A Look into Maternal Mortality Rate

Using a linear regression approach

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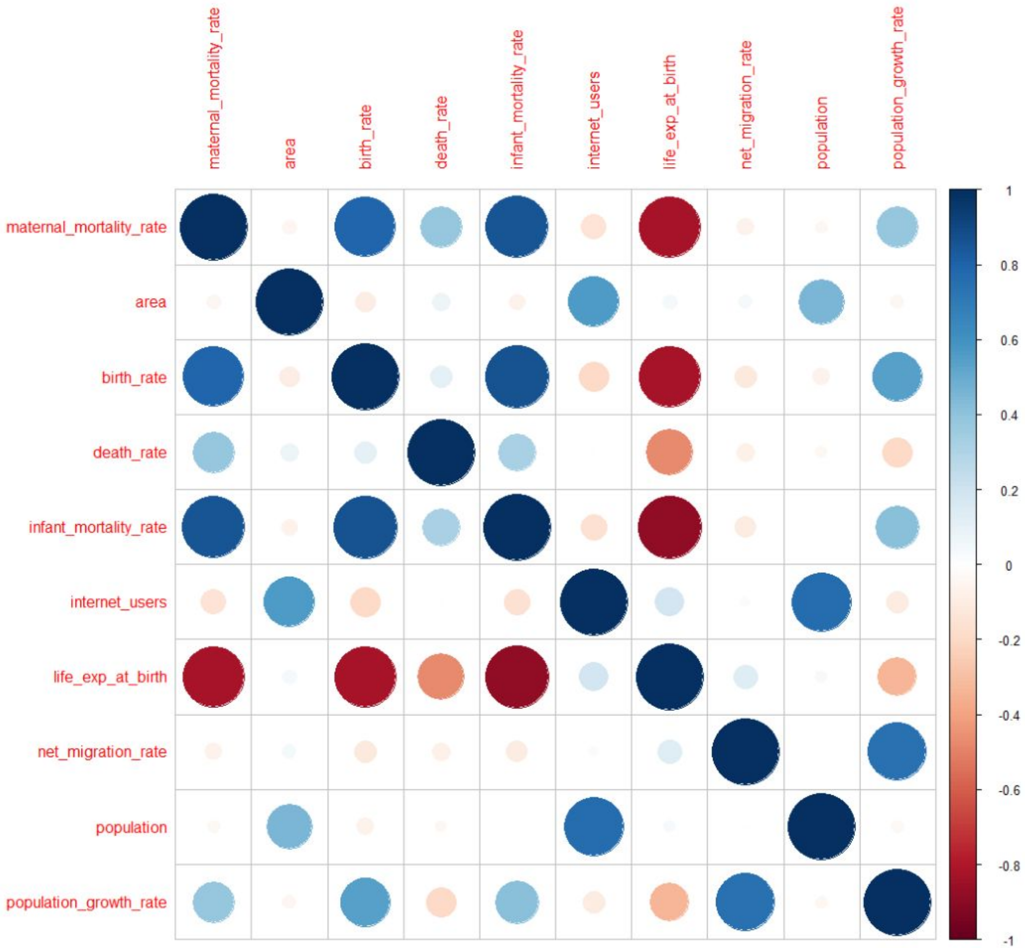
Data Description

- Country-level statistics from the US Central Intelligence Agency (CIA)
- Collected in 2017
- Data frame with 259 observations on 11 different variables

Goals

- Investigate what are the possible predictive variables in our data set that are linearly related to Maternal Mortality Rate?
- What are some of the inferences we can make with our data? What are some aspects we can improve to decrease maternal mortality rate?
- Try something new for our data set

CORRELATION MATRIX

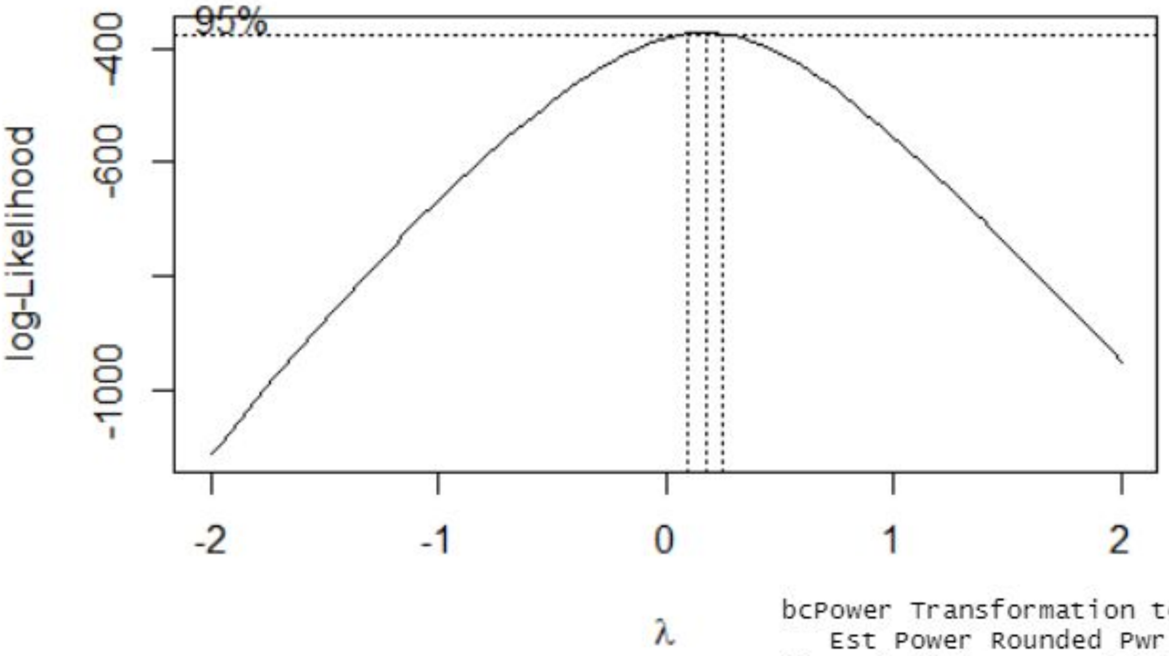


<u>Response</u> <u>Variable for Full Model</u>
Maternal Mortality Rate

<u>Predictive</u> <u>Variables for Full Model</u>
Area
Birth Rate
Death Rate
Infant Mortality Rate
Life Expectancy at Birth
Net Migration Rate
Population
Population Growth Rate

$$H_0 : \beta_j = 0$$

$$H_A : \beta_j \neq 0 : \text{for at least 1 predictor}$$



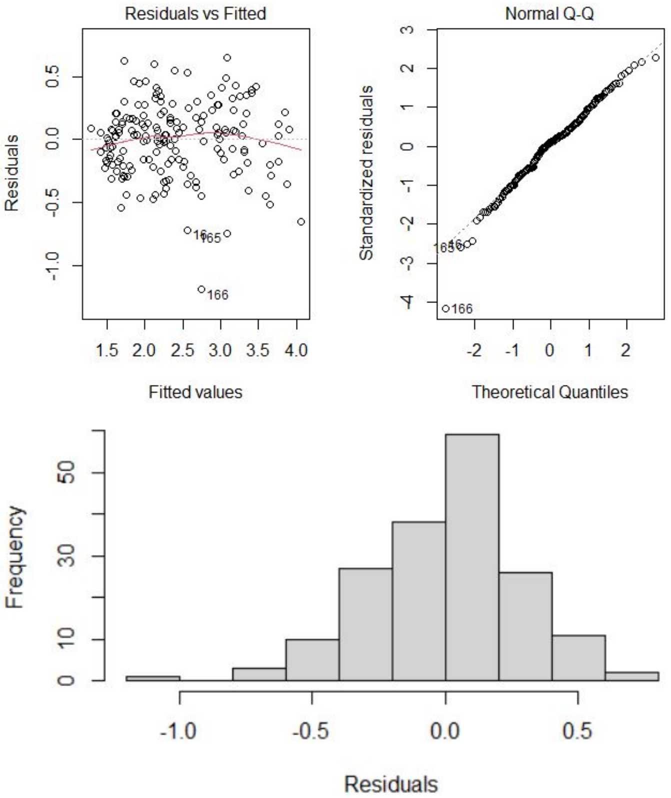
BOX-COX

```
bcPower Transformation to Normality
   Est Power Rounded Pwr Wald Lwr Bnd Wald Upr Bnd
Y1    0.1738        0.17       0.0989       0.2487

Likelihood ratio test that transformation parameter is equal to 0
 (log transformation)

Likelihood ratio test that no transformation is needed
```

Summary of Transformed Full Model

```
Call:
lm(formula = (maternal_mortality_rate)^(1/5) ~ area + internet_users +
    death_rate + infant_mortality_rate + life_exp_at_birth +
    birth_rate + net_migration_rate + population + population_growth_rate,
    data = df_final)

Residuals:
     Min       1Q   Median       3Q      Max
-1.19200 -0.17924  0.02994  0.17049  0.65045

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
(Intercept)             5.424e+00  6.300e-01   8.609 5.26e-15 ***
area                    8.479e-09  1.344e-08   0.631  0.52908
internet_users         -6.503e-10  1.046e-09  -0.622  0.53497
death_rate             -1.465e-01  7.584e-01  -0.193  0.84703
infant_mortality_rate   8.605e-03  2.293e-03   3.754  0.00024 ***
life_exp_at_birth      -4.534e-02  6.976e-03  -6.499 8.93e-10 ***
birth_rate              1.175e-01  7.576e-01   0.155  0.87697
net_migration_rate      1.031e-01  7.579e-01   0.136  0.89195
population              2.473e-10  2.471e-10   1.001  0.31836
population_growth_rate -1.048e+00  7.578e+00  -0.138  0.89019
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2902 on 167 degrees of freedom
Multiple R-squared:  0.8496,	Adjusted R-squared:  0.8415
F-statistic: 104.8 on 9 and 167 DF,  p-value: < 2.2e-16
```

Significant!!!



Improving Our Model Step-by-Step

- Performed a step function in R to reduce our number of predictors being used from 9 to 4

- Predictors are:
  - Birth Rate
  - Infant Mortality Rate
  - Death Rate
  - Life Expectancy at Birth

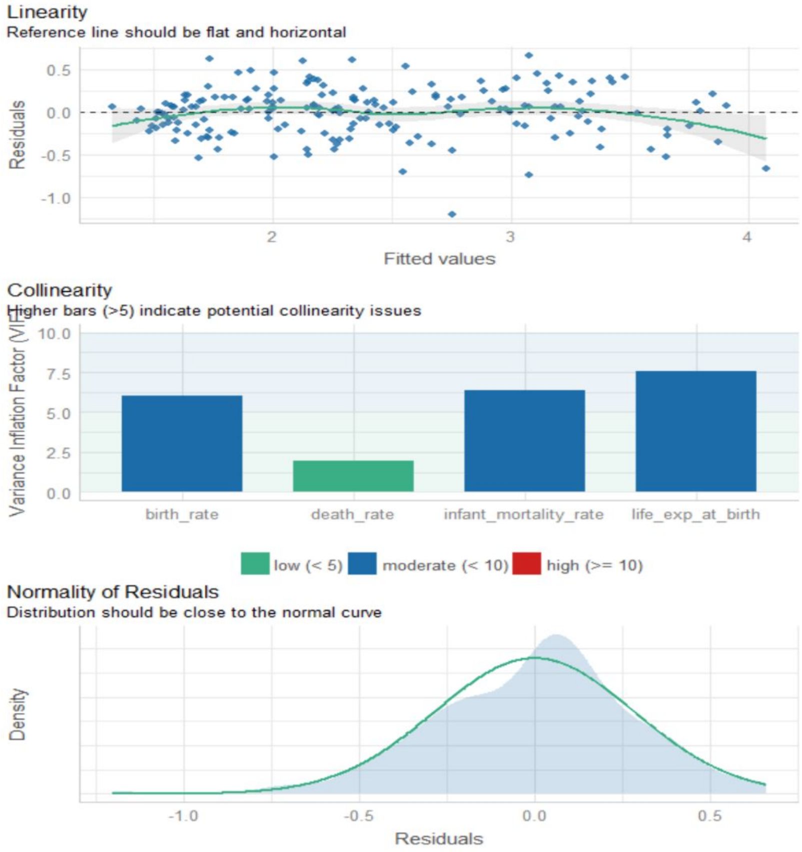
```
Step:  AIC=-435.54
(maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate +
    life_exp_at_birth + birth_rate

                        Df Sum of Sq    RSS     AIC
<none>                               14.282 -435.54
- birth_rate             1    0.3830 14.665 -432.85
- infant_mortality_rate  1    1.2956 15.578 -422.17
- death_rate             1    1.6637 15.945 -418.03
- life_exp_at_birth      1    3.9079 18.190 -394.73
```

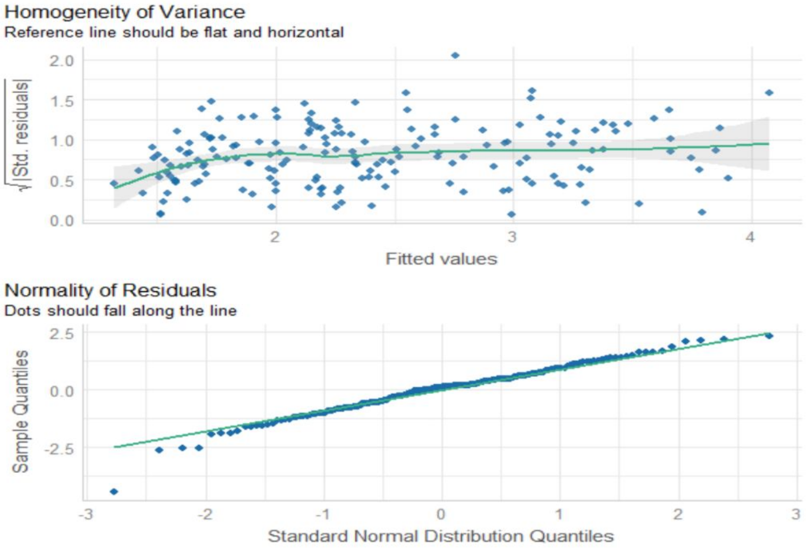
Done! Maybe..?

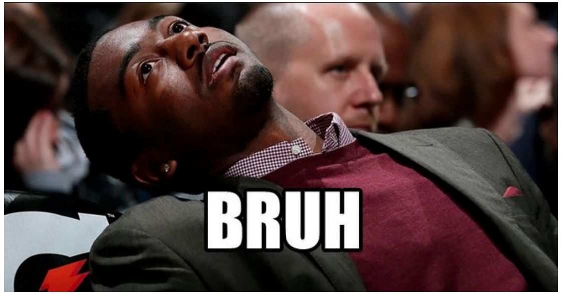
- 4 significant predictors
- Full model:
  - Adj. R^2: 0.841506
  - AIC: 75.99666
- Stepped model:
  - Adj. R^2: 0.8436858
  - AIC: 68.76710
- AOV p-value > 0.05 indicates that the 5 predictors can be dropped

```
Call:
lm(formula = (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate
+
    life_exp_at_birth + birth_rate, data = df_final)

Residuals:
    Min      1Q  Median      3Q     Max
-1.2042 -0.1742  0.0360  0.1739  0.6626

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            5.547843   0.614250   9.032 3.36e-16 ***
death_rate            -0.042858   0.009575  -4.476 1.38e-05 ***
infant_mortality_rate  0.008784   0.002224   3.950 0.000114 ***
life_exp_at_birth     -0.046587   0.006791  -6.860 1.19e-10 ***
birth_rate             0.011681   0.005439   2.148 0.033144 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2882 on 172 degrees of freedom
Multiple R-squared:  0.8472,	Adjusted R-squared:  0.8437
F-statistic: 238.5 on 4 and 172 DF,  p-value: < 2.2e-16
```

```
Analysis of Variance Table

Model 1: (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate +
    life_exp_at_birth + birth_rate
Model 2: (maternal_mortality_rate)^(1/5) ~ area + internet_users + death_rate +
    infant_mortality_rate + life_exp_at_birth + birth_rate +
    net_migration_rate + population + population_growth_rate
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1    172 14.282
2    167 14.060  5    0.2218 0.5269 0.7557
```







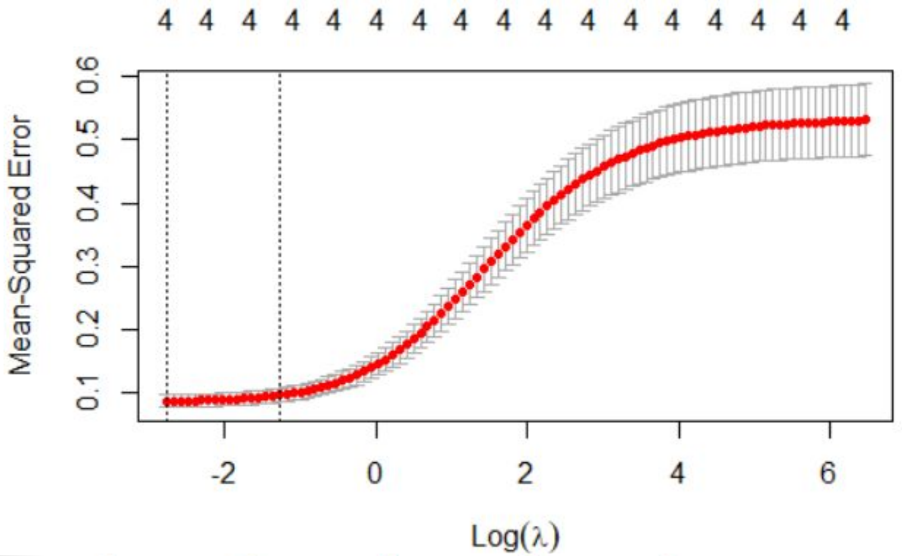
Collinearity Issue

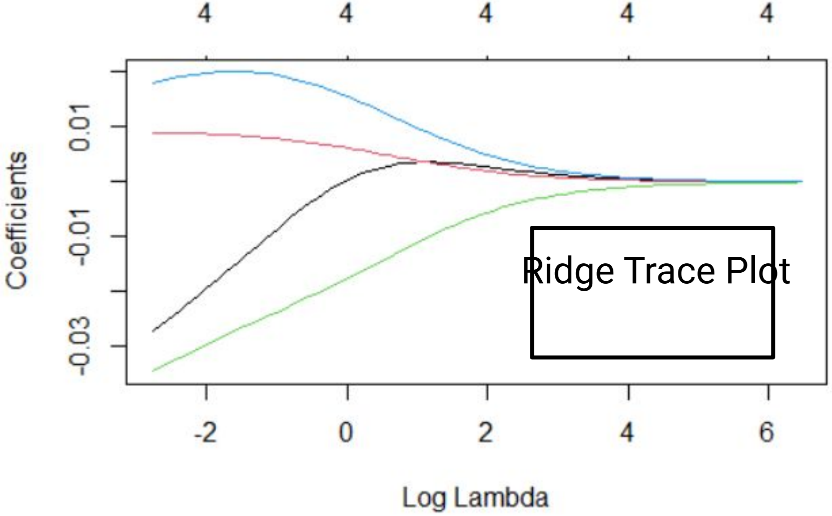
Ridge Regression

- We want to find the best lambda that produces the lowest MSE
  - The lowest MSE produces the best model
- Best Lambda: 0.06342977
- The ridge regression signifies that life_exp_at_birth is the least important predictor

```
5 x 1 sparse Matrix of class "dgCMatrix"
                              s0
(Intercept)          4.431683368
death_rate          -0.027119913
infant_mortality_rate 0.008939495
life_exp_at_birth   -0.034548217
birth_rate           0.018178334
```

Black
Red
Green
Blue





Collinearity & Low p-value

```
Analysis of Variance Table

Model 1: (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate +
    birth_rate
Model 2: (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate +
    life_exp_at_birth + birth_rate
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1    173 18.190
2    172 14.282  1    3.9079 47.063 1.189e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- The low p-value indicates that life_exp_at_birth is a significant predictor
  - We chose to drop it due to the results of the ridge regression
- Alternative option: stack the collinear data into 1 column

Insignificant Predictors: Round 2

- After removing life expectancy at birth, we find that death rate could also be removed
- Step #2

```
Call:
lm(formula = (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate
+
    birth_rate, data = df_final)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.00872 -0.21522  0.02784  0.21176  0.83474 

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)    
(Intercept)            1.384471   0.106733  12.971  < 2e-16 ***
death_rate            -0.004806   0.008782  -0.547    0.585    
infant_mortality_rate  0.015740   0.002227   7.068 3.71e-11 ***
birth_rate             0.029925   0.005339   5.605 8.08e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3243 on 173 degrees of freedom
Multiple R-squared:  0.8054,	Adjusted R-squared:  0.8021 
F-statistic: 238.7 on 3 and 173 DF,  p-value: < 2.2e-16
```

- Before 2nd Step:
  - Adj. R^2: 0.8020654
  - AIC: 109.5773
- After 2nd Step:
  - Adj. R^2: 0.8028622
  - AIC: 107.8835

```
Start:  AIC=-394.73
(maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate + 
    birth_rate

                        Df Sum of Sq    RSS     AIC
- death_rate             1    0.0315 18.221 -396.42
<none>                               18.190 -394.73
- birth_rate             1    3.3032 21.493 -367.19
- infant_mortality_rate  1    5.2521 23.442 -351.83

Step:  AIC=-396.42
(maternal_mortality_rate)^(1/5) ~ infant_mortality_rate + birth_rate

                        Df Sum of Sq    RSS     AIC
<none>                               18.221 -396.42
- birth_rate             1    4.0569 22.278 -362.84
- infant_mortality_rate  1    6.1802 24.401 -346.73
```

```
Analysis of Variance Table

Model 1: (maternal_mortality_rate)^(1/5) ~ infant_mortality_rate + birth_rate
Model 2: (maternal_mortality_rate)^(1/5) ~ death_rate + infant_mortality_rate +
    birth_rate
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1    174 18.221
2    173 18.190  1   0.03149 0.2995 0.5849
```

$$\text{Final Model}: \widehat{MaternalMortalityRate}^{.2} = \widehat{\beta}_0 + \widehat{InfantMortalityRate}x_1 + \widehat{BirthRate}x_2 = 1.339008 + 0.015183x_1 + 0.030970x_2$$

```
Call:
lm(formula = (maternal_mortality_rate)^(1/5) ~ infant_mortality_rate +
    birth_rate, data = df_final)

Residuals:
     Min       1Q   Median       3Q      Max
-1.00088 -0.20711  0.02856  0.21028  0.81003

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           1.339008   0.066876  20.022  < 2e-16 ***
infant_mortality_rate 0.015183   0.001976   7.682 1.09e-12 ***
birth_rate            0.030970   0.004976   6.224 3.51e-09 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3236 on 174 degrees of freedom
Multiple R-squared:  0.8051,	Adjusted R-squared:  0.8029
F-statistic: 359.4 on 2 and 174 DF,  p-value: < 2.2e-16
```

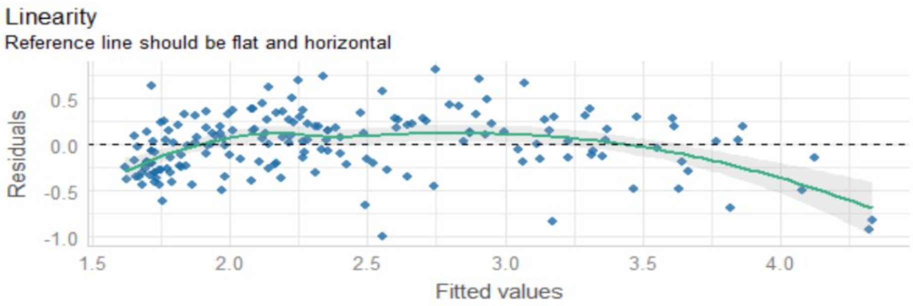
AOV & Final Model

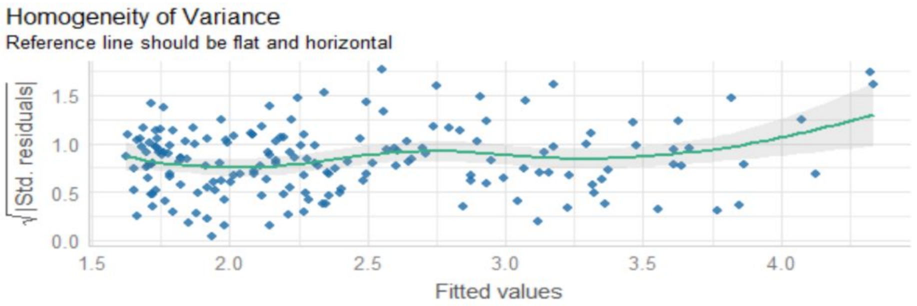
Final Model Interpretation

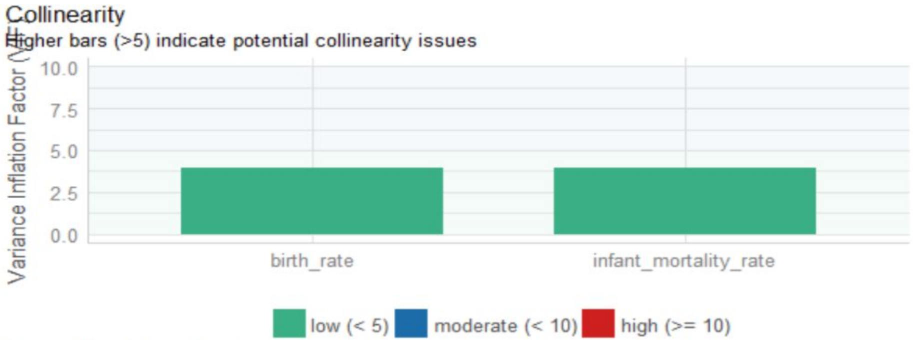
A one unit increase in infant_mortality_rate (1 more death per 1,000 live births), with the other predictor (birth_rate) held fixed, is associated with an increase in maternal_mortality_rate by (0.015183)^5 units, which equals 8.06841002E-10 units, which can be interpreted as 8.06841002E-10 more deaths (where the death is related to pregnancy or birth) per 100,000 live births.

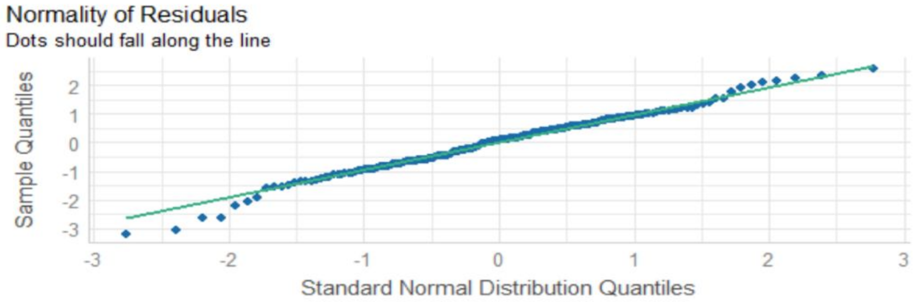
A one unit increase in birth_rate (1 birth per 1000 people), with the other predictor (infant_mortality_rate) held fixed, is associated with an increase in maternal_mortality_rate by (0.030970)^5 units, which equals 2.84908907E-8 units, which can be interpreted as 2.84908907E-8 more deaths (where the death is related to pregnancy or birth) per 100,000 live births.

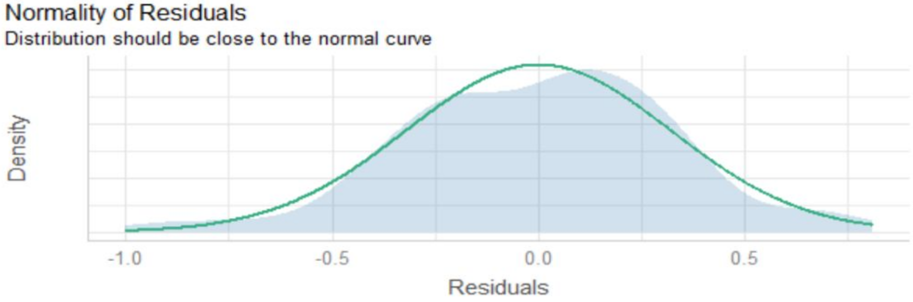
```
Call:
lm(formula = (maternal_mortality_rate)^(1/5) ~ infant_mortality_rate +
    birth_rate, data = df_final)

Residuals:
     Min       1Q   Median       3Q      Max
-1.00088 -0.20711  0.02856  0.21028  0.81003

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           1.339008   0.066876  20.022  < 2e-16 ***
infant_mortality_rate 0.015183   0.001976   7.682 1.09e-12 ***
birth_rate            0.030970   0.004976   6.224 3.51e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3236 on 174 degrees of freedom
Multiple R-squared:  0.8051,	Adjusted R-squared:  0.8029
F-statistic: 359.4 on 2 and 174 DF,  p-value: < 2.2e-16
```












```
Shapiro-Wilk normality test

data:  resid(lmlogstep_no_col2)
W = 0.99015, p-value = 0.2621
```

Outliers and Leverage Points

- 11 outliers
- 15 leverage points
  - ~0.033
- Final Step: investigate outliers