Categorical Predictor Variables

```
library(ISLR)
data(Carseats)
names(Carseats)
```

```
 [1] "Sales"       "CompPrice"   "Income"      "Advertising" "Population"
 [6] "Price"       "ShelveLoc"   "Age"         "Education"   "Urban"
[11] "US"
```

```
levels(Carseats$ShelveLoc)
```

```
[1] "Bad"    "Good"   "Medium"
```

Dummy Variables

```
levels(Carseats$ShelveLoc)
```

```
[1] "Bad"    "Good"   "Medium"
```

```
lm.fit=lm(Sales~.,data=Carseats)
summary(lm.fit)
```

```

Call:
lm(formula = Sales ~ ., data = Carseats)

Residuals:
    Min      1Q  Median      3Q     Max 
-2.8692 -0.6908  0.0211  0.6636  3.4115 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)       5.6606231  0.6034487   9.380  < 2e-16 ***
CompPrice         0.0928153  0.0041477  22.378  < 2e-16 ***
Income            0.0158028  0.0018451   8.565 2.58e-16 ***
Advertising       0.1230951  0.0111237  11.066  < 2e-16 ***
Population        0.0002079  0.0003705   0.561    0.575    
Price            -0.0953579  0.0026711 -35.700  < 2e-16 ***
ShelveLocGood     4.8501827  0.1531100  31.678  < 2e-16 ***
ShelveLocMedium   1.9567148  0.1261056  15.516  < 2e-16 ***
Age              -0.0460452  0.0031817 -14.472  < 2e-16 ***
Education        -0.0211018  0.0197205  -1.070    0.285    
UrbanYes          0.1228864  0.1129761   1.088    0.277    
```

```
USYes           -0.1840928  0.1498423  -1.229    0.220
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.019 on 388 degrees of freedom
Multiple R-squared:  0.8734,    Adjusted R-squared:  0.8698
F-statistic: 243.4 on 11 and 388 DF,  p-value: < 2.2e-16
```

```
contrasts(Carseats$ShelveLoc)
```

```
       Good Medium
Bad       0      0
Good      1      0
Medium    0      1
```

Re-leveling dummy variables

```
contrasts(Carseats$ShelveLoc)
```

```
       Good Medium
Bad       0      0
Good      1      0
Medium    0      1
```

```
Carseats$ShelveLoc <- relevel(Carseats$ShelveLoc, ref="Good")
contrasts(Carseats$ShelveLoc)
```

```
       Bad Medium
Good     0      0
Bad      1      0
Medium   0      1
```

```
summary(lm(Sales~.,data=Carseats)) # Check it out
```

```

Call:
lm(formula = Sales ~ ., data = Carseats)

Residuals:
    Min      1Q  Median      3Q     Max
-2.8692 -0.6908  0.0211  0.6636  3.4115

Coefficients:
```

```
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)     10.5108058  0.6039582  17.403  < 2e-16 ***
CompPrice        0.0928153  0.0041477  22.378  < 2e-16 ***
Income           0.0158028  0.0018451   8.565 2.58e-16 ***
Advertising      0.1230951  0.0111237  11.066  < 2e-16 ***
Population       0.0002079  0.0003705   0.561    0.575
Price           -0.0953579  0.0026711 -35.700  < 2e-16 ***
ShelveLocBad    -4.8501827  0.1531100 -31.678  < 2e-16 ***
ShelveLocMedium -2.8934679  0.1308928 -22.106  < 2e-16 ***
Age             -0.0460452  0.0031817 -14.472  < 2e-16 ***
Education       -0.0211018  0.0197205  -1.070    0.285
UrbanYes         0.1228864  0.1129761   1.088    0.277
USYes           -0.1840928  0.1498423  -1.229    0.220
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.019 on 388 degrees of freedom
Multiple R-squared:  0.8734,    Adjusted R-squared:  0.8698
F-statistic: 243.4 on 11 and 388 DF,  p-value: < 2.2e-16
```

Centered data

```
library(MASS)
data(Boston)

Boston.centered = data.frame(scale(Boston, center=TRUE, scale=FALSE))

summary(Boston.centered)
```

```
      crim                 zn                indus              chas        
 Min.   :-3.60720   Min.   :-11.364   Min.   :-10.677   Min.   :-0.06917  
 1st Qu.:-3.53148   1st Qu.:-11.364   1st Qu.: -5.947   1st Qu.:-0.06917  
 Median :-3.35701   Median :-11.364   Median : -1.447   Median :-0.06917  
 Mean   : 0.00000   Mean   :  0.000   Mean   :  0.000   Mean   : 0.00000  
 3rd Qu.: 0.06356   3rd Qu.:  1.136   3rd Qu.:  6.963   3rd Qu.:-0.06917  
 Max.   :85.36268   Max.   : 88.636   Max.   : 16.603   Max.   : 0.93083  
      nox                rm                 age               dis         
 Min.   :-0.1697   Min.   :-2.72363   Min.   :-65.675   Min.   :-2.6654  
 1st Qu.:-0.1057   1st Qu.:-0.39913   1st Qu.:-23.550   1st Qu.:-1.6949  
 Median :-0.0167   Median :-0.07613   Median :  8.925   Median :-0.5876  
 Mean   : 0.0000   Mean   : 0.00000   Mean   :  0.000   Mean   : 0.0000  
 3rd Qu.: 0.0693   3rd Qu.: 0.33887   3rd Qu.: 25.500   3rd Qu.: 1.3934  
 Max.   : 0.3163   Max.   : 2.49537   Max.   : 31.425   Max.   : 8.3315  
      rad                tax              ptratio             black        
 Min.   :-8.549   Min.   :-221.24   Min.   :-5.8555   Min.   :-356.35  
 1st Qu.:-5.549   1st Qu.:-129.24   1st Qu.:-1.0555   1st Qu.:  18.70  
 Median :-4.549   Median : -78.24   Median : 0.5945   Median :  34.77  
 Mean   : 0.000   Mean   :   0.00   Mean   : 0.0000   Mean   :   0.00  
 3rd Qu.:14.451   3rd Qu.: 257.76   3rd Qu.: 1.7445   3rd Qu.:  39.55  
 Max.   :14.451   Max.   : 302.76   Max.   : 3.5445   Max.   :  40.23  
     lstat              medv        
 Min.   :-10.923   Min.   :-17.533  
```

```
1st Qu.: -5.703   1st Qu.: -5.508
Median : -1.293   Median : -1.333
Mean   :  0.000   Mean   :  0.000
3rd Qu.:  4.302   3rd Qu.:  2.467
Max.   : 25.317   Max.   : 27.467
```

Model on centered data

```
summary(lm(medv~lstat+age,data=Boston))
```

```
Call:
lm(formula = medv ~ lstat + age, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max 
-15.981  -3.978  -1.283   1.968  23.158 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 33.22276    0.73085  45.458  < 2e-16 ***
lstat       -1.03207    0.04819 -21.416  < 2e-16 ***
age          0.03454    0.01223   2.826  0.00491 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.173 on 503 degrees of freedom
Multiple R-squared:  0.5513,    Adjusted R-squared:  0.5495 
F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

```
summary(lm(medv~lstat+age,data=Boston.centered))
```

```
Call:
lm(formula = medv ~ lstat + age, data = Boston.centered)
```

```
Residuals:
    Min      1Q  Median      3Q     Max
-15.981  -3.978  -1.283   1.968  23.158

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) -8.697e-16  2.744e-01   0.000  1.00000
lstat       -1.032e+00  4.819e-02 -21.416  < 2e-16 ***
age          3.454e-02  1.223e-02   2.826  0.00491 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.173 on 503 degrees of freedom
Multiple R-squared:  0.5513,    Adjusted R-squared:  0.5495
F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

Standardized data

```
Boston.standardized = data.frame(scale(Boston, center=TRUE, scale=TRUE))
summary(Boston.standardized)
```

```
      crim                 zn                indus        
 Min.   :-0.419367   Min.   :-0.48724   Min.   :-1.5563  
 1st Qu.:-0.410563   1st Qu.:-0.48724   1st Qu.:-0.8668  
 Median :-0.390280   Median :-0.48724   Median :-0.2109  
 Mean   : 0.000000   Mean   : 0.00000   Mean   : 0.0000  
 3rd Qu.: 0.007389   3rd Qu.: 0.04872   3rd Qu.: 1.0150  
 Max.   : 9.924110   Max.   : 3.80047   Max.   : 2.4202  
      chas               nox                rm                age         
 Min.   :-0.2723   Min.   :-1.4644   Min.   :-3.8764   Min.   :-2.3331  
 1st Qu.:-0.2723   1st Qu.:-0.9121   1st Qu.:-0.5681   1st Qu.:-0.8366  
 Median :-0.2723   Median :-0.1441   Median :-0.1084   Median : 0.3171  
 Mean   : 0.0000   Mean   : 0.0000   Mean   : 0.0000   Mean   : 0.0000  
 3rd Qu.:-0.2723   3rd Qu.: 0.5981   3rd Qu.: 0.4823   3rd Qu.: 0.9059  
 Max.   : 3.6648   Max.   : 2.7296   Max.   : 3.5515   Max.   : 1.1164  
      dis                rad                tax             ptratio       
 Min.   :-1.2658   Min.   :-0.9819   Min.   :-1.3127   Min.   :-2.7047  
 1st Qu.:-0.8049   1st Qu.:-0.6373   1st Qu.:-0.7668   1st Qu.:-0.4876  
 Median :-0.2790   Median :-0.5225   Median :-0.4642   Median : 0.2746  
 Mean   : 0.0000   Mean   : 0.0000   Mean   : 0.0000   Mean   : 0.0000  
 3rd Qu.: 0.6617   3rd Qu.: 1.6596   3rd Qu.: 1.5294   3rd Qu.: 0.8058  
 Max.   : 3.9566   Max.   : 1.6596   Max.   : 1.7964   Max.   : 1.6372  
     black              lstat              medv        
 Min.   :-3.9033   Min.   :-1.5296   Min.   :-1.9063  
 1st Qu.: 0.2049   1st Qu.:-0.7986   1st Qu.:-0.5989  
 Median : 0.3808   Median :-0.1811   Median :-0.1449  
 Mean   : 0.0000   Mean   : 0.0000   Mean   : 0.0000  
```

```
 3rd Qu.: 0.4332   3rd Qu.: 0.6024   3rd Qu.: 0.2683
 Max.   : 0.4406   Max.   : 3.5453   Max.   : 2.9865
```

Standardized data

```
for(v in names(Boston.standardized)){
  print(paste(v, as.character(round(sd(Boston[,v]),2)),
as.character(round(sd(Boston.standardized[,v]),2))))
}
```

```
[1] "crim 8.6 1"
[1] "zn 23.32 1"
[1] "indus 6.86 1"
[1] "chas 0.25 1"
[1] "nox 0.12 1"
[1] "rm 0.7 1"
[1] "age 28.15 1"
[1] "dis 2.11 1"
[1] "rad 8.71 1"
[1] "tax 168.54 1"
[1] "ptratio 2.16 1"
[1] "black 91.29 1"
[1] "lstat 7.14 1"
[1] "medv 9.2 1"
```

Model on standardized data

```
summary(lm(medv~lstat+age,data=Boston))
```

```
Call:
lm(formula = medv ~ lstat + age, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max 
-15.981  -3.978  -1.283   1.968  23.158 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 33.22276    0.73085  45.458  < 2e-16 ***
lstat       -1.03207    0.04819 -21.416  < 2e-16 ***
age          0.03454    0.01223   2.826  0.00491 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.173 on 503 degrees of freedom
Multiple R-squared:  0.5513,    Adjusted R-squared:  0.5495 
F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

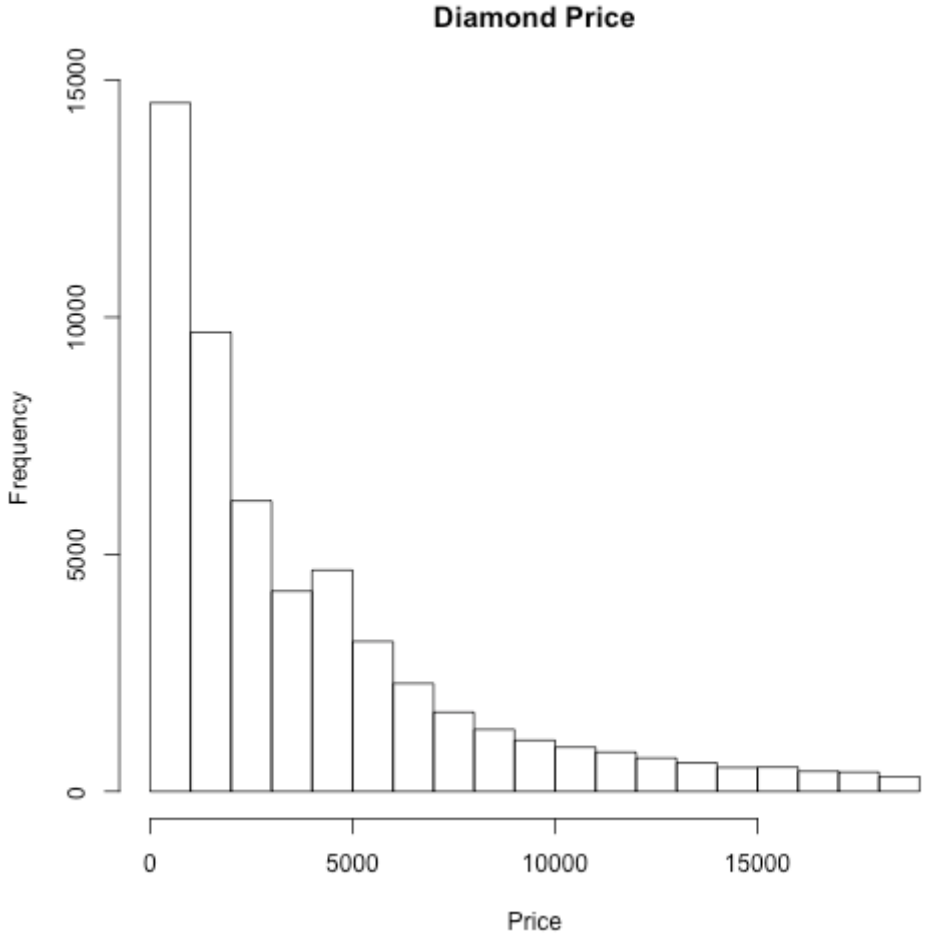
```
summary(lm(medv~lstat+age,data=Boston.standardized))
```

```
Call:
lm(formula = medv ~ lstat + age, data = Boston.standardized)
```

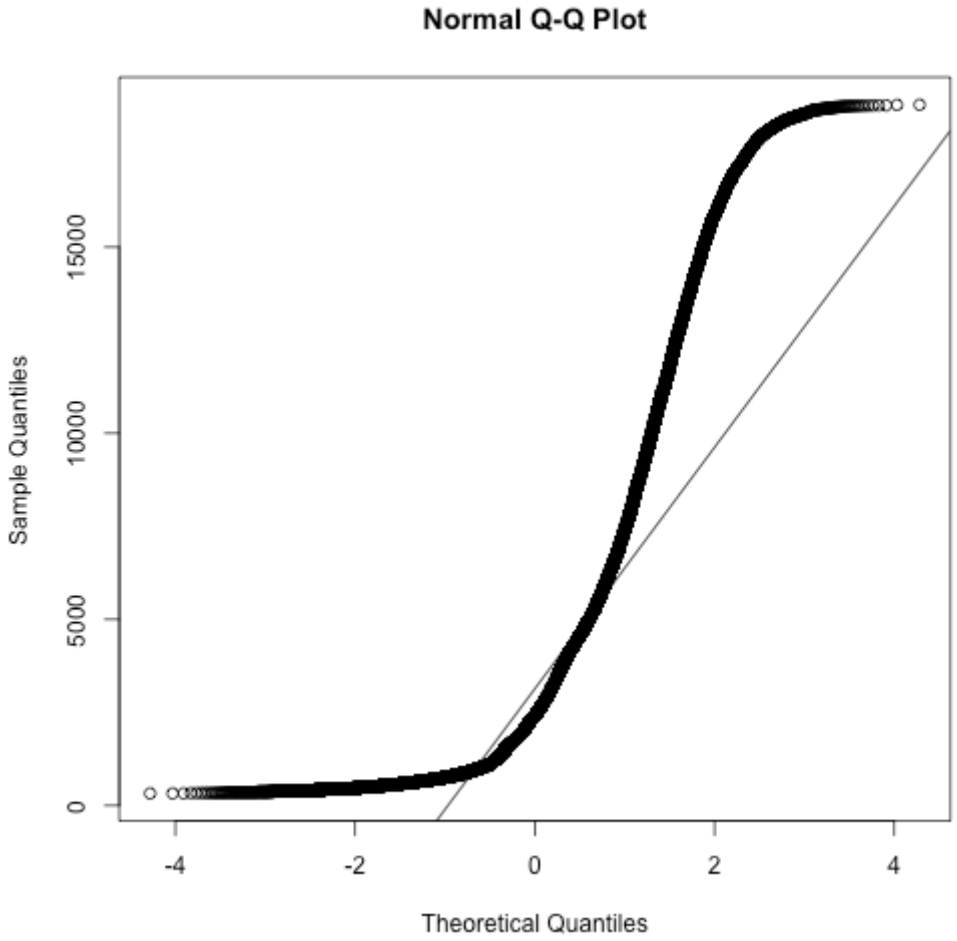
```
Residuals:
    Min      1Q  Median      3Q     Max
-1.7376 -0.4325 -0.1396  0.2140  2.5180

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -4.615e-16  2.984e-02   0.000  1.00000
lstat       -8.013e-01  3.742e-02 -21.416  < 2e-16 ***
age          1.057e-01  3.742e-02   2.826  0.00491 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.6712 on 503 degrees of freedom
Multiple R-squared:  0.5513,    Adjusted R-squared:  0.5495
F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

Log() may make data more normal

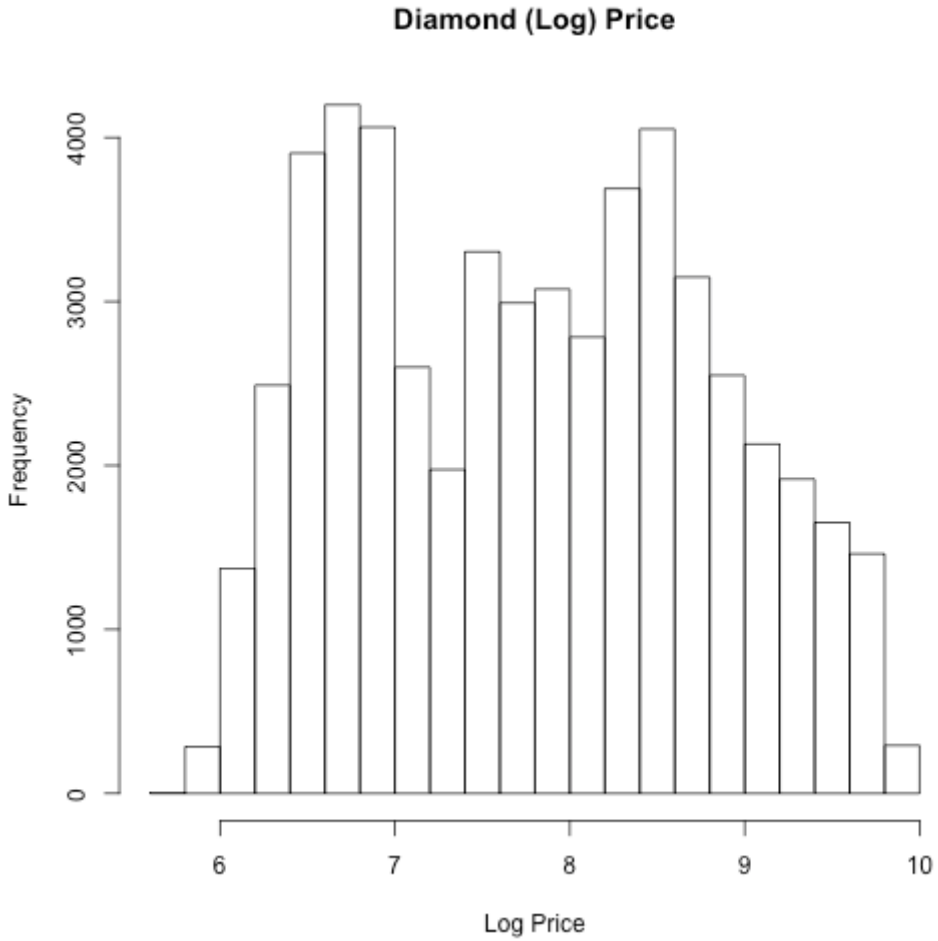
```
require(ggplot2)
attach(diamonds)

hist(diamonds$price, main="Diamond Price", xlab="Price")
```



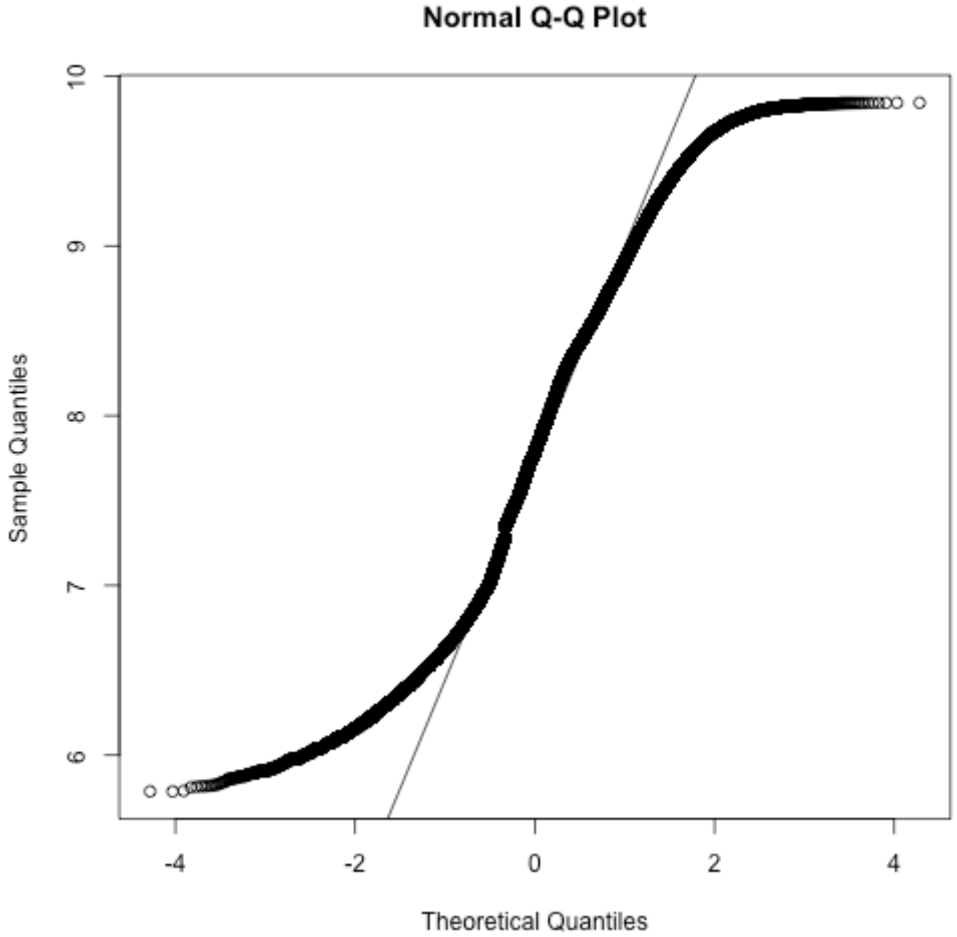

```
qqnorm(diamonds$price); qqline(diamonds$price)
```




```
hist(log(diamonds$price), main="Diamond (Log) Price", xlab="Log Price")
```

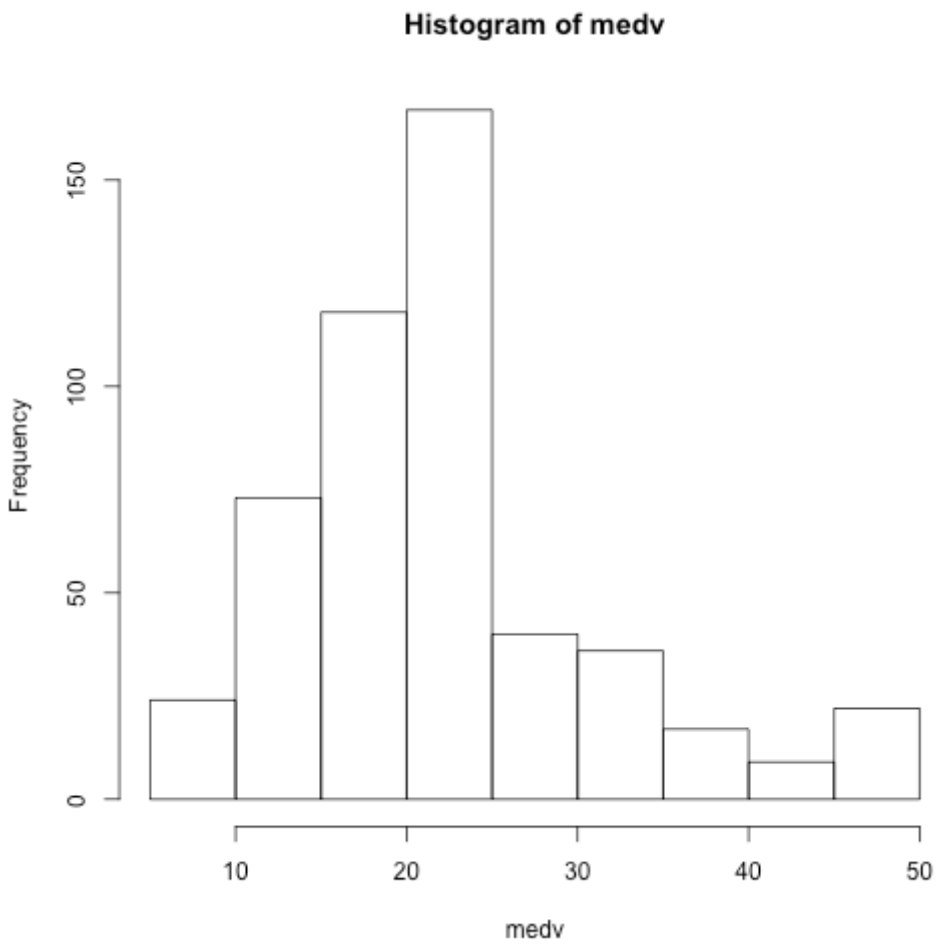



```
qqnorm(log(diamonds$price)); qqline(log(diamonds$price))
```

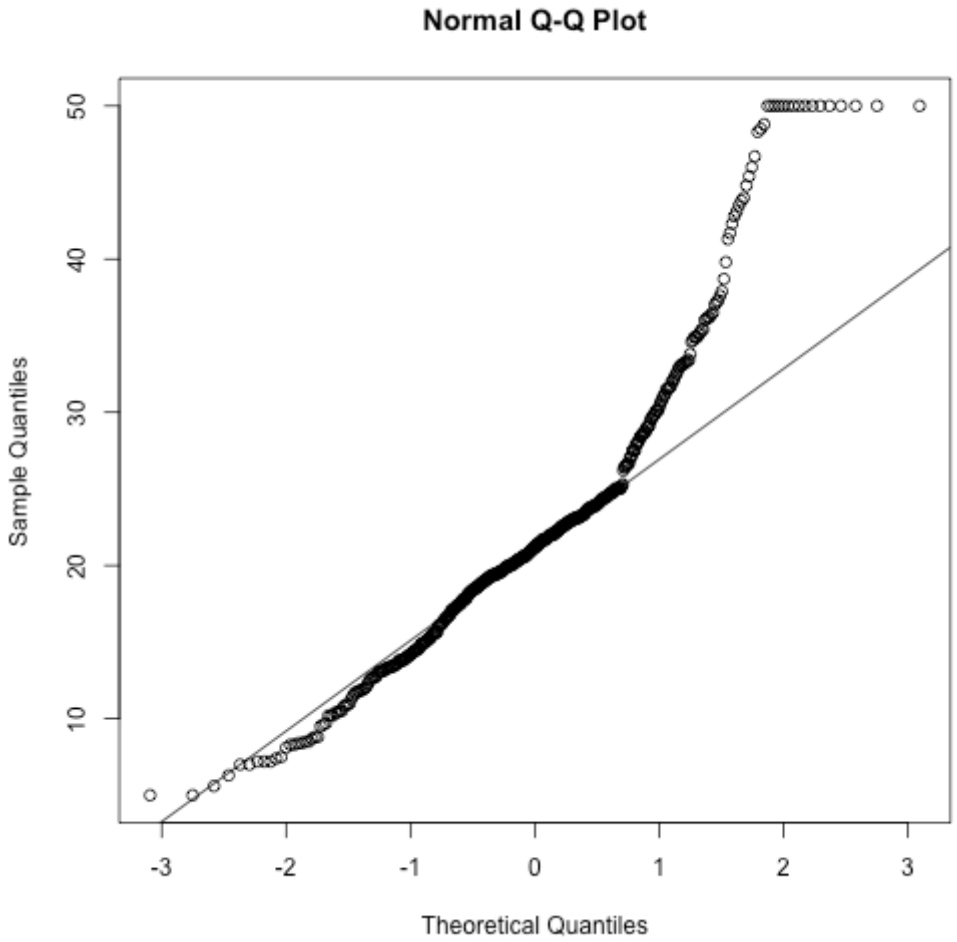

Normal Q-Q Plot
Sample Quantiles
Theoretical Quantiles
10
9
8
7
6
-4
-2
0
2
4

Log() may make data more normal

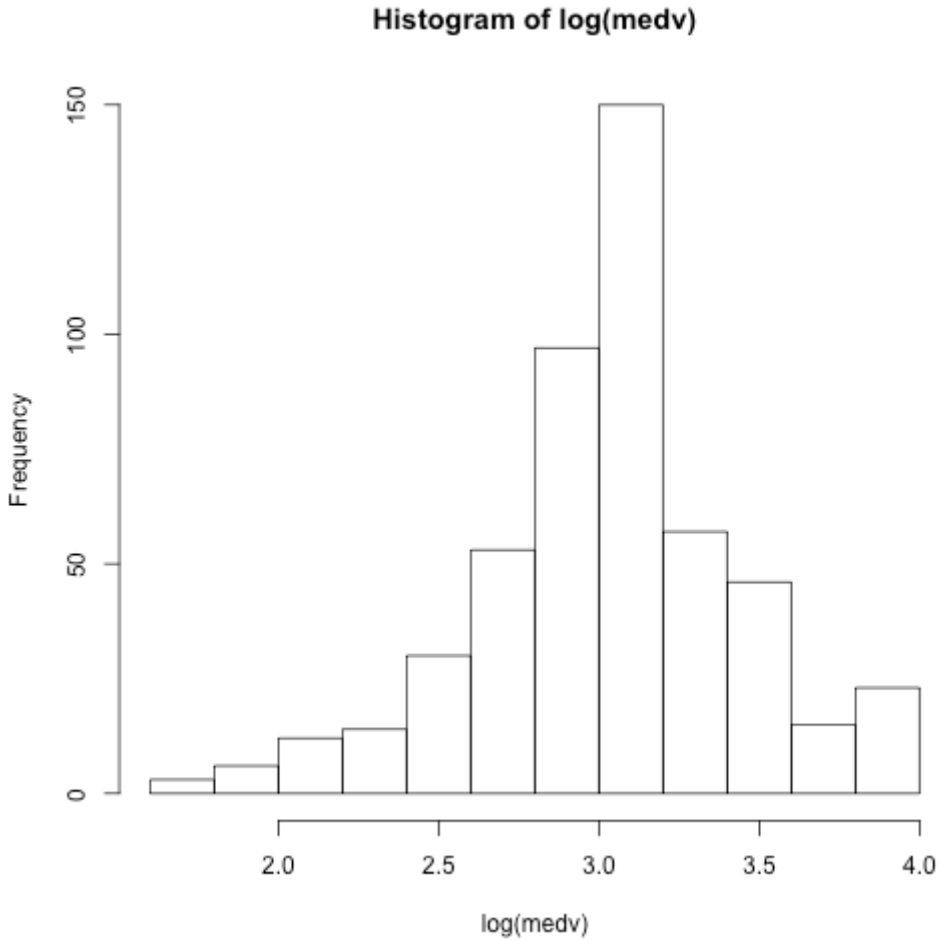
```
attach(Boston)
hist(medv)
```



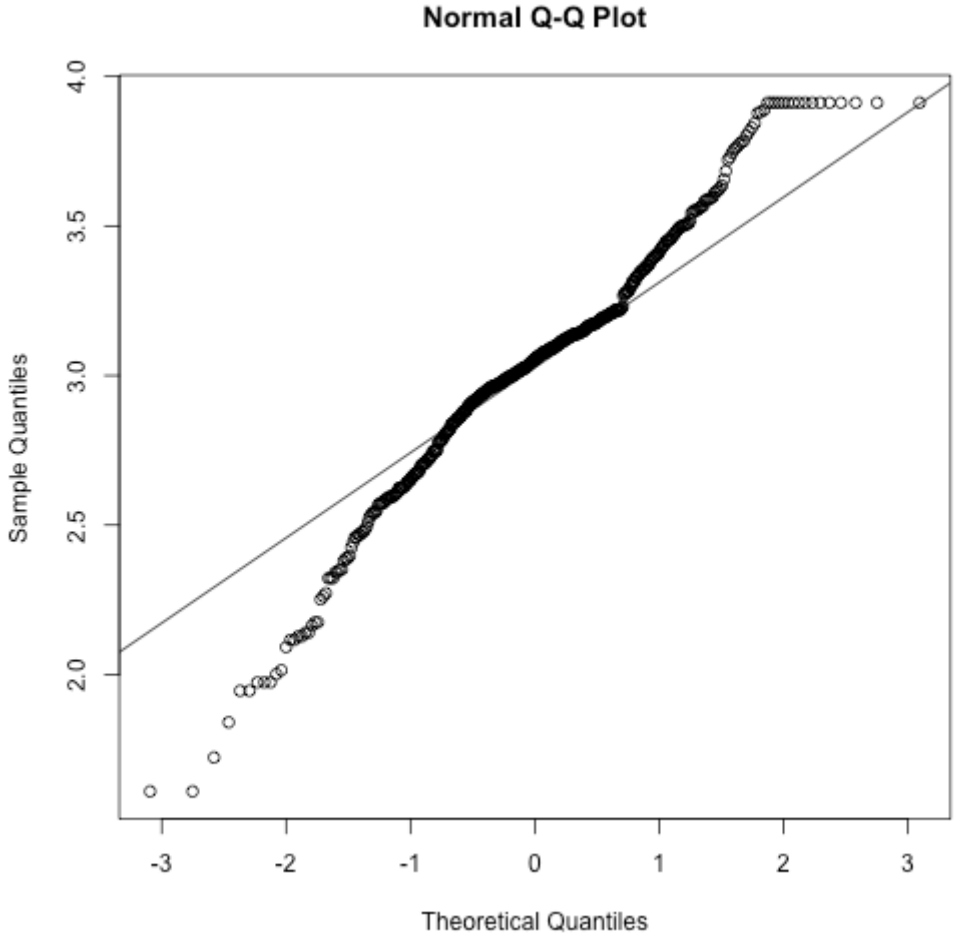
```
qqnorm(medv); qqline(medv)
```




```
hist(log(medv))
```




```
qqnorm(log(medv)); qqline(log(medv))
```


Normal Q-Q Plot
Sample Quantiles
Theoretical Quantiles
4.0
3.5
3.0
2.5
2.0
-3
-2
-1
0
1
2
3

Y = Log(X)*B

```
summary(lm(medv~log(rm),data=Boston))
```

```
Call:
lm(formula = medv ~ log(rm), data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max 
-19.487  -2.875  -0.104   2.837  39.816 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  -76.488      5.028  -15.21   <2e-16 ***
log(rm)       54.055      2.739   19.73   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.915 on 504 degrees of freedom
Multiple R-squared:  0.4358,    Adjusted R-squared:  0.4347 
F-statistic: 389.3 on 1 and 504 DF,  p-value: < 2.2e-16
```

Log(Y) = X*B

```
summary(lm(log(medv)~rm,data=Boston))
```

```
Call:
lm(formula = log(medv) ~ rm, data = Boston)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.20386 -0.09419  0.06416  0.16991  1.36088 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  0.72374    0.12699   5.699 2.05e-08 ***
rm           0.36769    0.02008  18.309  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3171 on 504 degrees of freedom
Multiple R-squared:  0.3995,    Adjusted R-squared:  0.3983 
F-statistic: 335.2 on 1 and 504 DF,  p-value: < 2.2e-16
```

Log(Y) = Log(X)*B

```
summary(lm(log(medv)~log(rm),data=Boston))
```

```
Call:
lm(formula = log(medv) ~ log(rm), data = Boston)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.21784 -0.08913  0.05841  0.17311  1.52771 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  -1.0348     0.2356  -4.392 1.37e-05 ***
log(rm)       2.2214     0.1284  17.302  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3241 on 504 degrees of freedom
Multiple R-squared:  0.3726,    Adjusted R-squared:  0.3714 
F-statistic: 299.4 on 1 and 504 DF,  p-value: < 2.2e-16
```

Count Data: Log(Y) = X*B

```
College <- read.table("../../data/College.csv", header=TRUE, sep=",")
options(scipen="2")
summary(lm(Apps~Outstate+PhD+S.F.Ratio, data=College))
```

```
Call:
lm(formula = Apps ~ Outstate + PhD + S.F.Ratio, data = College)

Residuals:
    Min      1Q  Median      3Q     Max
-5194.2 -1526.9  -625.3   462.0 17678.3

Coefficients:
               Estimate  Std. Error t value Pr(>|t|)
(Intercept) -6017.33972  1164.55442  -5.167 4.10e-07 ***
Outstate        0.09953     0.05149   1.933   0.0541 .
PhD            62.11394    10.55757   5.883 9.77e-09 ***
S.F.Ratio     211.54423    51.85450   4.080 5.65e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2865 on 334 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.1634,    Adjusted R-squared:  0.1559
F-statistic: 21.74 on 3 and 334 DF,  p-value: 6.927e-13
```

```
summary(glm(Apps~Outstate+PhD+S.F.Ratio, family=poisson(link="log"),
data=College))
```

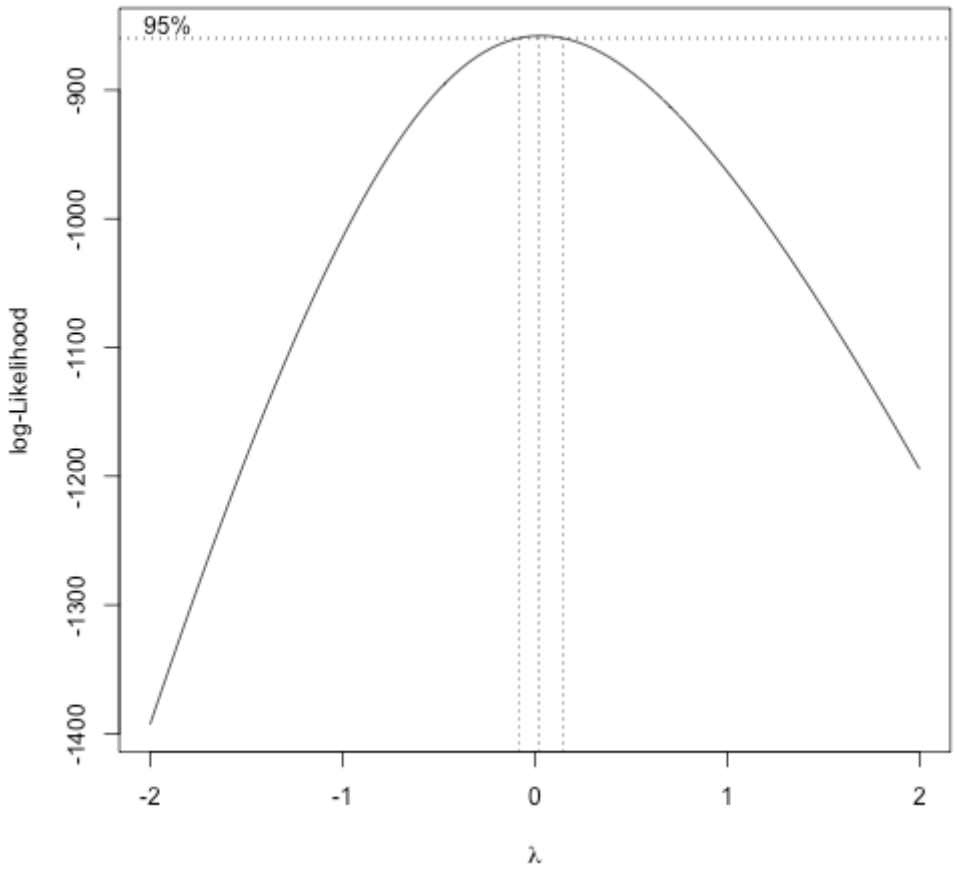
```
Call:
glm(formula = Apps ~ Outstate + PhD + S.F.Ratio, family = poisson(link =
"log"),
    data = College)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-113.785   -30.019   -13.824     9.366   209.813

Coefficients:
               Estimate  Std. Error z value Pr(>|z|)
(Intercept) 3.466289123 0.009928967  349.11   <2e-16 ***
Outstate    0.000030619 0.000000355   86.26   <2e-16 ***
PhD         0.035274463 0.000095444  369.58   <2e-16 ***
S.F.Ratio   0.093560077 0.000349618  267.61   <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: 877566  on 337  degrees of freedom
Residual deviance: 621594  on 334  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 624672

Number of Fisher Scoring iterations: 5
```

Box-Cox

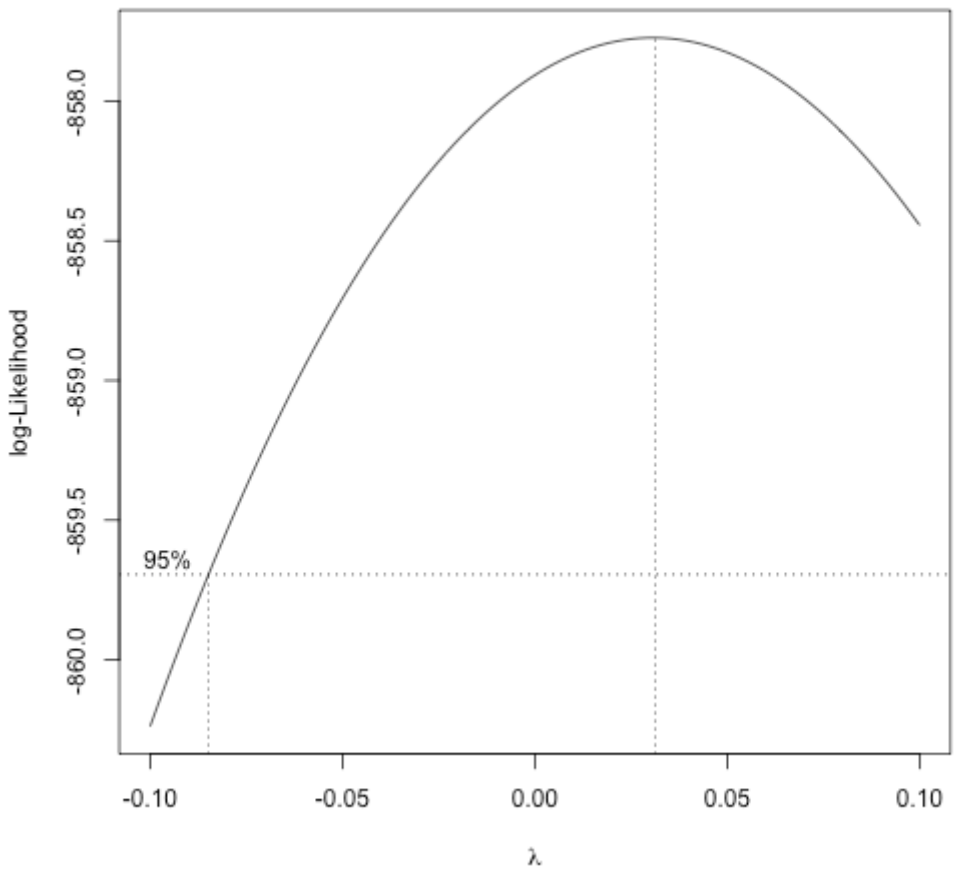
```
library(MASS)
attach(Boston)

lm.fit=lm(medv~lstat, data=Boston)
summary(lm.fit)
```

```
Call:
lm(formula = medv ~ lstat, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max 
-15.168  -3.990  -1.318   2.034  24.500 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 34.55384    0.56263   61.41   <2e-16 ***
lstat       -0.95005    0.03873  -24.53   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.216 on 504 degrees of freedom
Multiple R-squared:  0.5441,    Adjusted R-squared:  0.5432 
F-statistic: 601.6 on 1 and 504 DF,  p-value: < 2.2e-16
```

```
boxcox(lm.fit)
```




```
boxcox(lm.fit, lambda = seq(-0.1, 0.1, 0.01))
```




```
medv.box=medv^0.04
lm.fit.box.cox=lm(medv.box~lstat, data=Boston)
summary(lm.fit.box.cox)
```

```

Call:
lm(formula = medv.box ~ lstat, data = Boston)

Residuals:
```

```
      Min        1Q    Median        3Q       Max
-0.041296 -0.006786 -0.000995  0.005111  0.040816

Coefficients:
               Estimate  Std. Error t value Pr(>|t|)
(Intercept)  1.15544153  0.00099201 1164.75   <2e-16 ***
lstat       -0.00207355  0.00006829  -30.36   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01096 on 504 degrees of freedom
Multiple R-squared:  0.6465,    Adjusted R-squared:  0.6458
F-statistic: 921.9 on 1 and 504 DF,  p-value: < 2.2e-16
```

Polynomials (1st Degree vs. 2nd Degree)

```
lm.fit2=lm(medv~lstat+I(lstat^2), data=Boston)
summary(lm.fit2)
```

```
Call:
lm(formula = medv ~ lstat + I(lstat^2), data = Boston)

Residuals:
     Min       1Q   Median       3Q      Max 
-15.2834  -3.8313  -0.5295   2.3095  25.4148 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept) 42.862007   0.872084   49.15   <2e-16 ***
lstat       -2.332821   0.123803  -18.84   <2e-16 ***
I(lstat^2)   0.043547   0.003745   11.63   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.524 on 503 degrees of freedom
Multiple R-squared:  0.6407,    Adjusted R-squared:  0.6393 
F-statistic: 448.5 on 2 and 503 DF,  p-value: < 2.2e-16
```

```
lm.fit=lm(medv~lstat, data=Boston) # Model withouth quadratic term
summary(lm.fit)
```

```
Call:
```

```
lm(formula = medv ~ lstat, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max
-15.168  -3.990  -1.318   2.034  24.500

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 34.55384    0.56263   61.41   <2e-16 ***
lstat       -0.95005    0.03873  -24.53   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.216 on 504 degrees of freedom
Multiple R-squared:  0.5441,    Adjusted R-squared:  0.5432
F-statistic: 601.6 on 1 and 504 DF,  p-value: < 2.2e-16
```

```
anova(lm.fit,lm.fit2) # Tests if quadratic model is superior
```

```
Analysis of Variance Table

Model 1: medv ~ lstat
Model 2: medv ~ lstat + I(lstat^2)
  Res.Df   RSS Df Sum of Sq     F    Pr(>F)
1    504 19472
2    503 15347  1    4125.1 135.2 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Polynomials (1st Degree vs. 5th Degree)

```
lm.fit5=lm(medv~poly(lstat,5), data=Boston)
summary(lm.fit5) # See the higher R-Squared
```

```
Call:
lm(formula = medv ~ poly(lstat, 5), data = Boston)

Residuals:
     Min       1Q   Median       3Q      Max 
-13.5433  -3.1039  -0.7052   2.0844  27.1153 

Coefficients:
                 Estimate Std. Error t value   Pr(>|t|)    
(Intercept)       22.5328     0.2318  97.197    < 2e-16 ***
poly(lstat, 5)1 -152.4595     5.2148 -29.236    < 2e-16 ***
poly(lstat, 5)2   64.2272     5.2148  12.316    < 2e-16 ***
poly(lstat, 5)3  -27.0511     5.2148  -5.187 0.00000031 ***
poly(lstat, 5)4   25.4517     5.2148   4.881 0.00000142 ***
poly(lstat, 5)5  -19.2524     5.2148  -3.692   0.000247 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.215 on 500 degrees of freedom
Multiple R-squared:  0.6817,    Adjusted R-squared:  0.6785 
F-statistic: 214.2 on 5 and 500 DF,  p-value: < 2.2e-16
```

```
anova(lm.fit,lm.fit5) # Test if the polynomial model is superior
```

```
Analysis of Variance Table

Model 1: medv ~ lstat
Model 2: medv ~ poly(lstat, 5)
  Res.Df   RSS Df Sum of Sq      F    Pr(>F)
1    504 19472
2    500 13597  4    5875.3 54.013 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Lagged Models

```
HousingStarts=read.csv("../../data/HousingStarts.csv",header=T,na.strings="?")

HousingStarts=na.omit(HousingStarts) # Removes NA's

head(HousingStarts)
```

```
     Month T KUnits    S.P Q1 Q2 Q3 Q4
1 Jan 1990 1   99.2 329.08  1  0  0  0
2 Feb 1990 2   86.9 331.89  1  0  0  0
3 Mar 1990 3  108.5 339.94  1  0  0  0
4 Apr 1990 4  119.0 330.80  0  1  0  0
5 May 1990 5  121.1 361.23  0  1  0  0
6 Jun 1990 6  117.8 358.02  0  1  0  0
```

```
lm.KUnits = lm(KUnits~T+S.P+Q2+Q3+Q4, data=HousingStarts)
summary(lm.KUnits)
```

```

Call:
lm(formula = KUnits ~ T + S.P + Q2 + Q3 + Q4, data = HousingStarts)

Residuals:
    Min      1Q  Median      3Q     Max
-57.739 -19.253  -2.681  20.302  71.428

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 71.191003   6.033686  11.799  < 2e-16 ***
```

```
T           -0.290596   0.043991  -6.606 2.53e-10 ***
S.P          0.072582   0.008377   8.664 6.82e-16 ***
Q2          30.888546   5.327939   5.797 2.11e-08 ***
Q3          28.531099   5.392824   5.291 2.75e-07 ***
Q4           8.374365   5.393472   1.553    0.122
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 29.89 on 240 degrees of freedom
Multiple R-squared:  0.3431,    Adjusted R-squared:  0.3294
F-statistic: 25.07 on 5 and 240 DF,  p-value: < 2.2e-16
```

Lagged Models (DW Test)

```
require(lmtest)
dwtest(lm.KUnits)
```

```
    Durbin-Watson test

data:  lm.KUnits
DW = 0.30838, p-value < 2.2e-16
alternative hypothesis: true autocorrelation is greater than 0
```

Lagged Models

```
attach(HousingStarts)
library(DataCombine)

HousingStarts = slide(HousingStarts, Var="KUnits",
                      NewVar="KUnits.L1", slideBy=-1)
HousingStarts = slide(HousingStarts, Var="KUnits",
                      NewVar="KUnits.L2", slideBy=-2)
HousingStarts = slide(HousingStarts, Var="KUnits",
                      NewVar="KUnits.L3", slideBy=-3)
HousingStarts = slide(HousingStarts, Var="KUnits",
                      NewVar="KUnits.L4", slideBy=-4)
head(HousingStarts)
```

```
     Month T KUnits    S.P Q1 Q2 Q3 Q4 KUnits.L1 KUnits.L2 KUnits.L3
1 Jan 1990 1   99.2 329.08  1  0  0  0         NA         NA         NA
2 Feb 1990 2   86.9 331.89  1  0  0  0       99.2         NA         NA
3 Mar 1990 3  108.5 339.94  1  0  0  0       86.9       99.2         NA
4 Apr 1990 4  119.0 330.80  0  1  0  0      108.5       86.9       99.2
5 May 1990 5  121.1 361.23  0  1  0  0      119.0      108.5       86.9
6 Jun 1990 6  117.8 358.02  0  1  0  0      121.1      119.0      108.5
  KUnits.L4
1        NA
2        NA
3        NA
4        NA
5      99.2
6      86.9
```

Lagged Models

```
lm.KUnits.all = lm(KUnits~T+S.P+Q2+Q3+Q4+
                   KUnits.L1+KUnits.L2+KUnits.L3+KUnits.L4,
                   data=HousingStarts)
summary(lm.KUnits.all)
```

```
Call:
lm(formula = KUnits ~ T + S.P + Q2 + Q3 + Q4 + KUnits.L1 + KUnits.L2 +
    KUnits.L3 + KUnits.L4, data = HousingStarts)

Residuals:
    Min      1Q  Median      3Q     Max
-27.182  -8.056  -1.276   6.263  45.123

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  10.121072   3.593364   2.817 0.005271 **
T            -0.019198   0.019127  -1.004 0.316561
S.P           0.002363   0.003914   0.604 0.546513
Q2           -0.239829   4.065405  -0.059 0.953009
Q3           -9.567059   2.868058  -3.336 0.000991 ***
Q4          -17.224210   2.434830  -7.074 1.76e-11 ***
KUnits.L1     0.921704   0.074281  12.408  < 2e-16 ***
KUnits.L2     0.150916   0.087870   1.717 0.087222 .
KUnits.L3    -0.263768   0.086529  -3.048 0.002568 **
KUnits.L4     0.161815   0.070622   2.291 0.022843 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 11.86 on 232 degrees of freedom
```

```
  (4 observations deleted due to missingness)
Multiple R-squared:  0.8995,    Adjusted R-squared:  0.8956
F-statistic: 230.7 on 9 and 232 DF,  p-value: < 2.2e-16
```

```
dwtest(lm.KUnits.all)
```

```
    Durbin-Watson test

data:  lm.KUnits.all
DW = 2.3881, p-value = 0.997
alternative hypothesis: true autocorrelation is greater than 0
```