DAS-Project2

Yiheng Yang, Yuanqing Zhang

1 Load the data

```
data=read.csv("dataset04.csv")
```

2 Get packages

```
library(tidyverse)
library(moderndive)
library(gapminder)
library(sjPlot)
library(stats)
library(jtools)
library(tidyverse)
library(ggplot2)
library(MASS)
library(knitr)
library(tidyr)
library(gt)
library(janitor)
library(skimr)
library(kableExtra)
```

3 Exploratory Data Analysis

3.1 Summary of response variable

```
data%>%summarize('Mean' = mean(Total.Number.of.Family.members),
'Median' = median(Total.Number.of.Family.members),
'St.Dev' = sd(Total.Number.of.Family.members),
'Variance'=var(Total.Number.of.Family.members),
'Min' = min(Total.Number.of.Family.members),
'Max' = max(Total.Number.of.Family.members),
'IQR' = quantile(Total.Number.of.Family.members,0.75)-quantile(Total.Number.of.Family.memb
'Sample_size' = n())%>%
  gt()%>%
  fmt_number(decimals=2)%>%
  cols_label(
Mean = html("Mean"),
Median = html("Median"),
St.Dev = html("Std. Dev"),
Variance=html("Variance"),
Min = html("Minimum"),
Max = html("Maximum"),
IQR = html("Interquartile Range"),
Sample_size = html("Sample Size"))
```

Mean	Median	Std. Dev	Variance	Minimum	Maximum	Interquartile Range	Sample Size
4.53	4.00	2.22	4.91	1.00	19.00	3.00	2,122.00

We can see from this numerical summary, the mean of number of family members is 4.53 and the variance is 4.91. If variance is bigger than mean, we can determine that we have overdispersion. We will investigate this phenomenon later.

3.2 Convert some categorical variables to factors

```
data$Household.Head.Sex=as.factor(data$Household.Head.Sex)
data$Type.of.Household=as.factor(data$Type.of.Household)
data$Electricity=as.factor(data$Electricity)
levels(data$Electricity)=c("No","Yes")
data$Number.of.bedrooms=as.factor(data$Number.of.bedrooms)
levels(data$Number.of.bedrooms)=c("0","1","2","3","4","5","6","7")
```

3.3 Summary of categorical explanatory variables

```
data_categorical=data%>%
  dplyr::select("Household.Head.Sex","Type.of.Household","Electricity")
summary(data_categorical)
```

```
Household.Head.Sex                                Type.of.Household Electricity
Female: 362        Extended Family                         : 585    No : 363
Male  :1760        Single Family                           :1531    Yes:1759
                   Two or More Nonrelated Persons/Members:   6
```

The numerical summary shows that male owners, single families and households with electricity account for a major proportion.

3.4 Summary of numerical explanatory variables

```
data_numerical=data[,c(1,3,5,7,8,9,10)]
data_numerical$Number.of.bedrooms=as.numeric(as.character(data_numerical$Number.of.bedroom
my_skim <- skim_with(numeric = sfl(hist = NULL),
                     base = sfl(n = length))
my_skim(data_numerical) %>%
  transmute(Variable=skim_variable, Sample_size = n, Mean=numeric.mean, St.Dev=numeric.sd,
            Min=numeric.p0, Median=numeric.p50,  Max=numeric.p100,
            IQR = numeric.p75-numeric.p50) %>%
  kable(format.args = list(big.mark = ","), digits=2) %>%
  kable_styling(font_size = 10, latex_options = "hold_position")
```

Variable	Sample_size	Mean	St.Dev	Min	Median	Max	IQR
Total.Household.Income	2,122	182,984.80	228,231.07	15,204	120,362.0	3,168,662	74,314.00
Total.Food.Expenditure	2,122	71,738.09	44,938.17	7,783	63,305.5	729,606	24,496.75

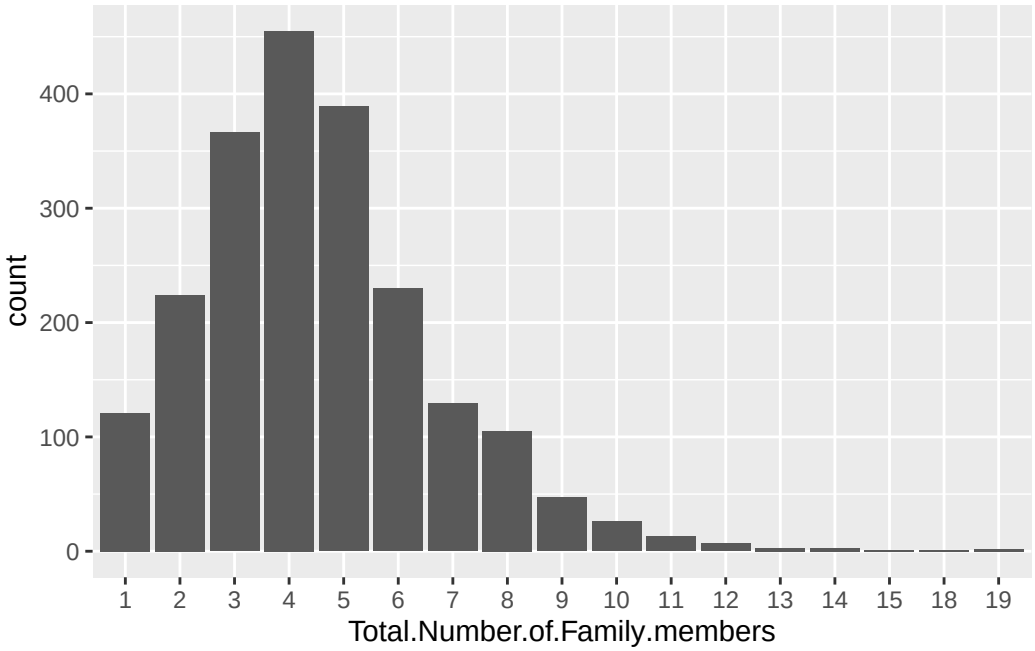
Household.Head.Age	2,122	49.28	14.16	9	48.0	99	11.00
Total.Number.of.Family.members	2,122	4.53	2.22	1	4.0	19	2.00
House.Floor.Area	2,122	35.74	34.67	5	26.5	450	13.50
House.Age	2,122	16.30	11.09	0	14.0	75	7.00
Number.of.bedrooms	2,122	1.77	1.00	0	2.0	7	0.00

3.5 Graphical summaries

As we want to plot a boxplot with x axis to be number of family members, so we need to change this variable to be a factor.

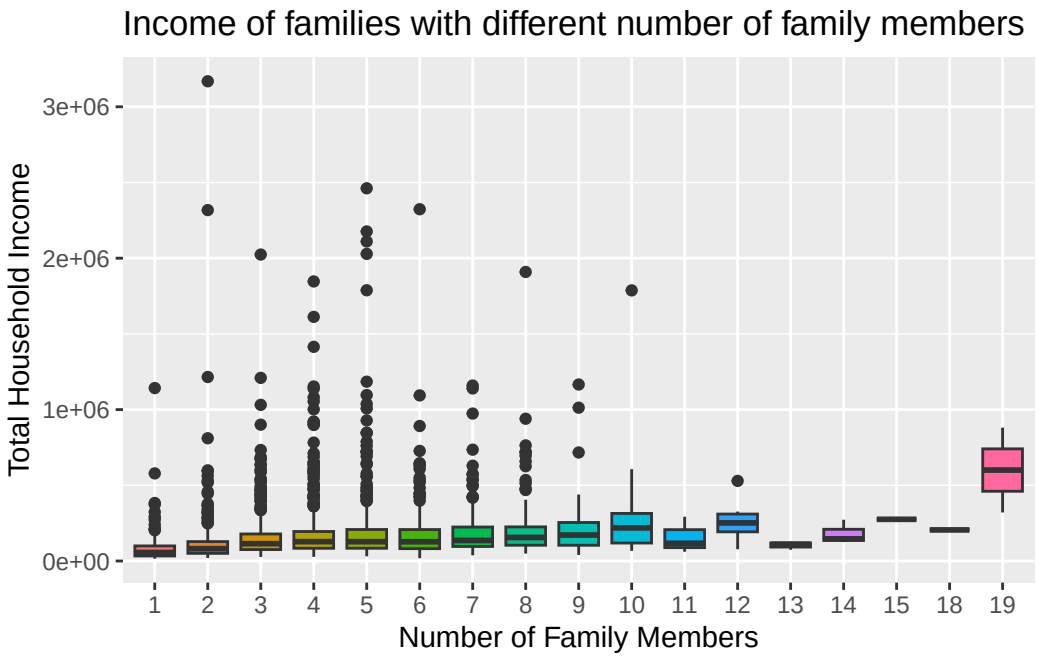
```
data$Total.Number.of.Family.members=as.factor(data$Total.Number.of.Family.members)
```

```
ggplot(data=data,aes(x=Total.Number.of.Family.members))+geom_bar()
```



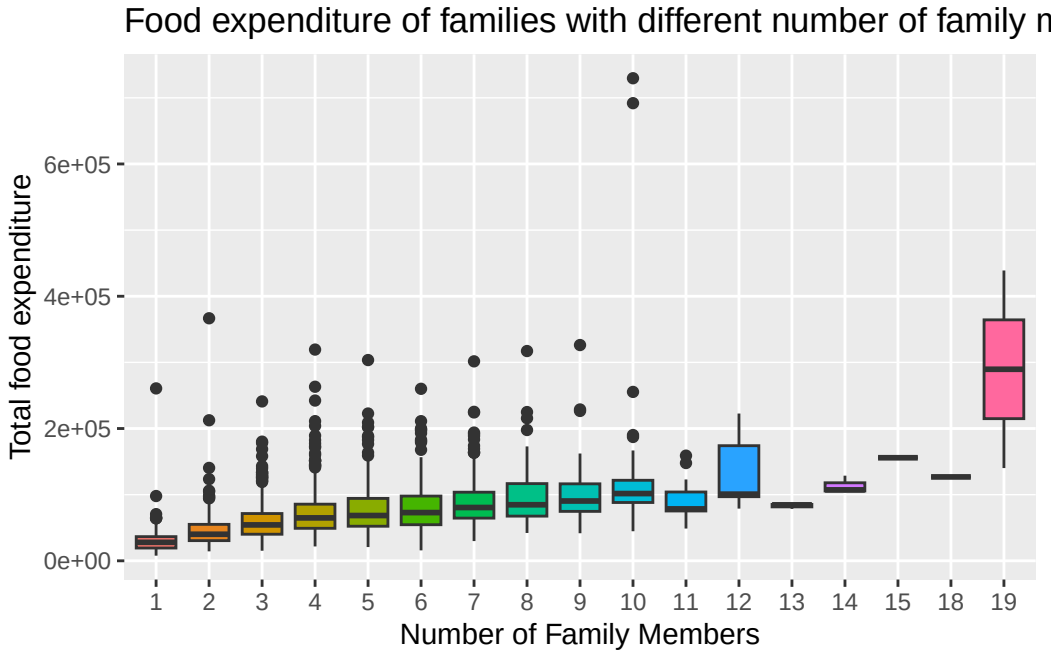
The boxplot shows that household with four family members accounts for the largest proportion. Most of the data is consisted of families with three to five family members.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,y=Total.Household.Income,fill=Total.
```



We can see from the above boxplot that the median of household income increase as number of family members increase.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,y=Total.Food.Expenditure,fill=Total.
```

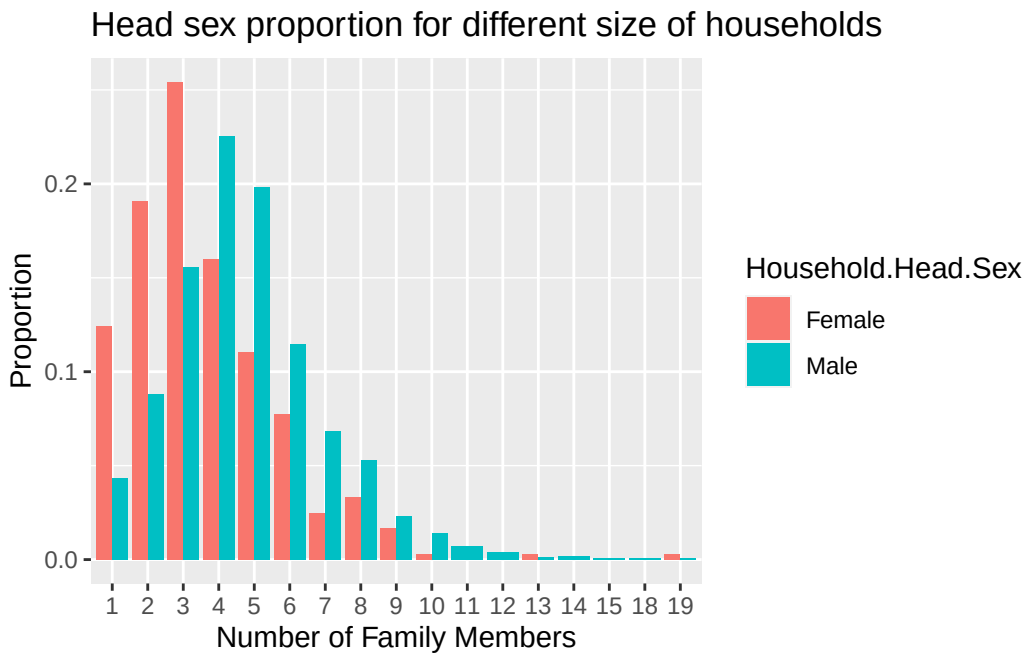


The boxplot indicates that median increase significantly as the number of family members increase. Household with 19 members have the largest variance in food expenditure.

```
data%>%
  tabyl(Household.Head.Sex,Total.Number.of.Family.members)%>%
  adorn_percentages()%>%
  adorn_pct_formatting()%>%
  adorn_ns()
```

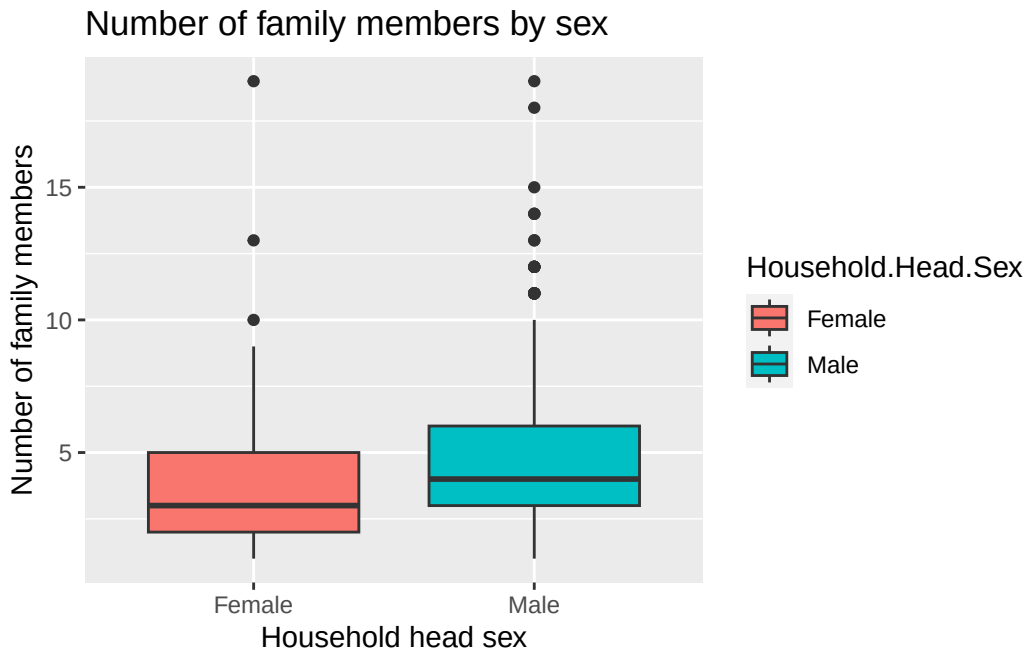
```
Household.Head.Sex          1           2           3           4           5
            Female 12.4% (45) 19.1%  (69) 25.4%  (92) 16.0%  (58) 11.0%  (40)
              Male  4.3% (76)  8.8% (155) 15.6% (274) 22.6% (397) 19.8(349)
          6           7         8         9        10        11       12
 7.7%  (28) 2.5%   (9) 3.3% (12) 1.7%  (6) 0.3%  (1) 0.0%  (0) 0.0     (0)
11.5% (202) 6.8% (120) 5.3% (93) 2.3% (41) 1.4% (25) 0.7% (13) 0.4     (7)
      13       14       15       18       19
0.3% (1) 0.0% (0) 0.0% (0) 0.0% (0) 0.3                                (1)
0.1% (2) 0.2% (3) 0.1% (1) 0.1% (1) 0.1
```

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,group=Household.Head.Sex))+geom_bar(
```



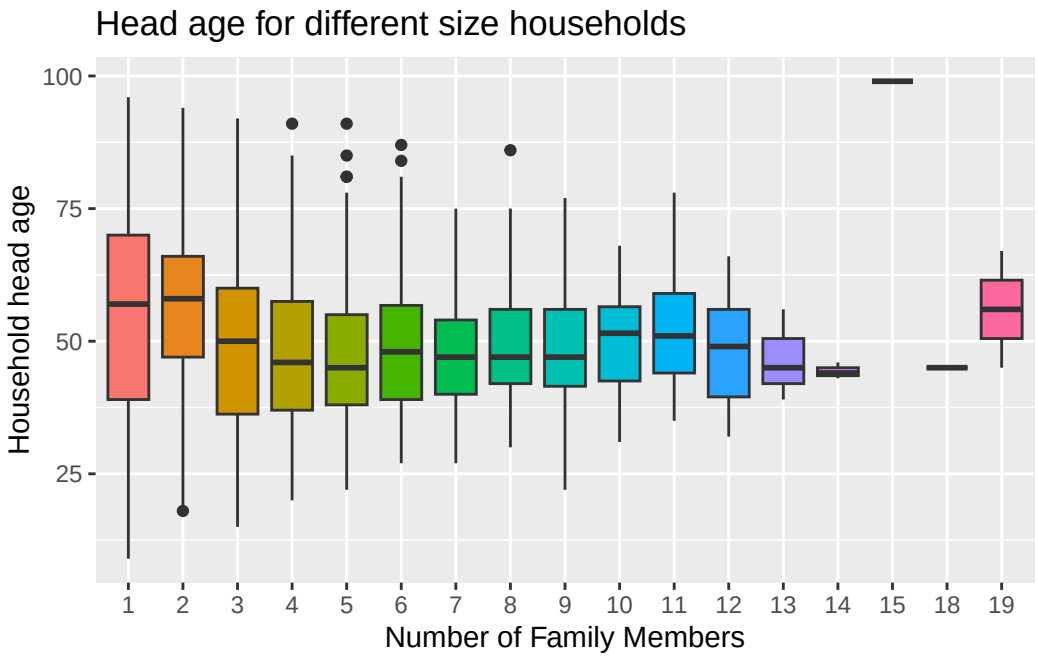
We can see from the barplot, for those small sized households, the proportion is much higher for females than for males. However, this situation does not exist for those household with four or more family members.

```
ggplot(data=data,aes(x=Household.Head.Sex,y=as.numeric(as.character(Total.Number.of.Family
```



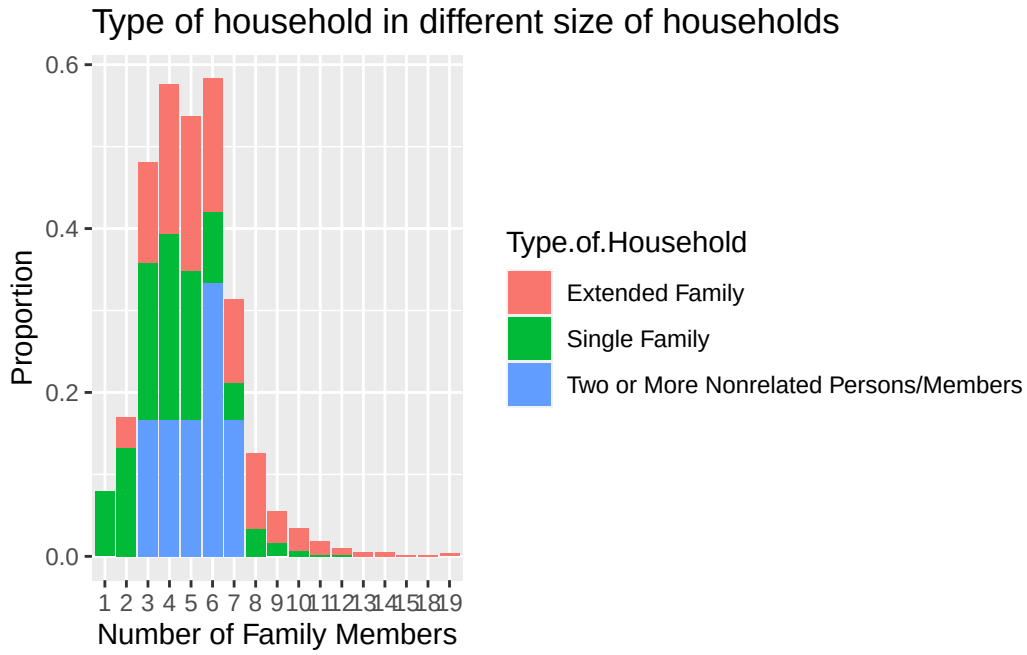
We can conclude from the boxplot that households tend to have more family members if their owner is male.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,y=Household.Head.Age,fill=Total.Numb
```



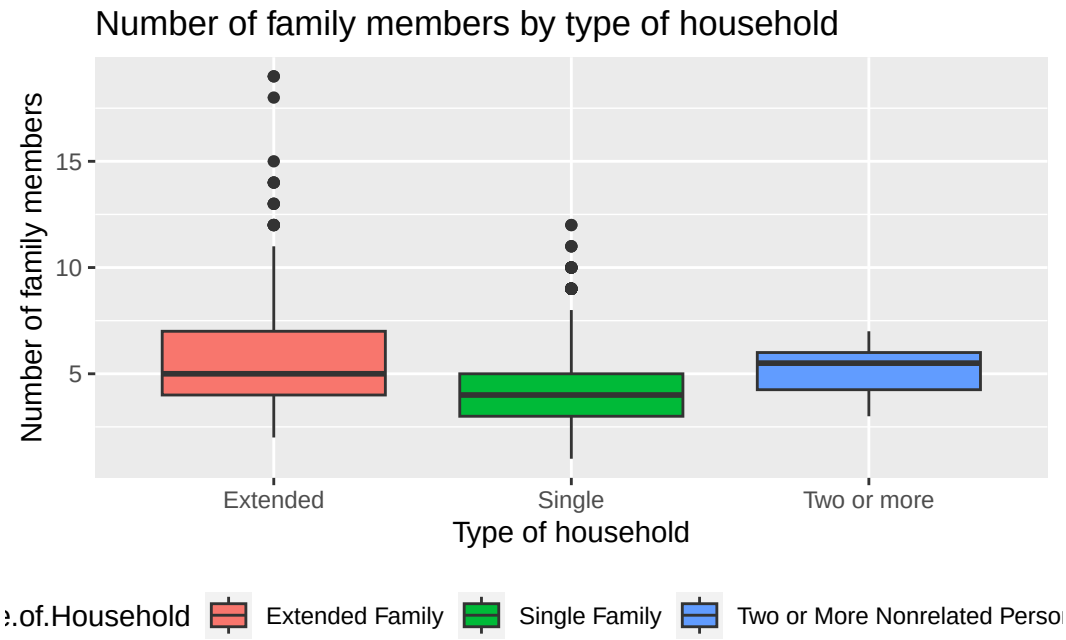
For different size of households, the median of household head age remain at a constant level around 50.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,group=Type.of.Household))+geom_bar(a
```

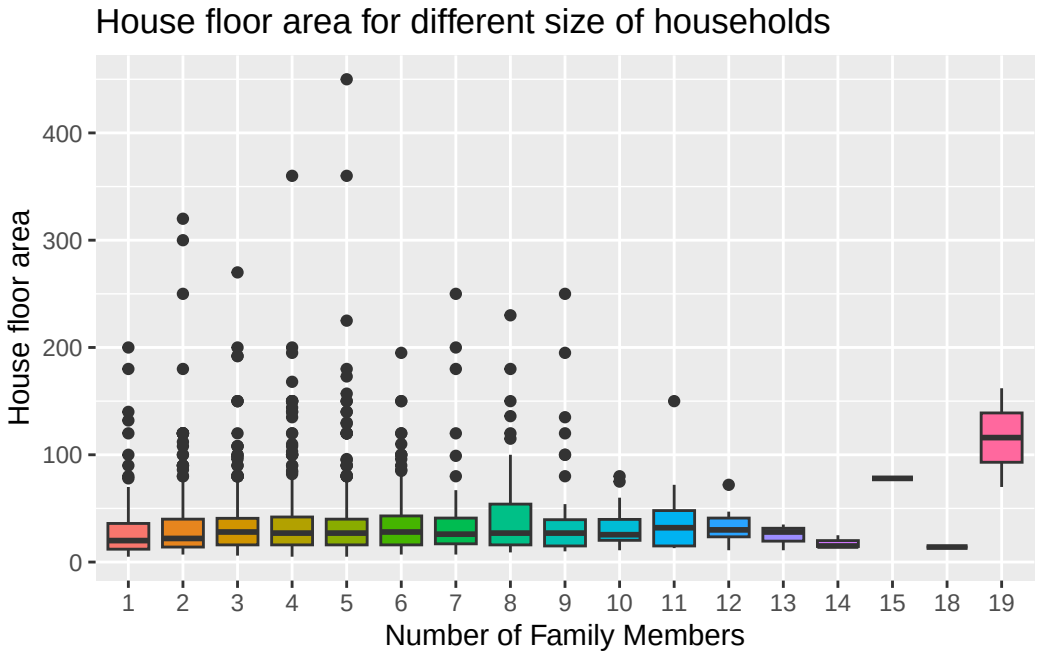


These families with two or more nonrelated members only exist in medium size household. As total family members increase more than 8, single family account for a very small proportion.

```
ggplot(data=data,aes(x=Type.of.Household,y=as.numeric(as.character(Total.Number.of.Family.
```

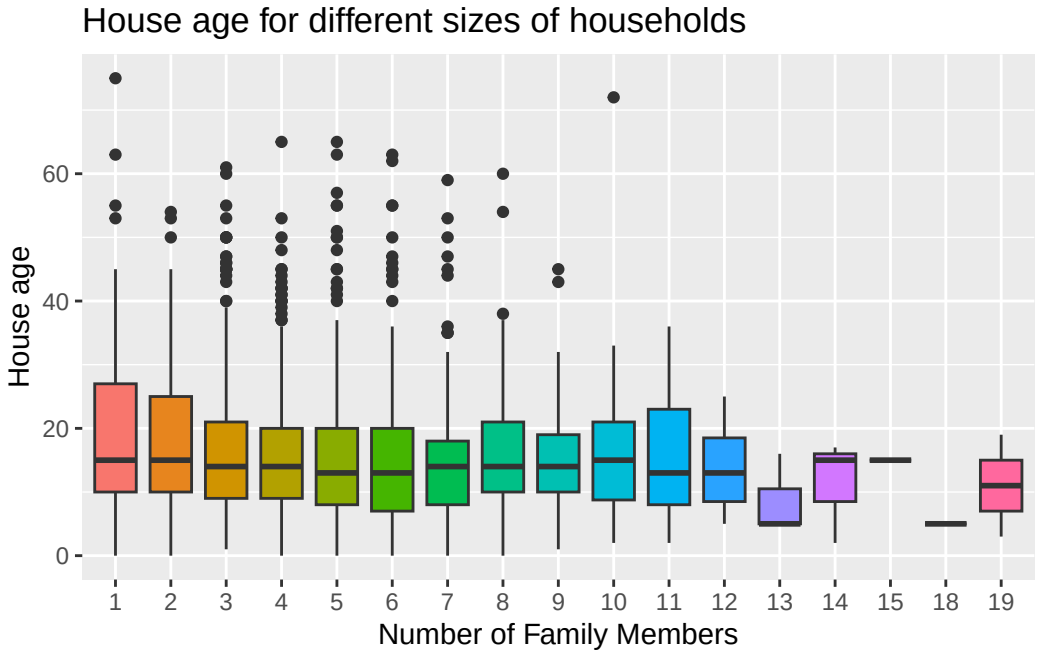



```
ggplot(data=data,aes(x=Total.Number.of.Family.members,y=House.Floor.Area,fill=Total.Number
```



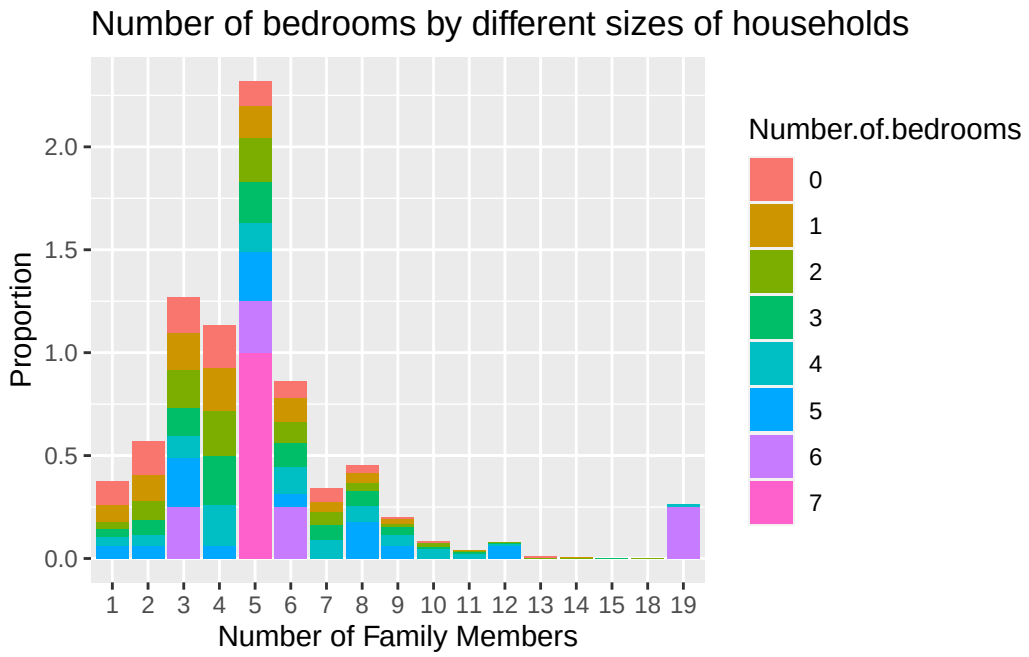
For different sizes of households, there are a few outliers. And the median of house floor area seems to be stable as number of family members increase.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,y=House.Age,fill=Total.Number.of.Fam
```



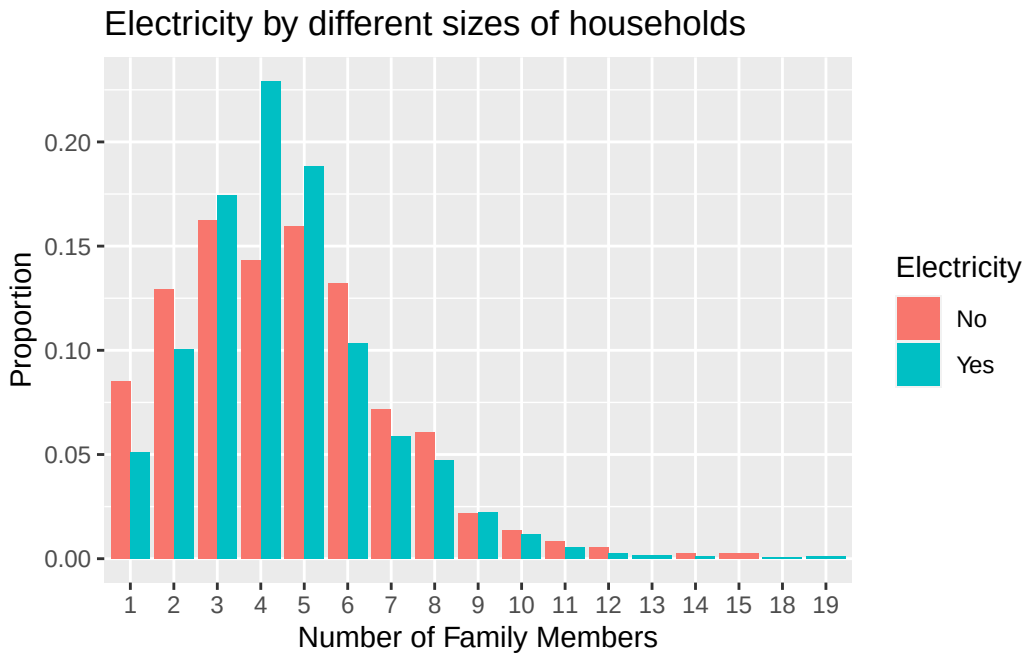
The median house age of different sizes of households are less than 20 years, which is relatively stable as number of family members increase.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,group=Number.of.bedrooms))+geom_bar(
```



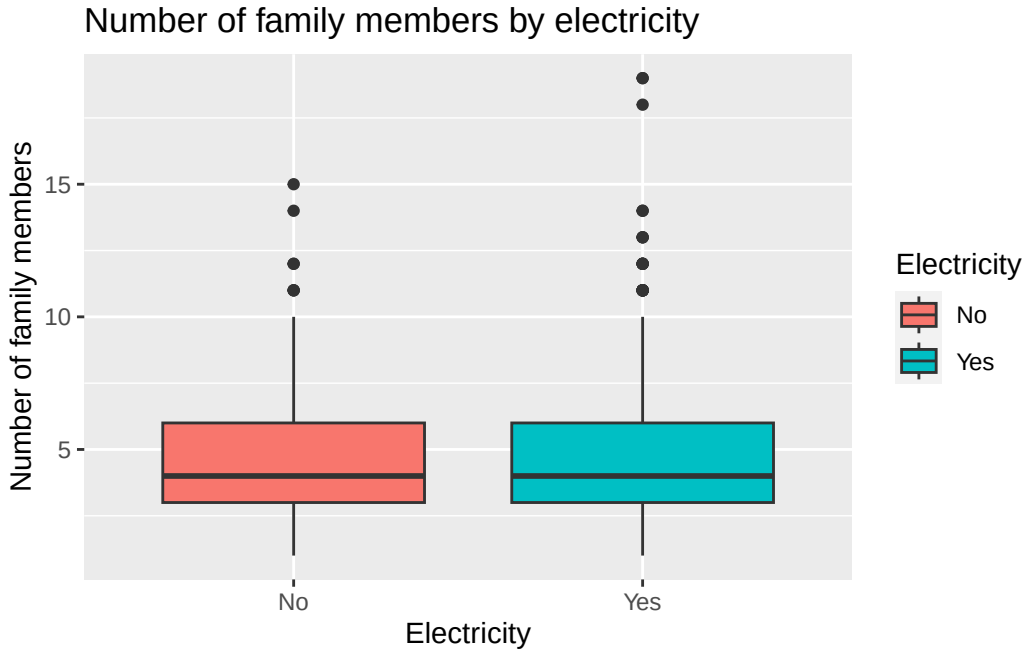
As the number of family members increases, number of bedrooms increase, but for household with 5 family members, proportion of 7 bedrooms is incredibly high.

```
ggplot(data=data,aes(x=Total.Number.of.Family.members,group=Electricity))+geom_bar(aes(y=.
```



For those small size households, the proportion wothout electricity is relatively high.

```
ggplot(data=data,aes(x=Electricity,y=as.numeric(as.character(Total.Number.of.Family.member
```



From the above boxplot, households with electricity and without electricity have the same distribution of family members.

4 Formal analysis

4.1 Poisson Regression Model

```
# As the response variable is the number of people living in a household, which is counts
data$Total.Number.of.Family.members=as.numeric(as.character(data$Total.Number.of.Family.me
data$Number.of.bedrooms=as.numeric(as.character(data$Number.of.bedrooms))
model1=glm(Total.Number.of.Family.members~Total.Household.Income+Total.Food.Expenditure+Ho
model1%>%
  summary()
```

```
Call:
glm(formula = Total.Number.of.Family.members ~ Total.Household.Income +
    Total.Food.Expenditure + Household.Head.Sex + Household.Head.Age +
    Type.of.Household + House.Floor.Area + House.Age + Number.of.bedrooms +
    Electricity, family = poisson, data = data)

Coefficients:
                                                        Estimate Std. Error
(Intercept)                                            1.597e+00  6.095e-02
Total.Household.Income                                -2.385e-07  5.634e-08
Total.Food.Expenditure                                 2.930e-06  1.880e-07
Household.Head.SexMale                                 2.631e-01  3.053e-02
Household.Head.Age                                    -3.797e-03  8.105e-04
Type.of.HouseholdSingle Family                        -3.467e-01  2.291e-02
Type.of.HouseholdTwo or More Nonrelated Persons/Members -1.058e-01  1.809e-01
House.Floor.Area                                      -4.940e-04  3.402e-04
House.Age                                             -3.715e-03  1.030e-03
Number.of.bedrooms                                     5.011e-02  1.234e-02
ElectricityYes                                        -9.028e-02  2.850e-02
                                                      z value Pr(>|z|)
(Intercept)                                            26.210  < 2e-16 ***
Total.Household.Income                                 -4.234 2.29e-05 ***
Total.Food.Expenditure                                 15.588  < 2e-16 ***
Household.Head.SexMale                                  8.616  < 2e-16 ***
Household.Head.Age                                     -4.684 2.81e-06 ***
```

```
Type.of.HouseholdSingle Family                             -15.135  < 2e-16 ***
Type.of.HouseholdTwo or More Nonrelated Persons/Members     -0.585 0.558423
House.Floor.Area                                            -1.452 0.146476
House.Age                                                   -3.606 0.000311 ***
Number.of.bedrooms                                           4.061 4.89e-05 ***
ElectricityYes                                              -3.168 0.001536 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2217.8  on 2121  degrees of freedom
Residual deviance: 1551.8  on 2111  degrees of freedom
AIC: 8511.9

Number of Fisher Scoring iterations: 5
```

```
confint(model1)%>%
  kable()
```

	2.5 %	97.5 %
(Intercept)	1.4777012	1.7166106
Total.Household.Income	-0.0000004	-0.0000001
Total.Food.Expenditure	0.0000026	0.0000033
Household.Head.SexMale	0.2036003	0.3232971
Household.Head.Age	-0.0053862	-0.0022092
Type.of.HouseholdSingle Family	-0.3915529	-0.3017466
Type.of.HouseholdTwo or More Nonrelated Persons/Members	-0.4820181	0.2294578
House.Floor.Area	-0.0011694	0.0001642
House.Age	-0.0057424	-0.0017039
Number.of.bedrooms	0.0259109	0.0742825
ElectricityYes	-0.1458759	-0.0341516

```
levels(data$Household.Head.Sex)
```

```
[1] "Female" "Male"
```

```
levels(data$Type.of.Household)
```

```
[1] "Extended Family"
[2] "Single Family"
[3] "Two or More Nonrelated Persons/Members"
```

```
levels(data$Electricity)
```

```
[1] "No"  "Yes"
```

The default baseline in R being taken as the one which comes first alphabetically. So these three categorical variables adopt female, Extended Family, 0 as baseline.

From the above summary we can observe that one continuous explanatory variable floor area is not significant and compared to extended family, Two or More Nonrelated Persons/Members is not significant while single family is significant according to the p-value and the 95% CI of estimates of coefficients.

4.1.1 Rate Ratio

```
model_summary <- summary(model1)
coef <- model_summary$coefficients[,1]
std_err <- model_summary$coefficients[,2]
rate_ratio <- exp(model_summary$coef)
conf_interval <- exp(cbind(coef - 1.96 * std_err, coef + 1.96 * std_err))
result <- data.frame(coef = coef, std_err = std_err, rate_ratio = rate_ratio, conf_interva
print(result)
```

```
                                                          coef
(Intercept)                                         1.597427e+00
Total.Household.Income                             -2.385545e-07
Total.Food.Expenditure                              2.930463e-06
Household.Head.SexMale                              2.630600e-01
Household.Head.Age                                 -3.796566e-03
Type.of.HouseholdSingle Family                     -3.467288e-01
Type.of.HouseholdTwo or More Nonrelated Persons/Members -1.058474e-01
House.Floor.Area                                   -4.940074e-04
House.Age                                          -3.714620e-03
Number.of.bedrooms                                  5.011218e-02
ElectricityYes                                     -9.028251e-02
                                                        std_err
```

(Intercept)	6.094682e-02
Total.Household.Income	5.634096e-08
Total.Food.Expenditure	1.879964e-07
Household.Head.SexMale	3.053305e-02
Household.Head.Age	8.104823e-04
Type.of.HouseholdSingle Family	2.290952e-02
Type.of.HouseholdTwo or More Nonrelated Persons/Members	1.808782e-01
House.Floor.Area	3.402039e-04
House.Age	1.030238e-03
Number.of.bedrooms	1.233996e-02
ElectricityYes	2.849982e-02

	rate_ratio.Estimate
(Intercept)	4.9403037
Total.Household.Income	0.9999998
Total.Food.Expenditure	1.0000029
Household.Head.SexMale	1.3009048
Household.Head.Age	0.9962106
Type.of.HouseholdSingle Family	0.7069970
Type.of.HouseholdTwo or More Nonrelated Persons/Members	0.8995620
House.Floor.Area	0.9995061
House.Age	0.9962923
Number.of.bedrooms	1.0513890
ElectricityYes	0.9136730

	rate_ratio.Std..Error
(Intercept)	1.062842
Total.Household.Income	1.000000
Total.Food.Expenditure	1.000000
Household.Head.SexMale	1.031004
Household.Head.Age	1.000811
Type.of.HouseholdSingle Family	1.023174
Type.of.HouseholdTwo or More Nonrelated Persons/Members	1.198269
House.Floor.Area	1.000340
House.Age	1.001031
Number.of.bedrooms	1.012416
ElectricityYes	1.028910

	rate_ratio.z.value
(Intercept)	2.415094e+11
Total.Household.Income	1.449251e-02
Total.Food.Expenditure	5.884700e+06
Household.Head.SexMale	5.516954e+03
Household.Head.Age	9.238931e-03
Type.of.HouseholdSingle Family	2.673506e-07
Type.of.HouseholdTwo or More Nonrelated Persons/Members	5.570024e-01

```
House.Floor.Area                                                  2.340801e-01
House.Age                                                         2.717131e-02
Number.of.bedrooms                                                5.803047e+01
ElectricityYes                                                    4.209497e-02
                                                                rate_ratio.Pr...z..
(Intercept)                                                               1.000000
Total.Household.Income                                                    1.000023
Total.Food.Expenditure                                                    1.000000
Household.Head.SexMale                                                    1.000000
Household.Head.Age                                                        1.000003
Type.of.HouseholdSingle Family                                            1.000000
Type.of.HouseholdTwo or More Nonrelated Persons/Members                   1.747914
House.Floor.Area                                                          1.157747
House.Age                                                                 1.000311
Number.of.bedrooms                                                        1.000049
ElectricityYes                                                            1.001537
                                                                        X1        X2
(Intercept)                                                     4.3840416 5.5671462
Total.Household.Income                                          0.9999997 0.9999999
Total.Food.Expenditure                                          1.0000026 1.0000033
Household.Head.SexMale                                          1.2253361 1.3811338
Household.Head.Age                                              0.9946294 0.9977944
Type.of.HouseholdSingle Family                                  0.6759532 0.7394666
Type.of.HouseholdTwo or More Nonrelated Persons/Members         0.6310510 1.2823238
House.Floor.Area                                                0.9988399 1.0001728
House.Age                                                       0.9942825 0.9983061
Number.of.bedrooms                                              1.0262649 1.0771283
ElectricityYes                                                  0.8640349 0.9661629
```

The result from the rate ratio agree with that from p-values and confidence intervals.

So we can remove the house floor area variable firstly.

4.1.2 Remove House.Floor.Area

```
model2=glm(Total.Number.of.Family.members~Total.Household.Income+Total.Food.Expenditure+Ho
model2%>%
  summary()
```

```
Call:
```

```
glm(formula = Total.Number.of.Family.members ~ Total.Household.Income +
    Total.Food.Expenditure + Household.Head.Sex + Household.Head.Age +
    Type.of.Household + House.Age + Number.of.bedrooms + Electricity,
    family = poisson, data = data)

Coefficients:
                                                    Estimate Std. Error
(Intercept)                                        1.596e+00  6.094e-02
Total.Household.Income                            -2.532e-07  5.538e-08
Total.Food.Expenditure                             2.935e-06  1.881e-07
Household.Head.SexMale                             2.634e-01  3.053e-02
Household.Head.Age                                -3.852e-03  8.096e-04
Type.of.HouseholdSingle Family                    -3.470e-01  2.291e-02
Type.of.HouseholdTwo or More Nonrelated Persons/Members -1.019e-01  1.809e-01
House.Age                                         -3.760e-03  1.030e-03
Number.of.bedrooms                                 4.445e-02  1.172e-02
ElectricityYes                                    -9.133e-02  2.849e-02
                                                  z value Pr(>|z|)
(Intercept)                                        26.199  < 2e-16 ***
Total.Household.Income                             -4.572 4.82e-06 ***
Total.Food.Expenditure                             15.599  < 2e-16 ***
Household.Head.SexMale                              8.629  < 2e-16 ***
Household.Head.Age                                 -4.757 1.96e-06 ***
Type.of.HouseholdSingle Family                    -15.150  < 2e-16 ***
Type.of.HouseholdTwo or More Nonrelated Persons/Members  -0.563 0.573307
House.Age                                          -3.651 0.000261 ***
Number.of.bedrooms                                  3.795 0.000148 ***
ElectricityYes                                     -3.206 0.001346 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2217.8  on 2121  degrees of freedom
Residual deviance: 1554.0  on 2112  degrees of freedom
AIC: 8512

Number of Fisher Scoring iterations: 5
```

After removed the continuous variable House.Floor.Area, the AIC of the model almost remained the same, and the BIC of the model dropped a bit. So we can prove that House.Floor.Area does not influence response variable significantly.

4.1.3 Remove Type.of.Household

```
model_2 <- glm(Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.Expend
               family = poisson(link = "log"))
```

```
summ(model_2)
```

Observations	2122
Dependent variable	Total.Number.of.Family.members
Type	Generalized linear model
Family	poisson
Link	log

$\chi^2(7)$	440.36
Pseudo-R^2 (Cragg-Uhler)	0.19
Pseudo-R^2 (McFadden)	0.05
AIC	8731.54
BIC	8776.82

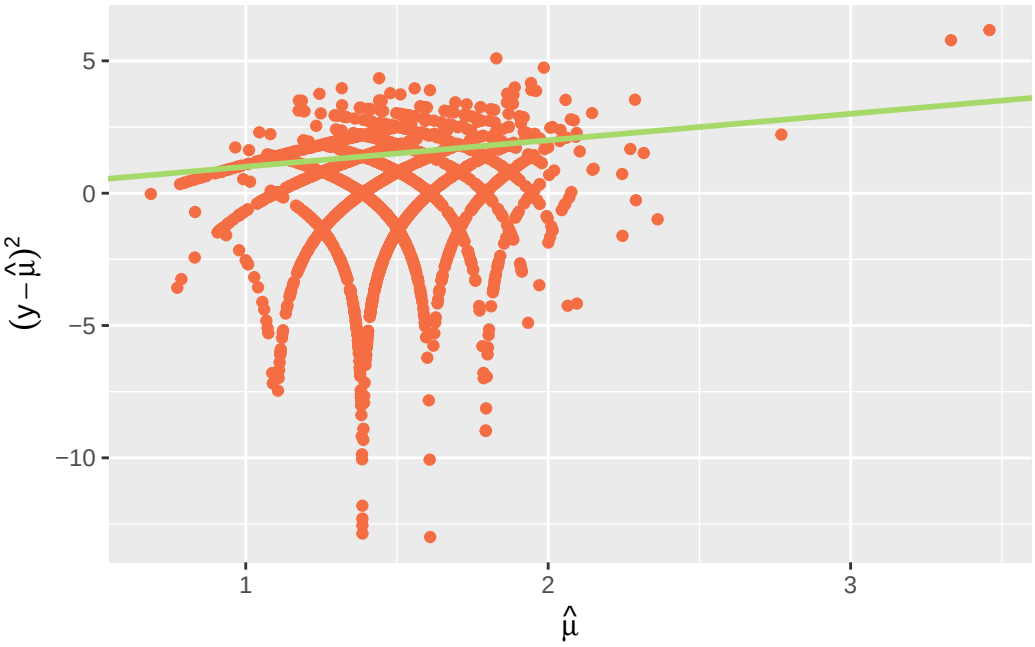
	Est.	S.E.	z val.	p
(Intercept)	1.20	0.06	21.79	0.00
Total.Household.Income	-0.00	0.00	-4.63	0.00
Total.Food.Expenditure	0.00	0.00	18.62	0.00
Household.Head.SexMale	0.22	0.03	7.27	0.00
Household.Head.Age	-0.00	0.00	-1.90	0.06
House.Age	-0.00	0.00	-3.18	0.00
Number.of.bedrooms	0.06	0.01	4.93	0.00
ElectricityYes	-0.07	0.03	-2.47	0.01

Standard errors: MLE

However, if we removed the categorical variable Type.of.Household from the model, the AIC and BIC both increased. Therefore, we cannot conclude that Type.of.Household will not influence the response variable and need to the Overdispersion case.

4.2 Overdispersion

```
ggplot(model2, aes(x=log(fitted(model2)), y=log((data$Total.Number.of.Family.members-fitte
geom_point(col="#f46d43") +
geom_abline(slope=1, intercept=0, col="#a6d96a", linewidth=1) +
ylab(expression((y-hat(mu))^2)) + xlab(expression(hat(mu)))
```



From the above scatterplot of mean and variance, we can find most of the points lie above the line of equality for mean and variance. In this case, we are not to able to determine which explanatory variables are significant.

4.2.1 Quasi-Poisson model

we can define a dispersion parameter ϕ such that $Var(Y_i) = \phi\mu_i$, we can estimate this parameter by

$$\hat{\phi} = \frac{X^2}{n-p}$$

```
X2=sum(resid(model1,type="pearson")^2)
dp=X2/model1$df.res
#With the use of the estimated dispersion parameter the Wald tests are not very reliable,
```

```r
drop1(model1,test="F")
```

```
Single term deletions

Model:
Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.Expenditure +
    Household.Head.Sex + Household.Head.Age + Type.of.Household +
    House.Floor.Area + House.Age + Number.of.bedrooms + Electricity
                      Df Deviance    AIC  F value    Pr(>F)
<none>                     1551.8 8511.9
Total.Household.Income  1   1570.8 8528.8  25.7704 4.182e-07 ***
Total.Food.Expenditure  1   1737.1 8695.2 252.0856 < 2.2e-16 ***
Household.Head.Sex      1   1630.4 8588.4 106.8233 < 2.2e-16 ***
Household.Head.Age      1   1573.8 8531.9  29.9530 4.952e-08 ***
Type.of.Household       2   1774.8 8730.9 151.6907 < 2.2e-16 ***
House.Floor.Area        1   1554.0 8512.0   2.9244 0.0873964 .
House.Age               1   1565.0 8523.1  17.9624 2.350e-05 ***
Number.of.bedrooms      1   1568.3 8526.3  22.3752 2.391e-06 ***
Electricity             1   1561.7 8519.8  13.4388 0.0002526 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

From the model summary above, we are supposed to delete the variable House.Floor.Area.

```r
model_quasi <- glm(Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.Ex
             family = quasipoisson(link = "log"))
drop1(model_quasi, test = "F")
```

```
Single term deletions

Model:
Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.Expenditure +
    Household.Head.Sex + Household.Head.Age + Type.of.Household +
    House.Age + Number.of.bedrooms + Electricity
                      Df Deviance F value    Pr(>F)
<none>                     1554.0
Total.Household.Income  1   1576.3  30.340 4.068e-08 ***
Total.Food.Expenditure  1   1739.5 252.114 < 2.2e-16 ***
Household.Head.Sex      1   1632.8 107.072 < 2.2e-16 ***
Household.Head.Age      1   1576.7  30.870 3.107e-08 ***
```

```
Type.of.Household       2   1777.5 151.879 < 2.2e-16 ***
House.Age               1   1567.5  18.406 1.865e-05 ***
Number.of.bedrooms      1   1568.3  19.497 1.058e-05 ***
Electricity             1   1564.1  13.750 0.0002143 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

After we try to fit a quasi-poisson model and delete House.Floor.Area, the summary shows all the remaining variables are significant.

4.2.2 Negative binomial models

Considering the Overdispersion, another choice is the Negative-binomial model.

```
model3=glm.nb(Total.Number.of.Family.members~Total.Household.Income+Total.Food.Expenditure
summary(model3)
```

```
Call:
glm.nb(formula = Total.Number.of.Family.members ~ Total.Household.Income +
    Total.Food.Expenditure + Household.Head.Sex + Household.Head.Age +
    Type.of.Household + House.Floor.Area + House.Floor.Area +
    House.Age + Number.of.bedrooms + Electricity, data = data,
    init.theta = 76069.34, link = log)

Coefficients:
                                                        Estimate Std. Error
(Intercept)                                            1.597e+00  6.095e-02
Total.Household.Income                                -2.386e-07  5.634e-08
Total.Food.Expenditure                                 2.931e-06  1.880e-07
Household.Head.SexMale                                 2.631e-01  3.053e-02
Household.Head.Age                                    -3.797e-03  8.105e-04
Type.of.HouseholdSingle Family                        -3.467e-01  2.291e-02
Type.of.HouseholdTwo or More Nonrelated Persons/Members -1.058e-01  1.809e-01
House.Floor.Area                                      -4.940e-04  3.402e-04
House.Age                                             -3.715e-03  1.030e-03
Number.of.bedrooms                                     5.011e-02  1.234e-02
ElectricityYes                                        -9.029e-02  2.850e-02
                                                      z value Pr(>|z|)
(Intercept)                                            26.209  < 2e-16 ***
Total.Household.Income                                 -4.234 2.29e-05 ***
```

```
Total.Food.Expenditure                                    15.588  < 2e-16 ***
Household.Head.SexMale                                     8.615  < 2e-16 ***
Household.Head.Age                                        -4.684 2.81e-06 ***
Type.of.HouseholdSingle Family                           -15.134  < 2e-16 ***
Type.of.HouseholdTwo or More Nonrelated Persons/Members   -0.585 0.558455
House.Floor.Area                                          -1.452 0.146465
House.Age                                                 -3.605 0.000312 ***
Number.of.bedrooms                                         4.061 4.89e-05 ***
ElectricityYes                                            -3.168 0.001536 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(76069.53) family taken to be 1)

    Null deviance: 2217.7  on 2121  degrees of freedom
Residual deviance: 1551.7  on 2111  degrees of freedom
AIC: 8513.9

Number of Fisher Scoring iterations: 1

              Theta:  76069
          Std. Err.:  280723
Warning while fitting theta: alternation limit reached

 2 x log-likelihood:  -8489.906
```

Similarly, we can see that the categorical variable Type.of.Household(Two or More Nonrelated Persons/Members) and continuous variable House.Floor.Area seem not to be statistically significant with the response variable.

```r
model_nb1 <- glm.nb(Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.E
summary(model_nb1)
```

```
Call:
glm.nb(formula = Total.Number.of.Family.members ~ Total.Household.Income +
    Total.Food.Expenditure + Household.Head.Sex + Household.Head.Age +
    Type.of.Household + House.Age + Number.of.bedrooms + Electricity,
    data = data, init.theta = 76118.81046, link = log)

Coefficients:
```

```
                                                        Estimate Std. Error
(Intercept)                                             1.596e+00  6.094e-02
Total.Household.Income                                 -2.533e-07  5.538e-08
Total.Food.Expenditure                                  2.935e-06  1.881e-07
Household.Head.SexMale                                  2.634e-01  3.053e-02
Household.Head.Age                                     -3.852e-03  8.096e-04
Type.of.HouseholdSingle Family                         -3.470e-01  2.291e-02
Type.of.HouseholdTwo or More Nonrelated Persons/Members -1.019e-01  1.809e-01
House.Age                                              -3.760e-03  1.030e-03
Number.of.bedrooms                                      4.445e-02  1.172e-02
ElectricityYes                                         -9.134e-02  2.849e-02
                                                       z value Pr(>|z|)
(Intercept)                                             26.198  < 2e-16 ***
Total.Household.Income                                  -4.573 4.82e-06 ***
Total.Food.Expenditure                                  15.599  < 2e-16 ***
Household.Head.SexMale                                   8.629  < 2e-16 ***
Household.Head.Age                                      -4.757 1.96e-06 ***
Type.of.HouseholdSingle Family                         -15.149  < 2e-16 ***
Type.of.HouseholdTwo or More Nonrelated Persons/Members  -0.563 0.573340
House.Age                                               -3.651 0.000261 ***
Number.of.bedrooms                                       3.794 0.000148 ***
ElectricityYes                                          -3.206 0.001346 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(76118.92) family taken to be 1)

    Null deviance: 2217.7  on 2121  degrees of freedom
Residual deviance: 1553.9  on 2112  degrees of freedom
AIC: 8514.1

Number of Fisher Scoring iterations: 1

              Theta:  76119
          Std. Err.:  280216
Warning while fitting theta: alternation limit reached

 2 x log-likelihood:  -8492.056
```

```
model_nb1$aic
```

```
[1] 8514.056
```

We first deleted the continuous variable House.Floor.Area and observed that the AIC of the model decreased. The summary of the latest model indicated we should delete the categorical variable Type.of.Household as well.

```
model_nb2 <- glm.nb(Total.Number.of.Family.members ~ Total.Household.Income + Total.Food.E
summary(model_nb2)
```

```
Call:
glm.nb(formula = Total.Number.of.Family.members ~ Total.Household.Income +
    Total.Food.Expenditure + Household.Head.Sex + Household.Head.Age +
    House.Age + Number.of.bedrooms + Electricity, data = data,
    init.theta = 27372.81126, link = log)

Coefficients:
                          Estimate Std. Error z value Pr(>|z|)
(Intercept)              1.204e+00  5.527e-02  21.790  < 2e-16 ***
Total.Household.Income -2.475e-07  5.348e-08  -4.628 3.69e-06 ***
Total.Food.Expenditure  3.259e-06  1.750e-07  18.625  < 2e-16 ***
Household.Head.SexMale  2.211e-01  3.041e-02   7.269 3.62e-13 ***
Household.Head.Age     -1.505e-03  7.935e-04  -1.897  0.05789 .
House.Age              -3.284e-03  1.034e-03  -3.178  0.00148 **
Number.of.bedrooms      5.805e-02  1.177e-02   4.931 8.16e-07 ***
ElectricityYes         -7.034e-02  2.844e-02  -2.473  0.01339 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(27372.73) family taken to be 1)

    Null deviance: 2217.5  on 2121  degrees of freedom
Residual deviance: 1777.1  on 2114  degrees of freedom
AIC: 8733.5

Number of Fisher Scoring iterations: 1

              Theta:  27373
          Std. Err.:  191914
Warning while fitting theta: alternation limit reached

 2 x log-likelihood:  -8715.542
```

```
model_nb2$aic
```

```
[1] 8733.542
```

The AIC rose after we deleted the categorical variable Type.of.Household. Therefore, we could conclude that the continuous variable House.Floor.Area is the only variable that might not influence the response variable Total.Number.of.Family.members.

5 Final model

```
c(model2$deviance,model2$aic)
```

```
[1] 1553.980 8512.034
```

```
c(model_nb1$deviance,model3$aic)
```

```
[1] 1553.876 8513.906
```

The final model is:

$Total.Number.of.Family.members = \beta_0 + \beta_1 \cdot Total.Household.Income + \beta_2 \cdot Total.Food.Expenditure + \beta_3 \cdot \mathbb{I}_{\text{Mal}}$

$$\mathbb{I}_{\text{Male}}(x) = \begin{cases} 1 & \text{if the head of household is Male,} \\ 0 & \text{if the head of household is female.} \end{cases}$$

$$\mathbb{I}_{\text{Family}}(x) = \begin{cases} 1 & \text{Single family,} \\ 0 & \text{Otherwise.} \end{cases}$$

$$\mathbb{I}_{\text{Electricity}}(x) = \begin{cases} 1 & \text{if the house has electricity,} \\ 0 & \text{Otherwise.} \end{cases}$$

For extended family and two or more nonrelated persons/members, the final model is:

$Total.Number.of.Family.members = 1.596 - 2.532 \times 10^{-7} \cdot Total.Household.Income + 2.953 \times 10^{-6} \cdot Total.Food.E$

For single family, the final model is:

$Total.Number.of.Family.members = 1.596 - 2.532 \times 10^{-7} \cdot Total.Household.Income + 2.953 \times 10^{-6} \cdot Total.Food.E$

6 Conclusion

Variables Total.Household.Income, Total.Food.Expenditure, Household.Head.Sex, Household.Head.Age, Type.of.Household, House.Age, Number.of.bedrooms and Electricity could influence response variable Total.Number.of.Family.members.