

Regression

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Combining consecutive years of data (needed to meet 10000+ row req) Separates make and model for easier analysis

```
library(readxl)
library(stringr)
library(ggplot2)

## Warning: package 'ggplot2' was built under R version 4.1.3

EPA_2016 <- read_excel("EPA_2016.xlsx")
EPA_2017 <- read_excel("EPA_2017.xlsx")
EPA_2018 <- read_excel("EPA_2018.xlsx")
EPA_2019 <- read_excel("EPA_2019.xlsx")
EPA_2020 <- read_excel("EPA_2020.xlsx")

EPA_allYears <- rbind(EPA_2016, EPA_2017, EPA_2018, EPA_2019, EPA_2020)

MakeAndModel <- str_split_fixed(EPA_allYears$Model, " ", 2)

EPA_allYears$Model <- NULL

EPA_allYears <- cbind(MakeAndModel, EPA_allYears)

colnames(EPA_allYears)[1] <- 'Make'
colnames(EPA_allYears)[2] <- 'Model'

EPA_allYears$Make <- as.factor(EPA_allYears$Make)

EPA_allYears$Displ <- as.numeric(EPA_allYears$Displ)
## Warning: NAs introduced by coercion

EPA_allYears$Cyl <- as.numeric(EPA_allYears$Cyl)
## Warning: NAs introduced by coercion

EPA_allYears$Trans <- as.factor(EPA_allYears$Trans)

EPA_allYears$Drive <- as.factor(EPA_allYears$Drive)

EPA_allYears$Fuel <- as.factor(EPA_allYears$Fuel)
```

```

EPA_allYears$`Cert Region` <- as.factor(EPA_allYears$`Cert Region`)

EPA_allYears$`Veh Class` <- as.factor(EPA_allYears$`Veh Class`)

EPA_allYears$`Air Pollution Score` <- as.numeric(EPA_allYears$`Air Pollution
Score`)

## Warning: NAs introduced by coercion

EPA_allYears$`City MPG` <- as.numeric(EPA_allYears$`City MPG`)

## Warning: NAs introduced by coercion

EPA_allYears$`Hwy MPG` <- as.numeric(EPA_allYears$`Hwy MPG`)

## Warning: NAs introduced by coercion

EPA_allYears$`Cmb MPG` <- as.numeric(EPA_allYears$`Cmb MPG`)

## Warning: NAs introduced by coercion

EPA_allYears$`Greenhouse Gas Score` <- as.numeric(EPA_allYears$`Greenhouse
Gas Score`)

## Warning: NAs introduced by coercion

EPA_allYears$SmartWay <- as.factor(EPA_allYears$SmartWay)

EPA_allYears$`Comb CO2` <- as.numeric(EPA_allYears$`Comb CO2`)

## Warning: NAs introduced by coercion

str(EPA_allYears)

## 'data.frame':    13126 obs. of  19 variables:
## $ Make          : Factor w/ 51 levels "ACURA","ALFA-ROMEO",...: 1 1
1 1 1 1 1 1 1 1 ...
## $ Model         : chr  "ILX" "ILX" "MDX" "MDX" ...
## $ Displ         : num  2.4 2.4 3.5 3.5 3.5 3.5 3.5 3.5 3.5 3.5 ...
## $ Cyl           : num  4 4 6 6 6 6 6 6 6 6 ...
## $ Trans         : Factor w/ 30 levels "AMS-6","AMS-7",...: 16 16 30
30 30 30 30 30 30 ...
## $ Drive         : Factor w/ 2 levels "2WD","4WD": 1 1 1 1 1 1 2 2 2
2 ...
## $ Fuel          : Factor w/ 7 levels "Diesel","Electricity",...: 5 5
5 5 5 5 5 5 5 ...
## $ Cert Region   : Factor w/ 2 levels "CA","FA": 2 1 2 2 1 1 2 2 1 1
...
## $ Stnd          : chr  "B5" "L3ULEV125" "B5" "B5" ...
## $ Stnd Description : chr  "Federal Tier 2 Bin 5" "California LEV-III
ULEV125" "Federal Tier 2 Bin 5" "Federal Tier 2 Bin 5" ...

```

```
## $ Underhood ID      : chr  "GHNXV02.4XH3" "GHNXV02.4XH3" "GHNXV03.5VA3"
"GHNXV03.5VA3" ...
## $ Veh Class         : Factor w/ 10 levels "large car","midsize car",...:
5 5 6 6 6 6 6 6 6 6 ...
## $ Air Pollution Score : num  5 6 5 5 6 6 5 5 6 6 ...
## $ City MPG          : num  25 25 19 20 19 20 18 19 18 19 ...
## $ Hwy MPG           : num  36 36 27 27 27 27 26 26 26 26 ...
## $ Cmb MPG           : num  29 29 22 23 22 23 21 22 21 22 ...
## $ Greenhouse Gas Score: num  7 7 5 5 5 5 5 5 5 5 ...
## $ SmartWay          : Factor w/ 3 levels "Elite","No","Yes": 2 3 2 2 2
2 2 2 2 2 ...
## $ Comb CO2          : num  305 305 403 390 403 390 412 409 412 409 ...
```

training

```
set.seed(620)
i <- sample(1:nrow(EPA_allYears), 0.8*nrow(EPA_allYears), replace=FALSE)
train <- EPA_allYears[i,]
test <- EPA_allYears[-i,]
```

Gaussian GLM model

```
glm_gaus <- glm(`Greenhouse Gas Score` ~ `Cmb MPG`, data=train,
family=gaussian)
summary(glm_gaus)

##
## Call:
## glm(formula = `Greenhouse Gas Score` ~ `Cmb MPG`, family = gaussian,
##      data = train)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -6.2272  -0.5772   0.1291   0.8355   3.2691
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.4233617  0.0254716   95.14  <2e-16 ***
## `Cmb MPG`    0.0978996  0.0008648  113.20  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 1.519849)
##
##      Null deviance: 34479  on 9873  degrees of freedom
## Residual deviance: 15004  on 9872  degrees of freedom
## (626 observations deleted due to missingness)
## AIC: 32159
##
## Number of Fisher Scoring iterations: 2
```

Quasi GLM model

```
glm_quasi <- glm(`Greenhouse Gas Score` ~ `Cmb MPG`, data=train,
family=quasi)
summary(glm_quasi)

##
## Call:
## glm(formula = `Greenhouse Gas Score` ~ `Cmb MPG`, family = quasi,
##      data = train)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -6.2272  -0.5772   0.1291   0.8355   3.2691
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.4233617  0.0254716   95.14  <2e-16 ***
## `Cmb MPG`    0.0978996  0.0008648  113.20  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasi family taken to be 1.519849)
##
##      Null deviance: 34479  on 9873  degrees of freedom
## Residual deviance: 15004  on 9872  degrees of freedom
## (626 observations deleted due to missingness)
## AIC: NA
##
## Number of Fisher Scoring iterations: 2
```

Poisson GLM model

```
glm_poiss <- glm(`Greenhouse Gas Score` ~ `Cmb MPG`, data=train,
family=poisson)
summary(glm_poiss)

##
## Call:
## glm(formula = `Greenhouse Gas Score` ~ `Cmb MPG`, family = poisson,
##      data = train)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.5254  -0.2940   0.0941   0.4452   1.4585
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.2565901  0.0075723  165.95  <2e-16 ***
## `Cmb MPG`    0.0124187  0.0002037   60.97  <2e-16 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##      Null deviance: 7009.0  on 9873  degrees of freedom
## Residual deviance: 4181.2  on 9872  degrees of freedom
##      (626 observations deleted due to missingness)
## AIC: 37720
##
## Number of Fisher Scoring iterations: 4
```

Binomial GLM model

```
glm_binom <- glm(`Make` ~ `Cmb MPG`, data=train, family=binomial)
summary(glm_binom)

##
## Call:
## glm(formula = Make ~ `Cmb MPG`, family = binomial, data = train)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.9783   0.1570   0.1605   0.1631   0.1722
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  4.093541   0.232489  17.607  <2e-16 ***
## `Cmb MPG`    0.010985   0.008876   1.238    0.216
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 1332.4  on 9889  degrees of freedom
## Residual deviance: 1330.5  on 9888  degrees of freedom
##      (610 observations deleted due to missingness)
## AIC: 1334.5
##
## Number of Fisher Scoring iterations: 7
```

Quasi Binomial GLM model

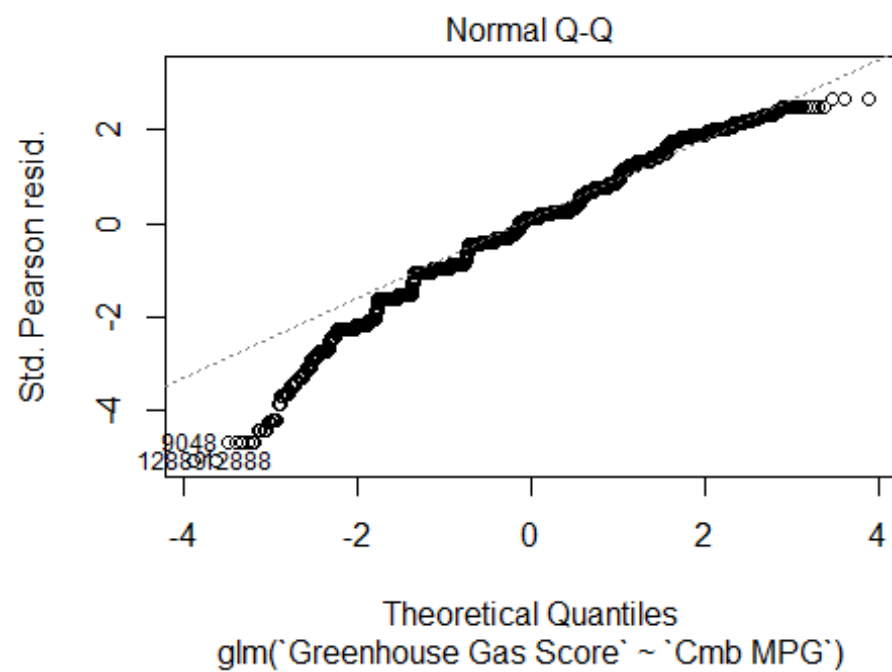
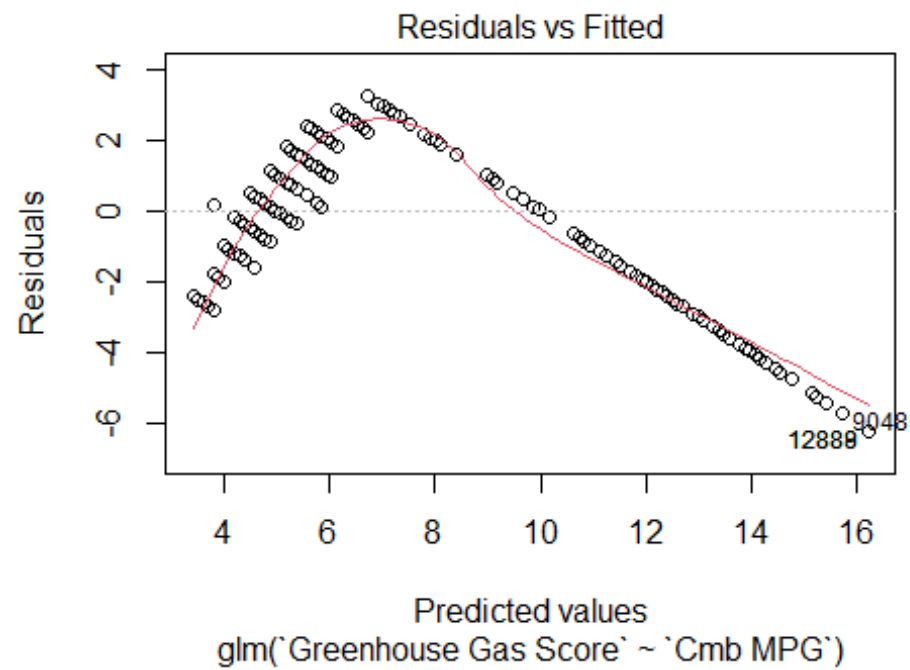
```
glm_qbi <- glm(`Make` ~ `Cmb MPG`, data=train, family=quasibinomial)
summary(glm_qbi)

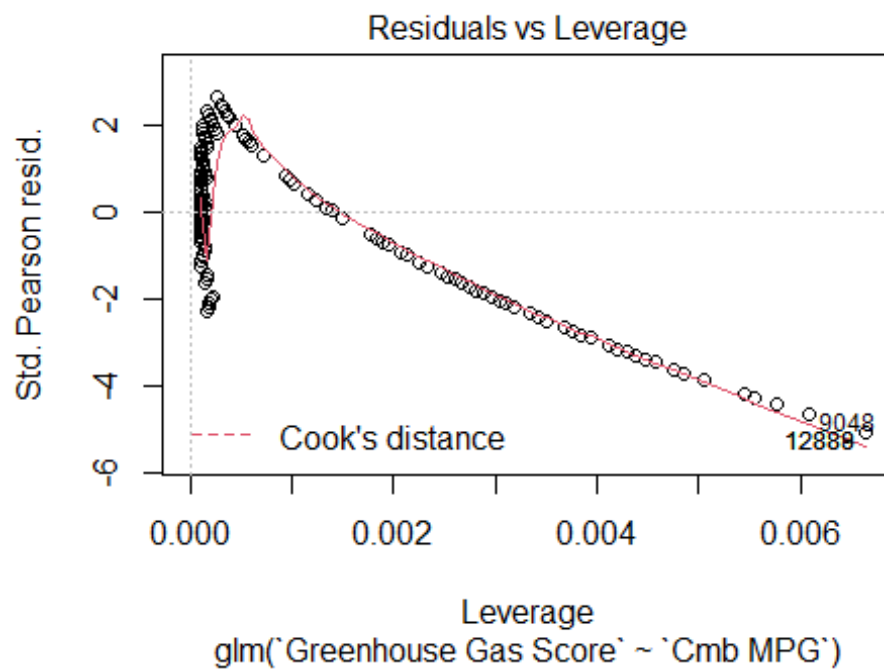
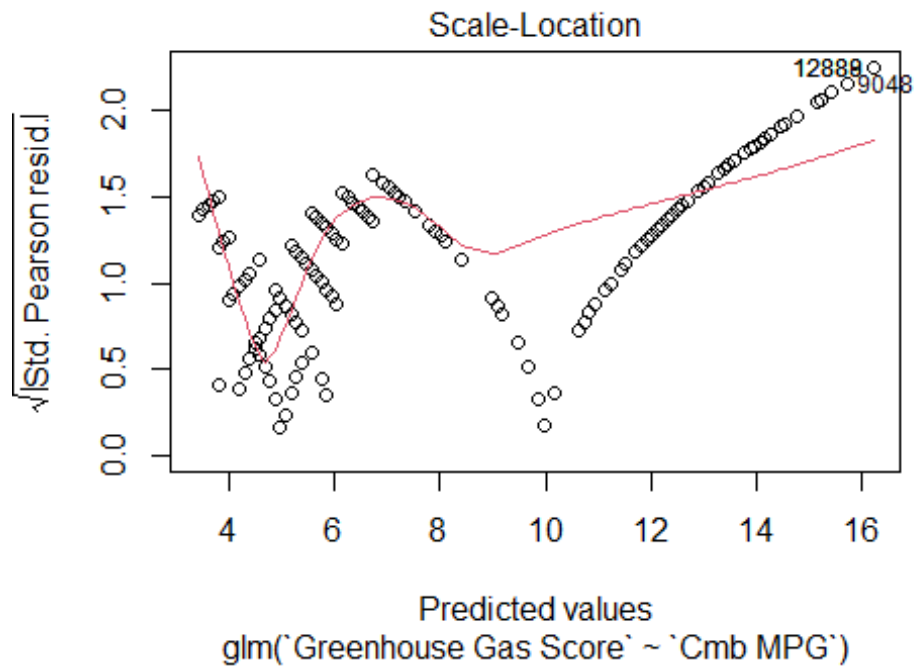
##
## Call:
## glm(formula = Make ~ `Cmb MPG`, family = quasibinomial, data = train)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
```

```
## -2.9783    0.1570    0.1605    0.1631    0.1722
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.093541    0.231656  17.671  <2e-16 ***
## `Cmb MPG`    0.010985    0.008844   1.242    0.214
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 0.9928485)
##
##      Null deviance: 1332.4  on 9889  degrees of freedom
## Residual deviance: 1330.5  on 9888  degrees of freedom
## (610 observations deleted due to missingness)
## AIC: NA
##
## Number of Fisher Scoring iterations: 7
```

Gaussian GLM Graph

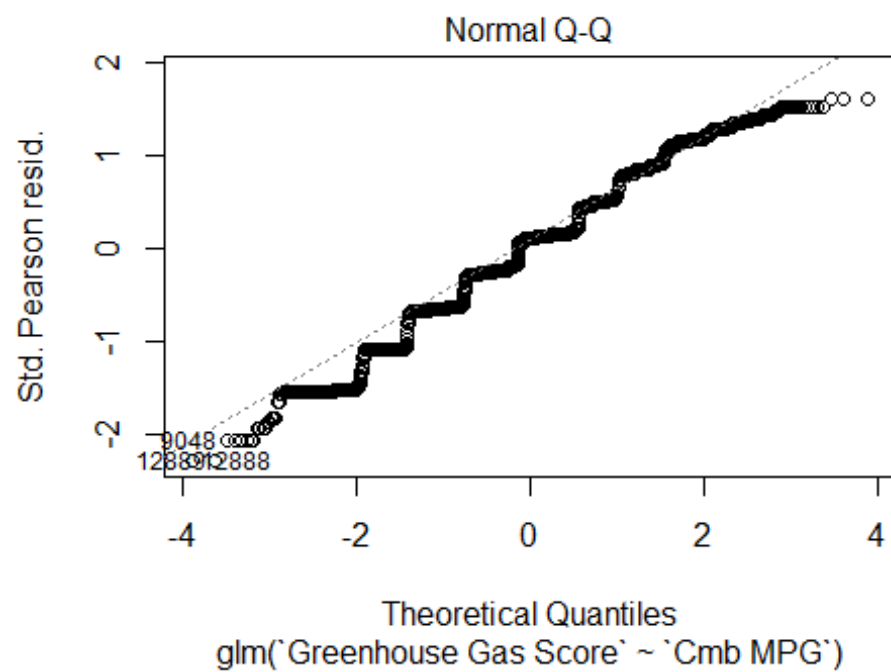
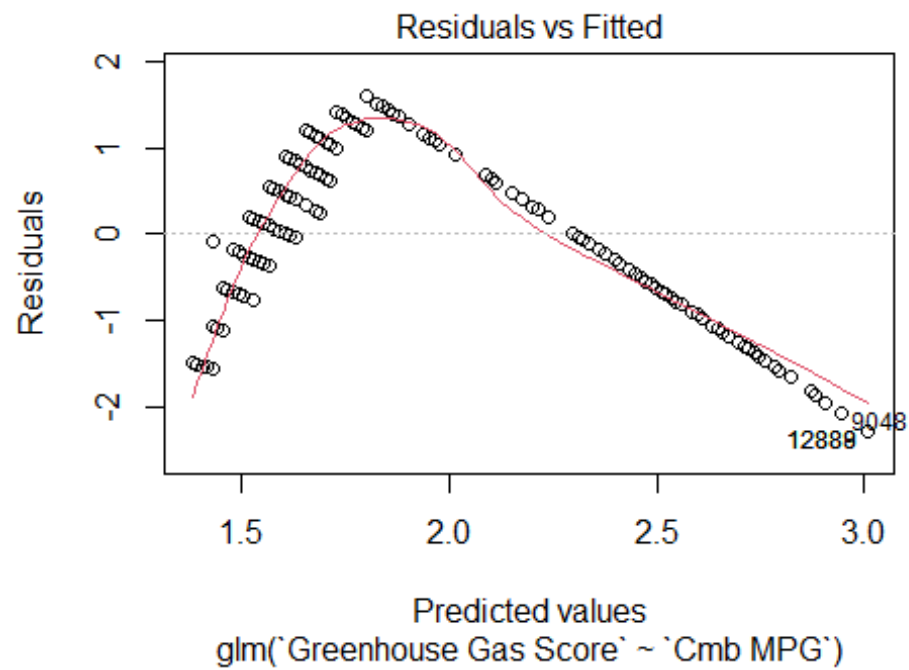
```
plot(glm_gaus)
```

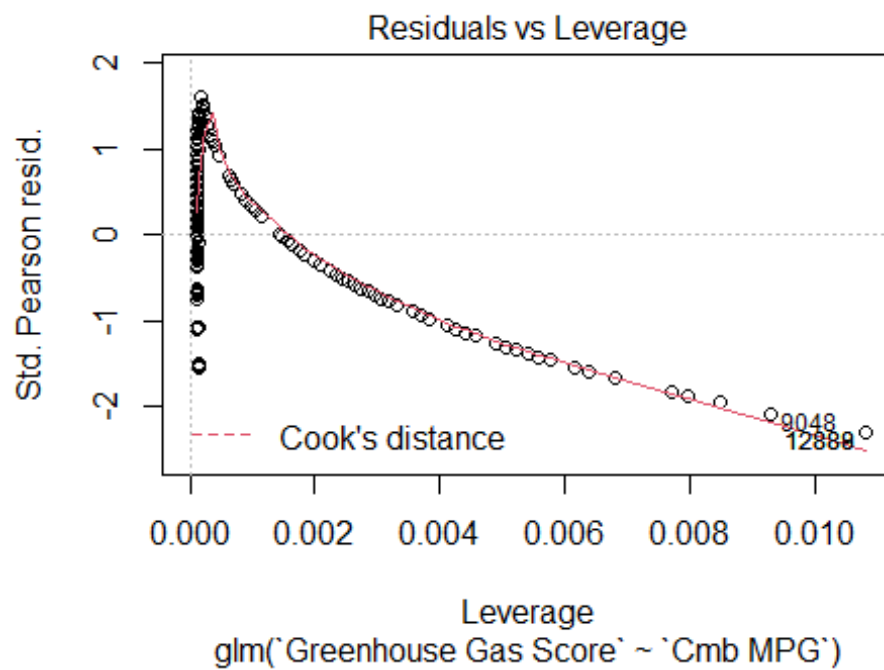
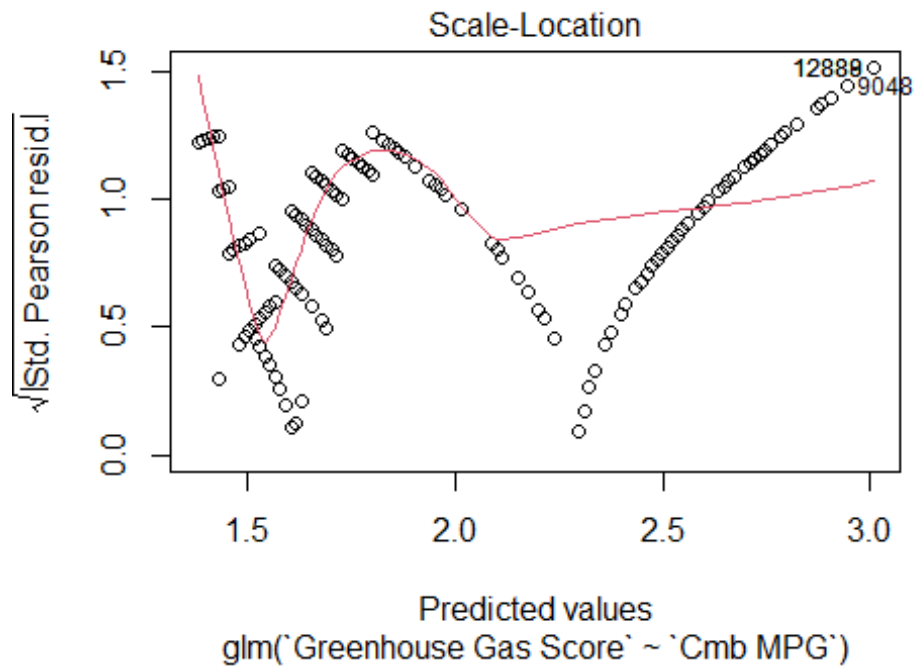




Poisson GLM Graph

```
plot(glm_poiss)
```

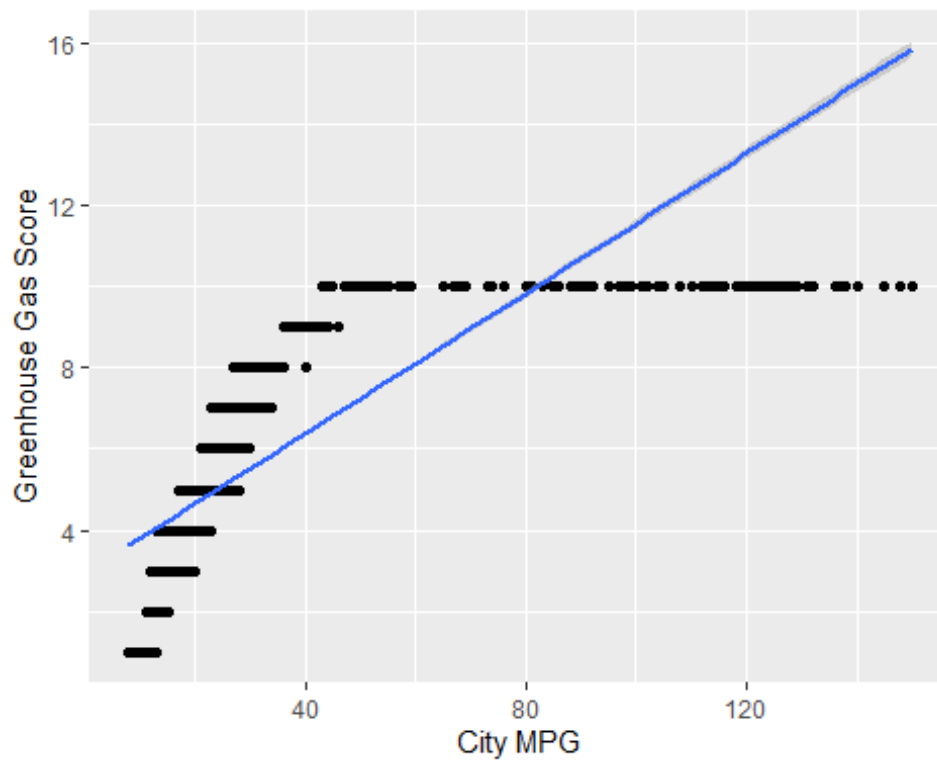





LM1 Graph

```
ggplot(EPA_allYears, aes(`City MPG`, `Greenhouse Gas Score`)) +
  geom_point() +
  stat_smooth(method = lm)

## `geom_smooth()` using formula 'y ~ x'
## Warning: Removed 781 rows containing non-finite values (stat_smooth).
## Warning: Removed 781 rows containing missing values (geom_point).
```



LM1 Basics

```
lm1 <- lm(`City MPG` ~ `Greenhouse Gas Score`, data = EPA_allYears)
lm1

##
## Call:
## lm(formula = `City MPG` ~ `Greenhouse Gas Score`, data = EPA_allYears)
##
## Coefficients:
##              (Intercept)  `Greenhouse Gas Score`
##                -6.345                5.991
```

LM1 Summary

```
summary(lm1)

##
## Call:
```

```
## lm(formula = `City MPG` ~ `Greenhouse Gas Score`, data = EPA_allYears)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -14.580  -4.608  -1.608   2.373   96.439
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -6.34478     0.27594  -22.99  <2e-16 ***
## `Greenhouse Gas Score`  5.99058     0.05226  114.63  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.82 on 12343 degrees of freedom
## (781 observations deleted due to missingness)
## Multiple R-squared:  0.5156, Adjusted R-squared:  0.5156
## F-statistic: 1.314e+04 on 1 and 12343 DF,  p-value: < 2.2e-16
```

LM2 Basics

```
lm2 <- lm(`City MPG`~ `Greenhouse Gas Score`+`Air Pollution Score`, data =
EPA_allYears)
lm2
##
## Call:
## lm(formula = `City MPG` ~ `Greenhouse Gas Score` + `Air Pollution Score`,
##     data = EPA_allYears)
##
## Coefficients:
##              (Intercept)  `Greenhouse Gas Score`  `Air Pollution Score`
##                -9.350                5.303                1.247
```

LM2 Summary

```
summary(lm2)
##
## Call:
## lm(formula = `City MPG` ~ `Greenhouse Gas Score` + `Air Pollution Score`,
##     data = EPA_allYears)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.296  -4.950  -1.513   2.397   93.851
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -9.34953     0.30447  -30.71  <2e-16 ***
## `Greenhouse Gas Score`  5.30315     0.06036   87.86  <2e-16 ***
## `Air Pollution Score`  1.24670     0.05769   21.61  <2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.63 on 12342 degrees of freedom
## (781 observations deleted due to missingness)
## Multiple R-squared:  0.5333, Adjusted R-squared:  0.5332
## F-statistic: 7052 on 2 and 12342 DF, p-value: < 2.2e-16
```

LM3 Basics

```
lm3 <- lm(`Cyl`~ `Cmb MPG` + `Air Pollution Score`, data = EPA_allYears)
lm3

##
## Call:
## lm(formula = Cyl ~ `Cmb MPG` + `Air Pollution Score`, data = EPA_allYears)
##
## Coefficients:
##              (Intercept)              `Cmb MPG`  `Air Pollution Score`
##              10.9315              -0.2077              -0.1025
```

LM3 Summary

```
summary(lm3)

##
## Call:
## lm(formula = Cyl ~ `Cmb MPG` + `Air Pollution Score`, data = EPA_allYears)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -3.0899 -0.8131 -0.1399  0.5720  7.4560
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    10.931459    0.051498   212.27  <2e-16 ***
## `Cmb MPG`       -0.207728    0.002129  -97.58  <2e-16 ***
## `Air Pollution Score` -0.102492    0.007048  -14.54  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.299 on 12007 degrees of freedom
## (1116 observations deleted due to missingness)
## Multiple R-squared:  0.5055, Adjusted R-squared:  0.5054
## F-statistic: 6136 on 2 and 12007 DF, p-value: < 2.2e-16
```

of my three linear regression models, lm2 using combined miles per gallon with greenhouse gas score, and air pollution score had the highest r^2 value, implying that it had the strongest correlation at .5333.