Economic Card Dataset

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Reading in Card Data and GLM construction

```
library("boot")
```

```
set.seed(101)

card = read.csv("card.csv")
card = card[,c("X",
               "educ",
               "wage",
               "age",
               "black",
               "married",
               "region",
               "south",
               "kww",
               "iq",
               "exper")]
card$black = as.factor(card$black)
card$married = as.factor(card$married)
card$region = as.factor(card$region)
card$south = as.factor(card$south)
head(card)
```

```
##   X educ     wage age black married region south kww       iq exper
## 1 1    7 27.24656  29     1       1      1     0  15 102.4498    16
## 2 2   12 23.91532  27     0       1      1     0  35  93.0000     9
## 3 3   12 35.84813  34     0       1      1     0  42 103.0000    16
## 4 4   11 12.43000  27     0       1      2     0  25  88.0000    10
## 5 5   12 36.24588  34     0       1      2     0  34 108.0000    16
## 6 6   12 24.86000  26     0       1      2     0  38  85.0000     8
```

```
newLogWage = glm(log(wage)~educ+age+black+married+region+iq+kww+south,data=card)
cv.glm(card,newLogWage,K=10)$delta[1]
```

```
## [1] 0.139402
```

```r
mean(((log(card$wage)-fitted(newLogWage))/(1-hatvalues(newLogWage)))^2)
```

```
## [1] 0.1392593
```

```r
# LOOCV and CV errors similar for the model fit
```

Evaluating the new model

```r
set.seed(101)

interactionLogModel = glm(log(wage)~black+married+
                            region+iq+kww+south
                          +iq*educ
                          +poly(age,2),
                          data=card)
summary(interactionLogModel)
```

```
##
## Call:
## glm(formula = log(wage) ~ black + married + region + iq + kww +
##     south + iq * educ + poly(age, 2), data = card)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.61121  -0.23088   0.00944   0.24094   1.44834
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     1.9640213  0.3357764   5.849 5.47e-09 ***
## black1         -0.1111143  0.0195996  -5.669 1.57e-08 ***
## married1        0.1399185  0.0155635   8.990  < 2e-16 ***
## region2         0.1206504  0.0357929   3.371 0.000759 ***
## region3         0.1535727  0.0351086   4.374 1.26e-05 ***
## region4         0.0174129  0.0414217   0.420 0.674237
## region5         0.1327480  0.0416196   3.190 0.001440 **
## region6         0.1239633  0.0448165   2.766 0.005709 **
## region7         0.1429622  0.0446398   3.203 0.001376 **
## region8        -0.0639819  0.0513274  -1.247 0.212662
## region9         0.1606599  0.0388842   4.132 3.70e-05 ***
## iq              0.0047246  0.0032508   1.453 0.146229
## kww             0.0087879  0.0011002   7.988 1.94e-15 ***
## south1         -0.1710010  0.0257528  -6.640 3.71e-11 ***
## educ            0.0637878  0.0245623   2.597 0.009451 **
## poly(age, 2)1   4.6732540  0.4271917  10.939  < 2e-16 ***
## poly(age, 2)2 -0.6659543  0.3768321  -1.767 0.077289 .
## iq:educ        -0.0003294  0.0002330  -1.414 0.157482
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.1383322)
```

```
##
##     Null deviance: 592.64  on 3009  degrees of freedom
## Residual deviance: 413.89  on 2992  degrees of freedom
## AIC: 2607.9
##
## Number of Fisher Scoring iterations: 2
```

```
cv.glm(card,interactionLogModel,K=10)$delta[1]
```

```
## [1] 0.1394704
```

```
mean(((log(card$wage)-fitted(interactionLogModel))/(1-hatvalues(interactionLogModel)))^2)
```

```
## [1] 0.1392527
```

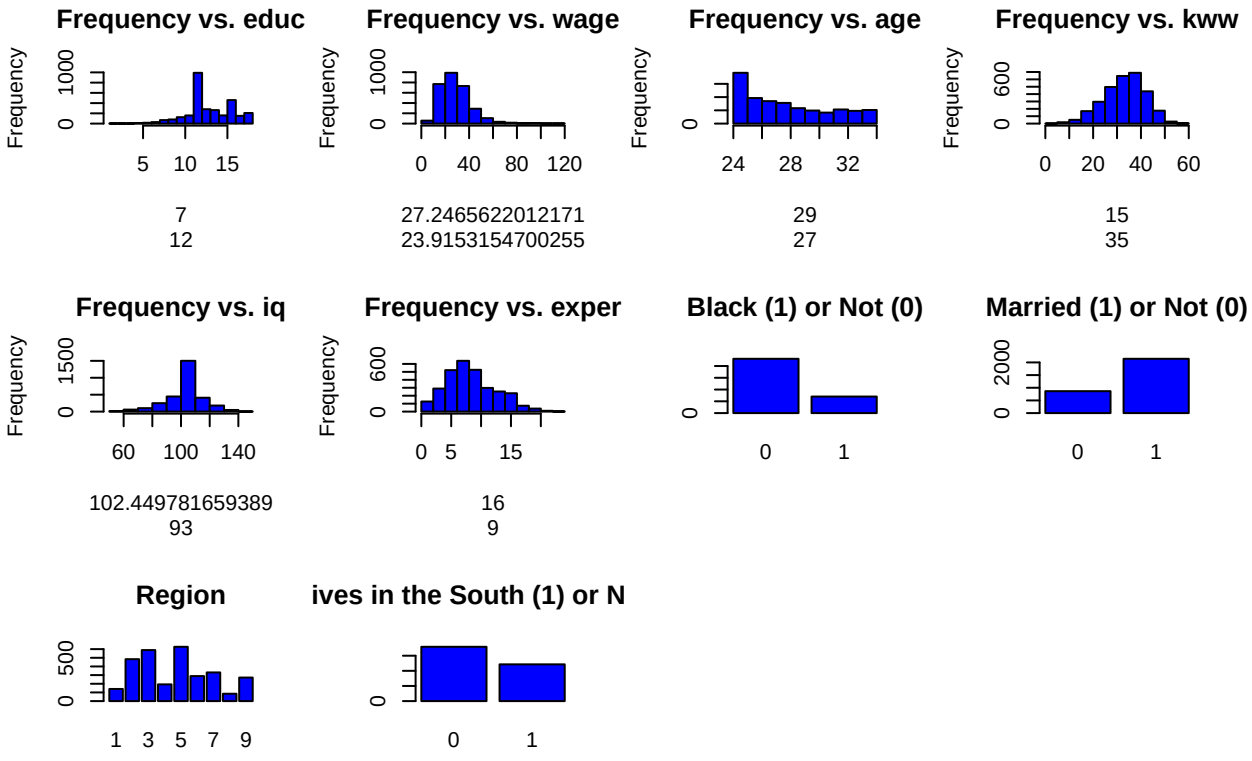
Further EDA on the Card Dataset

```
summary(card)
```

```
##        X                educ            wage                age         black
##  Min.   :   1.0   Min.   : 1.00   Min.   :  4.972   Min.   :24.00   0:2307
##  1st Qu.: 753.2   1st Qu.:12.00   1st Qu.: 19.602   1st Qu.:25.00   1: 703
##  Median :1505.5   Median :13.00   Median : 26.724   Median :28.00
##  Mean   :1505.5   Mean   :13.26   Mean   : 28.702   Mean   :28.12
##  3rd Qu.:2257.8   3rd Qu.:16.00   3rd Qu.: 35.239   3rd Qu.:31.00
##  Max.   :3010.0   Max.   :18.00   Max.   :119.527   Max.   :34.00
##
##  married      region    south         kww              iq
##  0: 866   5      :627   0:1795   Min.   : 4.00   Min.   : 50.0
##  1:2144   3      :589   1:1215   1st Qu.:28.00   1st Qu.: 98.0
##           2      :484            Median :34.00   Median :102.4
##           7      :331            Mean   :33.54   Mean   :102.4
##           6      :289            3rd Qu.:40.00   3rd Qu.:108.0
##           9      :272            Max.   :56.00   Max.   :149.0
##           (Other):418
##      exper
##  Min.   : 0.000
##  1st Qu.: 6.000
##  Median : 8.000
##  Mean   : 8.856
##  3rd Qu.:11.000
##  Max.   :23.000
##
```

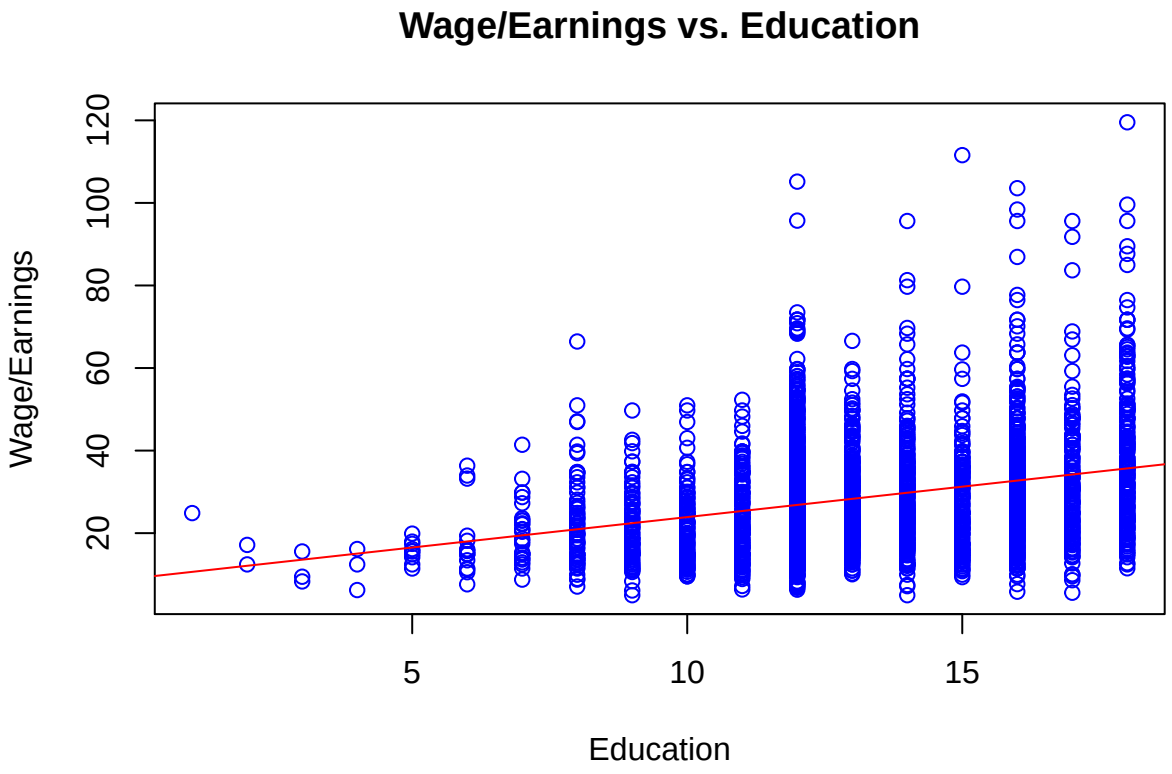
```
par(mfrow=c(3,4))
hist(card[["educ"]],
     xlab=card$educ,
     main=sprintf("Frequency vs. %s", "educ"),
     col="blue")
```

```r
hist(card[["wage"]],
     xlab=card$wage,
     main=sprintf("Frequency vs. %s", "wage"),
     col="blue")
hist(card[["age"]],
     xlab=card$age,
     main=sprintf("Frequency vs. %s", "age"),
     col="blue")
hist(card[["kww"]],
     xlab=card$kww,
     main=sprintf("Frequency vs. %s", "kww"),
     col="blue")
hist(card[["iq"]],
     xlab=card$iq,
     main=sprintf("Frequency vs. %s", "iq"),
     col="blue")
hist(card[["exper"]],
     xlab=card$exper,
     main=sprintf("Frequency vs. %s", "exper"),
     col="blue")
barplot(table(card$black),col="blue",main="Black (1) or Not (0)")
barplot(table(card$married),col="blue",main="Married (1) or Not (0)")
barplot(table(card$region),col="blue",main="Region")
barplot(table(card$south),col="blue",main="Lives in the South (1) or Not (0)")
```



Earnings vs. Education Regression and Plot

```
plot(x=card$educ,
     y=card$wage,
     xlab="Education",
     ylab="Wage/Earnings",
     main="Wage/Earnings vs. Education",
     col="blue")
educEarnModel = lm(wage~educ,data=card)
abline(educEarnModel,col="red")
```




```
summary(educEarnModel)
```

```
##
## Call:
## lm(formula = wage ~ educ, data = card)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -28.643  -8.619  -1.697   6.355  83.841
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   9.1459     1.1487   7.962 2.38e-15 ***
## educ          1.4745     0.0849  17.368  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

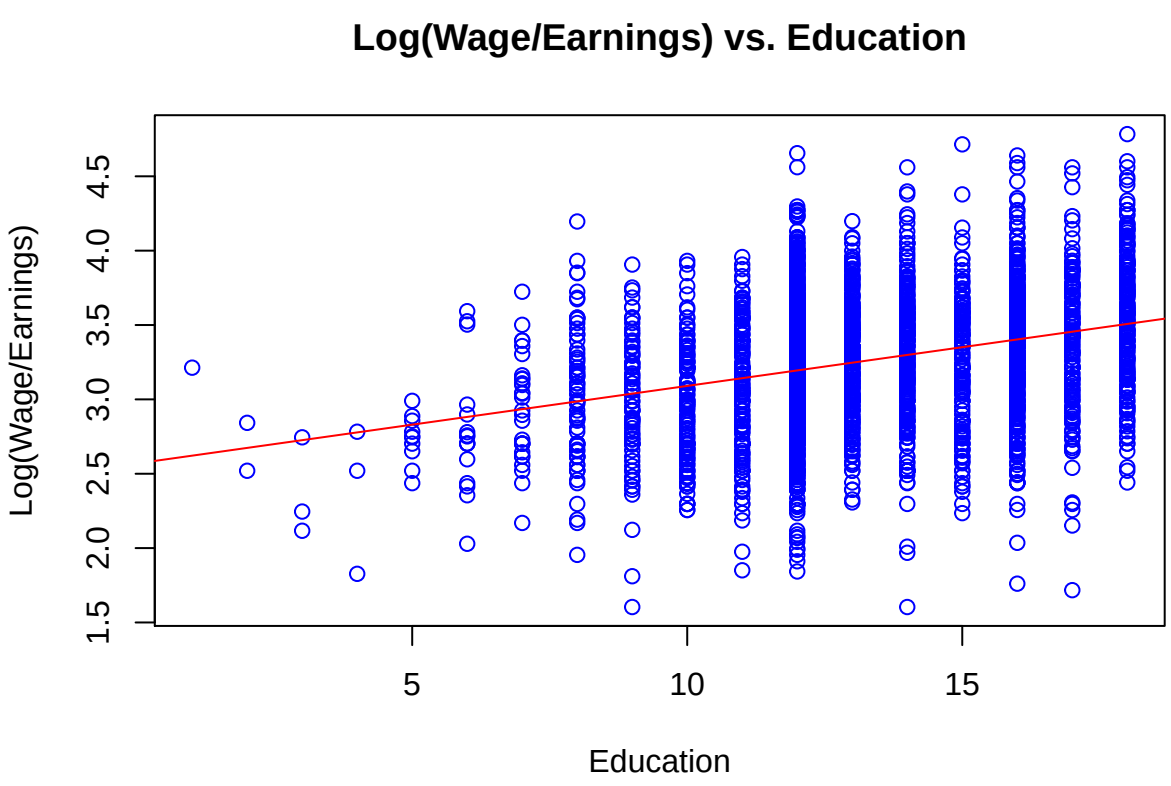
```
##
## Residual standard error: 12.47 on 3008 degrees of freedom
## Multiple R-squared:  0.09114,    Adjusted R-squared:  0.09084
## F-statistic: 301.6 on 1 and 3008 DF,  p-value: < 2.2e-16
```

```
confint(educEarnModel, 'educ', level=0.95)
```

```
##         2.5 %   97.5 %
## educ 1.308006 1.640931
```

Log Earnings vs. Education Regression and Plot

```
plot(x=card$educ,y=log(card$wage),
     xlab="Education",
     ylab="Log(Wage/Earnings)",
     main="Log(Wage/Earnings) vs. Education",
     col="blue")
logeducEarnModel = lm(log(wage)~educ,data=card)
abline(logeducEarnModel,col="red")
```




```
summary(logeducEarnModel)
```

```
##
## Call:
## lm(formula = log(wage) ~ educ, data = card)
##
```

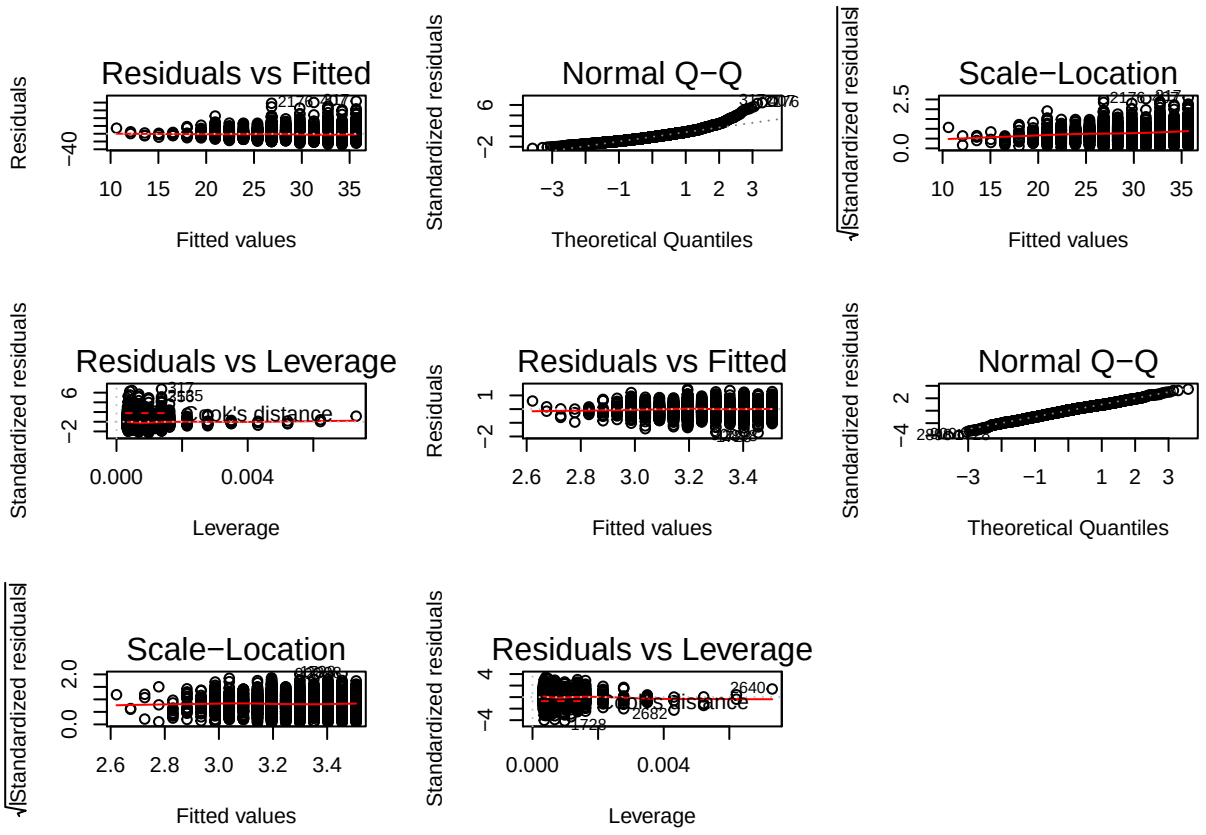
```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.73799 -0.27764  0.02373  0.28839  1.46080
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.56953    0.03883   66.17   <2e-16 ***
## educ         0.05209    0.00287   18.15   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4214 on 3008 degrees of freedom
## Multiple R-squared:  0.09874,    Adjusted R-squared:  0.09844
## F-statistic: 329.5 on 1 and 3008 DF,  p-value: < 2.2e-16
```

```
confint(logeducEarnModel, 'educ', level=0.95)
```

```
##           2.5 %     97.5 %
## educ 0.04646744 0.05772102
```

(c)

```
par(mfrow=c(3,3))
plot(educEarnModel)

plot(logeducEarnModel)
```



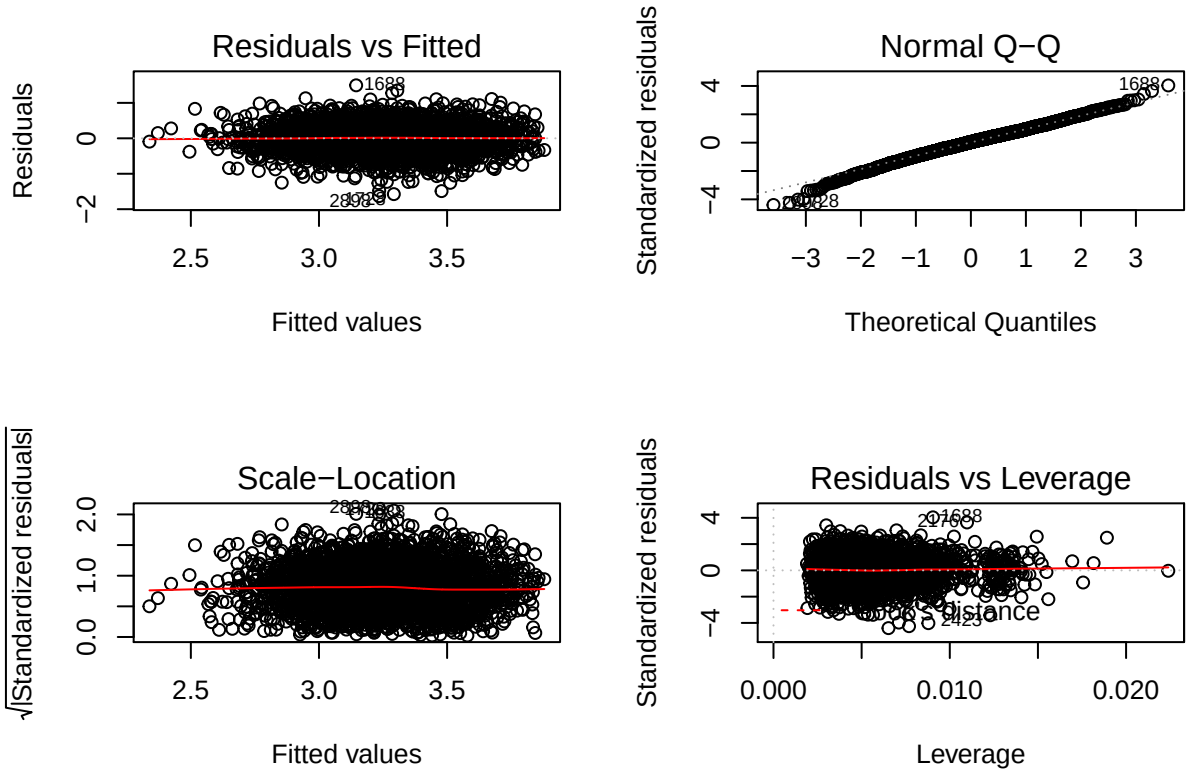
Log Earnings Regression vs Education, Age, Race, Marriage Status, Region, IQ, KWW, South

```
par(mfrow=c(2,2))
newLogWage = lm(log(wage)~educ+age+black+married+region+iq+kww+south,data=card)
summary(newLogWage)
```

```
##
## Call:
## lm(formula = log(wage) ~ educ + age + black + married + region +
##     iq + kww + south, data = card)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.63072 -0.22937  0.01542  0.24118  1.49509
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.6763037  0.0972067  17.245  < 2e-16 ***
## educ         0.0295873  0.0030650   9.653  < 2e-16 ***
## age          0.0266427  0.0024679  10.796  < 2e-16 ***
## black1      -0.1102251  0.0196038  -5.623 2.05e-08 ***
## married1     0.1426869  0.0155156   9.196  < 2e-16 ***
## region2      0.1200313  0.0358065   3.352 0.000812 ***
## region3      0.1547695  0.0351023   4.409 1.07e-05 ***
## region4      0.0196517  0.0414124   0.475 0.635152
```

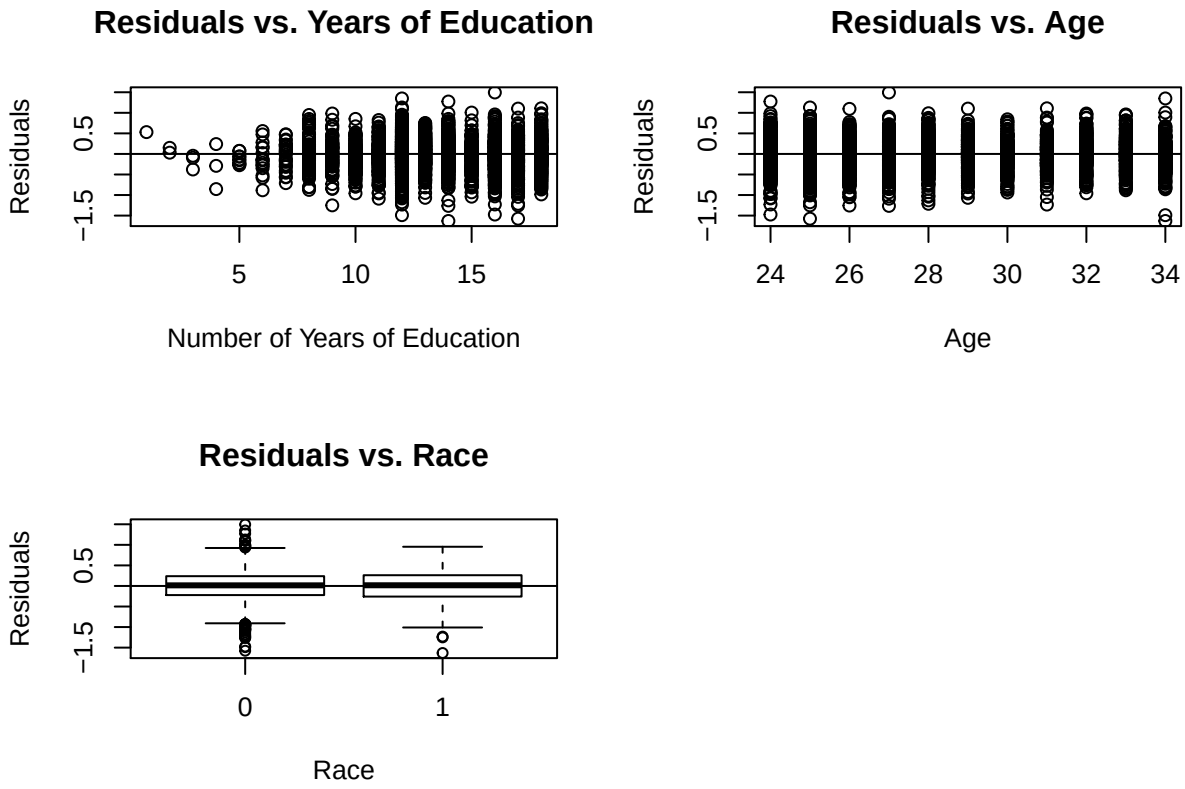
```
## region5      0.1338119  0.0416350   3.214 0.001323 **
## region6      0.1289298  0.0447631   2.880 0.004002 **
## region7      0.1458298  0.0446395   3.267 0.001100 **
## region8     -0.0601312  0.0513092  -1.172 0.241315
## region9      0.1617159  0.0388762   4.160 3.28e-05 ***
## iq           0.0001470  0.0005928   0.248 0.804118
## kww          0.0089672  0.0010976   8.170 4.49e-16 ***
## south1      -0.1714418  0.0257626  -6.655 3.36e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3721 on 2994 degrees of freedom
## Multiple R-squared:  0.3005, Adjusted R-squared:  0.297
## F-statistic: 85.76 on 15 and 2994 DF,  p-value: < 2.2e-16
```

```
plot(newLogWage)
```

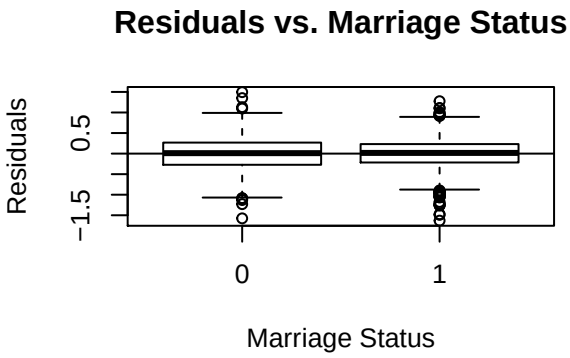


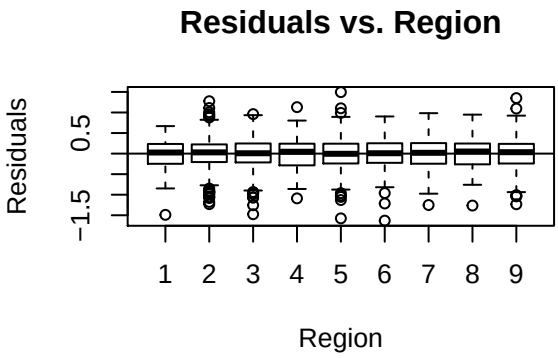

```
# aside from plotting residuals vs fitted we look at residual vs. covariate plots

plot(card$educ,resid(newLogWage),
     xlab="Number of Years of Education",
     ylab="Residuals",
     main="Residuals vs. Years of Education")
abline(a=0,b=0)
plot(card$age,resid(newLogWage),
     xlab="Age",
     ylab="Residuals",
     main="Residuals vs. Age")
```

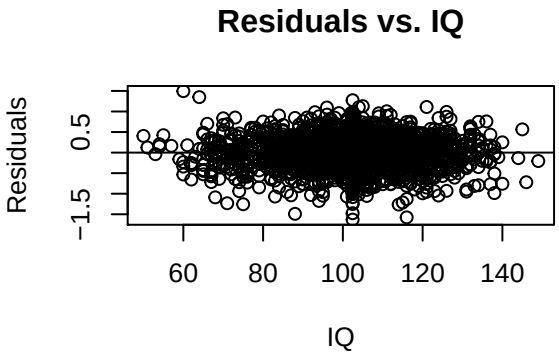
```
abline(a=0,b=0)
plot(card$black,resid(newLogWage),
     xlab="Race",
     ylab="Residuals",
     main="Residuals vs. Race")
abline(a=0,b=0)
```

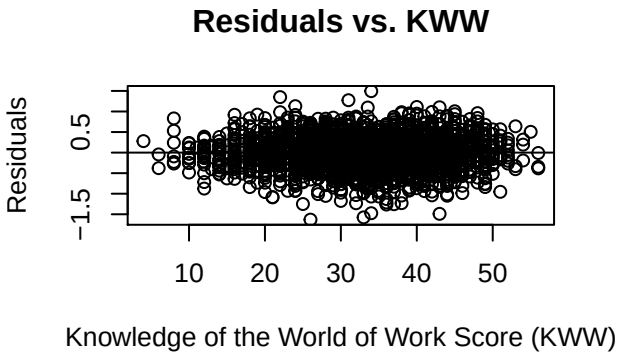



```
par(mfrow=c(2,2))
plot(card$married,resid(newLogWage),
     xlab="Marriage Status",
     ylab="Residuals",
     main="Residuals vs. Marriage Status")
abline(a=0,b=0)
plot(card$region,resid(newLogWage),
     xlab="Region",
     ylab="Residuals",
     main="Residuals vs. Region")
abline(a=0,b=0)
plot(card$iq,resid(newLogWage),
     xlab="IQ",
     ylab="Residuals",
     main="Residuals vs. IQ")
abline(a=0,b=0)
plot(card$kww,resid(newLogWage),
     xlab="Knowledge of the World of Work Score (KWW)",
     ylab="Residuals",
     main="Residuals vs. KWW")
abline(a=0,b=0)
```

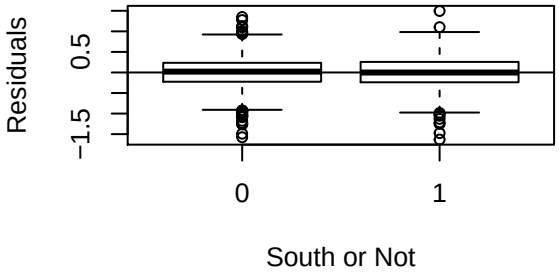









```
plot(card$south,
     resid(newLogWage),
     xlab="South or Not",
     ylab="Residuals",
     main="Residuals vs. South")
abline(a=0,b=0)
```



Confidence Interval of Race Coefficient

```
summary(newLogWage)$coefficients[4,] # race row
```

```
##      Estimate    Std. Error       t value      Pr(>|t|)
## -1.102251e-01  1.960375e-02 -5.622654e+00  2.053554e-08
```

```r
confint(newLogWage, "black1",level=0.95)
```

```
##             2.5 %      97.5 %
## black1 -0.1486633 -0.07178693
```

Confidence Interval of Education Coefficient

```r
summary(newLogWage)$coefficients[2,] # race row
```

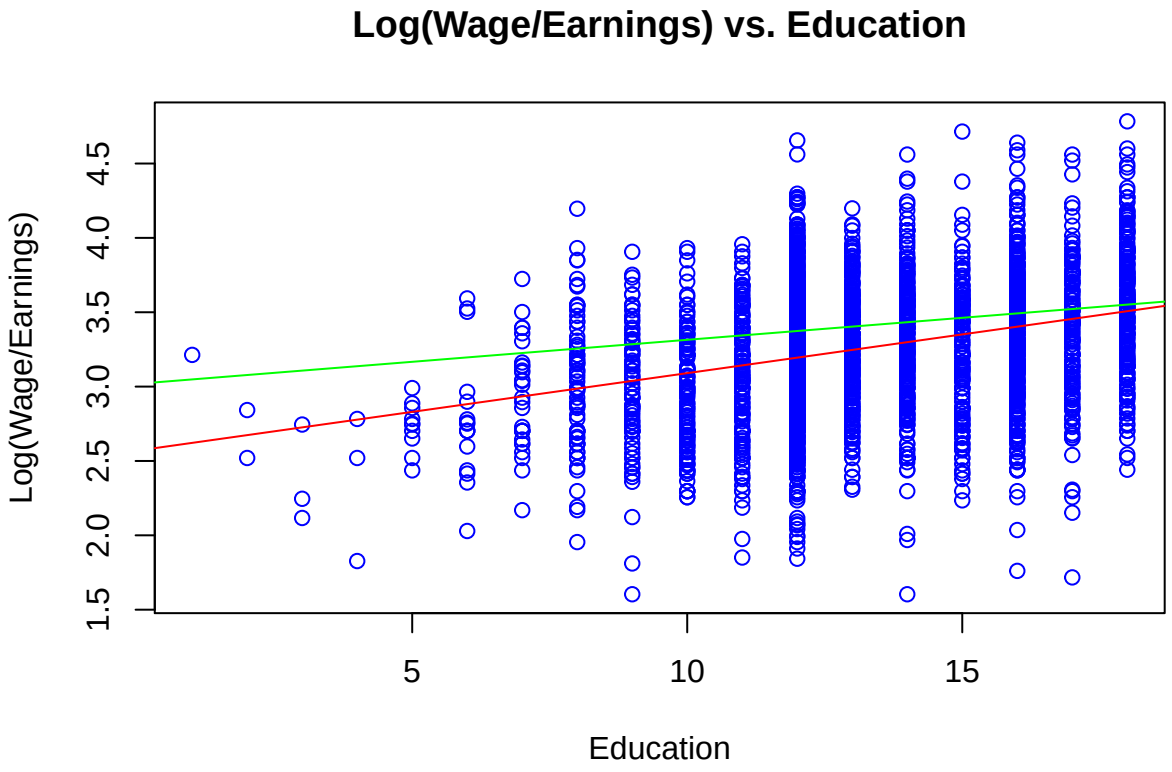
```
##     Estimate   Std. Error      t value     Pr(>|t|)
## 2.958727e-02 3.065042e-03 9.653134e+00 9.849542e-22
```

```r
confint(newLogWage, "educ",level=0.95)
```

```
##           2.5 %     97.5 %
## educ 0.02357746 0.03559707
```

Plotting Model Log Earnings vs. Education Holding Other Covariates Constant

```r
newEduModeld = lm(log(wage)~educ+region+age+iq+kww+married+black+south,data=card)
interceptval = newEduModeld$coefficients["(Intercept)"]+
  newEduModeld$coefficients["age"]*median(card$age)+
      newEduModeld$coefficients["married1"]+
        newEduModeld$coefficients["iq"]*median(card$iq)+
        newEduModeld$coefficients["kww"]*median(card$kww)+
        newEduModeld$coefficients["region5"]
educ = newEduModeld$coefficients["educ"]

plot(x=card$educ,y=log(card$wage),
     xlab="Education",
     ylab="Log(Wage/Earnings)",
     main="Log(Wage/Earnings) vs. Education",
     col="blue")
abline(a=interceptval,b=educ,col="green")
abline(logeducEarnModel,col="red")
```



Log Earnings vs Education, Region, Age, IQ, KWW, Marriage Status, Experience, Living in the South and Race

```
newMedModele = lm(log(wage)~educ+region+age+iq+kww+married+black+south+exper,data=card)
summary(newMedModele)
```

```
##
## Call:
## lm(formula = log(wage) ~ educ + region + age + iq + kww + married +
##     black + south + exper, data = card)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.63072 -0.22937  0.01542  0.24118  1.49509
##
## Coefficients: (1 not defined because of singularities)
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.6763037  0.0972067  17.245  < 2e-16 ***
## educ         0.0295873  0.0030650   9.653  < 2e-16 ***
## region2      0.1200313  0.0358065   3.352 0.000812 ***
## region3      0.1547695  0.0351023   4.409 1.07e-05 ***
## region4      0.0196517  0.0414124   0.475 0.635152
## region5      0.1338119  0.0416350   3.214 0.001323 **
## region6      0.1289298  0.0447631   2.880 0.004002 **
## region7      0.1458298  0.0446395   3.267 0.001100 **
## region8     -0.0601312  0.0513092  -1.172 0.241315
## region9      0.1617159  0.0388762   4.160 3.28e-05 ***
```

```
## age          0.0266427  0.0024679  10.796  < 2e-16 ***
## iq           0.0001470  0.0005928   0.248 0.804118
## kww          0.0089672  0.0010976   8.170 4.49e-16 ***
## married1     0.1426869  0.0155156   9.196  < 2e-16 ***
## black1      -0.1102251  0.0196038  -5.623 2.05e-08 ***
## south1      -0.1714418  0.0257626  -6.655 3.36e-11 ***
## exper               NA         NA      NA       NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3721 on 2994 degrees of freedom
## Multiple R-squared:  0.3005, Adjusted R-squared:  0.297
## F-statistic: 85.76 on 15 and 2994 DF,  p-value: < 2.2e-16
```

```
summary(lm(age~exper,data=card))
```

```
##
## Call:
## lm(formula = age ~ exper, data = card)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -7.827 -1.625 -0.157  1.375  5.219
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 23.001009   0.087262  263.59   <2e-16 ***
## exper        0.577971   0.008926   64.75   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.028 on 3008 degrees of freedom
## Multiple R-squared:  0.5823, Adjusted R-squared:  0.5821
## F-statistic:  4193 on 1 and 3008 DF,  p-value: < 2.2e-16
```

```
summary(lm(educ~exper,data=card))
```

```
##
## Call:
## lm(formula = educ ~ exper, data = card)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -7.827 -1.625 -0.157  1.375  5.219
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 17.001009   0.087262  194.83   <2e-16 ***
## exper       -0.422029   0.008926  -47.28   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.028 on 3008 degrees of freedom
```

```
## Multiple R-squared:  0.4264, Adjusted R-squared:  0.4262
## F-statistic:  2236 on 1 and 3008 DF,  p-value: < 2.2e-16
```

```r
summary(lm(iq~exper,data=card))
```

```
##
## Call:
## lm(formula = iq ~ exper, data = card)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -51.512  -5.054   0.118   6.762  45.126
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 109.70661    0.52948  207.19   <2e-16 ***
## exper        -0.81941    0.05416  -15.13   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.3 on 3008 degrees of freedom
## Multiple R-squared:  0.07072,    Adjusted R-squared:  0.07041
## F-statistic: 228.9 on 1 and 3008 DF,  p-value: < 2.2e-16
```

Notable conclusions are that there's stronger association when simply regressing log earnings compared to holding other factors constant. This could divulge that other factors such as being older, white or living in a specific region are associated with higher earnings. Also, the non-invertibility of the design matrix when experience is added in reveals correlation between education and experience.