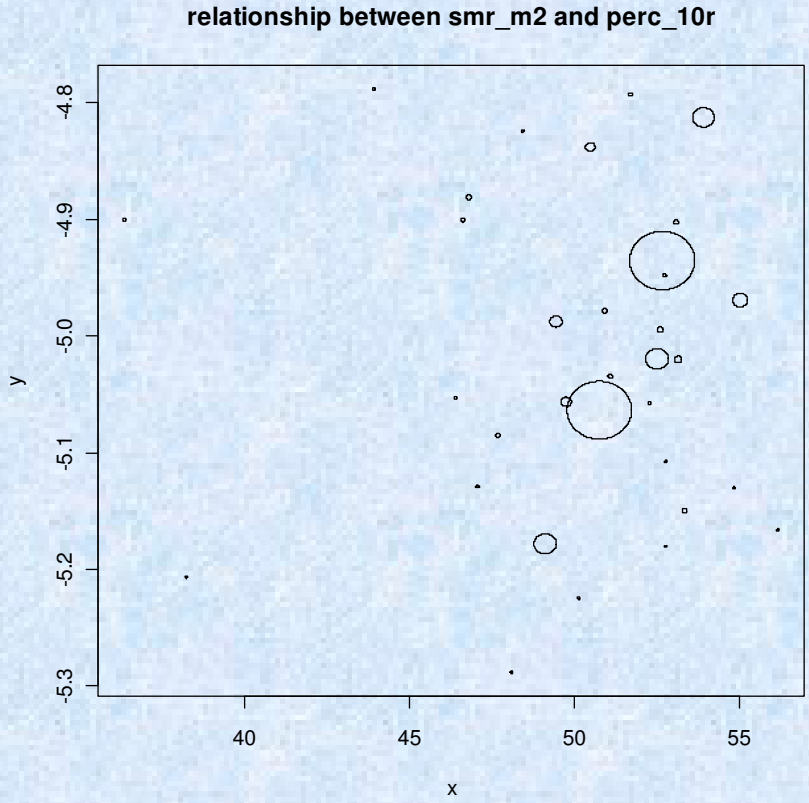


Model for men in the Northeast, no outliers

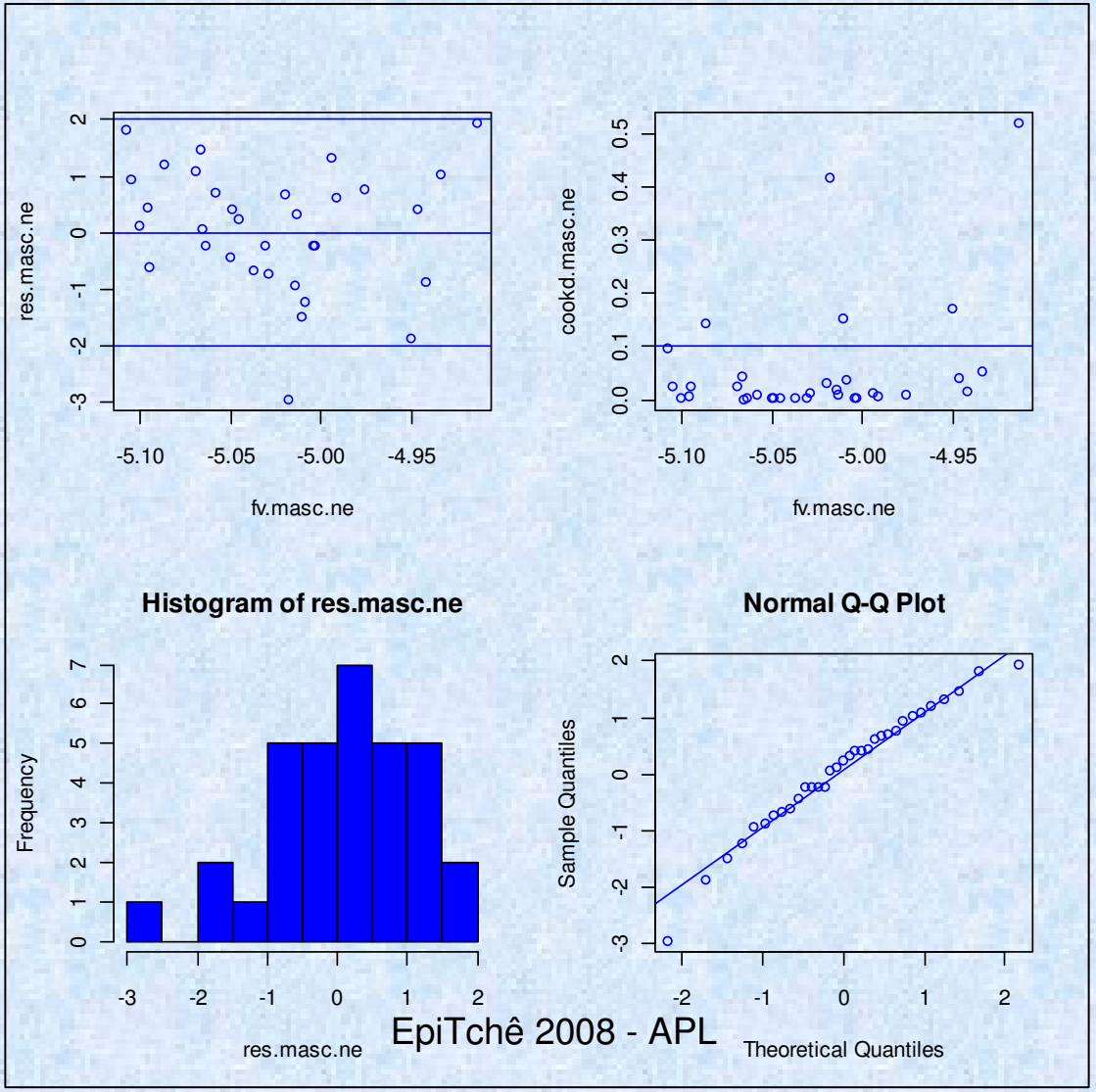
```
Call:
lm(formula = smr_m2 ~ rendamd + perc_10r + r_40p, weights = pop_3a_m)

Residuals:
    Min      1Q  Median      3Q     Max
-197.42  -46.70   17.84   62.45  136.89

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -4.7597647  0.4511318 -10.551 1.93e-11 ***
rendamd     -0.0001462  0.0004218  -0.347   0.7313
perc_10r    -0.0158965  0.0125383  -1.268   0.2149
r_40p        0.0207786  0.0101555   2.046   0.0499 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 83.8 on 29 degrees of freedom
Multiple R-squared: 0.2083,     Adjusted R-squared: 0.1264
F-statistic: 2.543 on 3 and 29 DF,  p-value: 0.07561
```

The difference it (Recife MR) makes





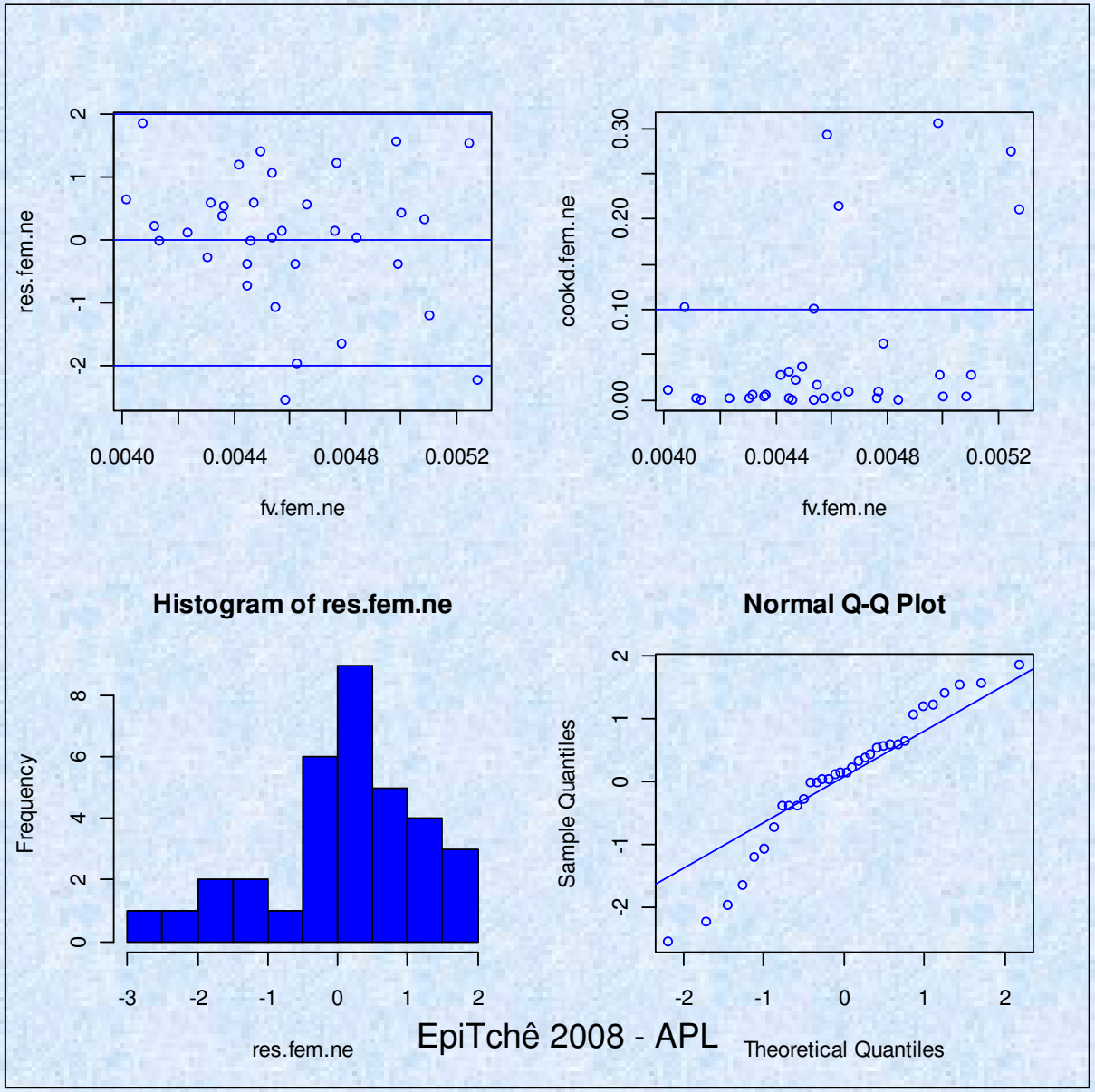
Residual diagnostics, no outliers (those for Cook´s distance > 0.5)



Model for women in the Northeast

```
Call:
lm(formula = smr_f ~ rendamd + perc_10r + r_40p, weights = pop_3a_f)

Residuals:
     Min       1Q   Median       3Q      Max
-0.94383 -0.17108  0.05564  0.24466  0.74198

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.752e-03  2.147e-03   3.611  0.00110 **
rendamd     -1.948e-06  2.135e-06  -0.913  0.36878
perc_10r    -1.346e-04  5.841e-05  -2.304  0.02830 *
r_40p        1.473e-04  4.820e-05   3.055  0.00469 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4426 on 30 degrees of freedom
Multiple R-squared: 0.2957,     Adjusted R-squared: 0.2253
F-statistic: 4.199 on 3 and 30 DF,  p-value: 0.01356
```

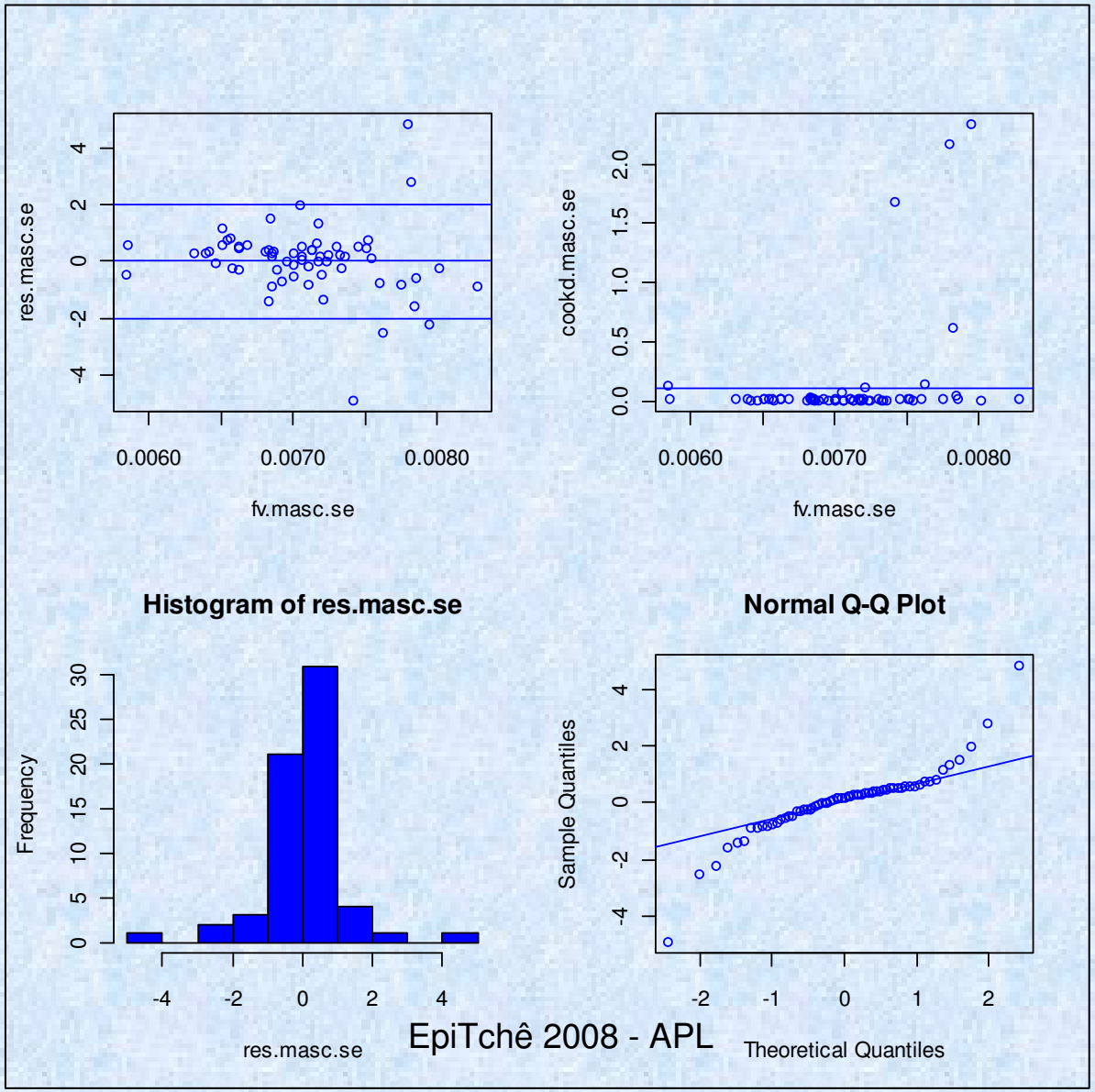
Residual diagnostics, all observations



Model for men in the Southeast

```
Call:
lm(formula = smr_m ~ rendamd + rper_1q + int_pobr + npr, weights =
pop_3a_m)

Residuals:
     Min       1Q   Median       3Q      Max
-1.80763 -0.16129  0.08237  0.24101  1.70174

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.657e-03  8.166e-04   6.927 3.59e-09 ***
rendamd      2.414e-07  2.107e-06   0.115  0.90920
rper_1q     -2.359e-05  8.874e-06  -2.658  0.01010 *
int_pobr     6.851e-05  2.462e-05   2.783  0.00722 **
npr         -2.813e-03  1.236e-03  -2.275  0.02653 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5272 on 59 degrees of freedom
Multiple R-squared: 0.4571,     Adjusted R-squared: 0.4203
F-statistic: 12.42 on 4 and 59 DF,  p-value: 2.167e-07
```

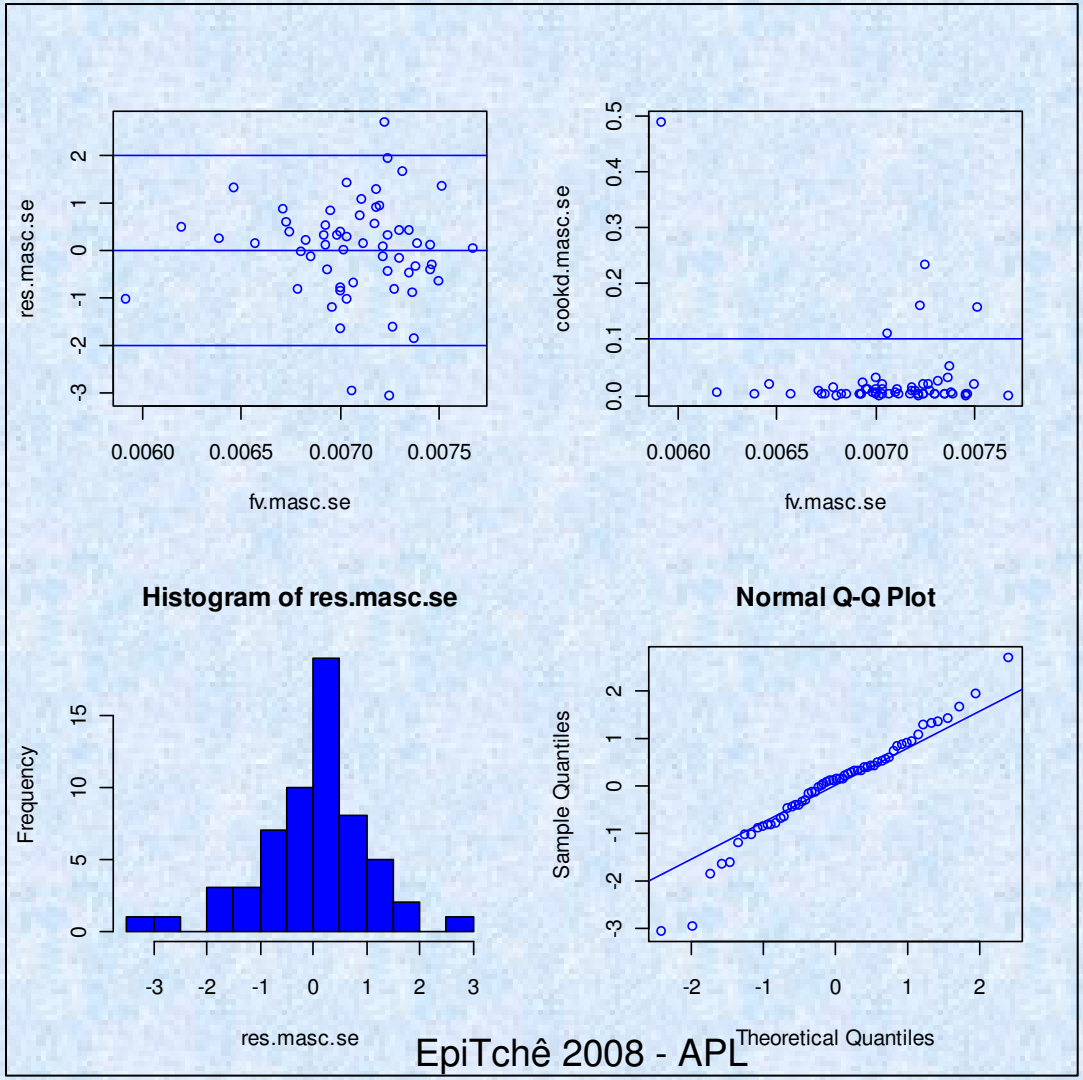
Residual diagnostics, all observations



Model for men in the Southeast, no outliers

```
Call:
lm(formula = smr_m ~ rendamd + rper_1q + int_pobr + npr, weights =
pop_3a_m)

Residuals:
     Min       1Q   Median       3Q      Max
-0.92859 -0.16819  0.04512  0.18483  0.83712

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  8.622e-03  8.842e-04   9.751 1.37e-13 ***
rendamd      4.871e-06  2.207e-06   2.207 0.031471 *
rper_1q     -3.885e-05  1.083e-05  -3.586 0.000713 ***
int_pobr    -2.598e-05  2.488e-05  -1.044 0.300905
npr         -1.574e-03  8.375e-04  -1.880 0.065427 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3468 on 55 degrees of freedom
Multiple R-squared: 0.2373,     Adjusted R-squared: 0.1818
F-statistic: 4.278 on 4 and 55 DF,  p-value: 0.004379
```

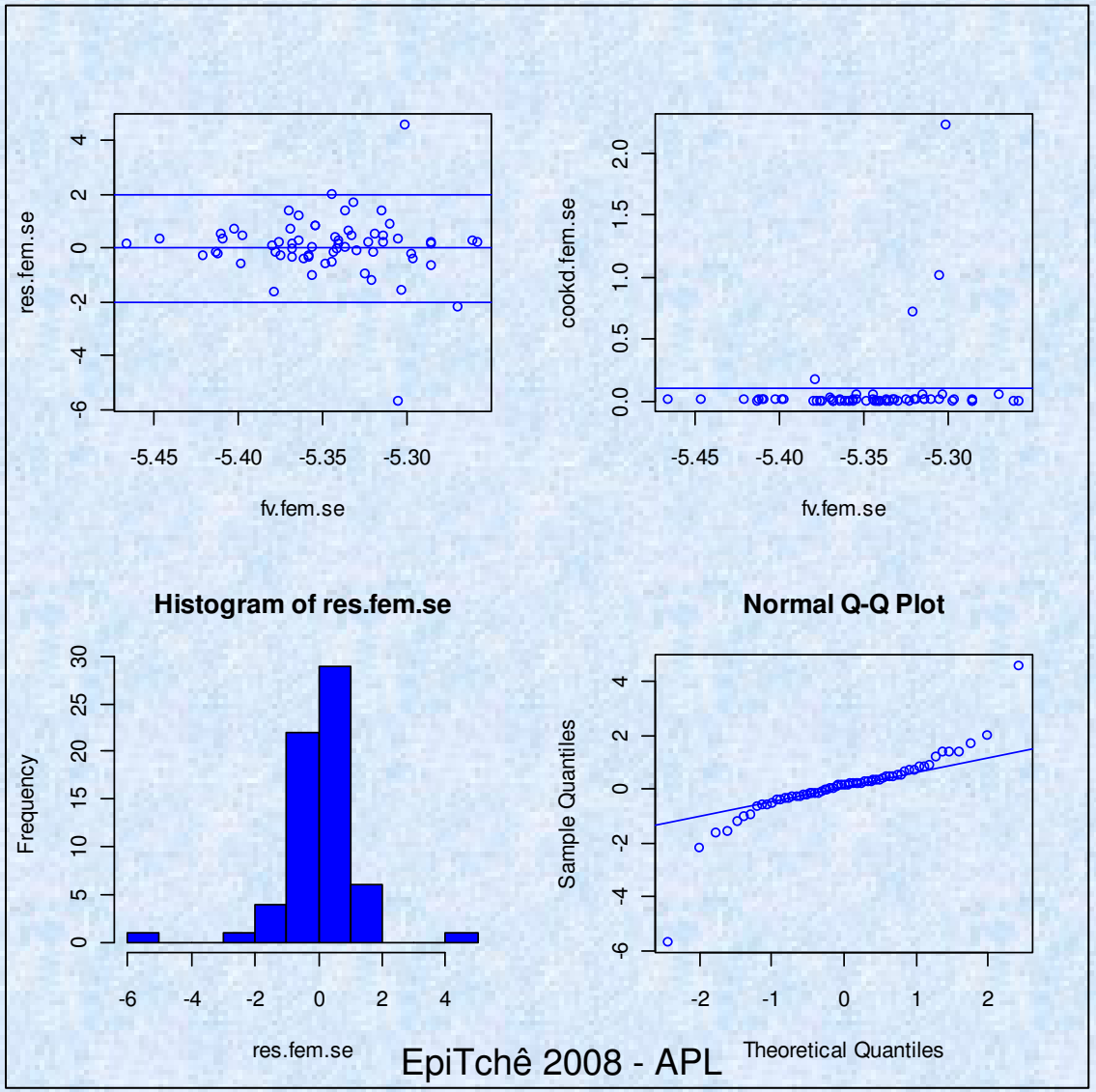
Residual diagnostics, no outliers (those for Cook´s distance > 0.5)



Model for women in the Southeast

```
Call:
lm(formula = smr_f2 ~ rendamd + rper_1q + npr, weights = pop_3a_f)

Residuals:
     Min       1Q   Median       3Q      Max
-266.848  -17.739    9.057   28.852  201.115

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -5.174e+00  6.168e-02 -83.890  < 2e-16 ***
rendamd      8.654e-05  1.304e-04   0.664 0.509316
rper_1q     -3.398e-03  8.420e-04  -4.035 0.000157 ***
npr         -2.698e-01  1.395e-01  -1.934 0.057859 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 63.13 on 60 degrees of freedom
Multiple R-squared: 0.2259,     Adjusted R-squared: 0.1872
F-statistic: 5.835 on 3 and 60 DF,  p-value: 0.001446
```

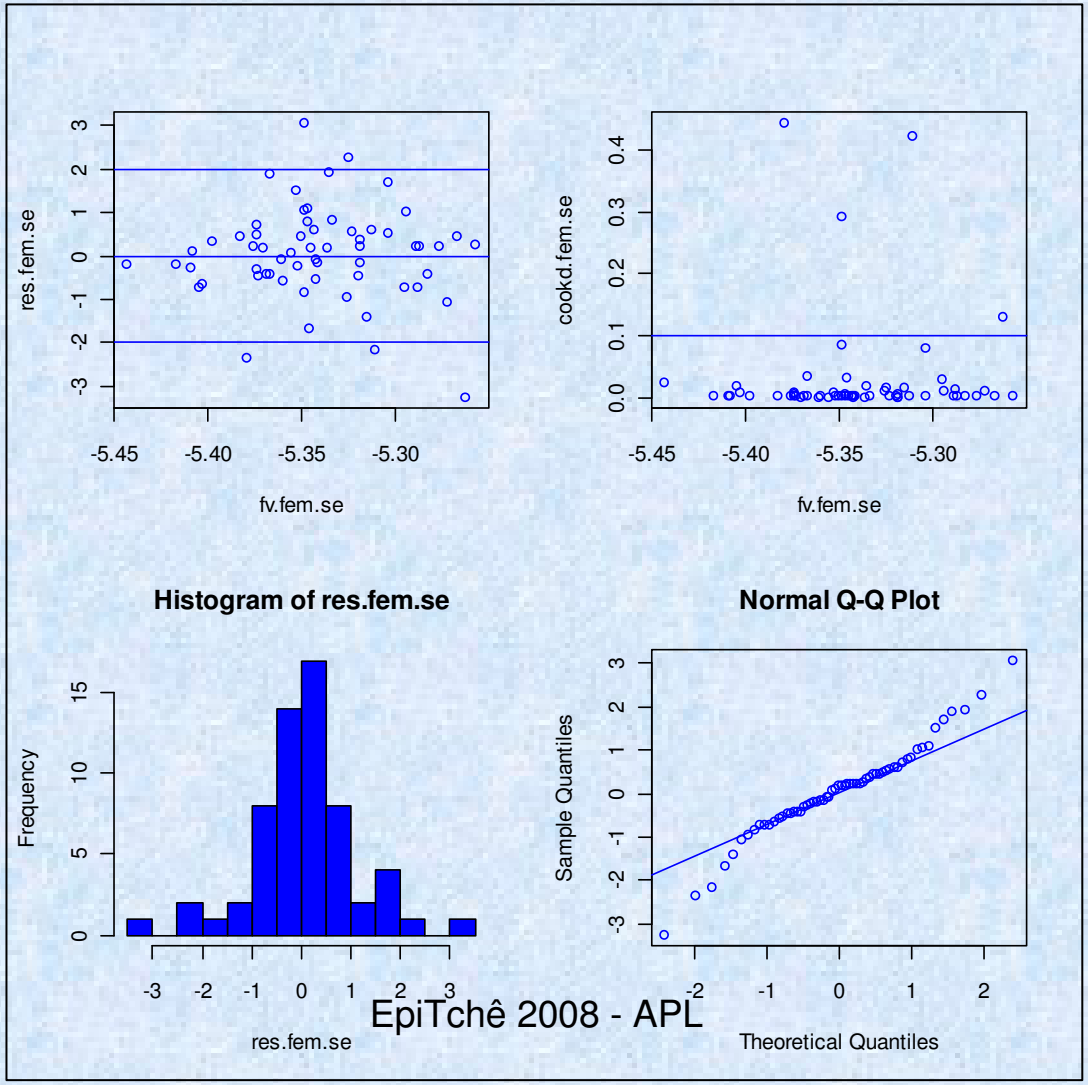
Residual diagnostics, all observations



Model for women in the Southeast, no outliers

```
Call:
lm(formula = smr_f2 ~ rendamd + rper_1q + npr, weights = pop_3a_f)

Residuals:
    Min      1Q  Median      3Q     Max
-135.40  -21.76    6.81   23.79  123.67

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -5.1436997  0.0523873 -98.186   <2e-16 ***
rendamd     -0.0001530  0.0001998  -0.766   0.4469
rper_1q     -0.0022521  0.0011437  -1.969   0.0538 .
npr         -0.2698995  0.1064576  -2.535   0.0140 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 46.26 on 57 degrees of freedom
Multiple R-squared: 0.2362,     Adjusted R-squared: 0.196
F-statistic: 5.877 on 3 and 57 DF,  p-value: 0.001441
```

Residual diagnostics, no outliers (those for Cook´s distance > 0.5)



Box-Cox transformations, based on given sets of independent variables

Northeast

boxcox(smr_m ~ rendamd + perc_10r + r_40p)

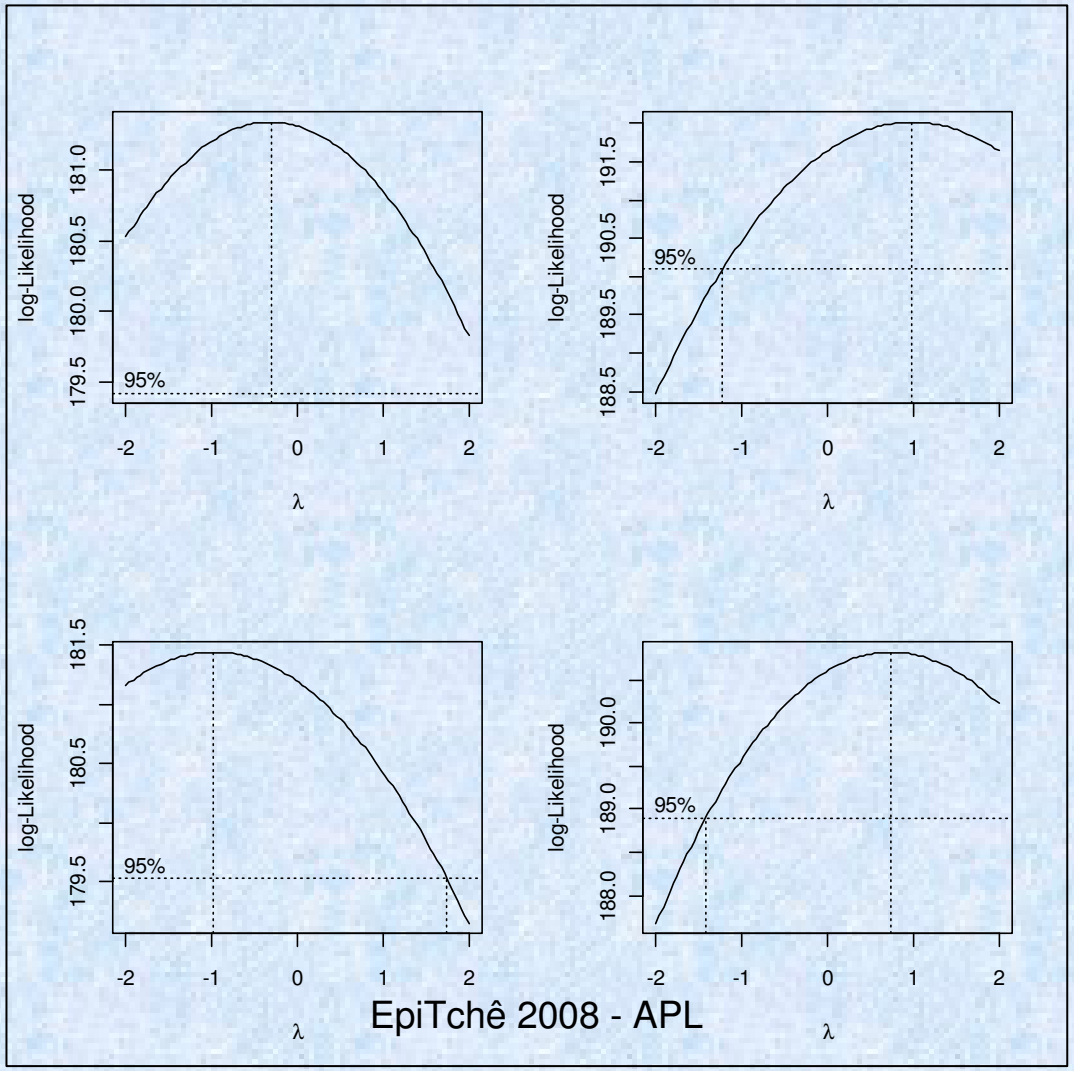
boxcox(smr_f ~ rendamd + perc_10r + r_40p)

Southeast

boxcox(smr_m ~ rendamd + rper_1q + int_pobr + npr)

boxcox(smr_f ~ rendamd + rper_1q + npr)

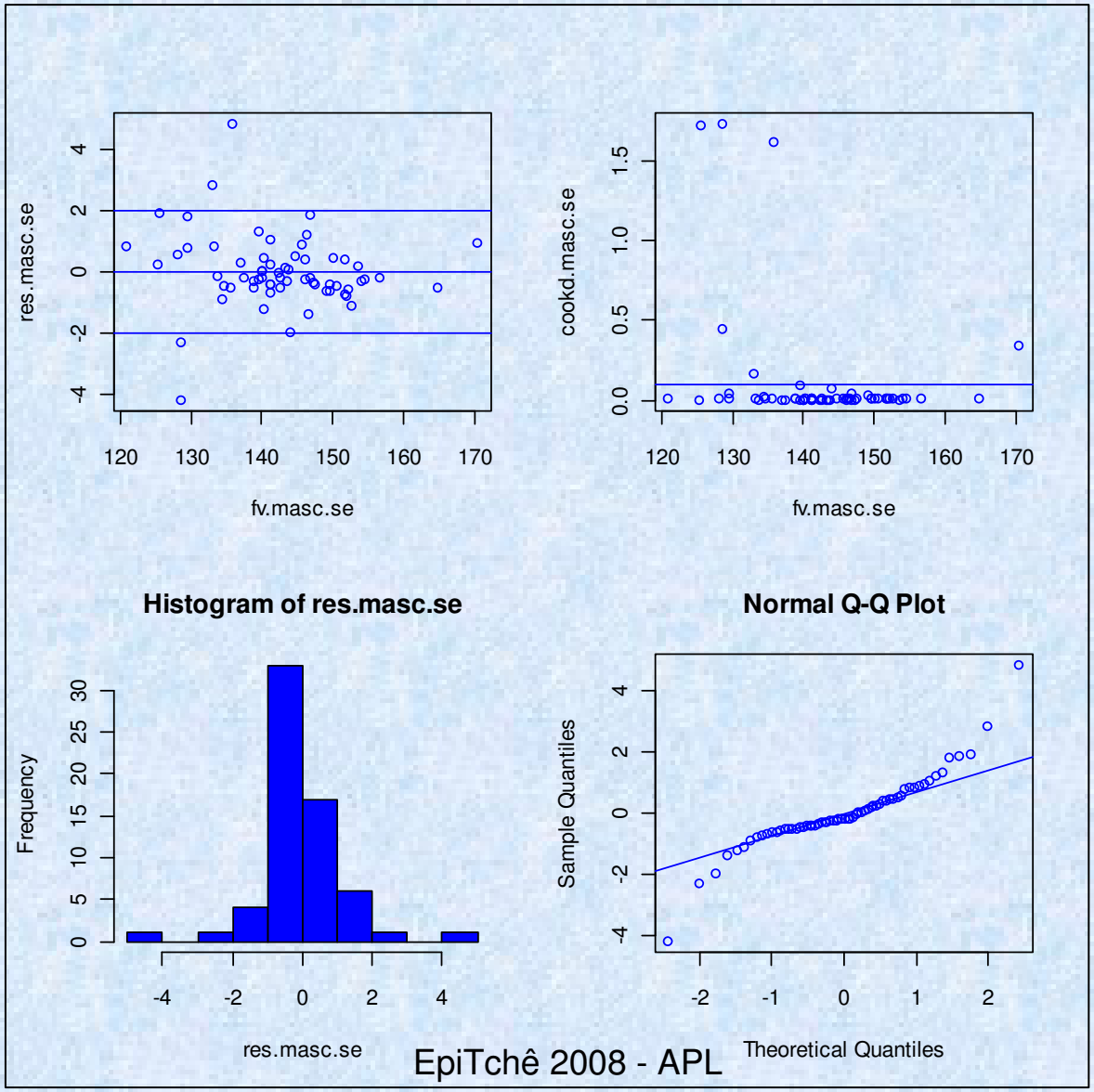
Box-Cox transformations, based on given sets of independent covariates



Model for men in the Southeast (inverse)

```
Call:
lm(formula = smr_mas ~ rendamd + rper_1q + int_pobr + npr, weights =
pop_3a_m)

Residuals:
   Min     1Q Median     3Q    Max
-28578  -5161  -2193   4174  33282

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 169.55906   15.29949  11.083 4.75e-16 ***
rendamd      -0.01219    0.03948  -0.309  0.75857
rper_1q       0.44979    0.16625   2.706  0.00890 **
int_pobr     -1.23255    0.46118  -2.673  0.00972 **
npr          56.20893   23.15961   2.427  0.01830 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9876 on 59 degrees of freedom
Multiple R-squared: 0.4682,     Adjusted R-squared: 0.4321
F-statistic: 12.98 on 4 and 59 DF,  p-value: 1.205e-07
```

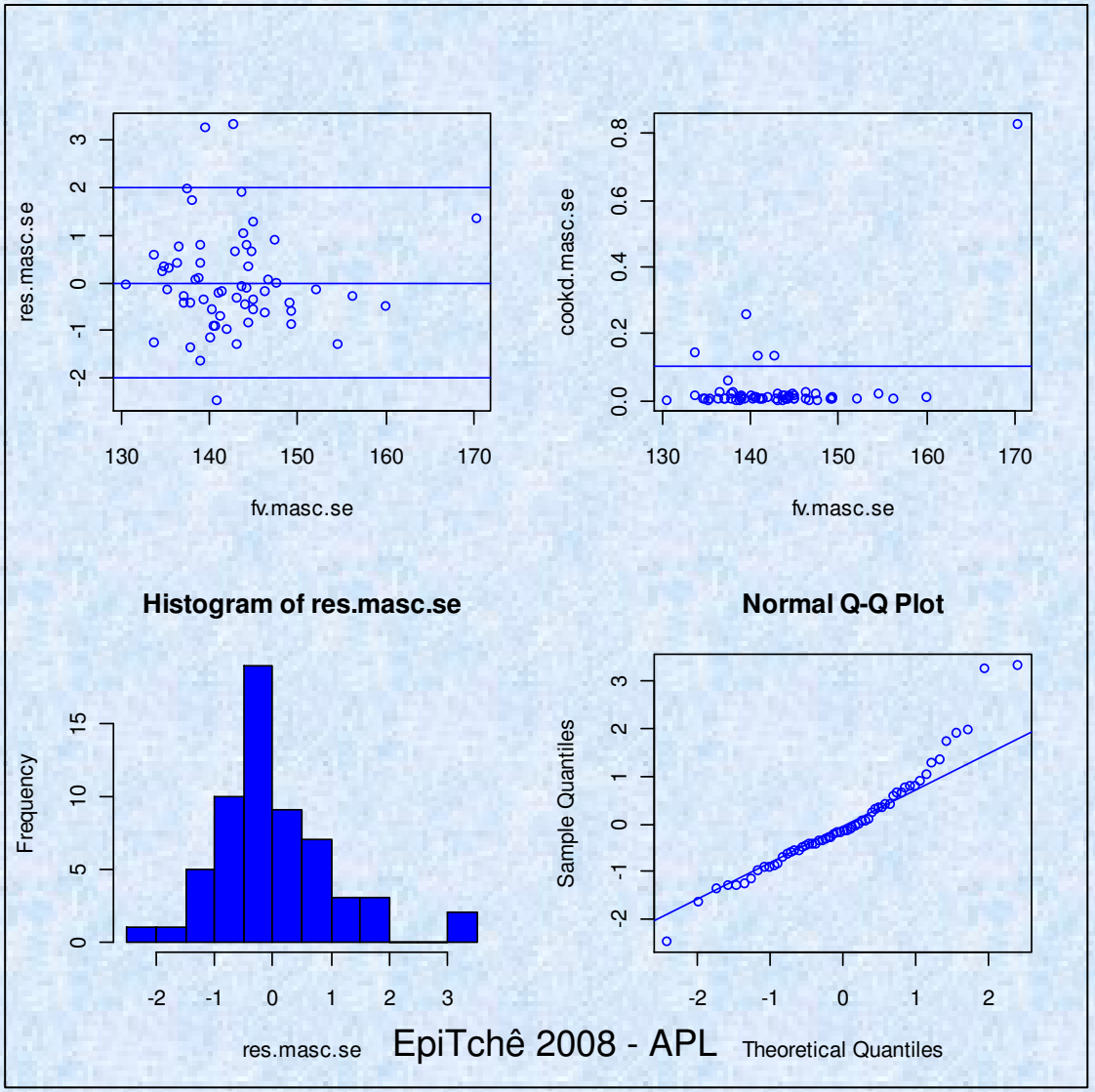
Residual diagnostics, all observations



Model for men in the Southeast, no outliers

```
Call:
lm(formula = smr_mas ~ rendamd + rper_1q + int_pobr + npr, weights =
pop_3a_m)

Residuals:
   Min     1Q Median     3Q    Max
-15805  -3974  -1265   3122  20997

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 115.07887   18.19420   6.325 4.78e-08 ***
rendamd      -0.10156    0.04541  -2.237 0.029387 *
rper_1q       0.77592    0.22288   3.481 0.000985 ***
int_pobr      0.46935    0.51196   0.917 0.363267
npr          36.07065   17.23314   2.093 0.040966 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7135 on 55 degrees of freedom
Multiple R-squared: 0.2354,     Adjusted R-squared: 0.1798
F-statistic: 4.234 on 4 and 55 DF,  p-value: 0.004654
```

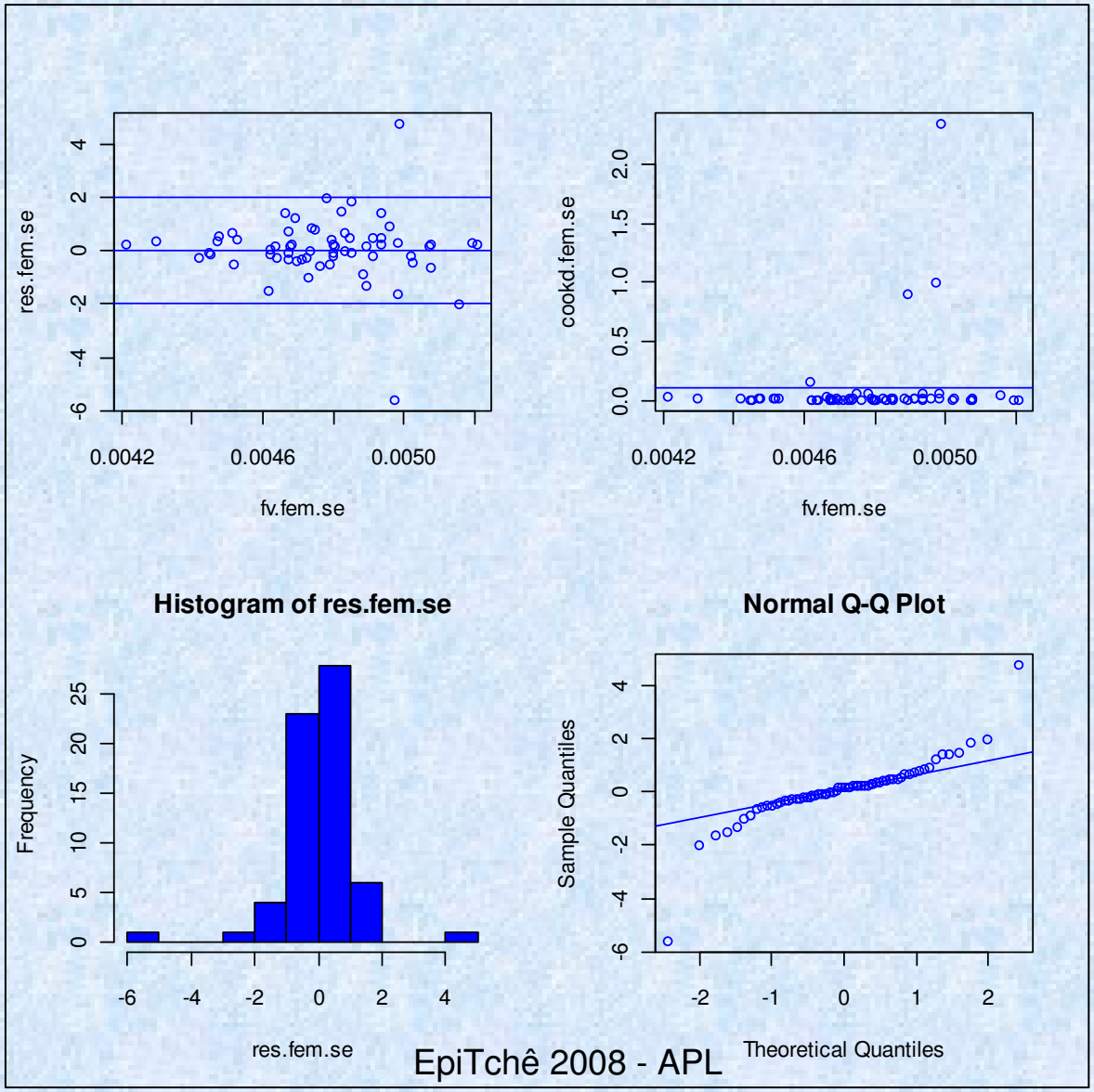
Residual diagnostics, no outliers (those for Cook´s distance > 0.5



Model for women in the Southeast (identity)

```
Call:
lm(formula = smr_fem ~ rendamd + rper_1q + npr, weights = pop_3a_f)

Residuals:
     Min       1Q   Median       3Q      Max
-1.28557 -0.08336  0.03916  0.13751  1.00279

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.634e-03  2.998e-04  18.792  < 2e-16 ***
rendamd      3.362e-07  6.337e-07   0.530 0.597768
rper_1q     -1.624e-05  4.093e-06  -3.967 0.000197 ***
npr         -1.306e-03  6.783e-04  -1.925 0.058998 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3069 on 60 degrees of freedom
Multiple R-squared: 0.2214,     Adjusted R-squared: 0.1825
F-statistic: 5.689 on 3 and 60 DF,  p-value: 0.0017
```

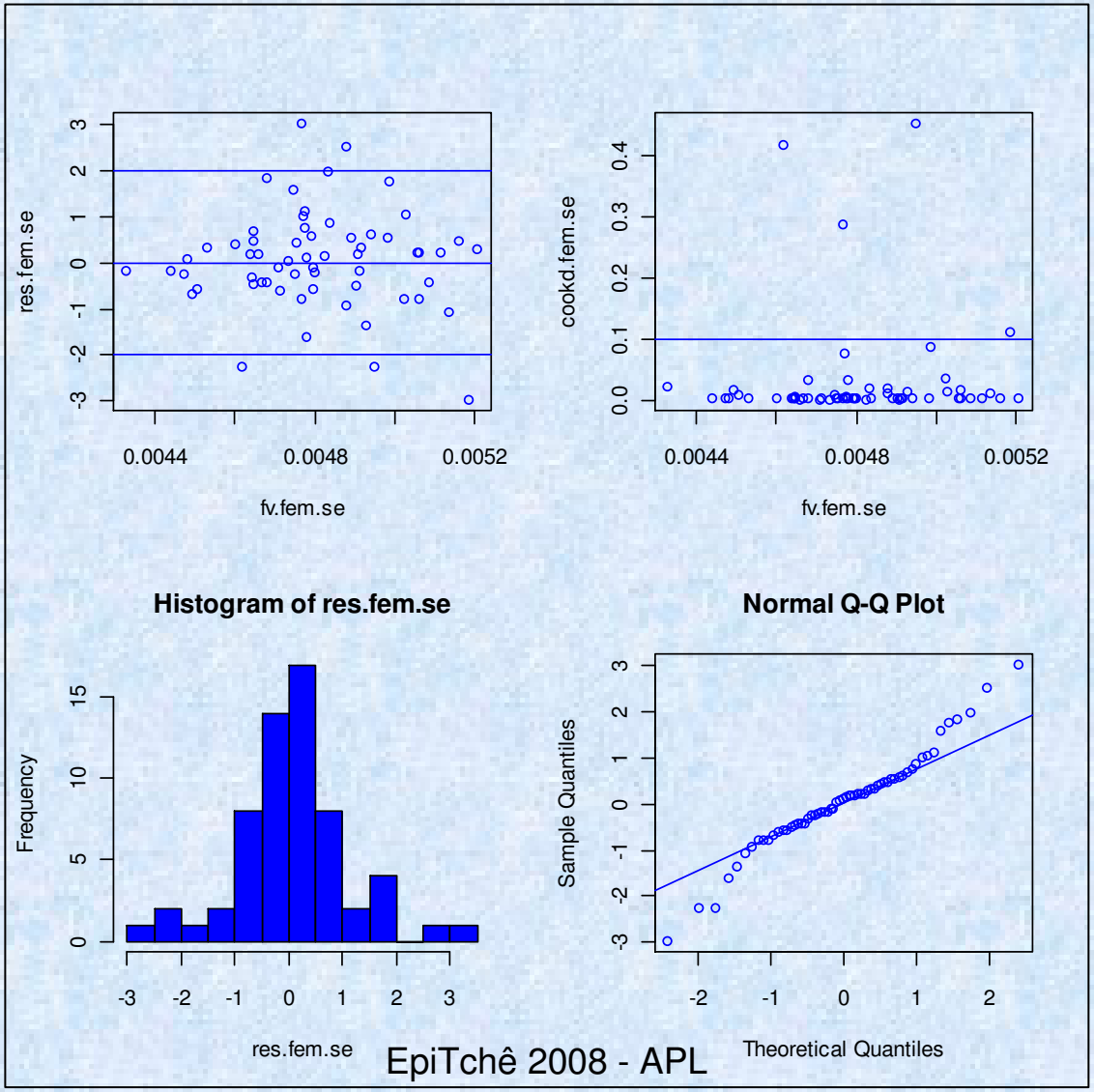
Residual diagnostics, all observations



Model for women in the Southeast, no outliers

```
Call:
lm(formula = smr_fem ~ rendamd + rper_1q + npr, weights = pop_3a_f)

Residuals:
     Min       1Q   Median       3Q      Max
-0.60727 -0.10373  0.02134  0.11645  0.59313

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.757e-03  2.537e-04  22.696   <2e-16 ***
rendamd     -7.523e-07  9.676e-07  -0.778   0.4401
rper_1q     -1.078e-05  5.538e-06  -1.947   0.0564 .
npr         -1.282e-03  5.155e-04  -2.488   0.0158 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.224 on 57 degrees of freedom
Multiple R-squared: 0.2346,     Adjusted R-squared: 0.1943
F-statistic: 5.822 on 3 and 57 DF,  p-value: 0.001529
```

Residual diagnostics, no outliers (those for Cook´s distance > 0.5)



Discussion

- Conglomerate level of analysis is adequate?
- Income from head of household?
- Need of transformations to approach normality;
- Municipalities / metropolitan regions;
- Regression techniques, and specially residual diagnostics as tools for refining and understanding the associations;

- After all, is there an association between income segregation and health ?