Hw7_Ex_3

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```
library(BioStatR)
library(olsrr)
```

```
##
## Attaching package: 'olsrr'
```

```
## The following object is masked from 'package:datasets':
##
##     rivers
```

Exercise 3 Homework 7

Reading the data

```
setwd('/home/noble_mannu/Documents/PhD/First/STAT_2131_Applied_Statistical_Methods_I/HW7')
Data <- data.frame(read.table(file = "Boston.txt", header = T, sep = "\t", stringsAsFactors = F))
Data <- Data[,!(colnames(Data)%in%c("LSTAT","b"))]
```

Make the multilinear regression model

```
linearMod <- lm(mvalue ~ ., data=Data)
```

Display summary of our model

```
summary(linearMod)
```

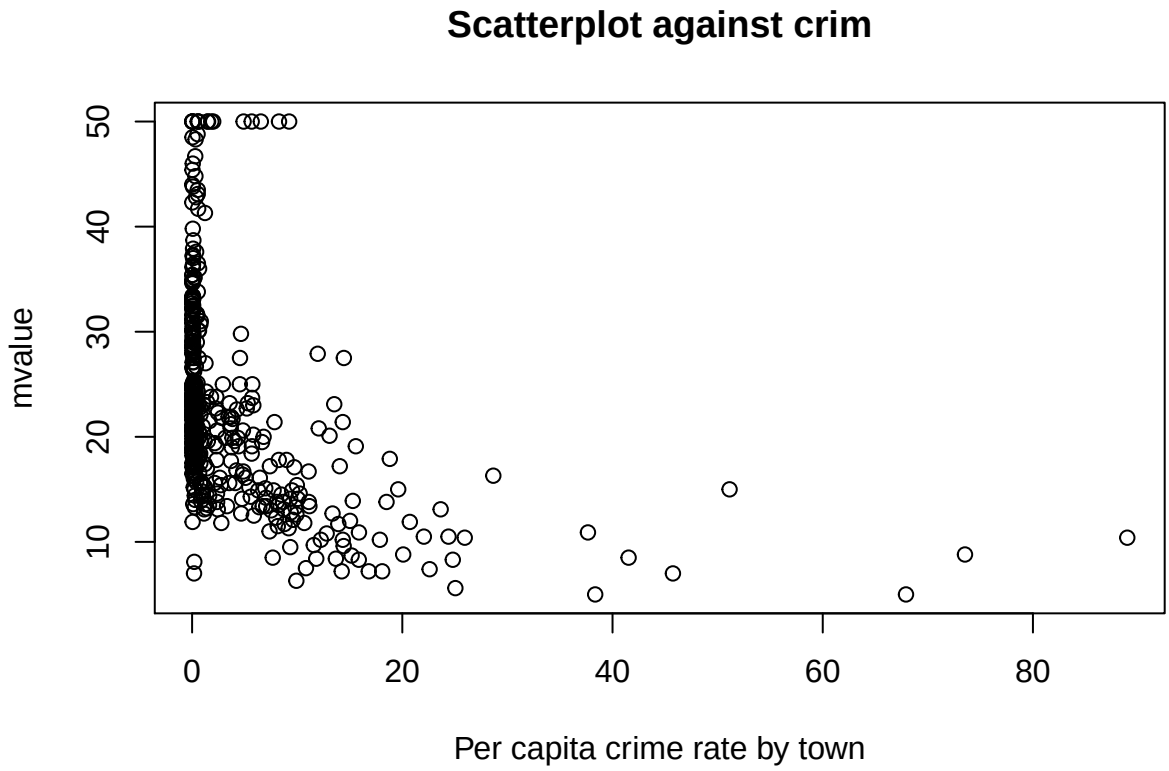
```
##
## Call:
## lm(formula = mvalue ~ ., data = Data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.846  -2.749  -0.624   1.994  37.089
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  27.152368   5.290506   5.132 4.12e-07 ***
## crim         -0.184032   0.036162  -5.089 5.12e-07 ***
## zn            0.039100   0.015424   2.535 0.011551 *
## indus        -0.042324   0.068920  -0.614 0.539425
## chas          3.487528   0.965890   3.611 0.000337 ***
## nox         -22.182110   4.271529  -5.193 3.03e-07 ***
## rooms         6.075744   0.397168  15.298  < 2e-16 ***
```

```
## age          -0.045188   0.013971  -3.234 0.001300 **
## distance     -1.583852   0.224166  -7.066 5.47e-12 ***
## radial        0.254722   0.074371   3.425 0.000666 ***
## tax          -0.012213   0.004229  -2.887 0.004053 **
## pt           -0.996206   0.146998  -6.777 3.50e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.339 on 494 degrees of freedom
## Multiple R-squared:  0.6703, Adjusted R-squared:  0.663
## F-statistic: 91.31 on 11 and 494 DF,  p-value: < 2.2e-16
```

Next we'll plot the scatterplot covariates vs mvalue and the residuals plots. The exercise only requires the residuals but I wanted to try with the scatterplots also to come up with ideas for my Proposed model.

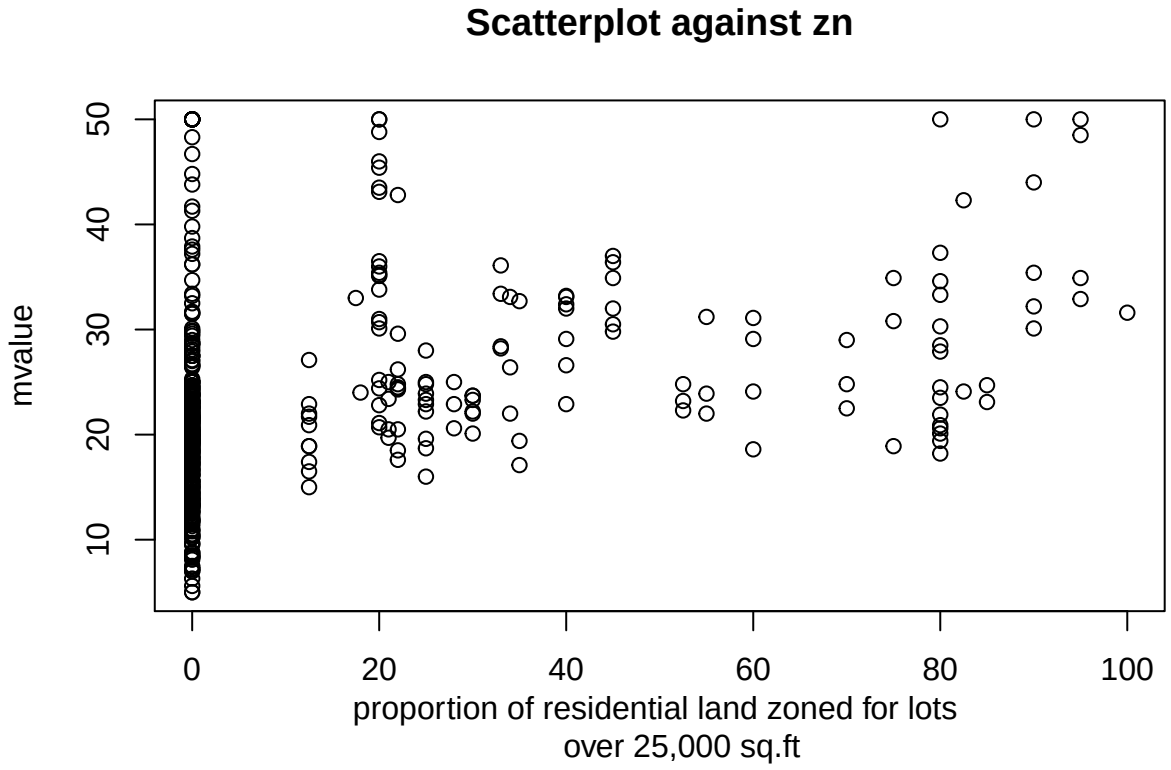
Plot the response against X1

```
plot(Data$crim, Data$mvalue, xlab = "Per capita crime rate by town", ylab = "mvalue",
     main = 'Scatterplot against crim')
```



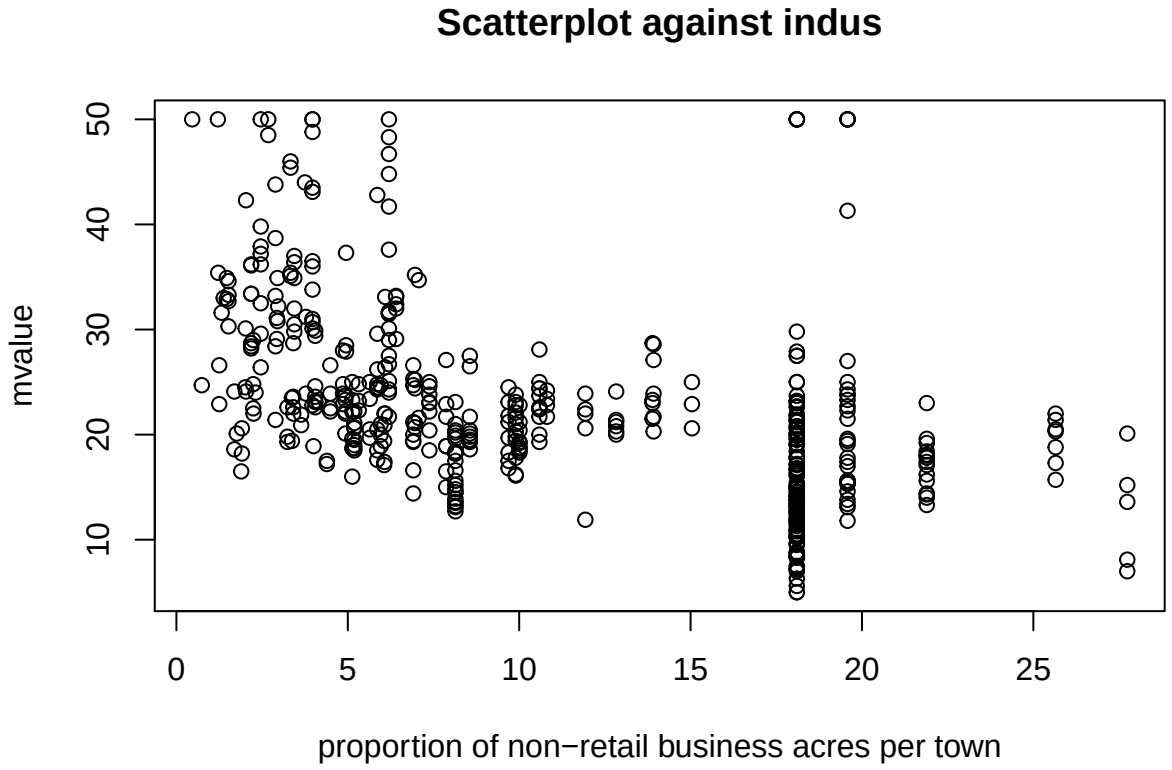
Plot the response against X2

```
plot(Data$zn, Data$mvalue, xlab = "proportion of residential land zoned for lots
     over 25,000 sq.ft", ylab = "mvalue", main = 'Scatterplot against zn')
```



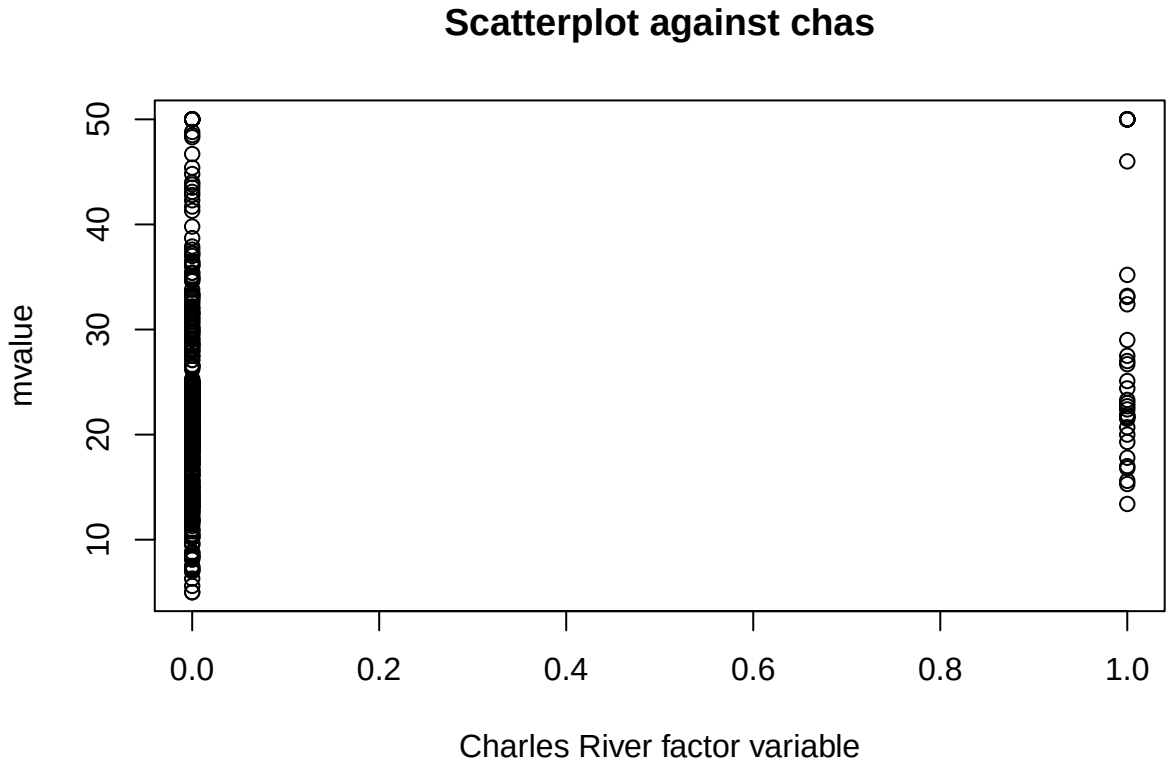
Plot the response against X3

```
plot(Data$indus, Data$mvalue, xlab = "proportion of non-retail business acres per town",
     ylab = "mvalue", main = 'Scatterplot against indus')
```



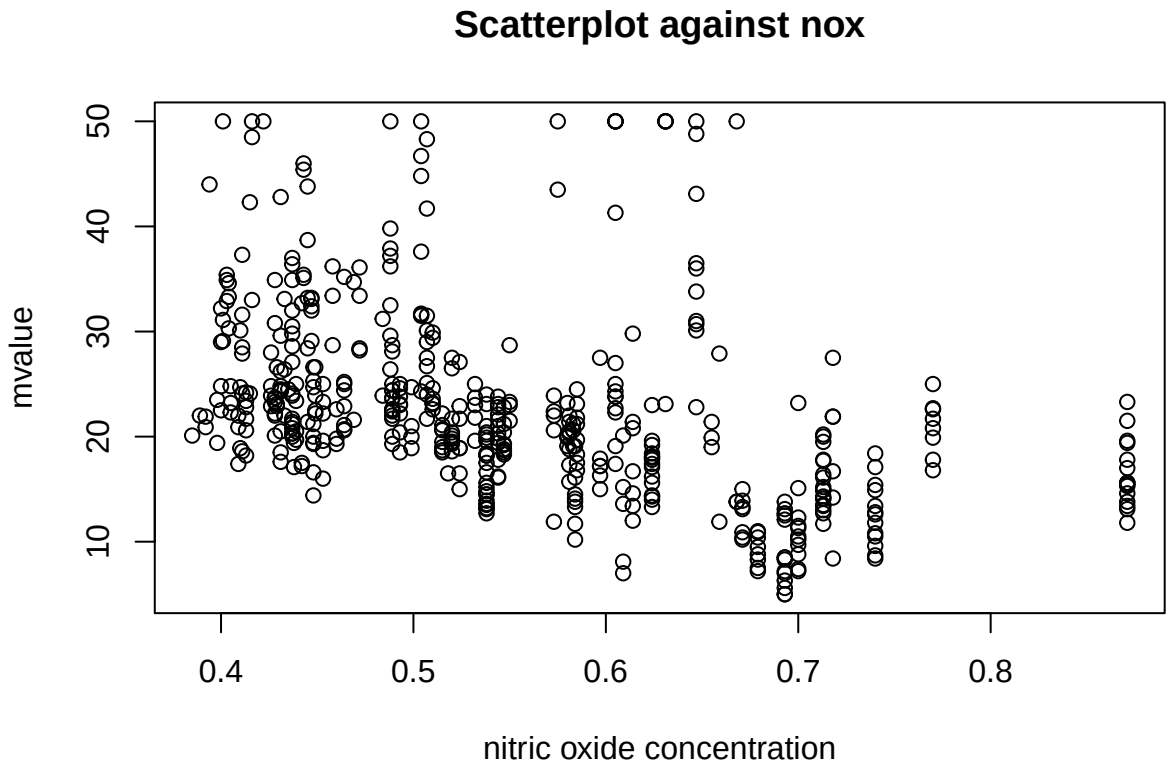
Plot the response against X4

```
plot(Data$chas, Data$mvalue, xlab = "Charles River factor variable", ylab = "mvalue",
     main = 'Scatterplot against chas')
```



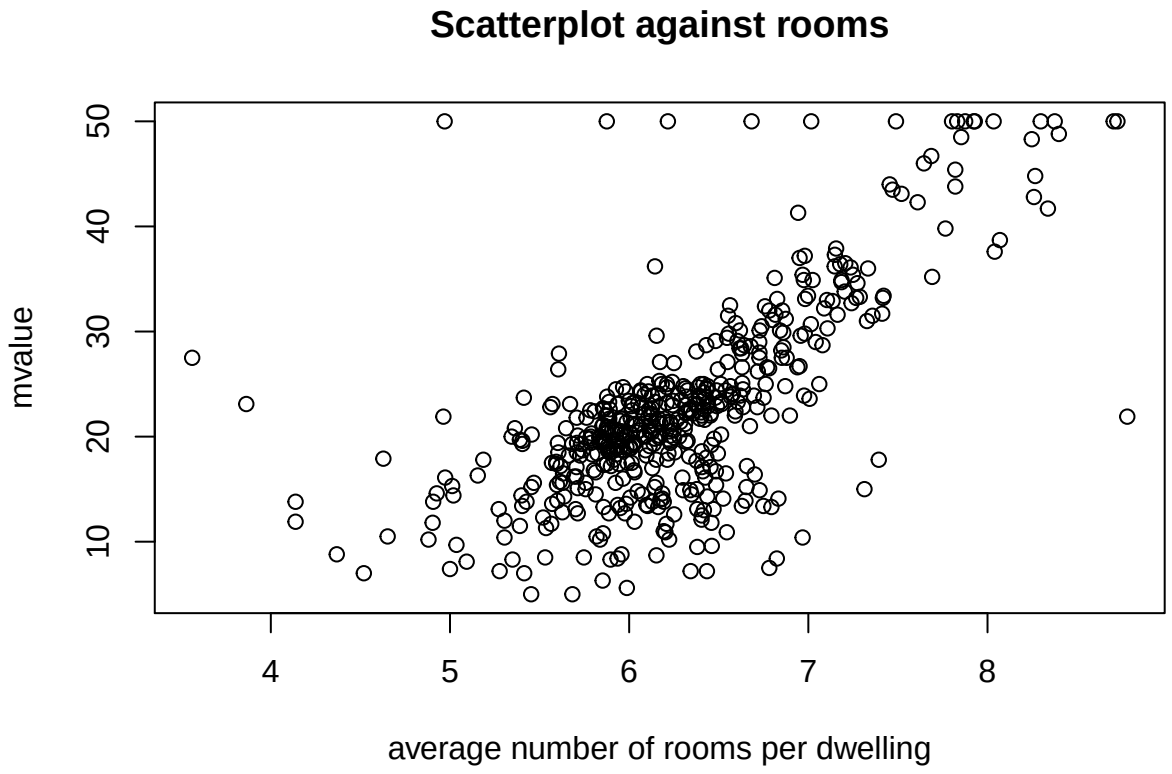
Plot the response against X5

```
plot(Data$nox, Data$mvalue, xlab = "nitric oxide concentration", ylab = "mvalue",
     main = 'Scatterplot against nox')
```



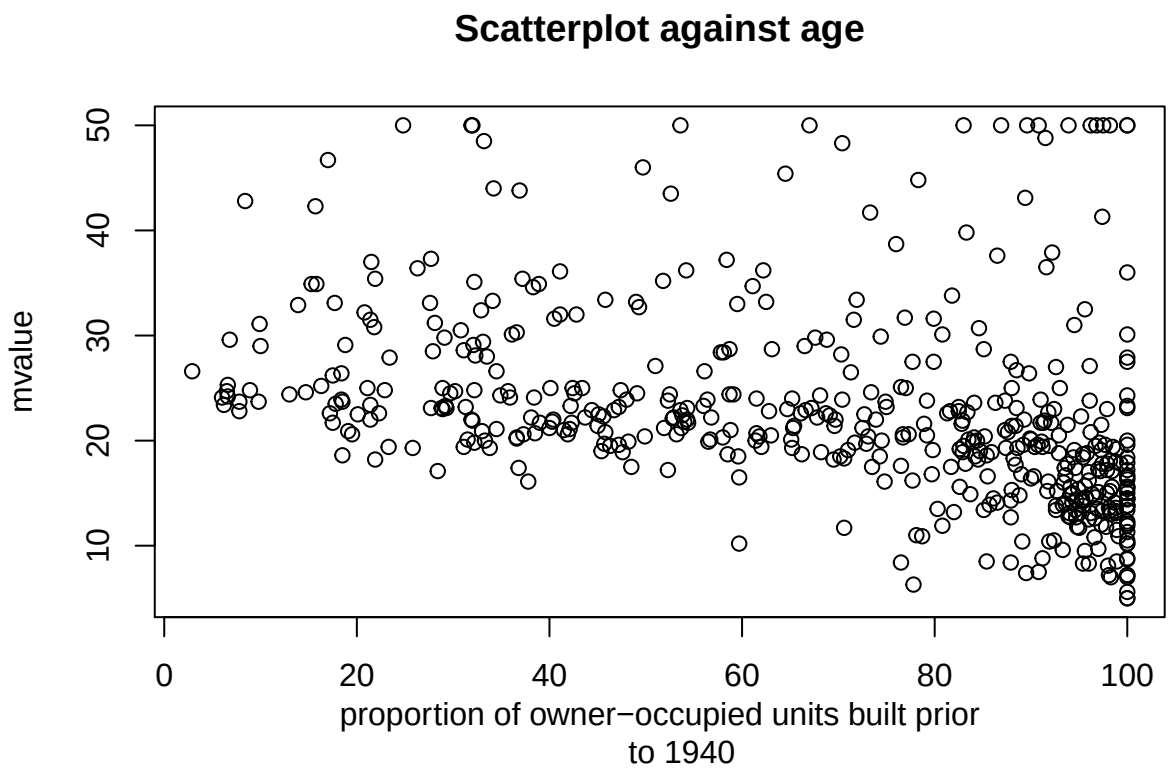
Plot the response against X6

```
plot(Data$rooms, Data$mvalue, xlab = "average number of rooms per dwelling",
     ylab = "mvalue", main = 'Scatterplot against rooms')
```



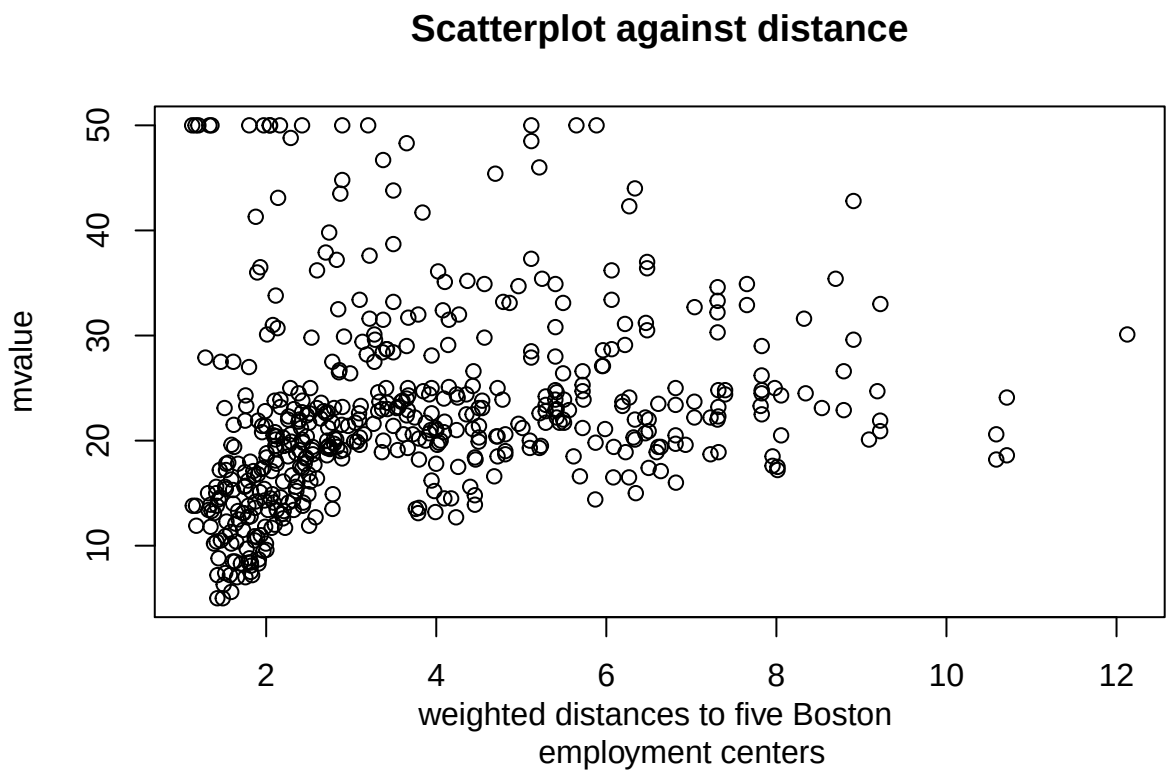
Plot the response against X7

```
plot(Data$age, Data$mvalue, xlab = "proportion of owner-occupied units built prior
     to 1940", ylab = "mvalue", main = 'Scatterplot against age')
```



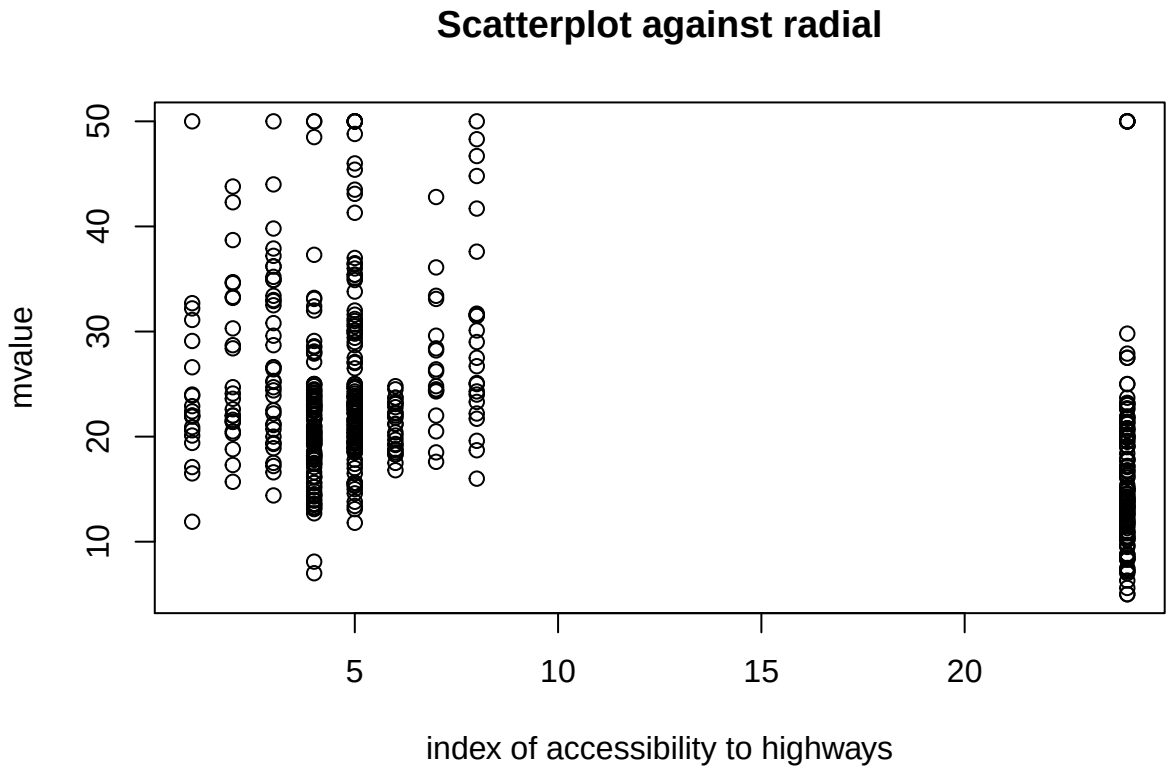
Plot the response against X8

```
plot(Data$distance, Data$mvalue, xlab = "weighted distances to five Boston
     employment centers", ylab = "mvalue", main = 'Scatterplot against distance')
```



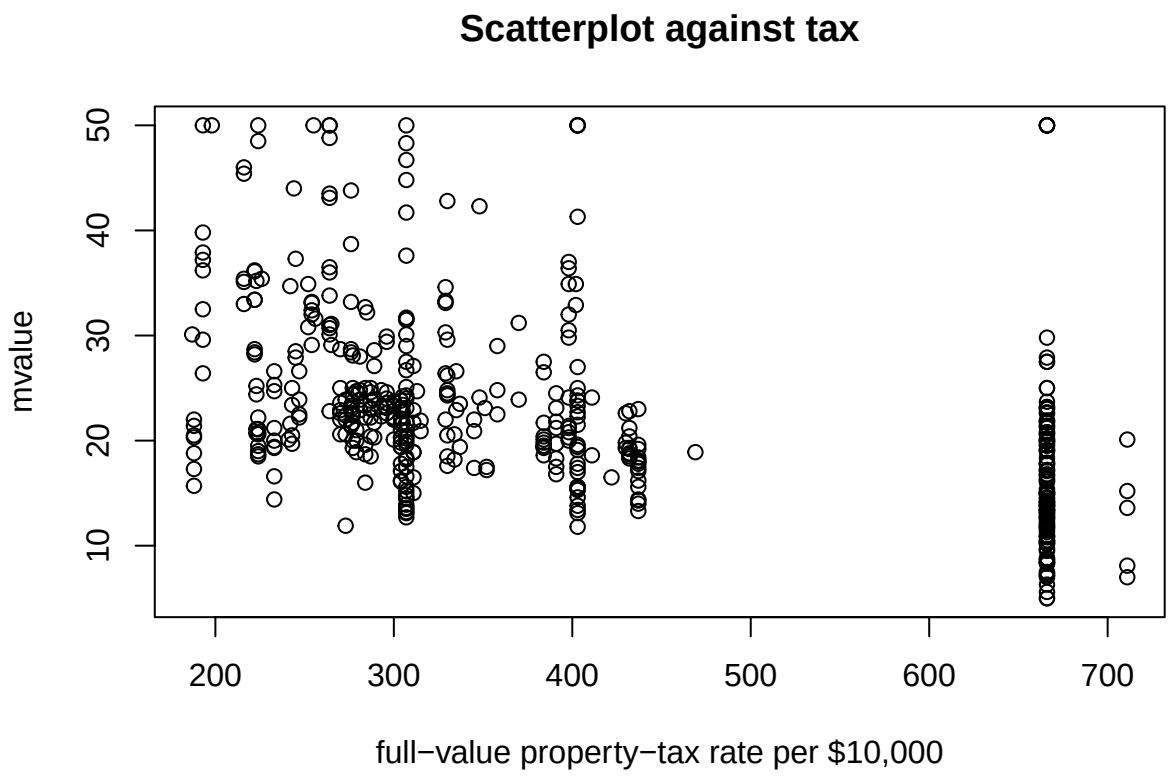
Plot the response against X9

```
plot(Data$radial, Data$mvalue, xlab = "index of accessibility to highways",
     ylab = "mvalue", main = 'Scatterplot against radial')
```



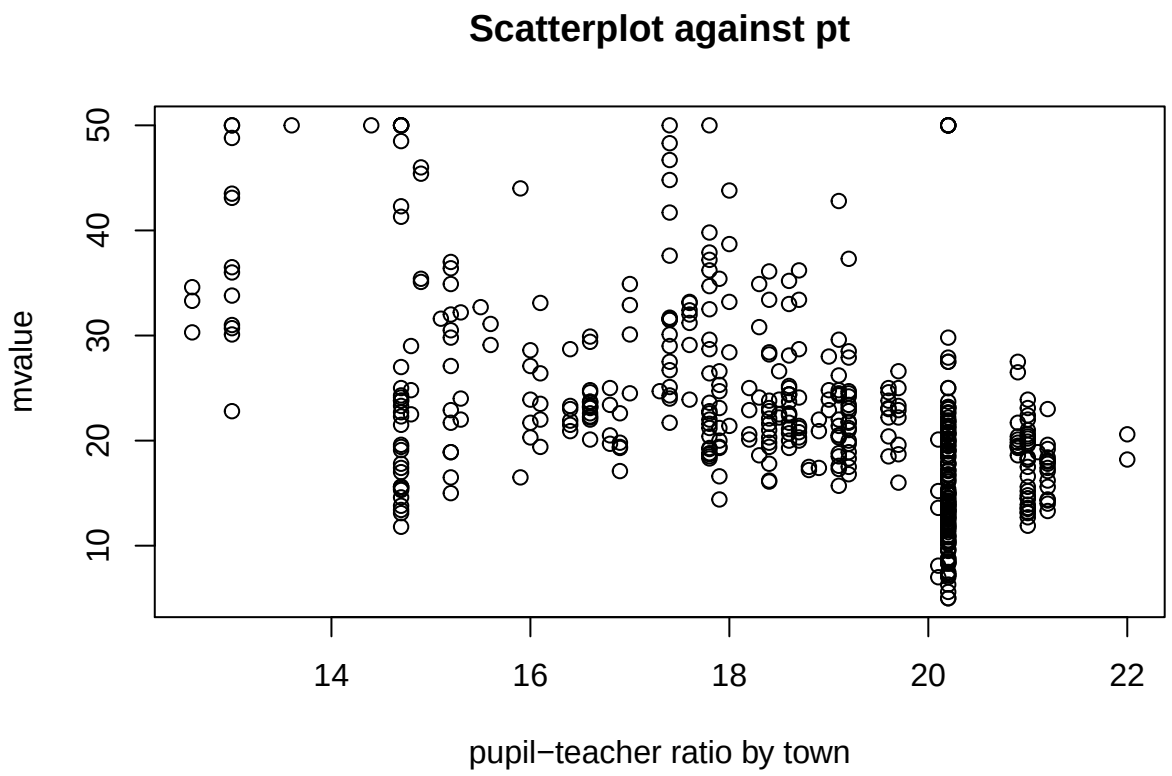
Plot the response against X10

```
plot(Data$tax, Data$mvalue, xlab = "full-value property-tax rate per $10,000",
     ylab = "mvalue", main = 'Scatterplot against tax')
```



Plot the response against X11

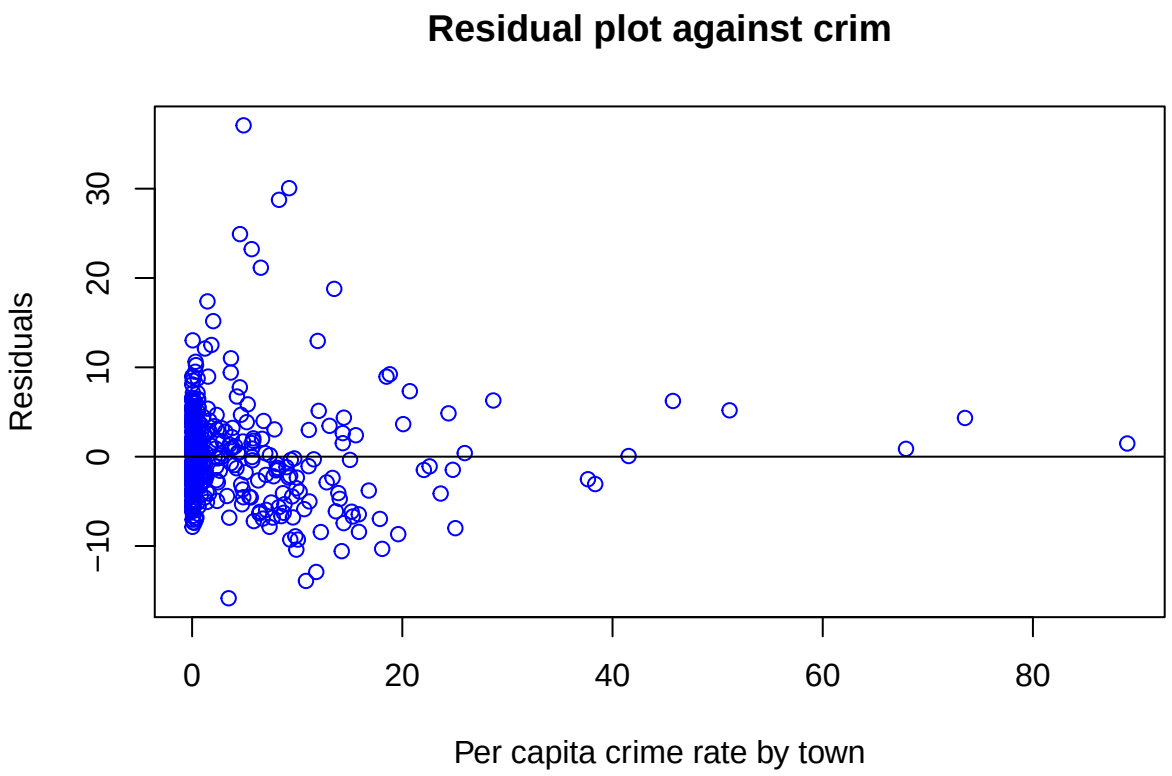
```
plot(Data$pt, Data$mvalue, xlab = "pupil-teacher ratio by town", ylab = "mvalue",
     main = 'Scatterplot against pt')
```



Residuals plots

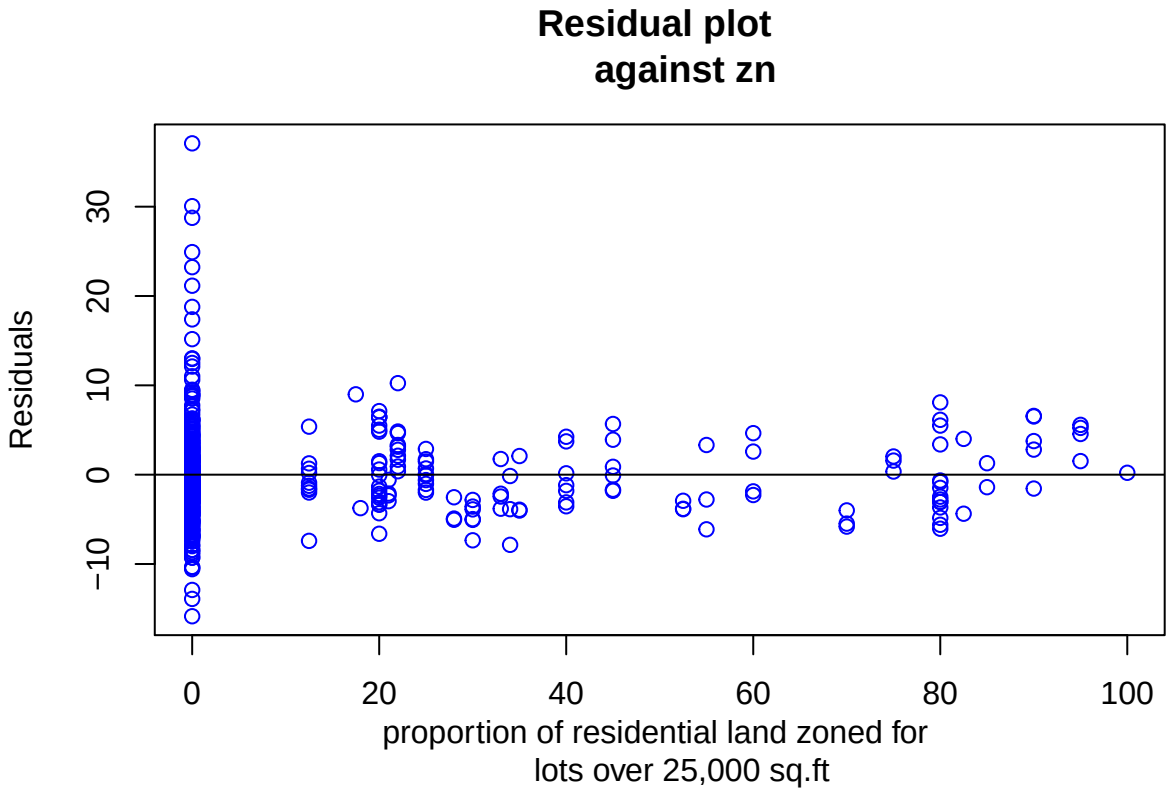
Plot the residuals against X1

```
plot(Data$crim, resid(linearMod), xlab = "Per capita crime rate by town",
     ylab = "Residuals", main = 'Residual plot against crim', col = 'blue')
abline(a=0, b=0)
```



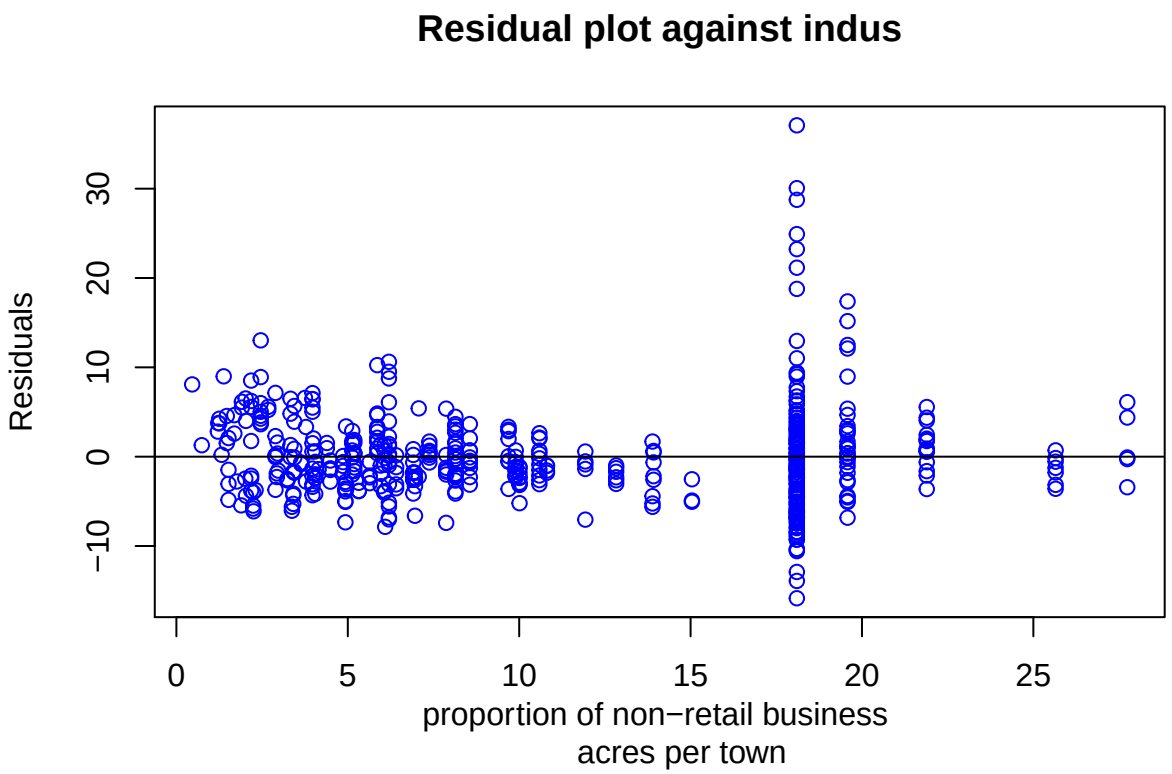
Plot the residuals against X2

```
plot(Data$zn, resid(linearMod), xlab = "proportion of residential land zoned for
     lots over 25,000 sq.ft", ylab = "Residuals", main = 'Residual plot
     against zn', col = 'blue')
abline(a=0, b=0)
```



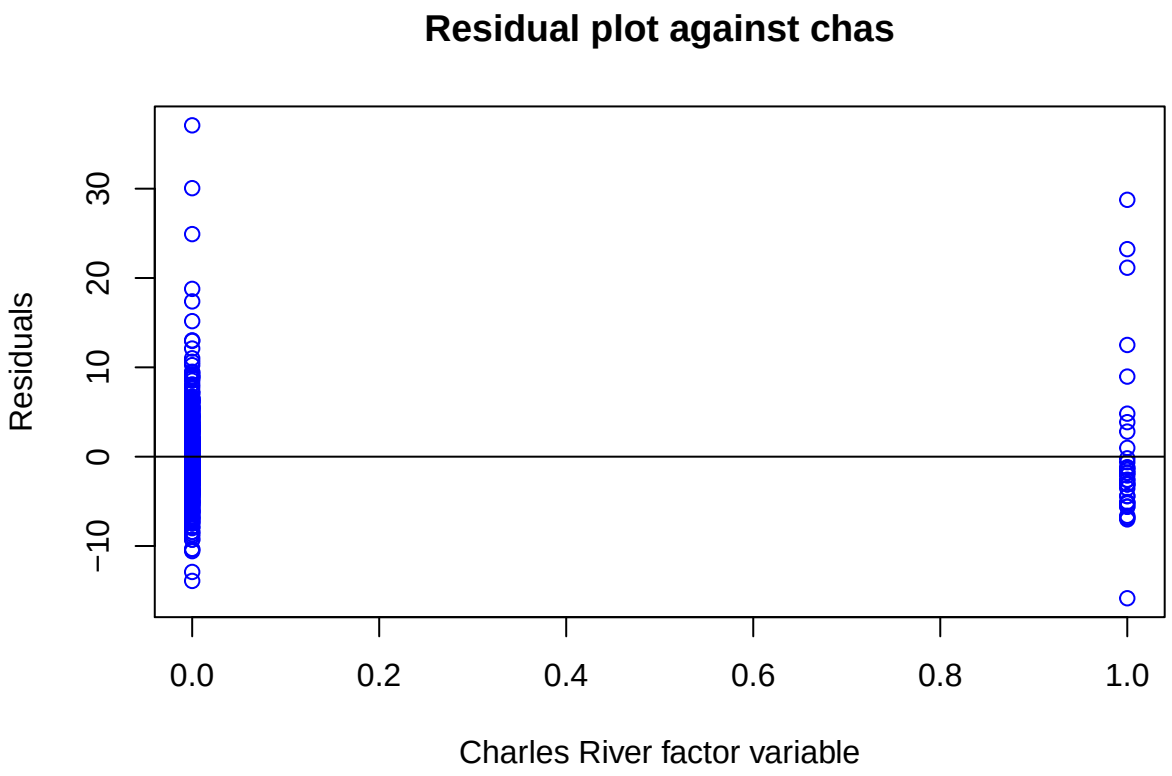
Plot the residuals against X3

```
plot(Data$indus, resid(linearMod), xlab = "proportion of non-retail business
     acres per town", ylab = "Residuals", main = 'Residual plot against indus',
     col = 'blue')
abline(a=0, b=0)
```



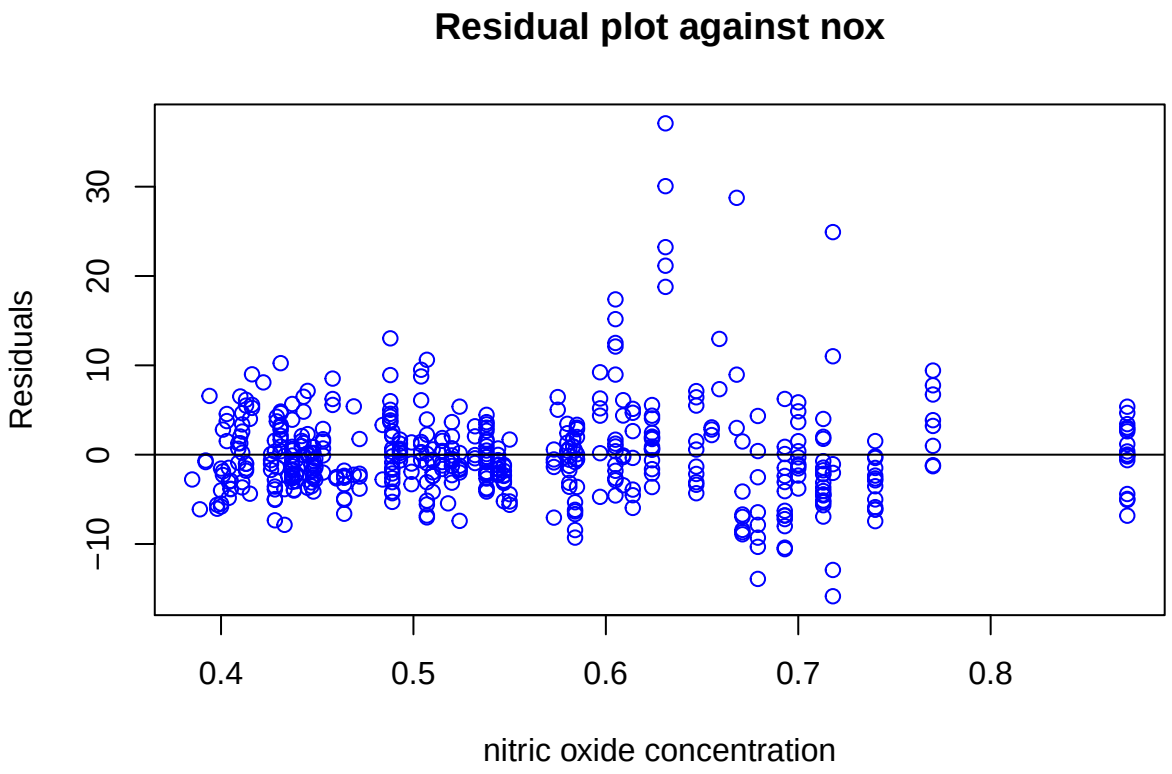
Plot the residuals against X4

```
plot(Data$chas, resid(linearMod), xlab = "Charles River factor variable",
     ylab = "Residuals", main = 'Residual plot against chas', col = 'blue')
abline(a=0, b=0)
```



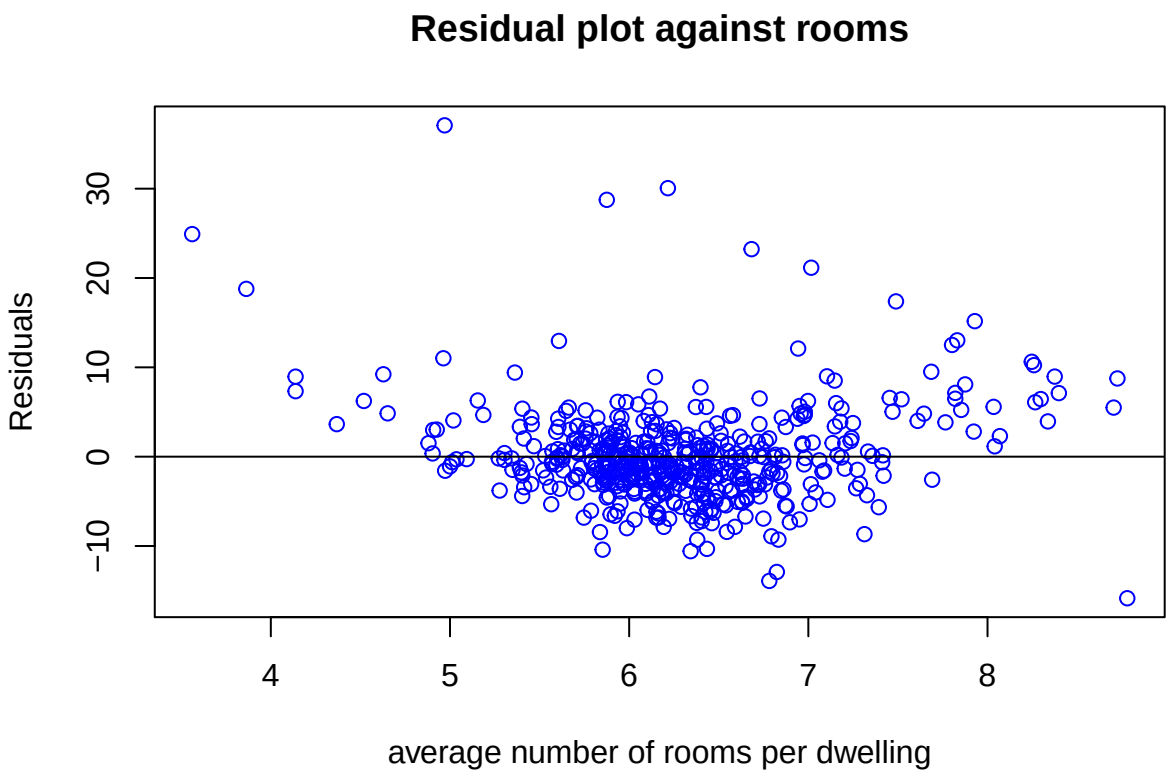
Plot the residuals against X5

```
plot(Data$nox, resid(linearMod), xlab = "nitric oxide concentration",
     ylab = "Residuals", main = 'Residual plot against nox', col = 'blue')
abline(a=0, b=0)
```



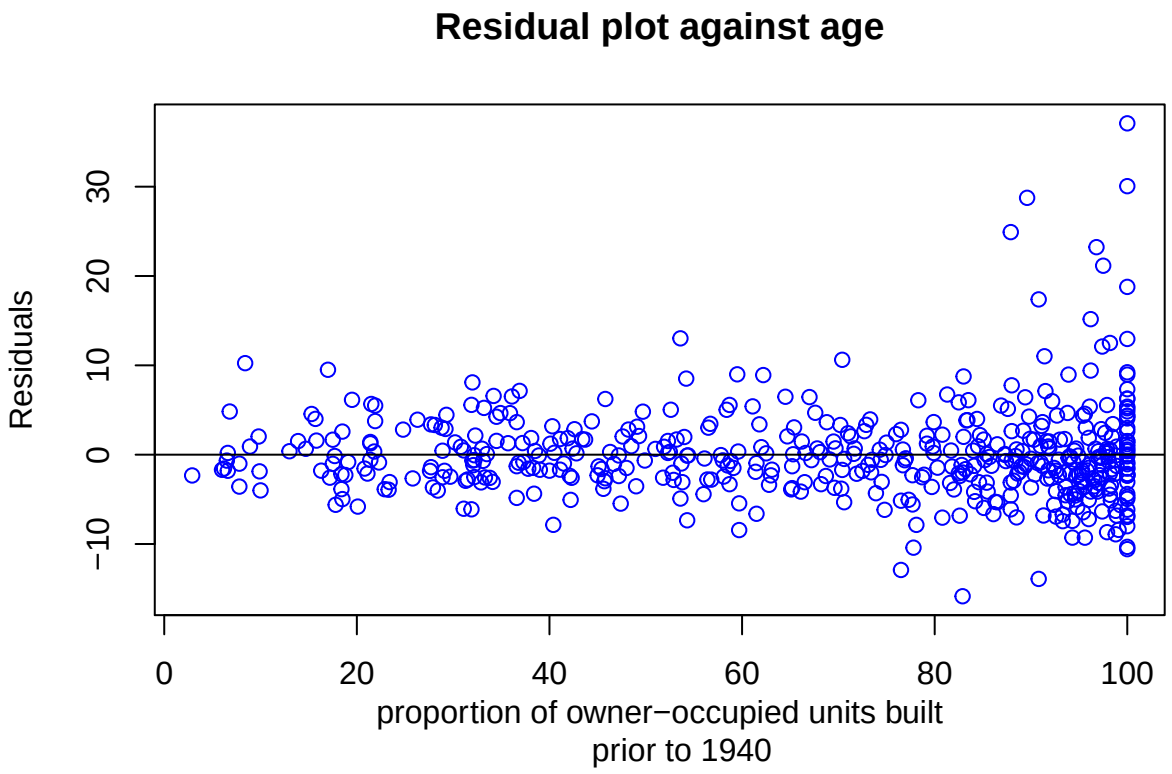
Plot the residuals against X6

```
plot(Data$rooms, resid(linearMod), xlab = "average number of rooms per dwelling",
     ylab = "Residuals", main = 'Residual plot against rooms', col = 'blue')
abline(a=0, b=0)
```



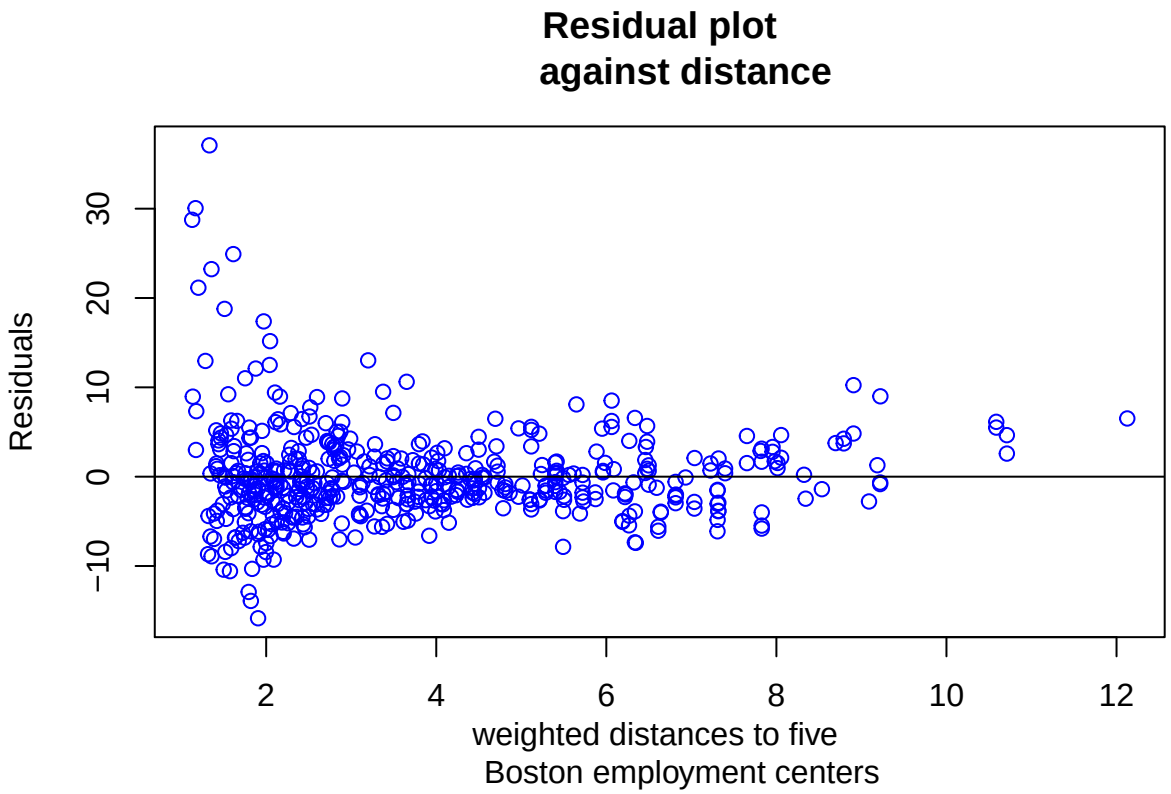
Plot the residuals against X7

```
plot(Data$age, resid(linearMod), xlab = "proportion of owner-occupied units built
     prior to 1940", ylab = "Residuals", main = 'Residual plot against age',
     col = 'blue')
abline(a=0, b=0)
```



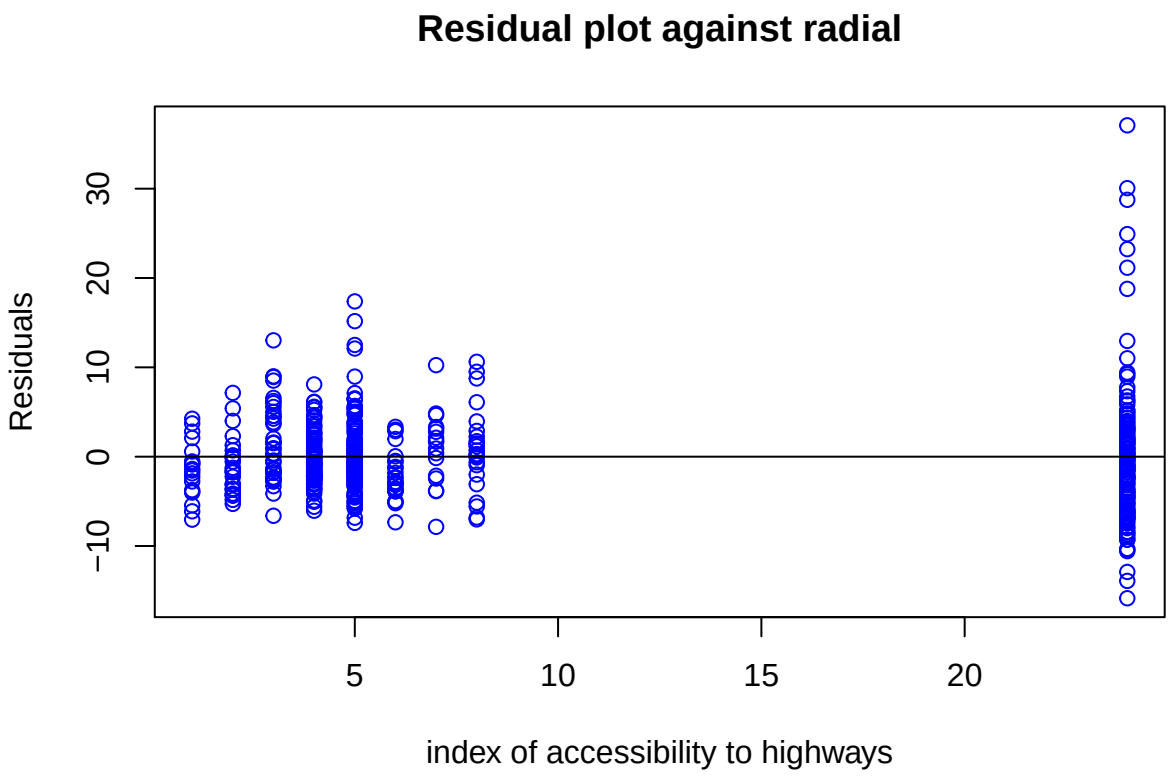
Plot the residuals against X8

```
plot(Data$distance, resid(linearMod), xlab = "weighted distances to five
     Boston employment centers", ylab = "Residuals", main = 'Residual plot
     against distance', col = 'blue')
abline(a=0, b=0)
```



PLot the residuals against X9

```
plot(Data$radial, resid(linearMod), xlab = "index of accessibility to highways",
     ylab = "Residuals", main = 'Residual plot against radial', col = 'blue')
abline(a=0, b=0)
```

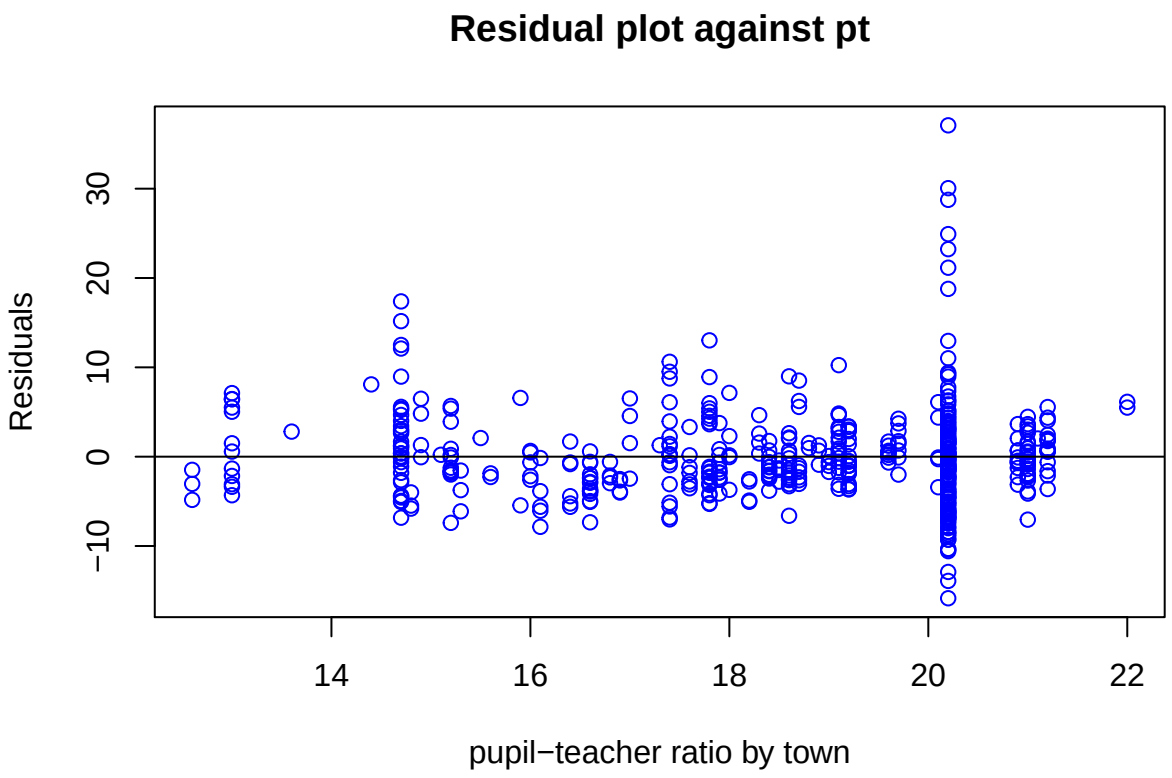


Plot the residuals against X10

```
plot(Data$tax, resid(linearMod), xlab = "full-value property-tax rate per $10,000",
     ylab = "Residuals", main = 'Residual plot against tax', col = 'blue')
abline(a=0, b=0)
```

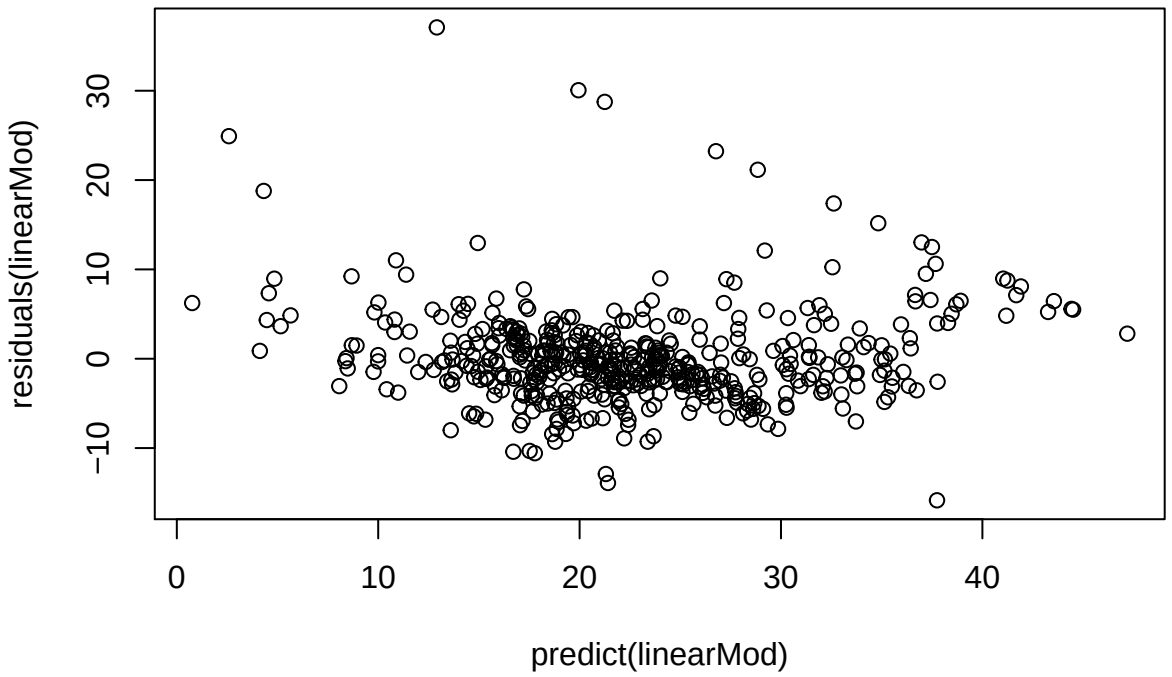
Plot the residuals against X11

```
plot(Data$pt, resid(linearMod), xlab = "pupil-teacher ratio by town", ylab = "Residuals",
     main = 'Residual plot against pt', col = 'blue')
abline(a=0, b=0)
```



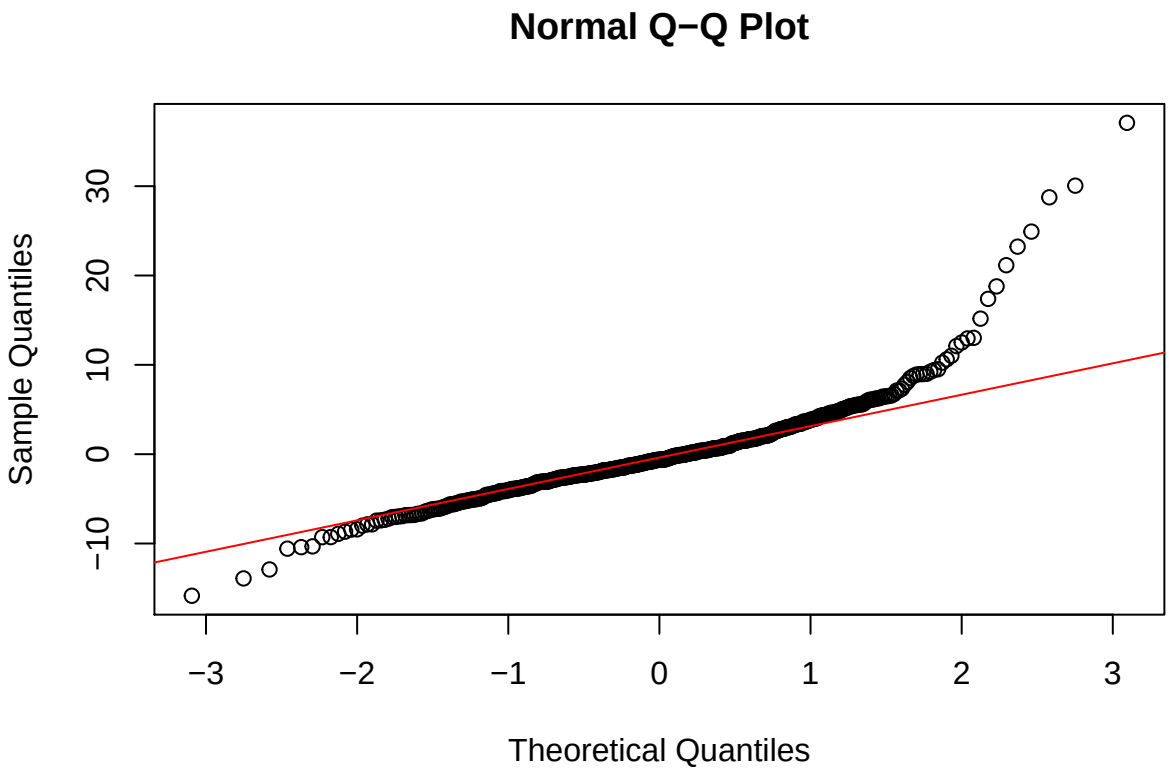
Predicted vs residuals

```
plot(predict(linearMod), residuals(linearMod))
```



Q-Q Plot

```
qqnorm(residuals(linearMod)); qqline(residuals(linearMod), col="red")
```



Fitting the full model and a proposed model

Making the full model seen in class

```
linearMod <- lm(mvalue ~ ., data=Data)
```

Making the improved model seen in class

This is the improved model we saw in class, where we dropped predictor 'indus'.

```
linearMod1 <- lm(mvalue ~ crim+zn+chas+nox+rooms+age+distance+radial+tax+pt, data=Data)
```

Making the proposed model (Based on residual plots and scatterplots)

This is my proposed model. By looking at the residuals (and the scatterplots to give me some ideas) I decided to add the square of indus, crim and distance as additional predictor variables. This will make up for my Proposed model.

```
test <- lm(mvalue ~ .+I(indus^2)+I(crim^2)+I(distance^2), data=Data)
```

After this I ran the best subset selection for the Original model and the Proposed model. We actually did this for the Original model in class and came up with the model were we dropped 'indus'. Nevertheless, I ran the code for this model again in addition to the one for my Proposed model so I could do comparisons between subsets of both models according to their R^2, adjusted R^2, AIC and BIC.

Running best subset selection for both models

I ran the best subset selection for both the Original we saw on class and the one I proposed. The second one took a while (probably because I added 3 extra predictors).

```
# Run best subset selection for the original model. This takes about 2 mins.
Best.subset <- olsrr::ols_step_best_subset(linearMod)
# Run best subset selection for the proposed model. This took my computer about 20-30. mins...
Best.subset.test <- olsrr::ols_step_best_subset(test)
```

As you will see in the following computations. Not in all criterias (R^2, AIC, etc.) I got the same submodel of my Proposed model with the square terms. However, overall my Proposed model was an improvement over the Original model we saw in class as you'll see next.

Comparing models Using R2 and adjusted R2

Here I compare the best subset of the Original and Proposed models using R^2 criteria and adjusted R^2 criteria.

```
# Choosing the model based on R2 (Original model)
which.max(Best.subset$rsquare)
```

```
## [1] 11
```

```
# Returns row 11, this corresponds to the model with all predictors
# Prints the names of the predictors used in the best model with R2 criteria
Best.subset$predictors[which.max(Best.subset$rsquare)]
```

```
## [1] "crim zn indus chas nox rooms age distance radial tax pt"
```

```
# Choosing the model based on adjusted R2 (Original model)
which.max(Best.subset$adjr)
```

```
## [1] 10
```

```
# Returns row 10, this corresponds to the model with all predictors except indus
# Prints the names of the predictors used in the best model with adjusted R2 criteria
Best.subset$predictors[which.max(Best.subset$adjr)]
```

```
## [1] "crim zn chas nox rooms age distance radial tax pt"
```

```
# Choosing the model based on R2 (Proposed model)
which.max(Best.subset.test$rsquare)
```

```
## [1] 14
```

```
# Returns row 14, this corresponds to the model with all predictors
# Prints the names of the predictors used in the best model (Proposed model) with R2 criteria
Best.subset.test$predictors[which.max(Best.subset.test$rsquare)]
```

```
## [1] "crim zn indus chas nox rooms age distance radial tax pt I(indus^2) I(crim^2) I(distance^2)"
```

```
# Choosing the model based on adjusted R2 (Proposed model)
which.max(Best.subset.test$adjr)
```

```
## [1] 13
```

```
# Returns row 13, this corresponds to the model with all predictors except zn
# Prints the names of the predictors used in the best model (Proposed model) with adjusted R2 criteria
Best.subset.test$predictors[which.max(Best.subset.test$adjr)]
```

```
## [1] "crim indus chas nox rooms age distance radial tax pt I(indus^2) I(crim^2) I(distance^2)"
```

Comparing best subset of Original model vs best subset of Proposed model with R^2 criteria

```
r_origin <- Best.subset$rsquare[which.max(Best.subset$rsquare)]
r_prop <- Best.subset.test$rsquare[which.max(Best.subset.test$rsquare)]
r_prop > r_origin
```

```
## [1] TRUE
```

```
# This indicates the Proposed model is an improvement over the Original model using R^2 criteria
```

Comparing best subset of Original model vs best subset of Proposed model with adjusted R^2 criteria

```
r_adj_origin <- Best.subset$adjr[which.max(Best.subset$adjr)]
r_adj_prop <- Best.subset.test$adjr[which.max(Best.subset.test$adjr)]
r_adj_prop > r_adj_origin
```

```
## [1] TRUE
```

```
# This indicates the Proposed model is an improvement over the Original model using
# adjusted R^2 criteria
```

Comparing models Using AIC

Here I compare the best subset of the Original and Proposed models using AIC criteria.

```
# Choosing the model based on AIC (Original model)
which.min(Best.subset$aic)
```

```
## [1] 10
```

```
# Returns row 10, this corresponds to the model with all predictors except indus
# Prints the names of the predictors used in the best model with AIC criteria
Best.subset$predictors[which.min(Best.subset$aic)]
```

```
## [1] "crim zn chas nox rooms age distance radial tax pt"
```

```
# Choosing the model based on AIC (Proposed model)
which.min(Best.subset.test$aic)
```

```
## [1] 13
```

```
# Returns row 13, this corresponds to the model with all predictors exceptc zn
# Prints the names of the predictors used in the best model with AIC criteria
Best.subset.test$predictors[which.min(Best.subset.test$aic)]
```

```
## [1] "crim indus chas nox rooms age distance radial tax pt I(indus^2) I(crim^2) I(distance^2)"
```

Comparing best subset of Original model vs best subset of Proposed model with IAC criteria

```
aic_origin <- Best.subset$aic[which.min(Best.subset$aic)]
aic_prop <- Best.subset.test$aic[which.min(Best.subset.test$aic)]
aic_origin > aic_prop
```

```
## [1] TRUE
```

```
# This indicates the Proposed model is an improvement over the Original model using AIC criteria
```

Comparing models using BIC

```
# Choosing the model based on BIC (Original model)
which.min(Best.subset$sbc)
```

```
## [1] 10
```

```
# Returns row 10, this corresponds to the model with all predictors exceptc indus
# Prints the names of the predictors used in the best model with BIC criteria
Best.subset$predictors[which.min(Best.subset$sbc)]
```

```
## [1] "crim zn chas nox rooms age distance radial tax pt"
```

```
# Choosing the model based on BIC (Proposed model)
which.min(Best.subset.test$sbc)
```

```
## [1] 11
```

```
# Returns row 11, this corresponds to the model that omits zn, indus and indus^2
# Prints the names of the predictors used in the best model with BIC criteria
Best.subset.test$predictors[which.min(Best.subset.test$sbc)]
```

```
## [1] "crim chas nox rooms age distance radial tax pt I(crim^2) I(distance^2)"
```

Comparing best subset of Original model vs best subset of Proposed model with BIC criteria

Here I compare the best subset of the Original and Proposed models using AIC criteria.

```
bic_origin <- Best.subset$sbc[which.min(Best.subset$sbc)]
bic_prop <- Best.subset.test$sbc[which.min(Best.subset.test$sbc)]
bic_origin > bic_prop
```

```
## [1] TRUE
```

```
# This indicates the Proposed model is an improvement over the Original model using BIC criteria
```

In all criterias (R2, adjusted R2, AIC and BIC), the best subset of my Proposed model proved to be superior over the best subset of the Original model we saw in class.