MACSS30200 PS#3

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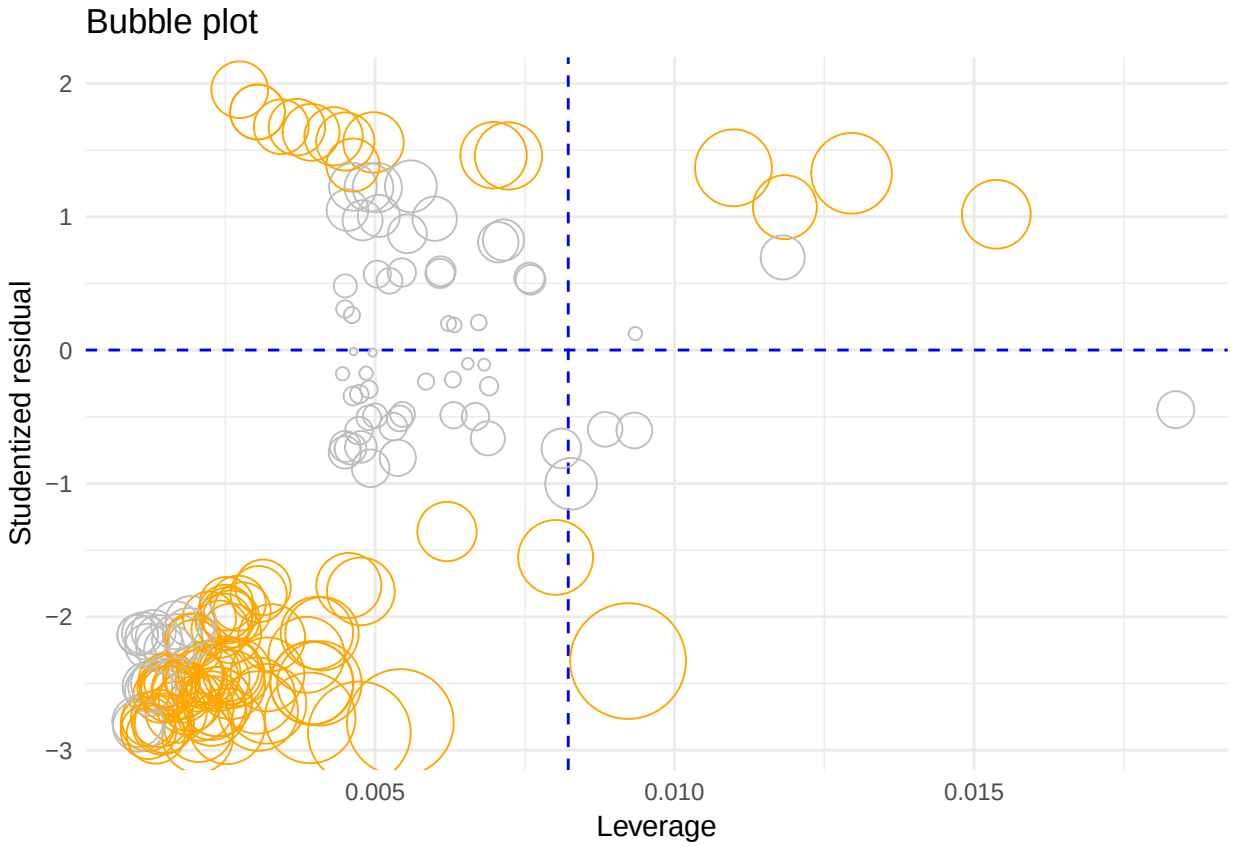
Regression diagnostics

```
##
## Call:
## lm(formula = biden ~ age + female + educ, data = df_biden)
##
## Residuals:
##    Min     1Q Median     3Q    Max
##  -67.1  -14.7    0.7   18.9   45.1
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  68.6210     3.5960   19.08  < 2e-16 ***
## age           0.0419     0.0325    1.29      0.2
## female        6.1961     1.0967    5.65  1.9e-08 ***
## educ         -0.8887     0.2247   -3.96  7.9e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.2 on 1803 degrees of freedom
## Multiple R-squared:  0.0272, Adjusted R-squared:  0.0256
## F-statistic: 16.8 on 3 and 1803 DF,  p-value: 8.88e-11
```

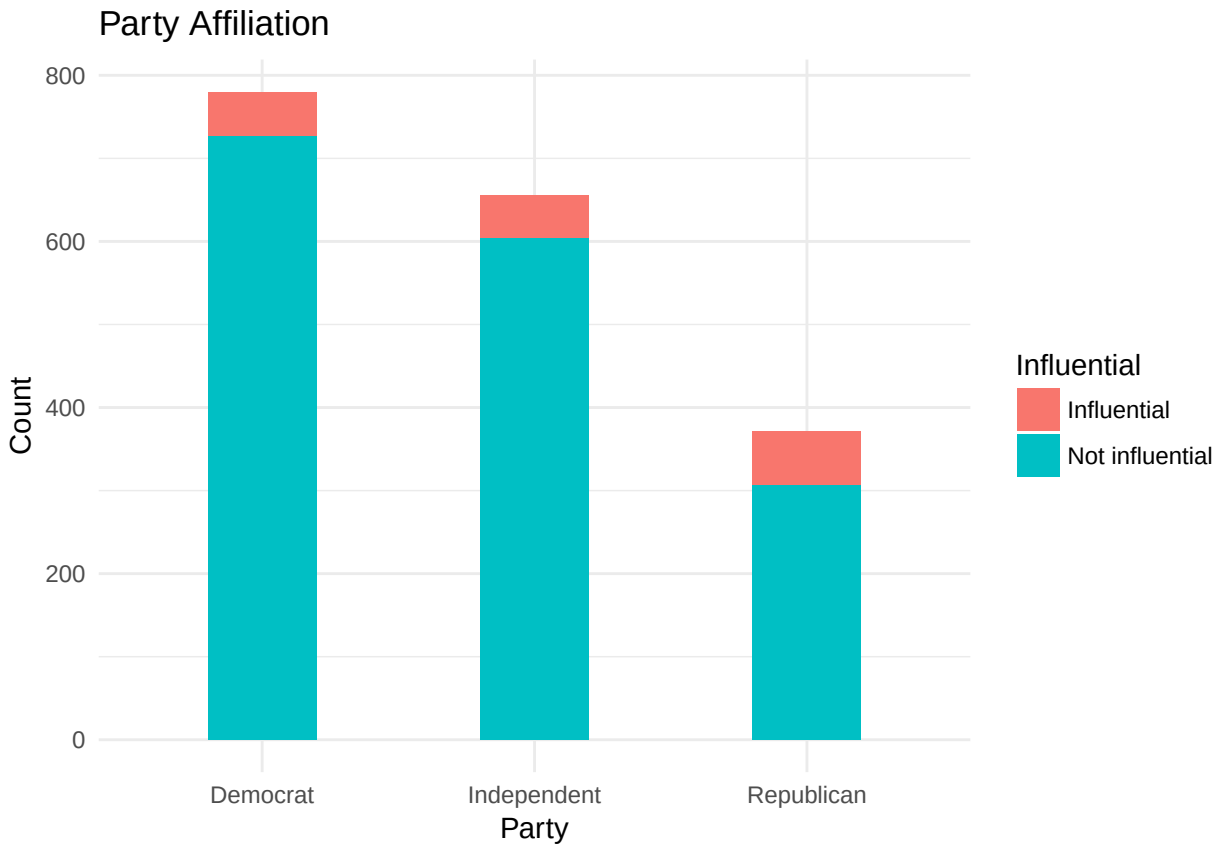
β_0 for intercept of the multiple linear regression is 68.6210 and standard error is 3.5960 and β_1 for age is 0.0419 and standard error is 0.0325. β_2 for gender is 6.1961 and standard error is 1.0967 and β_3 for education is -0.8887 and standard error is 0.2247.

1

```
## [1] 167
```

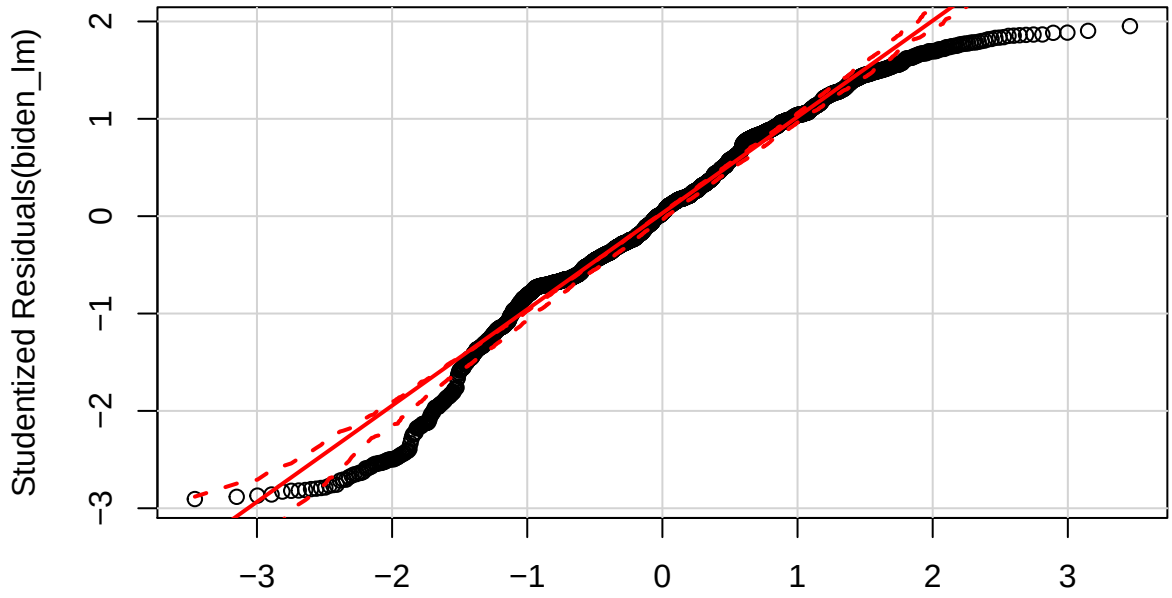


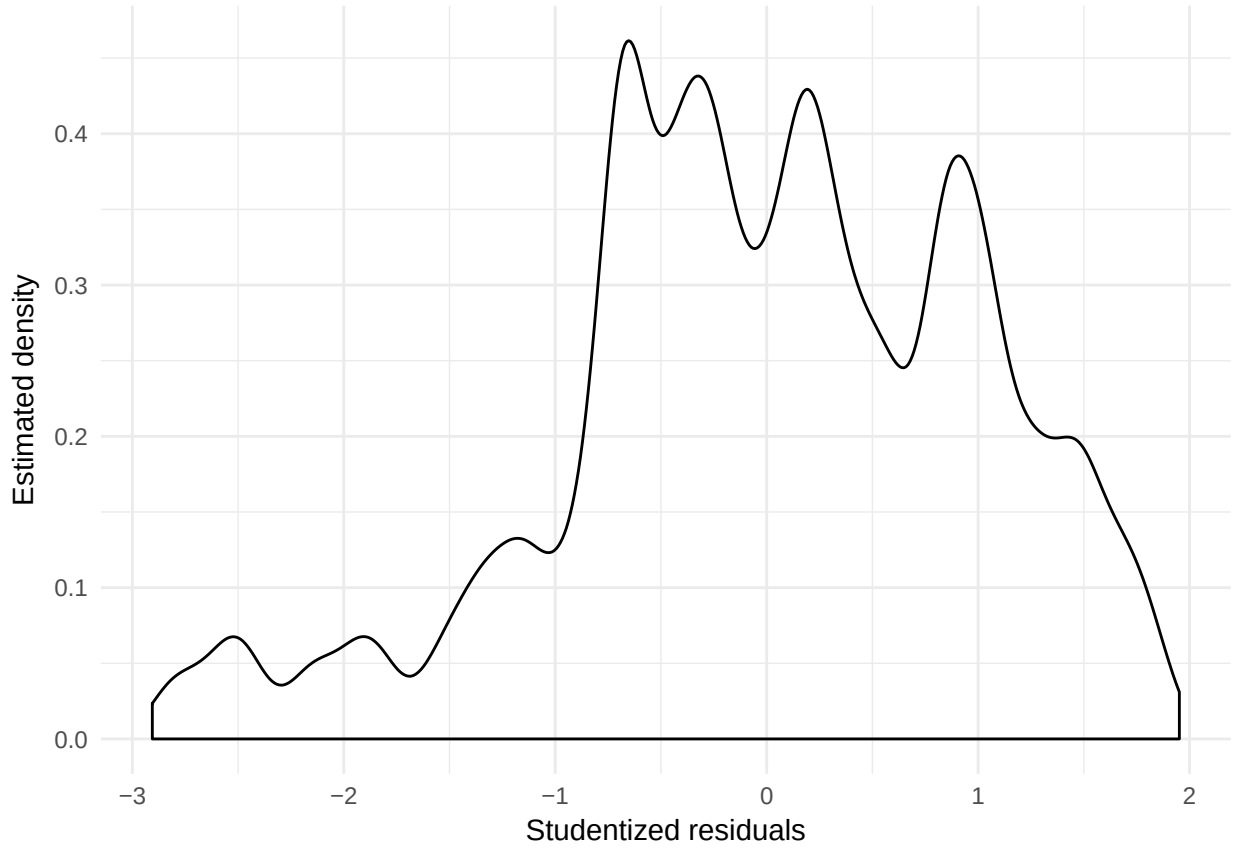
From above Bubble plot, we can observe 167 unusual and influential obseravations. Here, orange bubble means high Cooks D and grey bubble means low Cooks D. We can see that these unusual and influential obsearvations located in lower left side of Bubble plot. It means that they have high discrepancy and low leverage. Let's try digging into the history of the observation to find out what causes this situation.



From previous homeworks, we already knew that biden feeling is somewhat related with party affiliation. When we draw histogram of the data set by Party affiliation, Republican has the smallest portion in the data set, but the proportion of influential observations in Republican group is higher than other two parties. It indicates that Party affiliation may affects on unusual observations. Thus, moving forward with this research, I will additionally collect the variables 'dem' and 'rep' to control for unusual influential effect.

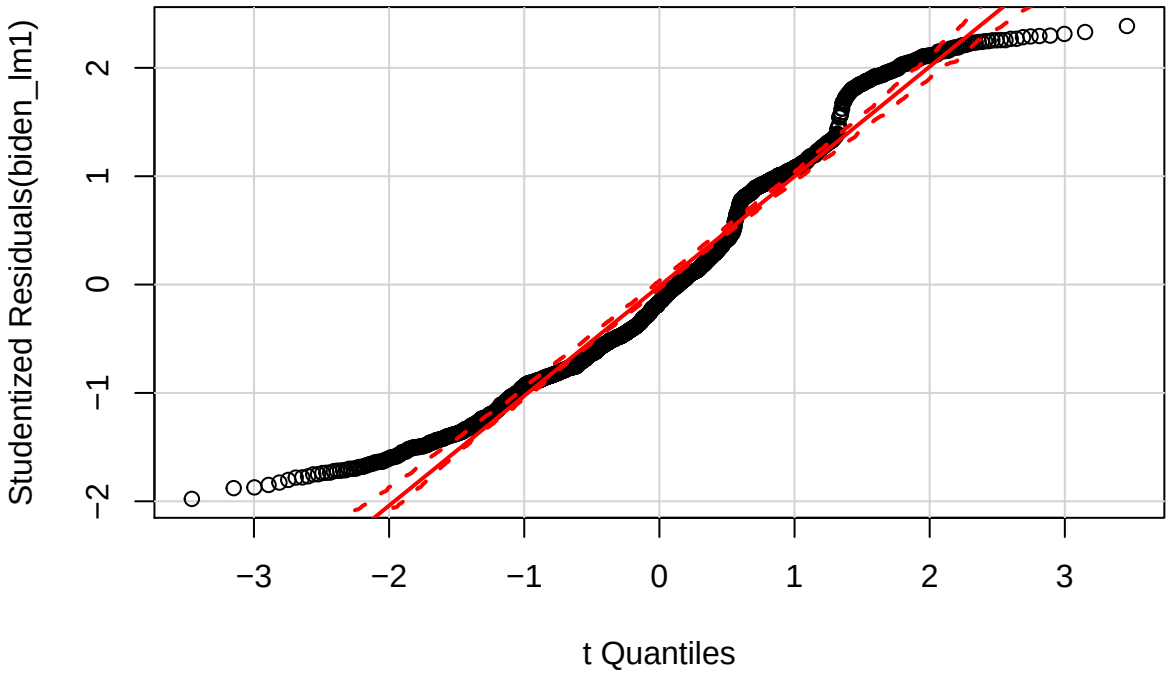
2



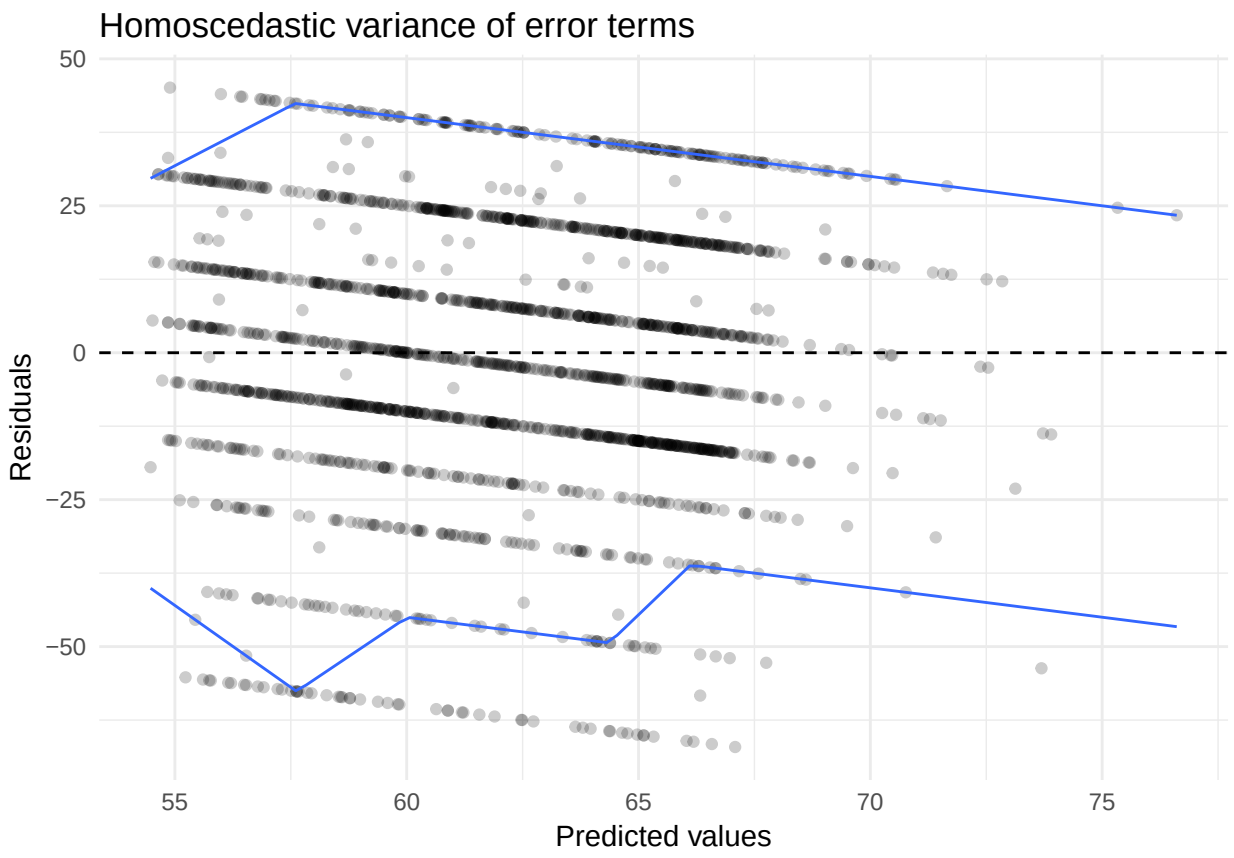


The dashed lines in quantile-comparison plot indicate 95% confidence intervals calculated under the assumption that the errors are normally distributed. We can see that there are observations fall outside this range, thus this indicates the assumption of normality has been violated.If the data is not normally distributed, then

power and log transformations of response are typically used to correct the violation.



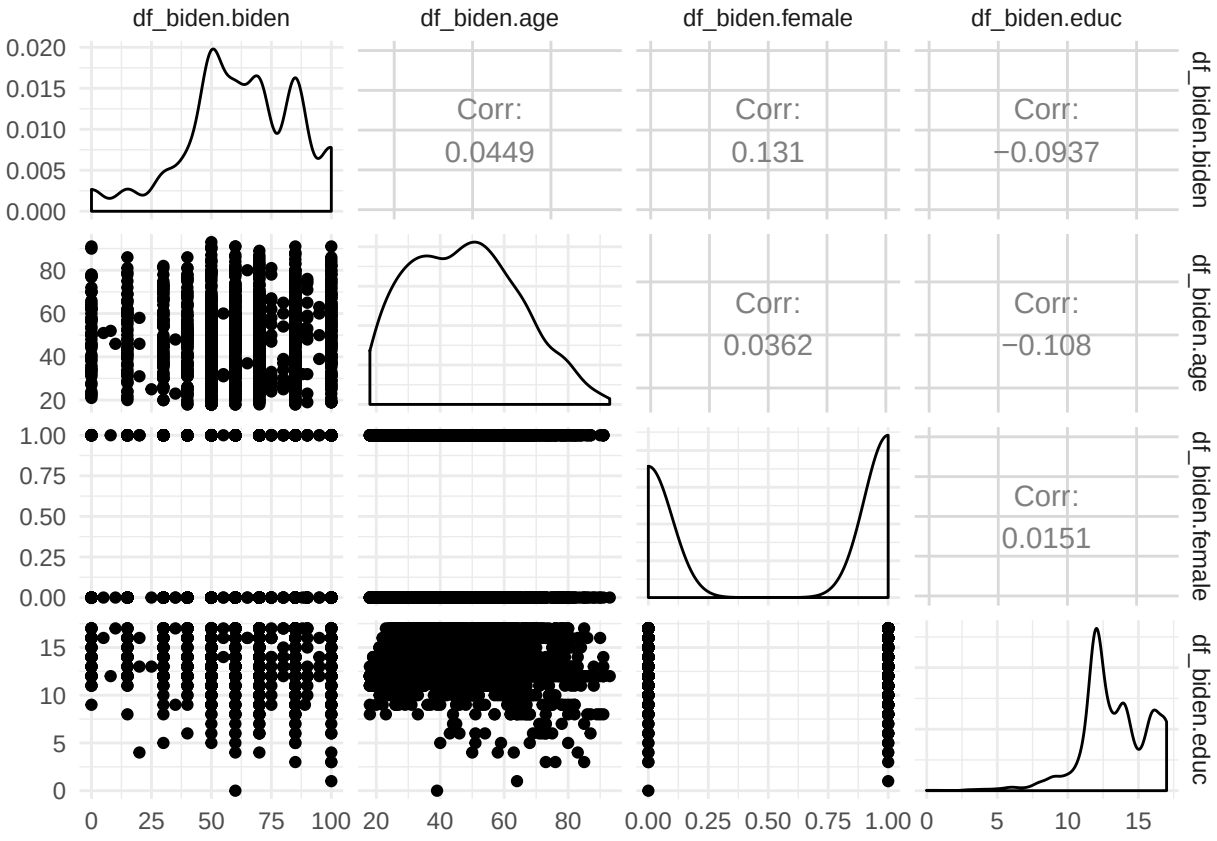
3




```
##
##  studentized Breusch-Pagan test
##
## data:  biden_lm
## BP = 20, df = 3, p-value = 5e-05
```

From the graph, wee can see a distinct decreasing shape to the relationship between the predicted values and the residuals. As the predicted values increases, the residuals decreased. We can say that the data has non-constant error variance. From the Breusch-Pagan test, The resulting statistic p-value is 5e-05, so it is statistically significant. Thus we reject the null hypothesis that the data has constant variance. We conclude that heteroscedasticity is present in the data. This violation leads the estimates of the standard errors to measure inaccurate - they will either be inflated or deflated, leading to incorrect inferences about the statistical significance of predictor variables.

4




```
##    age female   educ
##   1.01   1.00   1.01
```

Above correlation matrices shows that there is no multicollinearity in this model. From variance inflation factor(VIF) scores, no scores are greater than 10, we can also say that there is no multicollinearity in this model.

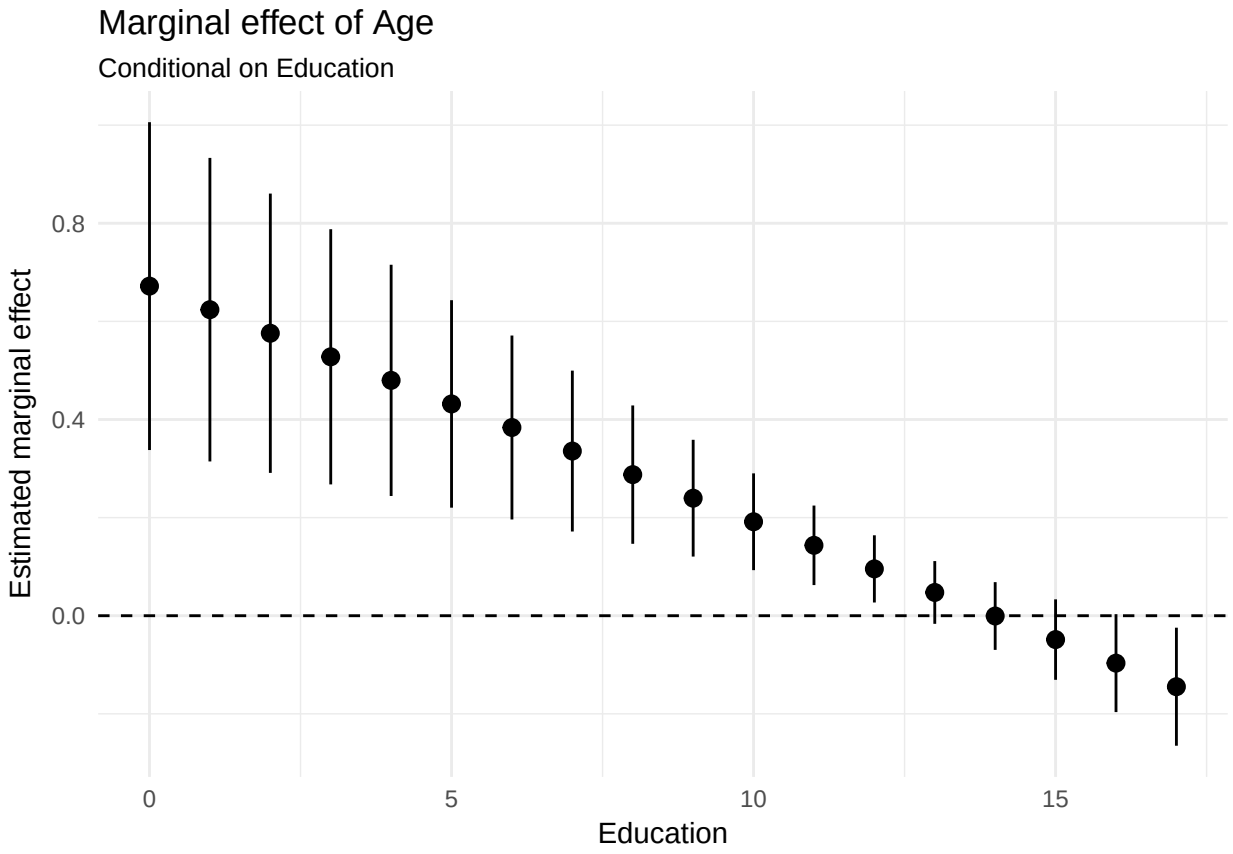
Interaction terms

```
##
## Call:
## lm(formula = biden ~ age + educ + age * educ, data = df_biden)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -70.54 -12.24  -0.94  20.50  44.74
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  38.3735     9.5636    4.01  6.3e-05 ***
## age           0.6719     0.1705    3.94  8.4e-05 ***
## educ          1.6574     0.7140    2.32    2e-02 *
## age:educ     -0.0480     0.0129   -3.72    2e-04 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.3 on 1803 degrees of freedom
## Multiple R-squared:  0.0176, Adjusted R-squared:  0.0159
## F-statistic: 10.7 on 3 and 1803 DF,  p-value: 5.37e-07
```

β_0 for intercept of the multiple linear regression is 38.3735 and standard error is 9.5636 and β_1 for age is 0.6719 and standard error is 0.1705. β_2 for education is 1.6574 and standard error is 0.7140 and β_3 for age*education is -0.0480 and standard error is 0.0129.

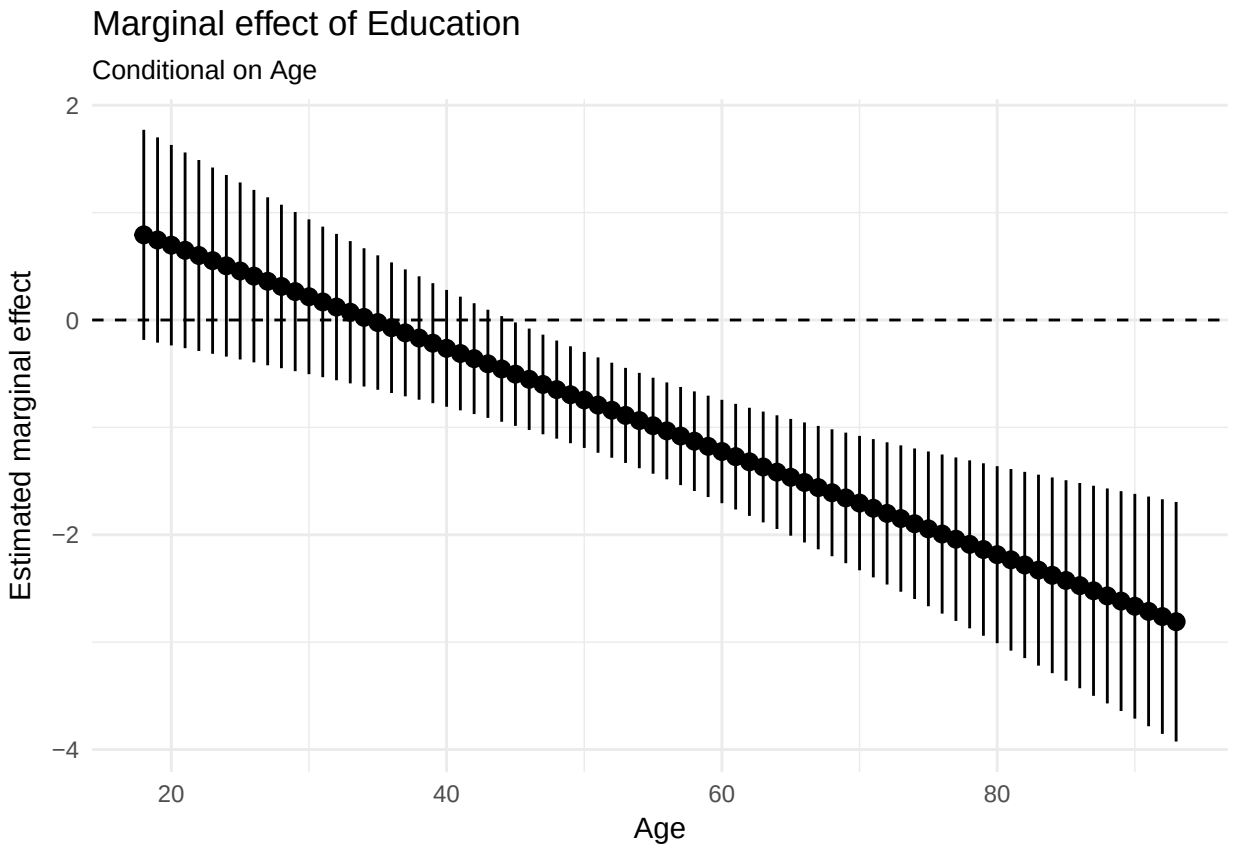
1




```
## Linear hypothesis test
##
## Hypothesis:
## age  + age:educ = 0
##
## Model 1: restricted model
## Model 2: biden ~ age + educ + age * educ
##
##   Res.Df    RSS Df Sum of Sq    F Pr(>F)
## 1   1804 985149
## 2   1803 976688  1      8461 15.6  8e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can observe that the magnitude and direction of Age go down and below 0 . From Hypothesis testing the p-value is 8e-05, so we can conclude that the marginal effect of age is statistically significant.

2




```
## Linear hypothesis test
##
## Hypothesis:
## educ  + age:educ = 0
##
## Model 1: restricted model
## Model 2: biden ~ age + educ + age * educ
##
##   Res.Df    RSS Df Sum of Sq    F Pr(>F)
## 1   1804 979537
## 2   1803 976688  1      2849 5.26  0.022 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can observe that the magnitude and direction of Education go down and below 0 in the above plot. From Hypothesis testing the p-value is 0.022, so we can conclude that the marginal effect of age is statistically significant.

Missing data

First, consider the multivariate normality assumption, we conduct Henze-Zirkler' Multivariate Normality Test and Shapiro-Wilk Multivariate Normality test to see out data set distributed as a multivariate normal distribution. Since female is a binary variable, we will test only age and educ variabels are distributed multivariate normally or not.

```
##   Henze-Zirkler's Multivariate Normality Test
## ---------------------------------------------
##   data : biden_nom
##
##   HZ      : 17
##   p-value : 0
##
##   Result  : Data are not multivariate normal.
## ---------------------------------------------
```

```
## $`Descriptive Statistics`
## NULL
##
## $`Shapiro-Wilk's Normality Test`
##    Variable Statistic   p-value Normality
## 1    age        0.980         0    NO
## 2   educ        0.918         0    NO
```

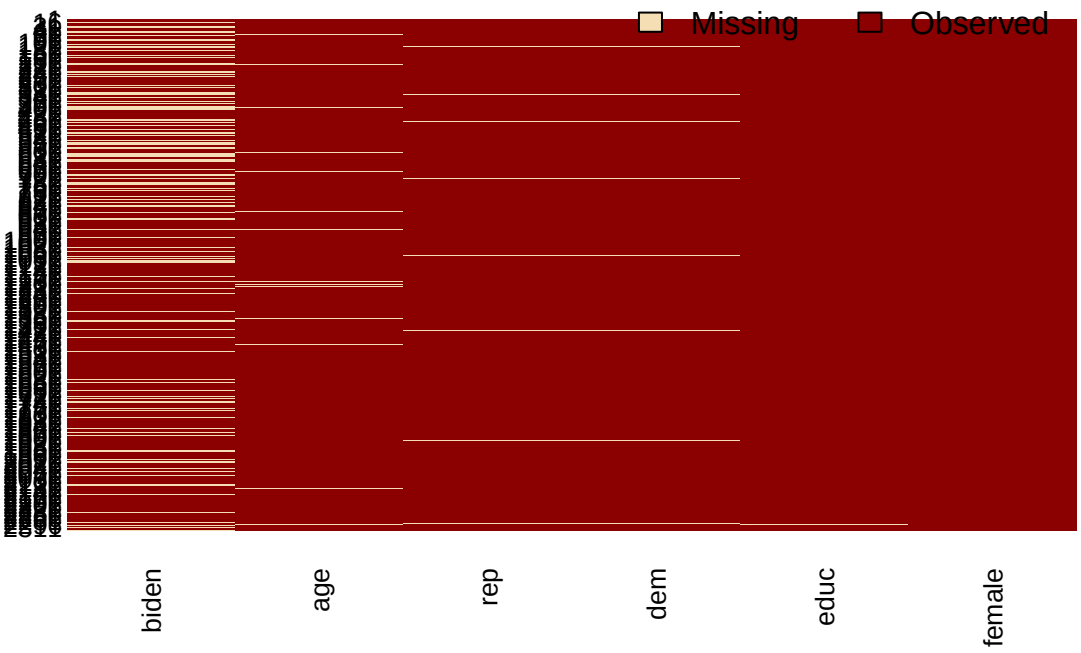
From above two results, we can see that the data set does not distributed multivariate normally and also the age and education variabels are not normally distributed itself. We can try power transformation for square root as trial and error.

```
## [1] "After transformation"
```

```
##   Henze-Zirkler's Multivariate Normality Test
## ---------------------------------------------
##   data : biden_nom3
##
##   HZ      : 15.3
##   p-value : 0
##
##   Result  : Data are not multivariate normal.
## ---------------------------------------------
```

```
## $`Descriptive Statistics`
## NULL
##
## $`Shapiro-Wilk's Normality Test`
##    Variable Statistic   p-value Normality
## 1 sqrt_age      0.984         0    NO
## 2 sqrt_educ     0.864         0    NO
```

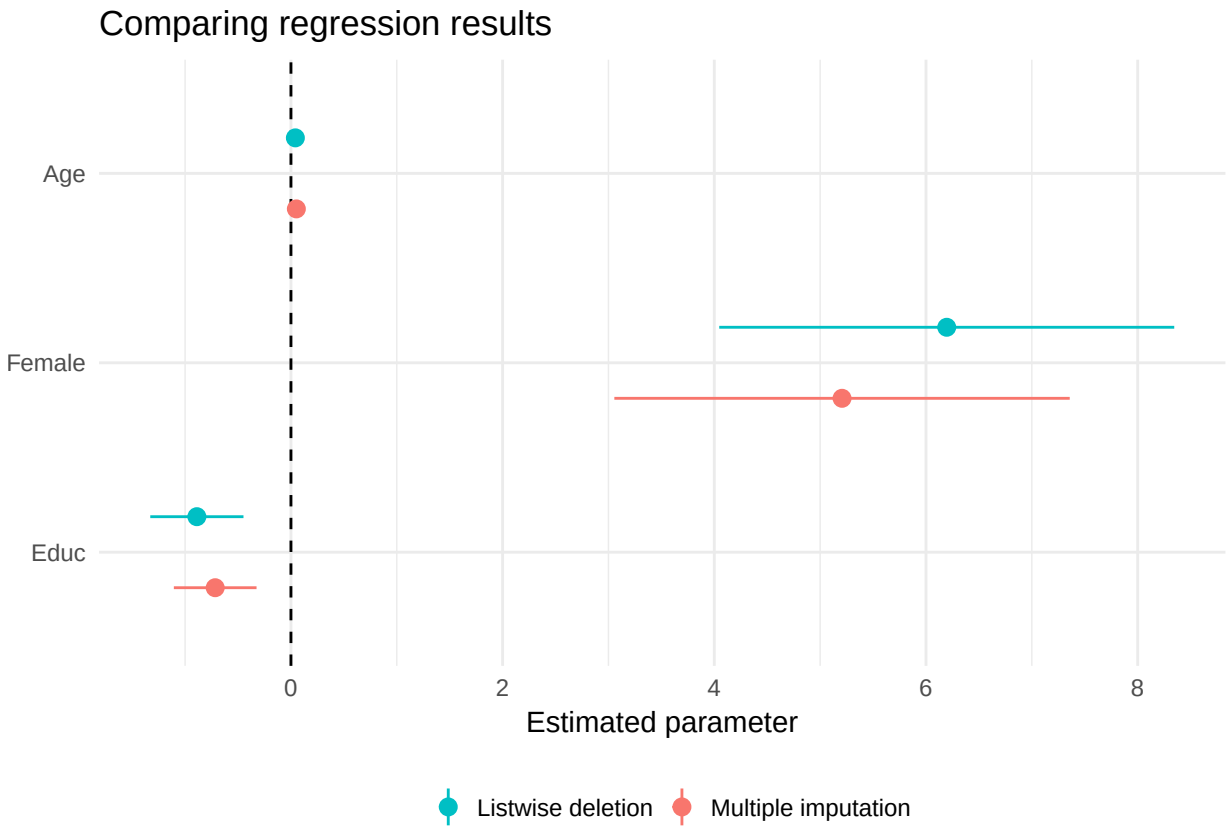
Testing again with squared transformation of response, still it is not distributed multivariate normally, but the HZ statistic is bit mitigated. With above transformation, we will calcualte appropriate estimates of the parameters and the standard errors and see how the results differ from the original, non-imputed model.




```
## # A tibble: 20 × 6
##       id        term estimate std.error statistic   p.value
##    <chr>       <chr>    <dbl>     <dbl>     <dbl>     <dbl>
## 1   imp1 (Intercept)  61.9354    2.9944     20.68  2.32e-87
## 2   imp1         age   0.0612    0.0278      2.20  2.79e-02
## 3   imp1      female   5.5607    0.9665      5.75  9.90e-09
## 4   imp1        educ  -0.4691    0.1861     -2.52  1.18e-02
## 5   imp2 (Intercept)  67.3854    3.0135     22.36 1.87e-100
## 6   imp2         age   0.0410    0.0279      1.47  1.42e-01
## 7   imp2      female   5.6536    0.9724      5.81  6.93e-09
## 8   imp2        educ  -0.7874    0.1874     -4.20  2.75e-05
## 9   imp3 (Intercept)  66.5443    2.9933     22.23  2.04e-99
## 10  imp3         age   0.0653    0.0278      2.35  1.90e-02
## 11  imp3      female   5.5545    0.9664      5.75  1.02e-08
## 12  imp3        educ  -0.7930    0.1854     -4.28  1.97e-05
## 13  imp4 (Intercept)  67.3280    3.0178     22.31 4.74e-100
## 14  imp4         age   0.0405    0.0279      1.45  1.47e-01
## 15  imp4      female   5.6839    0.9704      5.86  5.38e-09
## 16  imp4        educ  -0.8044    0.1871     -4.30  1.78e-05
## 17  imp5 (Intercept)  65.4769    3.0682     21.34  2.08e-92
## 18  imp5         age   0.0347    0.0285      1.22  2.24e-01
## 19  imp5      female   6.0930    0.9905      6.15  9.03e-10
## 20  imp5        educ  -0.6437    0.1903     -3.38  7.30e-04
```

```
## [1] "Comparison between imputed model and original model"
```

```
##          term estimate std.error estimate.mi std.error.mi
## 1 (Intercept)  68.6210    3.5960     65.7340       3.9028
## 2         age   0.0419    0.0325      0.0485       0.0318
## 3      female   6.1961    1.0967      5.7091       1.0032
## 4        educ  -0.8887    0.2247     -0.6995       0.2453
```



From above results, table and plot, we can see that there is no significant differences in the estimated coefficients and standard errors between imputed model and original, non-imputed model. From missingmap, and amelia function, we can see that there are not many missing variabels so it explains why the differences are not significant.