p8130_hw5_yl5508

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2023/12/7

```
library(tidyverse)
library(faraway)
```

Problem 1

(a)

```
#load data set
sta_data = as.data.frame(state.x77)
sta_data |>
  summary() |>
  knitr::kable(digits = 1)
```

	Population	Income	Illiteracy	Life Exp	Murder	HS Grad	Frost	Area
	Min. : 365	Min. :3098	Min. :0.500	Min. :67.96	Min. : 1.400	Min. :37.80	Min. : 0.00	Min. : 1049
	1st Qu.: 1080	1st Qu.:3993	1st Qu.:0.625	1st Qu.:70.12	1st Qu.: 4.350	1st Qu.:48.05	1st Qu.: 66.25	1st Qu.: 36985
	Median : 2838	Median :4519	Median :0.950	Median :70.67	Median : 6.850	Median :53.25	Median :114.50	Median : 54277
	Mean : 4246	Mean :4436	Mean :1.170	Mean :70.88	Mean : 7.378	Mean :53.11	Mean :104.46	Mean : 70736
	3rd Qu.: 4968	3rd Qu.:4814	3rd Qu.:1.575	3rd Qu.:71.89	3rd Qu.:10.675	3rd Qu.:59.15	3rd Qu.:139.75	3rd Qu.: 81163
	Max. :21198	Max. :6315	Max. :2.800	Max. :73.60	Max. :15.100	Max. :67.30	Max. :188.00	Max. :566432

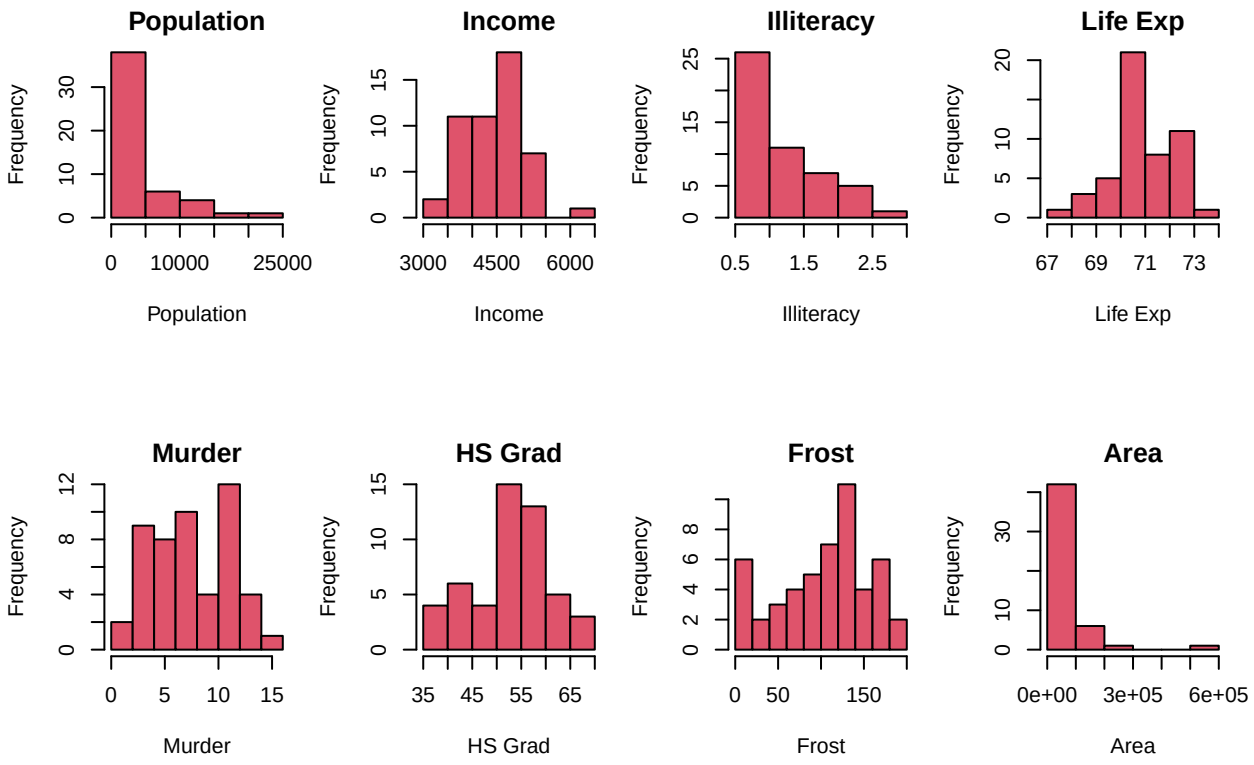
Continuous variables includes `Population`, `Income`, `Illiteracy`, `Life Exp`, `Murder`, `HS Grad`, `Frost`, `Area`.

No variable listed in the data set is categorical.

(b)

```
#histogram of variables
par(mfrow = c(2, 4), mar = c(8, 4, 2, 1))

for (i in 1:8) {
```

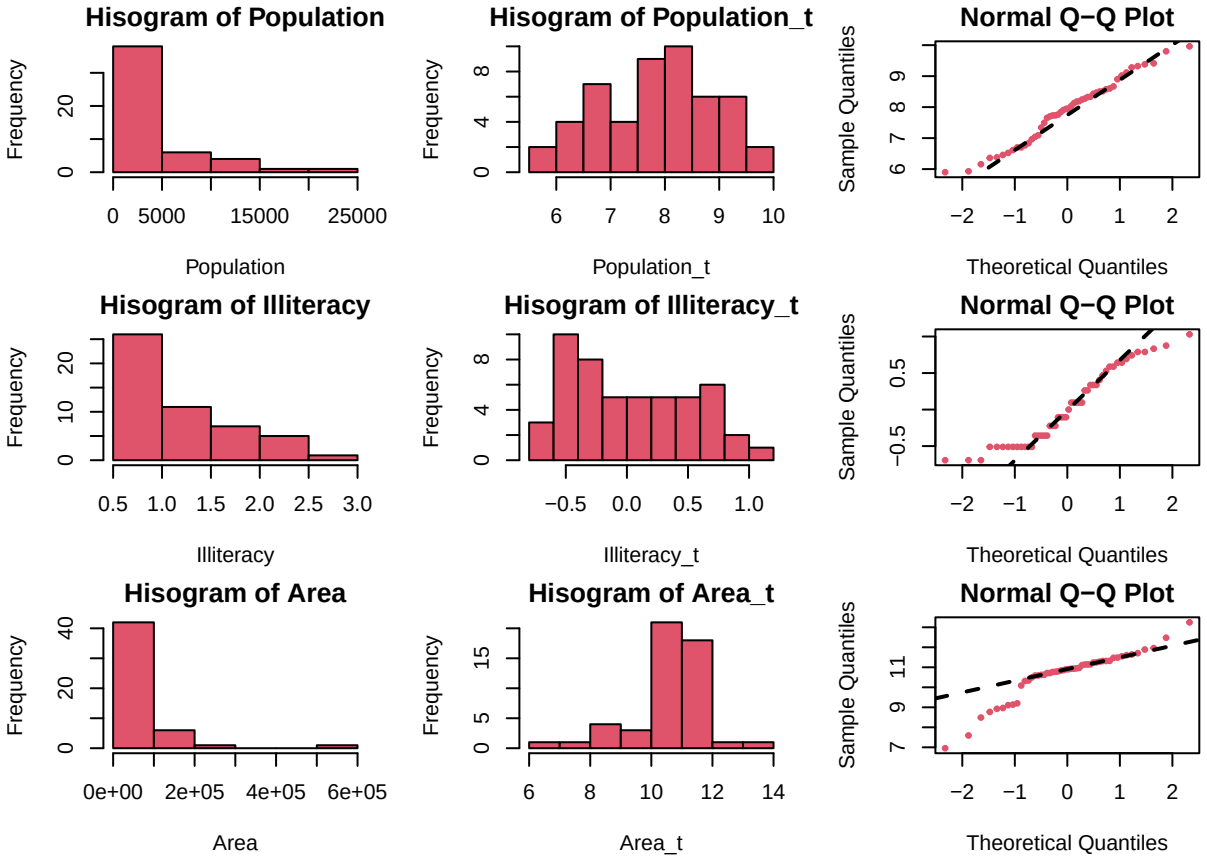
```
  sta_data[,i] |>
  hist(main = colnames(sta_data[i]), xlab = colnames(sta_data[i]), freq = T, col = 2)
}
```



From the histograms, we notice that `Population`, `Illiteracy`, `Area` need to be transformed in order to get a normal distribution.

```
#log transformation
sta_transformed =
  sta_data |>
  mutate(
    Population_t = log(Population),
    Illiteracy_t = log(Illiteracy),
    Area_t = log(Area)) |>
  select(Population, Population_t, Illiteracy, Illiteracy_t, Area, Area_t)

sta_tidy =
  sta_data |>
  mutate(
    Population_t = log(Population),
    Illiteracy_t = log(Illiteracy),
    Area_t = log(Area)) |>
  select(-Population, -Illiteracy, -Area)

par(mfrow = c(3, 3), mar = c(4, 4, 2, 2))
```

```r
for (i in seq(1, 5, 2)) {
  #untransformed variables
  sta_transformed[,i] |>
    hist(main = str_c("Hisogram of ", colnames(sta_transformed[i])), xlab = colnames(sta_transformed[i]))

  #log transformed variables
  sta_transformed[,i+1] |>
    hist(main = str_c("Hisogram of ", colnames(sta_transformed[i+1])), xlab = colnames(sta_transformed[i+1]))

  #Q-Q plot
  qqnorm(sta_transformed[,i+1], col = 2, pch = 19, cex = 0.5)
  qqline(sta_transformed[,i+1], col = 1, lwd = 2, lty = 2)
}
```



(c)

```r
#global variables
lm(`Life Exp` ~ ., data = sta_tidy) |>
  summary()
```

```
##
## Call:
## lm(formula = `Life Exp` ~ ., data = sta_tidy)
##
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -1.44702 -0.42901  0.04546  0.50742  1.68911
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   6.799e+01  1.798e+00  37.809  < 2e-16 ***
## Income       -4.417e-06  2.475e-04  -0.018   0.9858
## Murder       -3.114e-01  4.659e-02  -6.684 4.12e-08 ***
## `HS Grad`     5.482e-02  2.552e-02   2.148   0.0375 *
## Frost        -4.669e-03  3.173e-03  -1.471   0.1487
## Population_t  2.537e-01  1.311e-01   1.936   0.0597 .
## Illiteracy_t  1.883e-01  4.204e-01   0.448   0.6565
## Area_t        7.314e-02  1.102e-01   0.663   0.5107
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7335 on 42 degrees of freedom
## Multiple R-squared:  0.7441, Adjusted R-squared:  0.7014
## F-statistic: 17.45 on 7 and 42 DF,  p-value: 1.368e-10
```

```r
#forward stepwise
model_fw = lm(`Life Exp` ~ ., data = sta_tidy) |>
  step(direction = "forward")
```

```
## Start:  AIC=-23.71
## `Life Exp` ~ Income + Murder + `HS Grad` + Frost + Population_t +
##     Illiteracy_t + Area_t
```

```r
model_fw |> summary()
```

```
##
## Call:
## lm(formula = `Life Exp` ~ Income + Murder + `HS Grad` + Frost +
##     Population_t + Illiteracy_t + Area_t, data = sta_tidy)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.44702 -0.42901  0.04546  0.50742  1.68911
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   6.799e+01  1.798e+00  37.809  < 2e-16 ***
## Income       -4.417e-06  2.475e-04  -0.018   0.9858
## Murder       -3.114e-01  4.659e-02  -6.684 4.12e-08 ***
## `HS Grad`     5.482e-02  2.552e-02   2.148   0.0375 *
## Frost        -4.669e-03  3.173e-03  -1.471   0.1487
## Population_t  2.537e-01  1.311e-01   1.936   0.0597 .
## Illiteracy_t  1.883e-01  4.204e-01   0.448   0.6565
## Area_t        7.314e-02  1.102e-01   0.663   0.5107
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7335 on 42 degrees of freedom
```

```
## Multiple R-squared:  0.7441, Adjusted R-squared:  0.7014
## F-statistic: 17.45 on 7 and 42 DF,  p-value: 1.368e-10
```

```
model_fw |> anova()
```

```
## Analysis of Variance Table
##
## Response: Life Exp
##              Df Sum Sq Mean Sq F value    Pr(>F)
## Income        1 10.223  10.223 19.0014 8.269e-05 ***
## Murder        1 46.020  46.020 85.5392 1.095e-11 ***
## `HS Grad`     1  2.388   2.388  4.4395  0.041130 *
## Frost         1  4.479   4.479  8.3251  0.006148 **
## Population_t  1  2.279   2.279  4.2356  0.045825 *
## Illiteracy_t  1  0.078   0.078  0.1449  0.705363
## Area_t        1  0.237   0.237  0.4401  0.510707
## Residuals    42 22.596   0.538
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#backward stepwise
model_bk = lm(`Life Exp` ~ ., data = sta_tidy) |>
  step(direction = "backward")
```

```
## Start:  AIC=-23.71
## `Life Exp` ~ Income + Murder + `HS Grad` + Frost + Population_t +
##     Illiteracy_t + Area_t
##
##                Df Sum of Sq    RSS     AIC
## - Income        1    0.0002 22.596 -25.712
## - Illiteracy_t  1    0.1079 22.704 -25.475
## - Area_t        1    0.2368 22.833 -25.192
## <none>                      22.596 -23.713
## - Frost         1    1.1645 23.760 -23.200
## - Population_t  1    2.0155 24.611 -21.441
## - `HS Grad`     1    2.4822 25.078 -20.502
## - Murder        1   24.0347 46.631  10.512
##
## Step:  AIC=-25.71
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t + Illiteracy_t +
##     Area_t
##
##                Df Sum of Sq    RSS      AIC
## - Illiteracy_t  1    0.1095 22.705 -27.4708
## - Area_t        1    0.2616 22.858 -27.1370
## <none>                      22.596 -25.7125
## - Frost         1    1.2628 23.859 -24.9936
## - Population_t  1    2.3859 24.982 -22.6937
## - `HS Grad`     1    4.4112 27.007 -18.7959
## - Murder        1   24.4834 47.079   8.9907
##
## Step:  AIC=-27.47
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t + Area_t
```

```
##
##                Df Sum of Sq    RSS     AIC
## - Area_t        1    0.2157 22.921 -28.998
## <none>                      22.705 -27.471
## - Population_t  1    2.2792 24.985 -24.688
## - Frost         1    2.3760 25.082 -24.495
## - `HS Grad`     1    4.9491 27.655 -19.612
## - Murder        1   29.2296 51.935  11.899
##
## Step:  AIC=-29
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t
##
##                Df Sum of Sq    RSS     AIC
## <none>                      22.921 -28.998
## - Frost         1     2.214 25.135 -26.387
## - Population_t  1     2.450 25.372 -25.920
## - `HS Grad`     1     6.959 29.881 -17.741
## - Murder        1    34.109 57.031  14.578
```

```
model_bk |> summary()
```

```
##
## Call:
## lm(formula = `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t,
##     data = sta_tidy)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.41760 -0.43880  0.02539  0.52066  1.63048
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  68.720810   1.416828  48.503  < 2e-16 ***
## Murder       -0.290016   0.035440  -8.183 1.87e-10 ***
## `HS Grad`     0.054550   0.014758   3.696 0.000591 ***
## Frost        -0.005174   0.002482  -2.085 0.042779 *
## Population_t  0.246836   0.112539   2.193 0.033491 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7137 on 45 degrees of freedom
## Multiple R-squared:  0.7404, Adjusted R-squared:  0.7173
## F-statistic: 32.09 on 4 and 45 DF,  p-value: 1.17e-12
```

```
model_bk |> anova()
```

```
## Analysis of Variance Table
##
## Response: Life Exp
##              Df Sum Sq Mean Sq  F value    Pr(>F)
## Murder        1 53.838  53.838 105.6966 2.168e-13 ***
## `HS Grad`     1  4.691   4.691   9.2095  0.003992 **
## Frost         1  4.399   4.399   8.6358  0.005184 **
```

```
## Population_t  1  2.450   2.450   4.8107  0.033491 *
## Residuals    45 22.921   0.509
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#both
model_bth = lm(`Life Exp` ~ ., data = sta_tidy) |>
  step(direction = "both")
```

```
## Start:  AIC=-23.71
## `Life Exp` ~ Income + Murder + `HS Grad` + Frost + Population_t +
##     Illiteracy_t + Area_t
##
##                Df Sum of Sq    RSS     AIC
## - Income        1    0.0002 22.596 -25.712
## - Illiteracy_t  1    0.1079 22.704 -25.475
## - Area_t        1    0.2368 22.833 -25.192
## <none>                      22.596 -23.713
## - Frost         1    1.1645 23.760 -23.200
## - Population_t  1    2.0155 24.611 -21.441
## - `HS Grad`     1    2.4822 25.078 -20.502
## - Murder        1   24.0347 46.631  10.512
##
## Step:  AIC=-25.71
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t + Illiteracy_t +
##     Area_t
##
##                Df Sum of Sq    RSS      AIC
## - Illiteracy_t  1    0.1095 22.705 -27.4708
## - Area_t        1    0.2616 22.858 -27.1370
## <none>                      22.596 -25.7125
## - Frost         1    1.2628 23.859 -24.9936
## + Income        1    0.0002 22.596 -23.7129
## - Population_t  1    2.3859 24.982 -22.6937
## - `HS Grad`     1    4.4112 27.007 -18.7959
## - Murder        1   24.4834 47.079   8.9907
##
## Step:  AIC=-27.47
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t + Area_t
##
##                Df Sum of Sq    RSS     AIC
## - Area_t        1    0.2157 22.921 -28.998
## <none>                      22.705 -27.471
## + Illiteracy_t  1    0.1095 22.596 -25.712
## + Income        1    0.0017 22.704 -25.475
## - Population_t  1    2.2792 24.985 -24.688
## - Frost         1    2.3760 25.082 -24.495
## - `HS Grad`     1    4.9491 27.655 -19.612
## - Murder        1   29.2296 51.935  11.899
##
## Step:  AIC=-29
## `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t
##
##                Df Sum of Sq    RSS     AIC
```

```
## <none>                      22.921 -28.998
## + Area_t        1     0.216 22.705 -27.471
## + Illiteracy_t  1     0.064 22.858 -27.137
## + Income        1     0.011 22.911 -27.021
## - Frost         1     2.214 25.135 -26.387
## - Population_t  1     2.450 25.372 -25.920
## - `HS Grad`     1     6.959 29.881 -17.741
## - Murder        1    34.109 57.031  14.578
```

```
model_bth |> summary()
```

```
##
## Call:
## lm(formula = `Life Exp` ~ Murder + `HS Grad` + Frost + Population_t,
##     data = sta_tidy)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.41760 -0.43880  0.02539  0.52066  1.63048
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  68.720810   1.416828  48.503  < 2e-16 ***
## Murder       -0.290016   0.035440  -8.183 1.87e-10 ***
## `HS Grad`     0.054550   0.014758   3.696 0.000591 ***
## Frost        -0.005174   0.002482  -2.085 0.042779 *
## Population_t  0.246836   0.112539   2.193 0.033491 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7137 on 45 degrees of freedom
## Multiple R-squared:  0.7404, Adjusted R-squared:  0.7173
## F-statistic: 32.09 on 4 and 45 DF,  p-value: 1.17e-12
```

```
model_bth |> anova()
```

```
## Analysis of Variance Table
##
## Response: Life Exp
##              Df Sum Sq Mean Sq  F value    Pr(>F)
## Murder        1 53.838  53.838 105.6966 2.168e-13 ***
## `HS Grad`     1  4.691   4.691   9.2095  0.003992 **
## Frost         1  4.399   4.399   8.6358  0.005184 **
## Population_t  1  2.450   2.450   4.8107  0.033491 *
## Residuals    45 22.921   0.509
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```