Assignment5_stat359

Koki Itagaki

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#1. Beef consumption (in pounds per capita) in the United States between 1922 and 1941 are given in the data set beef.txt. Other variables of interest are beef price (in cents per pound divided by CPI), income (disposable income capita in dollars divided by the CPI), and pork consumption(pounds per capita). [CPI= Consumer price index]. Find a model that best describes beef consumption in the United States. Complete a full analysis of the data (initial plots, model selection, residual plots etc.). Discuss your results.

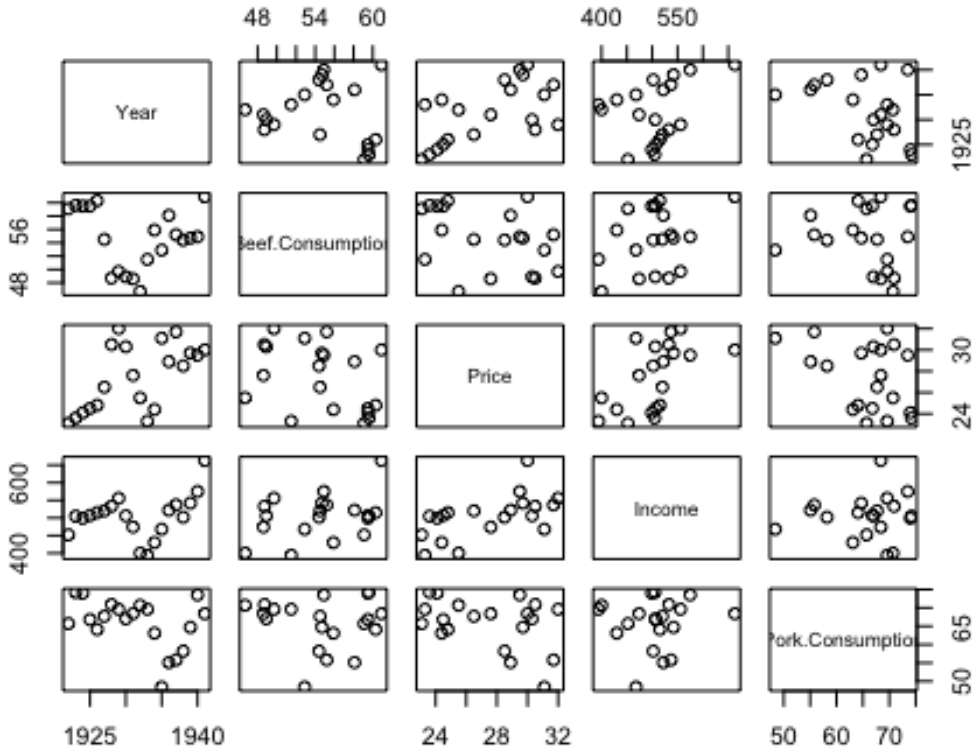
```
beef<-read.table(file='~/Desktop/stat359/data/beef.txt', header = T)
attach(beef)
head(beef)
```

```
##   Year Beef.Consumption Price Income Pork.Consumption
## 1 1922             59.1  23.1    452             65.7
## 2 1923             59.6  23.6    505             74.2
## 3 1924             59.5  24.1    499             74.0
## 4 1925             59.5  24.5    507             66.8
## 5 1926             60.3  24.8    515             64.1
## 6 1927             54.5  26.5    520             67.7
```

```
dim(beef)
```

```
## [1] 20  5
```

```
par(mar = c(4,4,2,2))
pairs(beef)
```




```
#From the graph, it is not clear relationships between
#beef consumption and price. There is a positive trend between beef
consumption and income. For the plot of beef consumption and pork
consumption, it seems to be that there is quadratic relationship. First of
all,I will do backward selection

model1<-
lm(Beef.Consumption~Price*Income*Pork.Consumption+I(Pork.Consumption^2))
summary(model1)

##
## Call:
## lm(formula = Beef.Consumption ~ Price * Income * Pork.Consumption +
##     I(Pork.Consumption^2))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.62382 -0.46222  0.00502  0.58318  1.50781
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    1.339e+03  5.010e+02   2.672   0.0217 *
## Price                         -4.286e+01  1.691e+01  -2.535   0.0277 *
```

```
## Income                          -2.224e+00  9.204e-01  -2.416   0.0342 *
## Pork.Consumption                -1.988e+01  7.864e+00  -2.528   0.0281 *
## I(Pork.Consumption^2)            2.221e-02  1.321e-02   1.681   0.1208
## Price:Income                     8.143e-02  3.235e-02   2.517   0.0286 *
## Price:Pork.Consumption           5.885e-01  2.485e-01   2.368   0.0373 *
## Income:Pork.Consumption          3.312e-02  1.348e-02   2.456   0.0319 *
## Price:Income:Pork.Consumption -1.169e-03  4.748e-04  -2.462   0.0316 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.114 on 11 degrees of freedom
## Multiple R-squared:  0.9642, Adjusted R-squared:  0.9382
## F-statistic: 37.08 on 8 and 11 DF,  p-value: 6.962e-07

#I(Pork.Consumption^2) is the least significant(p-value = 0.1208)

model2<-update(model1,.~.- I(Pork.Consumption^2))
summary(model2)

##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption +
##     Price:Income + Price:Pork.Consumption + Income:Pork.Consumption +
##     Price:Income:Pork.Consumption)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.02168 -0.27308 -0.05372  0.68234  1.33237
##
## Coefficients:
##                                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      8.896e+02  4.549e+02   1.956   0.0742 .
## Price                           -2.778e+01  1.538e+01  -1.806   0.0960 .
## Income                          -1.701e+00  9.300e-01  -1.829   0.0923 .
## Pork.Consumption                -1.182e+01  6.692e+00  -1.767   0.1027
## Price:Income                     5.822e-02  3.141e-02   1.854   0.0885 .
## Price:Pork.Consumption           3.691e-01  2.270e-01   1.626   0.1299
## Income:Pork.Consumption          2.556e-02  1.365e-02   1.873   0.0856 .
## Price:Income:Pork.Consumption -8.319e-04  4.620e-04  -1.800   0.0970 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.196 on 12 degrees of freedom
## Multiple R-squared:  0.9551, Adjusted R-squared:  0.9288
## F-statistic: 36.43 on 7 and 12 DF,  p-value: 3.726e-07

#Price x Income x Pork.Consumption is not significant(p-value = 0.0970)
#so I remove it.
```

```
model3<-update(model2,.~.- Price:Income:Pork.Consumption)
summary(model3)
```

```
##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption +
##     Price:Income + Price:Pork.Consumption + Income:Pork.Consumption)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.10301 -0.70695  0.07241  0.91580  1.54105
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              76.844287  60.954562   1.261   0.2296
## Price                    -0.188936   1.440797  -0.131   0.8977
## Income                   -0.037127   0.111746  -0.332   0.7450
## Pork.Consumption          0.156318   0.779510   0.201   0.8442
## Price:Income              0.001785   0.002165   0.825   0.4245
## Price:Pork.Consumption   -0.038524   0.018233  -2.113   0.0545 .
## Income:Pork.Consumption   0.001080   0.001250   0.864   0.4034
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.295 on 13 degrees of freedom
## Multiple R-squared:  0.9429, Adjusted R-squared:  0.9166
## F-statistic: 35.79 on 6 and 13 DF,  p-value: 2.382e-07
```

```
#Income x Pork.Consumption is not significant(p-value = 0.4034) and is
removed
```

```
model4<-update(model3,.~.- Income:Pork.Consumption)
summary(model4)
```

```
##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption +
##     Price:Income + Price:Pork.Consumption)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.16857 -0.77188  0.03519  0.79001  1.54407
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              38.548559  41.447049   0.930    0.368
## Price                    -0.124739   1.425767  -0.087    0.932
## Income                    0.045175   0.057842   0.781    0.448
## Pork.Consumption          0.651428   0.523434   1.245    0.234
## Price:Income              0.001460   0.002112   0.691    0.501
```

```
## Price:Pork.Consumption -0.036947   0.017976  -2.055    0.059 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.283 on 14 degrees of freedom
## Multiple R-squared:  0.9396, Adjusted R-squared:  0.9181
## F-statistic: 43.59 on 5 and 14 DF,  p-value: 4.793e-08
```

```
#Price x Income is not significant(p-value = 0.501) and is removed

model5<-update(model4, .~. -Price:Income)
summary(model5)
```

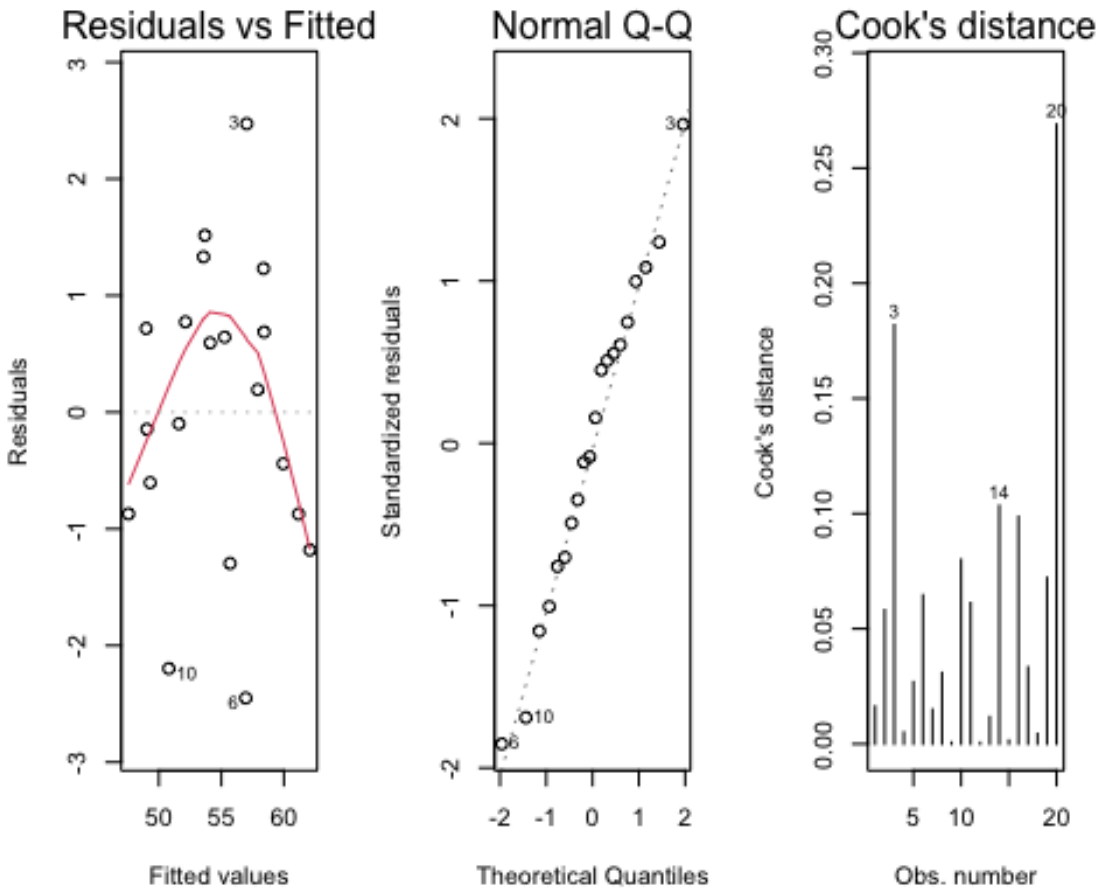
```
##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption +
##     Price:Pork.Consumption)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.36261 -0.44530 -0.07958  0.81633  1.56448
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)            23.213104  34.392252   0.675   0.5100
## Price                   0.431027   1.156673   0.373   0.7146
## Income                  0.084899   0.006371  13.327 1.02e-09 ***
## Pork.Consumption        0.582059   0.504697   1.153   0.2668
## Price:Pork.Consumption -0.034183   0.017218  -1.985   0.0657 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.261 on 15 degrees of freedom
## Multiple R-squared:  0.9376, Adjusted R-squared:  0.9209
## F-statistic: 56.32 on 4 and 15 DF,  p-value: 7.412e-09
```

```
#Price x Pork.Consumption is not significant(p-value = 0.0657) and is removed


model6<-update(model5,.~. -Price:Pork.Consumption)
summary(model6)
```

```
##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.44996 -0.87212  0.04715  0.73206  2.47242
##
```

```
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      90.813646   5.266047  17.245 9.28e-12 ***
## Price            -1.849850   0.145990 -12.671 9.32e-10 ***
## Income            0.083190   0.006868  12.113 1.80e-09 ***
## Pork.Consumption -0.415085   0.053945  -7.695 9.15e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.372 on 16 degrees of freedom
## Multiple R-squared:  0.9212, Adjusted R-squared:  0.9064
## F-statistic: 62.33 on 3 and 16 DF,  p-value: 4.799e-09
```

```
par(mfrow = c(1,3))
plot(model6,which = c(1,2,4))
```

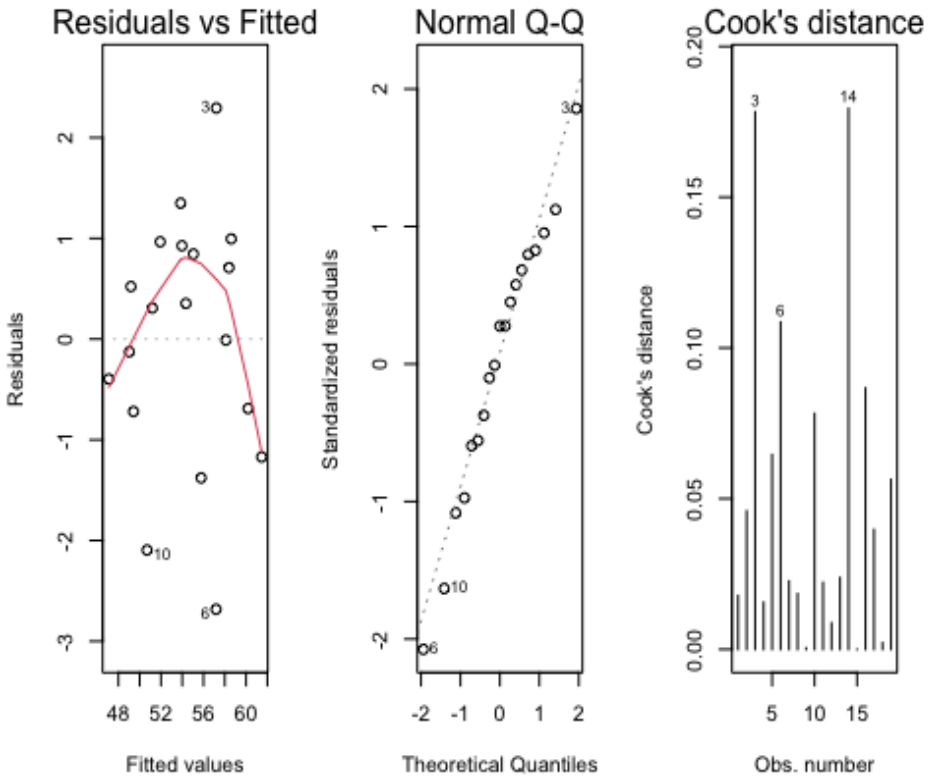



```
#Now, R^2 is 0.9212 which is considerably high and the coefficient estimates
#appear stable and all the effects are significant.Now I check the three
#important plots.
#It is clear that the variance of residuals is now constant
#from Residuals vs Fitted plot. Moreover, the qq plot describes that the
#distribution of the residuals is normally distributed. However, the graph
#of Cooks distance shows that the observation 20 is the most influential
```

```r
element
#so i remove it and see the result

model7<-update(model6,.~.,subset=(1:length(Beef.Consumption)!=20))
summary(model7)
```

```
##
## Call:
## lm(formula = Beef.Consumption ~ Price + Income + Pork.Consumption,
##     subset = (1:length(Beef.Consumption) != 20))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.6827 -0.7045  0.3086  0.8855  2.2941
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      89.400665   5.344763  16.727 4.13e-11 ***
## Price            -1.894812   0.149369 -12.685 2.02e-09 ***
## Income            0.089333   0.008584  10.406 2.95e-08 ***
## Pork.Consumption -0.420366   0.053526  -7.854 1.08e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.356 on 15 degrees of freedom
## Multiple R-squared:  0.9191, Adjusted R-squared:  0.903
## F-statistic: 56.84 on 3 and 15 DF,  p-value: 2.007e-08
```

```r
par(mfrow = c(1,3))
plot(model7,which = c(1,2,4))
```

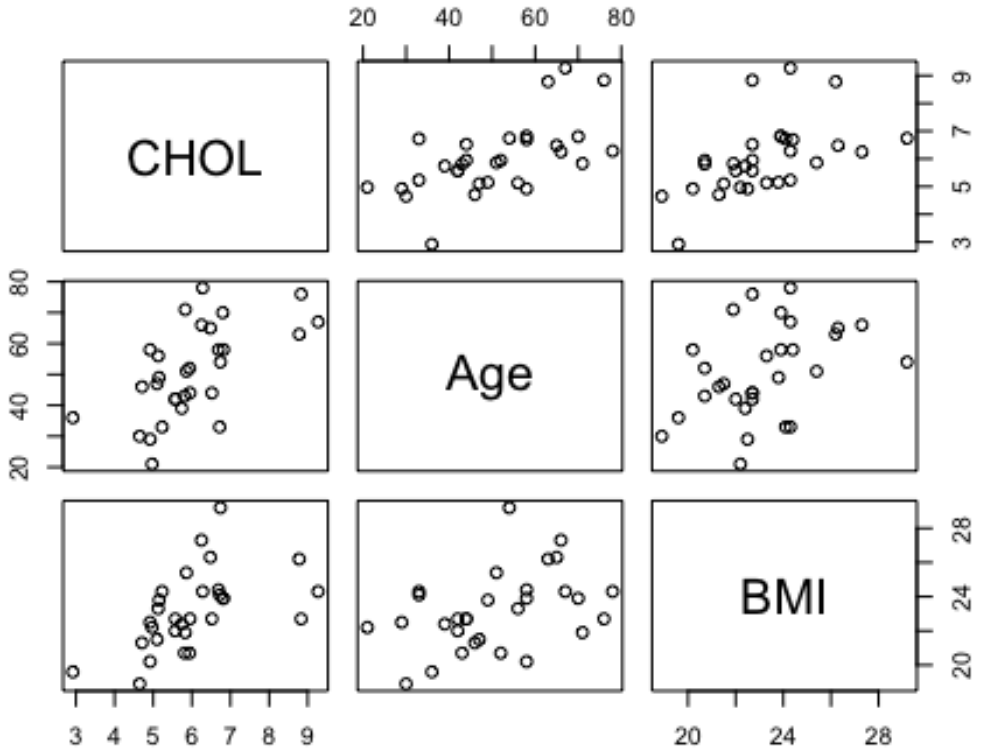



```
confint(model7)

##                          2.5 %      97.5 %
## (Intercept)       78.00857212 100.7927589
## Price             -2.21318371  -1.5764406
## Income             0.07103601   0.1076305
## Pork.Consumption -0.53445295  -0.3062786
```

In conclusion,price, income,and pork consumption as main effects are related to the mean of beef comsumption ,but the interaction of any variables are not related. The equation is Beef.Consumption = 89.400665 +Price-*1.894812 + Income*0.089333 + Pork.Consumption*-0.420366 Also It is clear that there is a postive relationship between beef consumption and Income. When one unit increases in income, the beef consumption increases by 0.089333. On the other hand, there are negative relationships between beef consumption and price,and between beef consumption and pork consumption. When one unit increases in price, the beef consumption decreases by 1.894812 When one unit increases in pork consumption, the beef consumption decreases by 0.420366. The 95% Confidence nterval of intercept is (78.00857212, 100.7927589). The 95% Confidence interval of Price is (-2.21318371, -1.5764406). The 95% Confidence interval of Income is (0.07103601, 0.1076305). The 95% Confidence interval of Pork.Consumption is (-0.53445295 -0.3062786). The variance of residuals is constant and the qq plot shows that the graph is normally distributed. However, R^2 is 0.9191 which means the graph explains the variability of the distribution by Price,Income and Pork.Consumption. Therefore, this model is adequate since The variance of residuals is constant, and it is normally distributed. Also R^2 is pretty high.

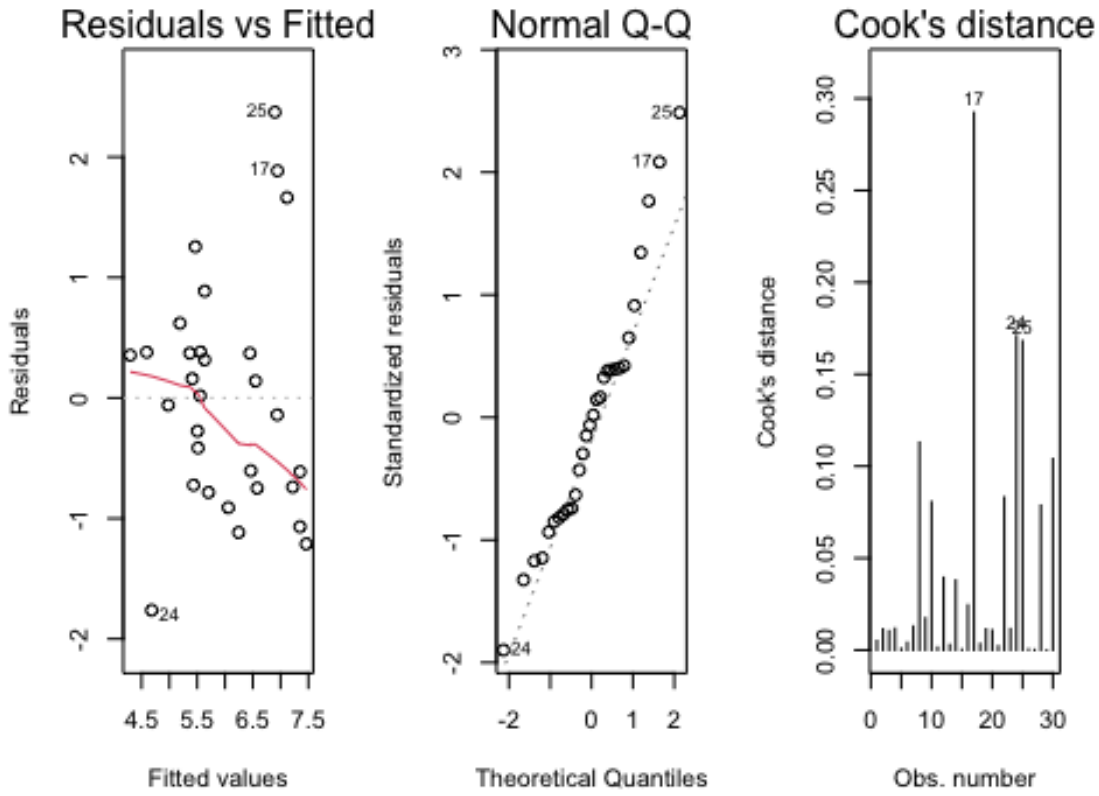
#2. It is well known that the concentrations of cholesterol in blood serum increases with age, but it is less clear whether cholesterol level is also associated with body weight. The data set chol.txt contains data for 30 women and has measures of serum cholesterol (CHOL) in millimoles per liter, age (years) and body mass index (BMI). Use multiple regression to test whether serum cholesterol is associated with body mass index when age is included in the model. Consider carefully how both variables should be included, include initial plots, residual plots etc. Discuss your results carefully.

```
chol <- read.table(file
='~/Desktop/stat359/data/chol.txt',header=TRUE,sep="")
attach(chol)
head(chol)

##   CHOL Age  BMI
## 1 5.94  52 20.7
## 2 4.71  46 21.3
## 3 5.86  51 25.4
## 4 6.52  44 22.7
## 5 6.80  70 23.9
## 6 5.23  33 24.3

summary(chol)

##       CHOL            Age             BMI
##  Min.   :2.920   Min.   :21.00   Min.   :18.90
##  1st Qu.:5.135   1st Qu.:42.00   1st Qu.:21.93
##  Median :5.845   Median :50.00   Median :22.70
##  Mean   :6.005   Mean   :50.70   Mean   :23.18
##  3rd Qu.:6.647   3rd Qu.:61.75   3rd Qu.:24.30
##  Max.   :9.270   Max.   :78.00   Max.   :29.20

pairs(chol)
```




```
#From the graphs, it is clear that there is a positive linear relationship
#between serum cholesterol (CHOL) and body mass index. Also there is a
positive
#linear relationship between serum cholesterol (CHOL) and Age. So I start
with
#the model which will has 2 main effects:Age and BMI and the interaction of
Age
#and BMI.



model <- lm(CHOL ~ Age * BMI, data = chol)
summary(model)

##
## Call:
## lm(formula = CHOL ~ Age * BMI, data = chol)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.56312 -0.72399 -0.05217  0.40839  2.40946
##
## Coefficients:
```

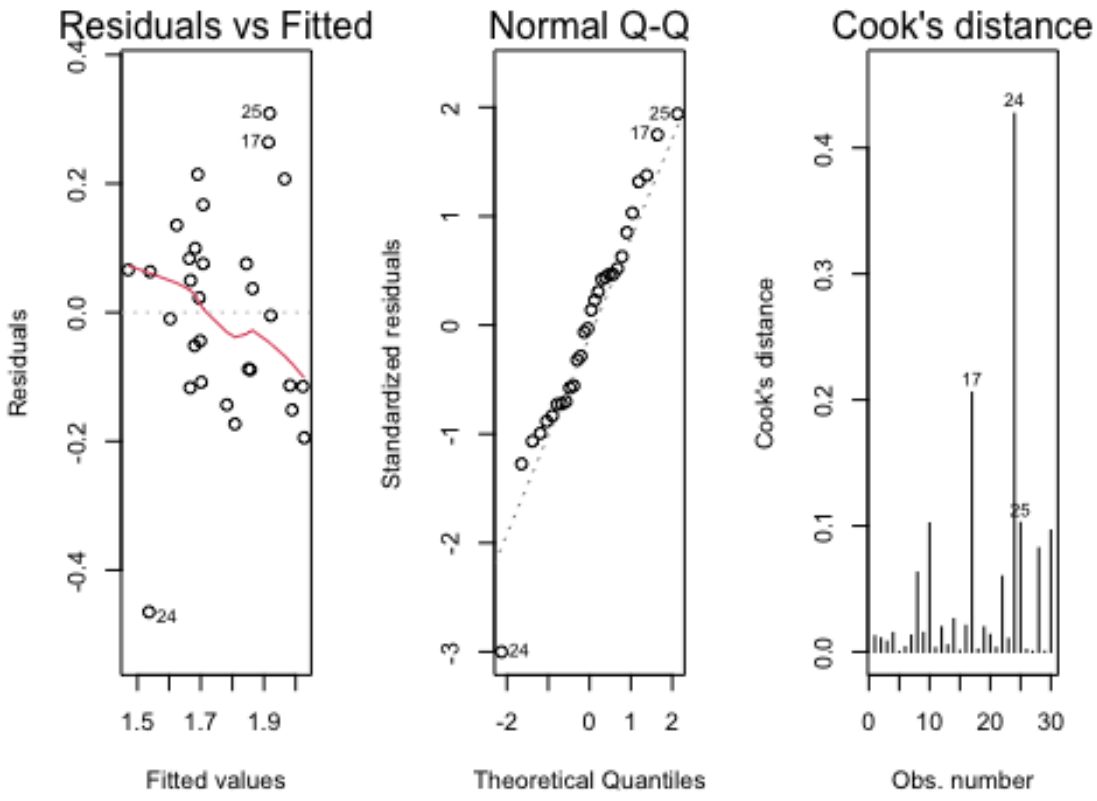
```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -6.546427   8.947853  -0.732    0.471
## Age          0.154186   0.170975   0.902    0.375
## BMI          0.457127   0.395281   1.156    0.258
## Age:BMI     -0.004933   0.007426  -0.664    0.512
##
## Residual standard error: 1.002 on 26 degrees of freedom
## Multiple R-squared:  0.4743, Adjusted R-squared:  0.4137
## F-statistic:  7.82 on 3 and 26 DF,  p-value: 0.0007002

#This initial model has an R^2 = 0.4743 which is considerably small, and
#the interaction term is not significant.So, I will remove it from the model
and
#keep fitting the model with the rest of the data.


model2<-update(model, .~. - Age:BMI)
summary(model2)

##
## Call:
## lm(formula = CHOL ~ Age + BMI, data = chol)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.7619 -0.7353 -0.0205  0.3772  2.3717
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.73983    1.89641  -0.390  0.69951
## Age          0.04097    0.01363   3.006  0.00567 **
## BMI          0.20137    0.08876   2.269  0.03149 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.992 on 27 degrees of freedom
## Multiple R-squared:  0.4654, Adjusted R-squared:  0.4258
## F-statistic: 11.75 on 2 and 27 DF,  p-value: 0.000213

#This second model has an R^2 = 0.4654 which is stil very small but now all
of
#effects are significant. Then I will check the 3 important graphs now.
par(mfrow = c(1,3))
plot(model2, which = c(1,2,4))
```




```
#It is clear that the variance of residuals is not constant and increases
with
#fitted values from Residuals vs Fitted plot.
#Moreover, the qq plot shows that the graph might be right skewed
#Now, I use log tranformation to make the model better.



model3<-lm(log(CHOL)~Age+BMI, data = chol)

summary(model3)

##
## Call:
## lm(formula = log(CHOL) ~ Age + BMI, data = chol)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.46502 -0.11212  0.00883  0.08151  0.30894
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) 0.548262   0.316618   1.732   0.0948 .
## Age         0.006449   0.002276   2.834   0.0086 **
## BMI         0.038581   0.014819   2.604   0.0148 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1656 on 27 degrees of freedom
## Multiple R-squared:  0.4787, Adjusted R-squared:  0.4401
## F-statistic:  12.4 on 2 and 27 DF,  p-value: 0.0001516
```

```
par(mfrow = c(1,3))
plot(model3, which = c(1,2,4))
```



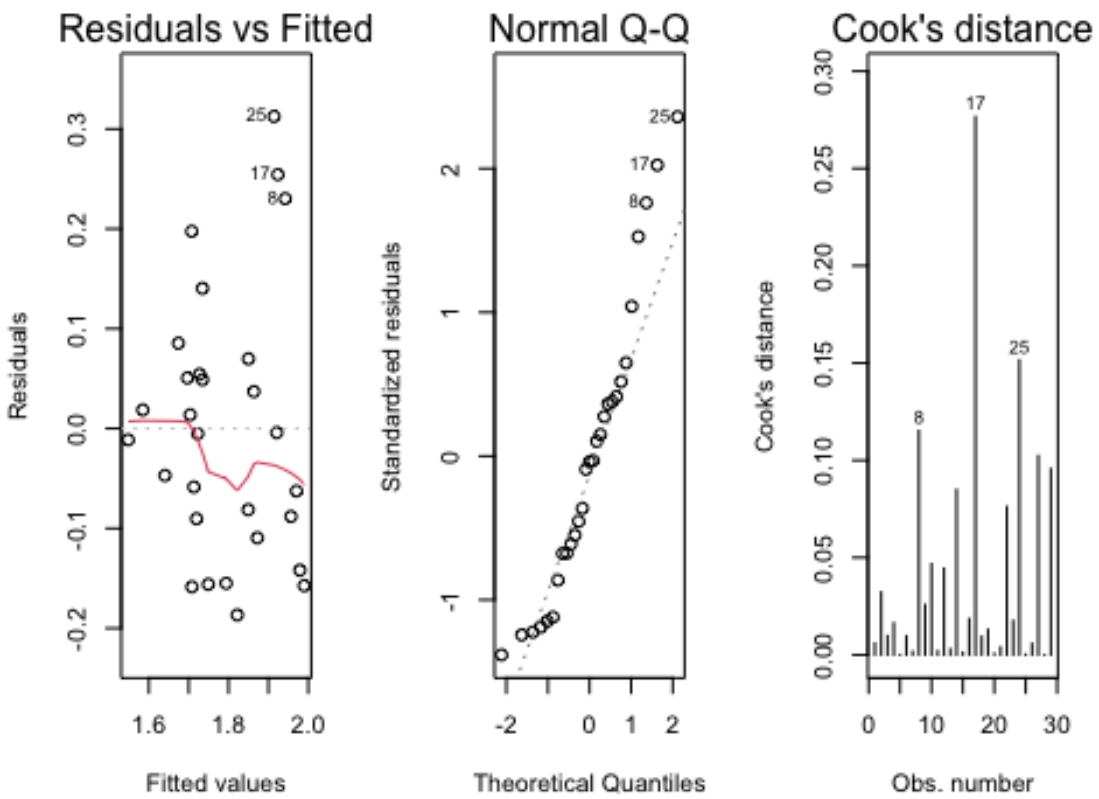

```
#Now the variance of the residuals looks constant, and the distribution of
the
#residuals also normally distributed.However,observation 24 might be
potentially
#influential. So I will remove the observation.
```

```
model4<-update(model3,.~.,subset =(1:length(CHOL)!= 24))
summary(model4)
```

```
##
## Call:
```

```
## lm(formula = log(CHOL) ~ Age + BMI, data = chol, subset = (1:length(CHOL)
!=
##     24))
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.186747 -0.090342 -0.005277  0.054324  0.312609
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.856019   0.276883   3.092  0.00471 **
## Age         0.005917   0.001899   3.116  0.00443 **
## BMI         0.027230   0.012724   2.140  0.04190 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1378 on 26 degrees of freedom
## Multiple R-squared:  0.4616, Adjusted R-squared:  0.4202
## F-statistic: 11.15 on 2 and 26 DF,  p-value: 0.0003195
```

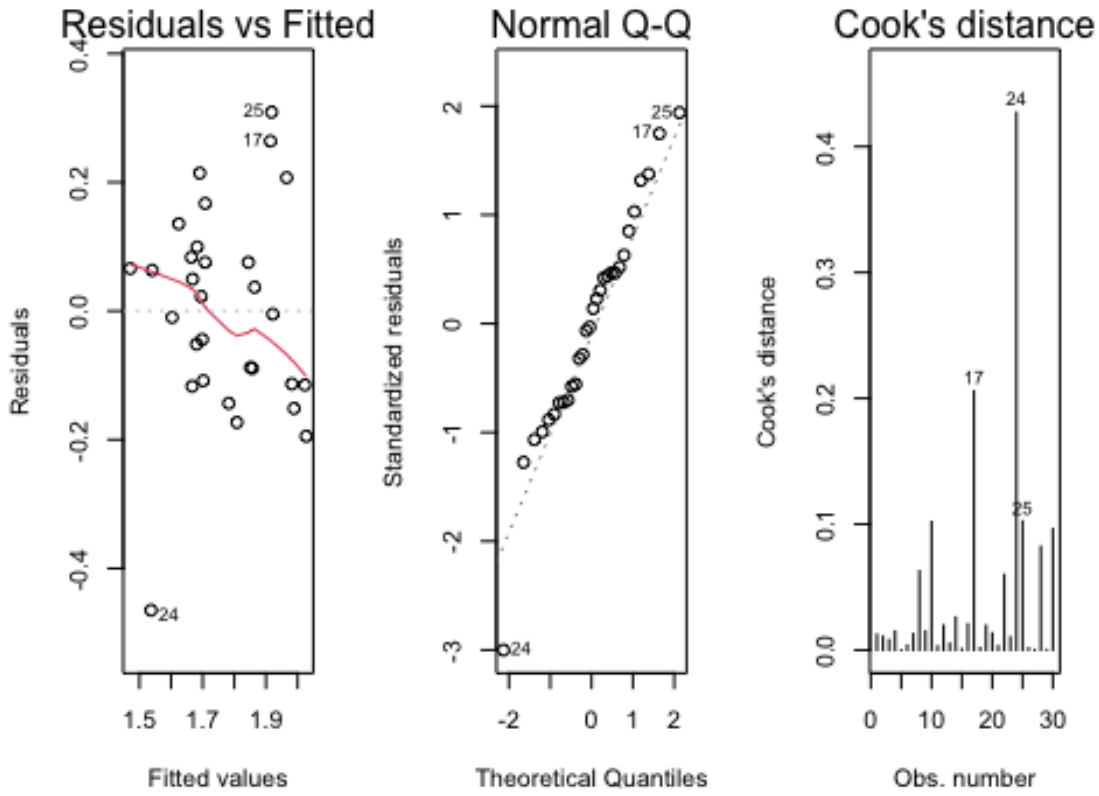
```
par(mfrow = c(1,3))
plot(model4, which = c(1,2,4))
```



```r
#After removing observation 24, the coefficient estimates appear stable
#and also R^2 is stable. However, when I see the plots, model3 has more
constant
#variance of the residuals, and it is more normally distributed.
#So, I will use model3 in this case as the result.



summary(model3)
```

```
##
## Call:
## lm(formula = log(CHOL) ~ Age + BMI, data = chol)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.46502 -0.11212  0.00883  0.08151  0.30894
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.548262   0.316618   1.732   0.0948 .
## Age         0.006449   0.002276   2.834   0.0086 **
## BMI         0.038581   0.014819   2.604   0.0148 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1656 on 27 degrees of freedom
## Multiple R-squared:  0.4787, Adjusted R-squared:  0.4401
## F-statistic:  12.4 on 2 and 27 DF,  p-value: 0.0001516
```

```r
par(mfrow = c(1,3))
plot(model3, which = c(1,2,4))
```




```
confint(model3)

##                    2.5 %     97.5 %
## (Intercept) -0.101383385 1.19790770
## Age          0.001779404 0.01111773
## BMI          0.008176087 0.06898639
```

In conclusion,age and BMI is related to the mean of log concentrations of cholesterol in blood serum,but the interaction of age and BMI is not related. The equation is log(CHOL) = 0.5483 + Age**0.006449 + BMI**0.038581 Also It is clear that BMI is more assortiated with the mean of cholesterol level than Age.Everytime when one unit increases in BMI, log Chol increases by 0.038581 which is much higher than increasing one unit of age which lead log CHOL to increase by 0.001779404. The 95% Confidence interval of intercept is (-0.101383385, 1.19790770). The 95% Confidence interval of Age is (0.001779404, 0.01111773). The 95% Confidence interval of BMI is (0.008176087 0.06898639).

The variance of residuals is constant and the qq plot shows that the graph is normally distributed.However, R^2 is 0.4787 which means only half of variability can be explained by Age and BMI. However,this model is adequate since The variance of residuals is constant,and it is normally distributed.