Problem 7

Part A

We can see a statistically significant association between crim and zn, indus, nox, rm, age, dis, rad, tax, ptratio, black, and lstat, all of which have p values < 0.05.

```r
library(MASS)
summary(Boston)
```

```
##       crim                zn             indus            chas
##  Min.   : 0.00632   Min.   :  0.00   Min.   : 0.46   Min.   :0.00000
##  1st Qu.: 0.08204   1st Qu.:  0.00   1st Qu.: 5.19   1st Qu.:0.00000
##  Median : 0.25651   Median :  0.00   Median : 9.69   Median :0.00000
##  Mean   : 3.61352   Mean   : 11.36   Mean   :11.14   Mean   :0.06917
##  3rd Qu.: 3.67708   3rd Qu.: 12.50   3rd Qu.:18.10   3rd Qu.:0.00000
##  Max.   :88.97620   Max.   :100.00   Max.   :27.74   Max.   :1.00000
##       nox               rm             age              dis
##  Min.   :0.3850   Min.   :3.561   Min.   :  2.90   Min.   : 1.130
##  1st Qu.:0.4490   1st Qu.:5.886   1st Qu.: 45.02   1st Qu.: 2.100
##  Median :0.5380   Median :6.208   Median : 77.50   Median : 3.207
##  Mean   :0.5547   Mean   :6.285   Mean   : 68.57   Mean   : 3.795
##  3rd Qu.:0.6240   3rd Qu.:6.623   3rd Qu.: 94.08   3rd Qu.: 5.188
##  Max.   :0.8710   Max.   :8.780   Max.   :100.00   Max.   :12.127
##       rad              tax           ptratio          black
##  Min.   : 1.000   Min.   :187.0   Min.   :12.60   Min.   :  0.32
##  1st Qu.: 4.000   1st Qu.:279.0   1st Qu.:17.40   1st Qu.:375.38
##  Median : 5.000   Median :330.0   Median :19.05   Median :391.44
##  Mean   : 9.549   Mean   :408.2   Mean   :18.46   Mean   :356.67
##  3rd Qu.:24.000   3rd Qu.:666.0   3rd Qu.:20.20   3rd Qu.:396.23
##  Max.   :24.000   Max.   :711.0   Max.   :22.00   Max.   :396.90
##      lstat            medv
##  Min.   : 1.73   Min.   : 5.00
##  1st Qu.: 6.95   1st Qu.:17.02
##  Median :11.36   Median :21.20
##  Mean   :12.65   Mean   :22.53
##  3rd Qu.:16.95   3rd Qu.:25.00
##  Max.   :37.97   Max.   :50.00
```

```
layout(matrix(c(1,2), 2, 2, byrow = TRUE))

for (i in 3:length(Boston) - 1) {
  cat(colnames(Boston)[i])
  cat('\n===================')
  fit = lm(crim ~ Boston[,i], data=Boston)
  print(summary(fit))
  plot(Boston[,c(1, i)])
  abline(fit)
}
```
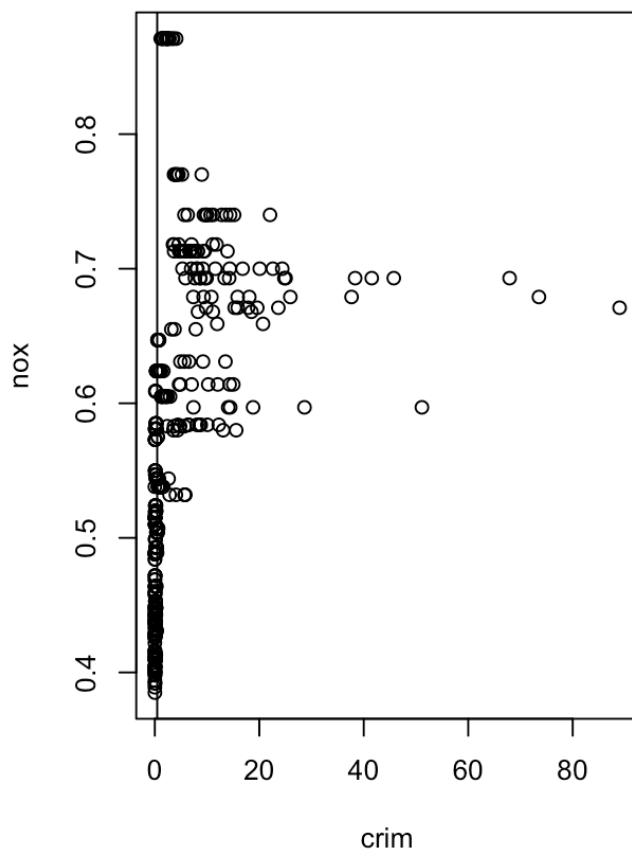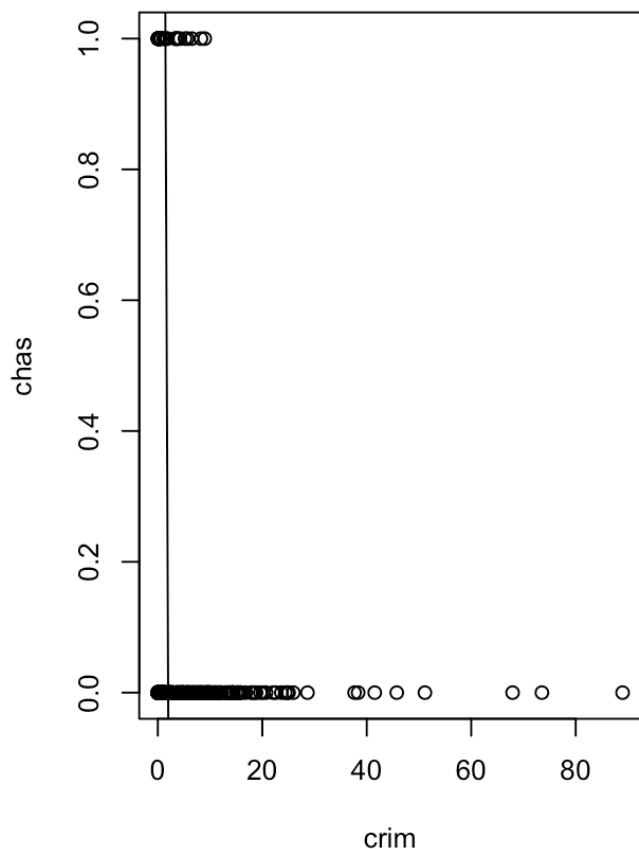
```
## zn
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.429 -4.222 -2.620  1.250 84.523
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.45369    0.41722  10.675  < 2e-16 ***
## Boston[, i] -0.07393    0.01609  -4.594 5.51e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.435 on 504 degrees of freedom
## Multiple R-squared:  0.04019,    Adjusted R-squared:  0.03828
## F-statistic:  21.1 on 1 and 504 DF,  p-value: 5.506e-06
```

```
## indus
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -11.972  -2.698  -0.736   0.712  81.813
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.06374    0.66723  -3.093  0.00209 **
## Boston[, i]  0.50978    0.05102   9.991  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.866 on 504 degrees of freedom
## Multiple R-squared:  0.1653, Adjusted R-squared:  0.1637
## F-statistic: 99.82 on 1 and 504 DF,  p-value: < 2.2e-16
```
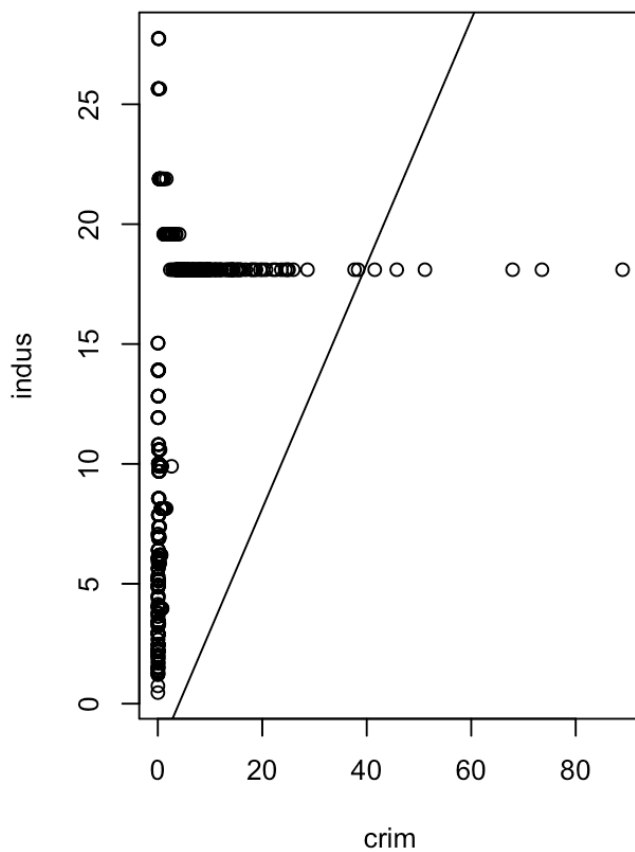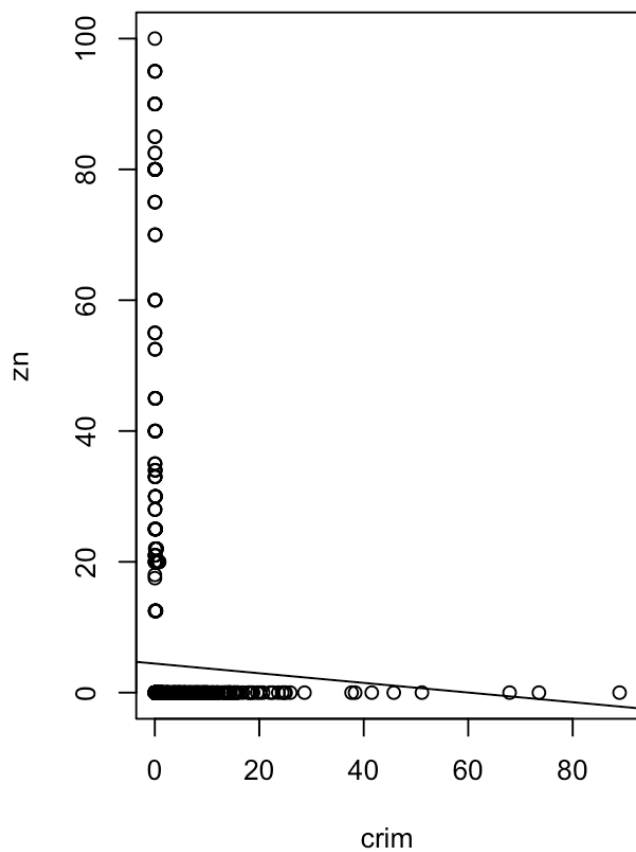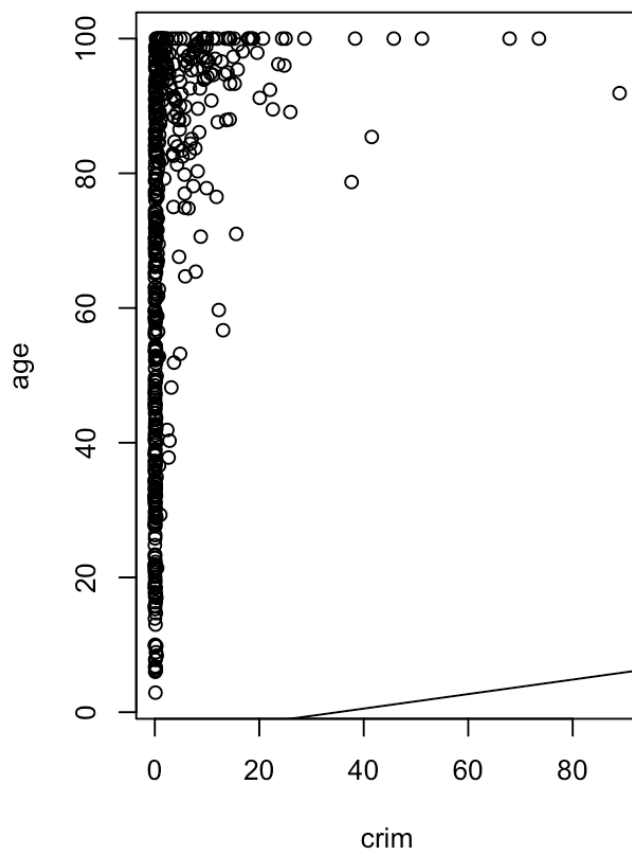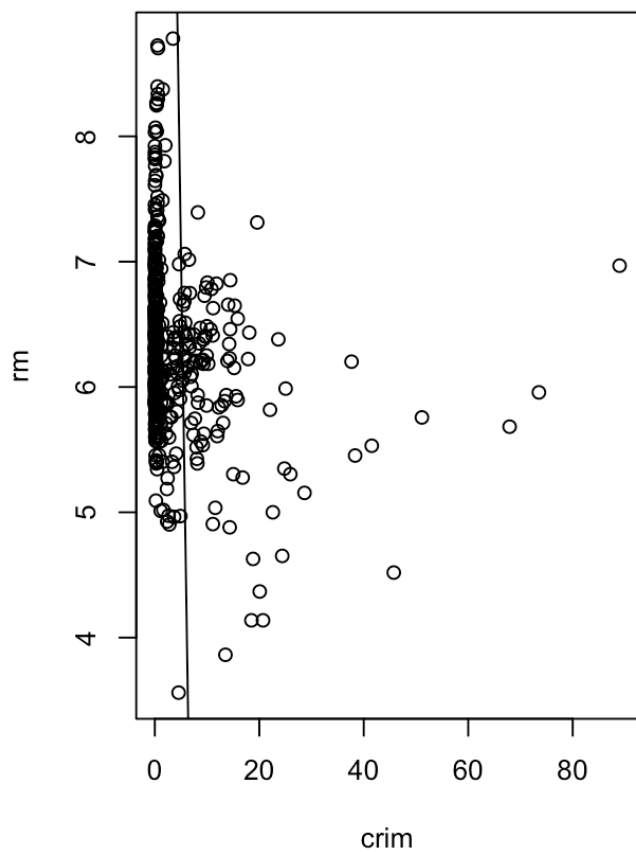
```
## chas
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -3.738 -3.661 -3.435  0.018 85.232
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    3.7444     0.3961   9.453   <2e-16 ***
## Boston[, i]   -1.8928     1.5061  -1.257    0.209
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.597 on 504 degrees of freedom
## Multiple R-squared:  0.003124,   Adjusted R-squared:  0.001146
## F-statistic: 1.579 on 1 and 504 DF,  p-value: 0.2094
```

```
## nox
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.371  -2.738  -0.974   0.559  81.728
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -13.720      1.699  -8.073 5.08e-15 ***
## Boston[, i]    31.249      2.999  10.419  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.81 on 504 degrees of freedom
## Multiple R-squared:  0.1772, Adjusted R-squared:  0.1756
## F-statistic: 108.6 on 1 and 504 DF,  p-value: < 2.2e-16
```
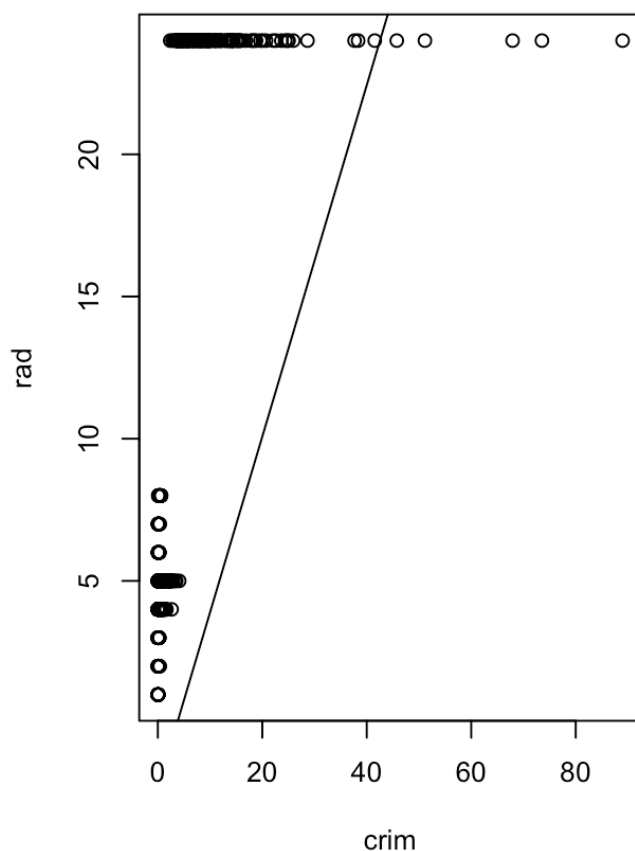
```
## rm
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -6.604 -3.952 -2.654  0.989 87.197
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   20.482      3.365   6.088 2.27e-09 ***
## Boston[, i]   -2.684      0.532  -5.045 6.35e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.401 on 504 degrees of freedom
## Multiple R-squared:  0.04807,    Adjusted R-squared:  0.04618
## F-statistic: 25.45 on 1 and 504 DF,  p-value: 6.347e-07
```
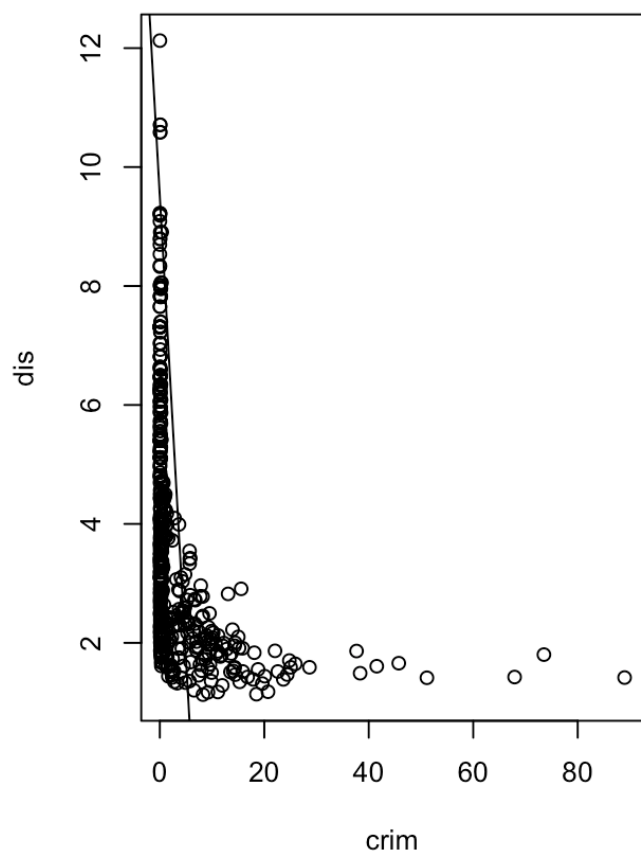
```
## age
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##    Min    1Q Median    3Q    Max
## -6.789 -4.257 -1.230  1.527 82.849
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -3.77791    0.94398  -4.002 7.22e-05 ***
## Boston[, i]  0.10779    0.01274   8.463 2.85e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.057 on 504 degrees of freedom
## Multiple R-squared:  0.1244, Adjusted R-squared:  0.1227
## F-statistic: 71.62 on 1 and 504 DF,  p-value: 2.855e-16
```

```
## dis
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -6.708 -4.134 -1.527  1.516 81.674
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    9.4993     0.7304  13.006   <2e-16 ***
## Boston[, i]   -1.5509     0.1683  -9.213   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.965 on 504 degrees of freedom
## Multiple R-squared:  0.1441, Adjusted R-squared:  0.1425
## F-statistic: 84.89 on 1 and 504 DF,  p-value: < 2.2e-16
```

```
## rad
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.164  -1.381  -0.141   0.660  76.433
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.28716    0.44348  -5.157 3.61e-07 ***
## Boston[, i]  0.61791    0.03433  17.998  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.718 on 504 degrees of freedom
## Multiple R-squared:  0.3913, Adjusted R-squared:   0.39
## F-statistic: 323.9 on 1 and 504 DF,  p-value: < 2.2e-16
```
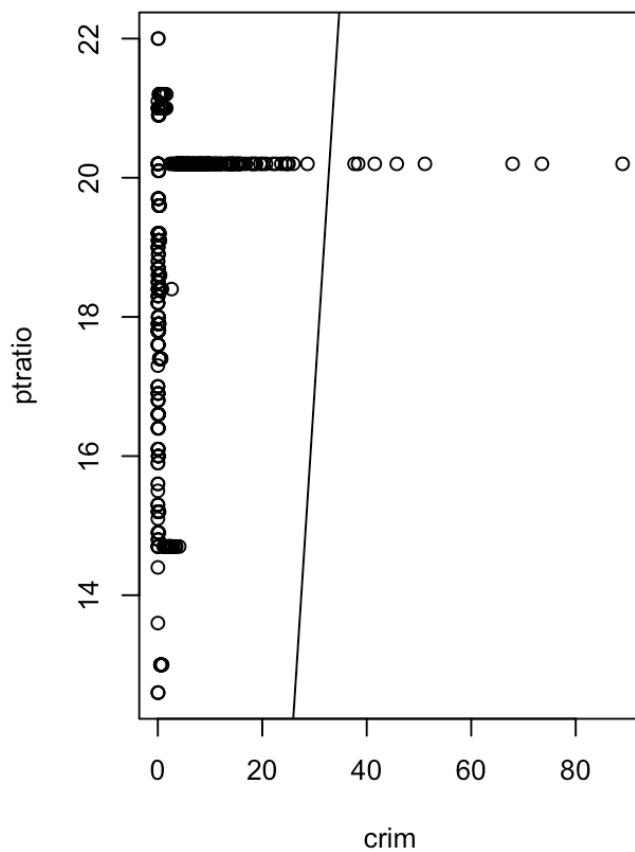
```
## tax
## ===================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.513  -2.738  -0.194   1.065  77.696
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -8.528369   0.815809  -10.45   <2e-16 ***
## Boston[, i]  0.029742   0.001847   16.10   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.997 on 504 degrees of freedom
## Multiple R-squared:  0.3396, Adjusted R-squared:  0.3383
## F-statistic: 259.2 on 1 and 504 DF,  p-value: < 2.2e-16
```
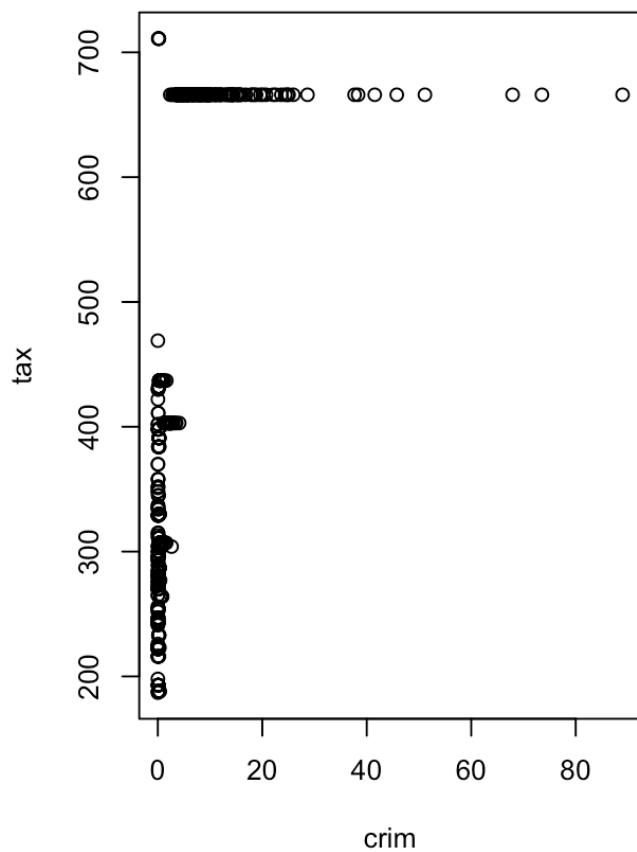
```
## ptratio
## ==================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.654  -3.985  -1.912   1.825  83.353
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -17.6469     3.1473  -5.607 3.40e-08 ***
## Boston[, i]    1.1520     0.1694   6.801 2.94e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.24 on 504 degrees of freedom
## Multiple R-squared:  0.08407,    Adjusted R-squared:  0.08225
## F-statistic: 46.26 on 1 and 504 DF,  p-value: 2.943e-11
```

```
## black
## ==================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##      Min      1Q  Median      3Q     Max
## -13.756  -2.299  -2.095  -1.296  86.822
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 16.553529   1.425903  11.609   <2e-16 ***
## Boston[, i] -0.036280   0.003873  -9.367   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.946 on 504 degrees of freedom
## Multiple R-squared:  0.1483, Adjusted R-squared:  0.1466
## F-statistic: 87.74 on 1 and 504 DF,  p-value: < 2.2e-16
```

```
## lstat
## ==================
## Call:
## lm(formula = crim ~ Boston[, i], data = Boston)
##
## Residuals:
##      Min      1Q  Median      3Q     Max
## -13.925  -2.822  -0.664   1.079  82.862
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -3.33054    0.69376  -4.801 2.09e-06 ***
## Boston[, i]  0.54880    0.04776  11.491  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.664 on 504 degrees of freedom
## Multiple R-squared:  0.2076, Adjusted R-squared:  0.206
## F-statistic:   132 on 1 and 504 DF,  p-value: < 2.2e-16
```
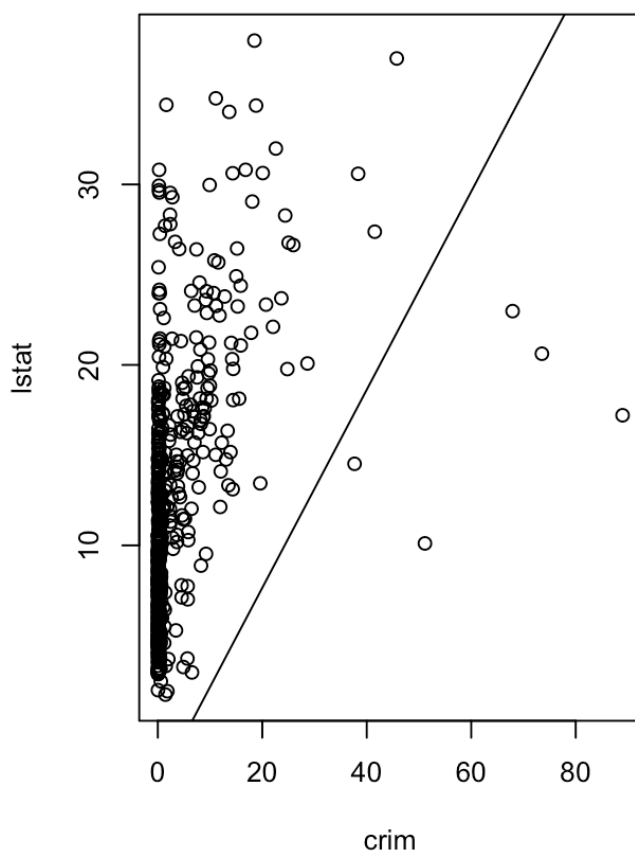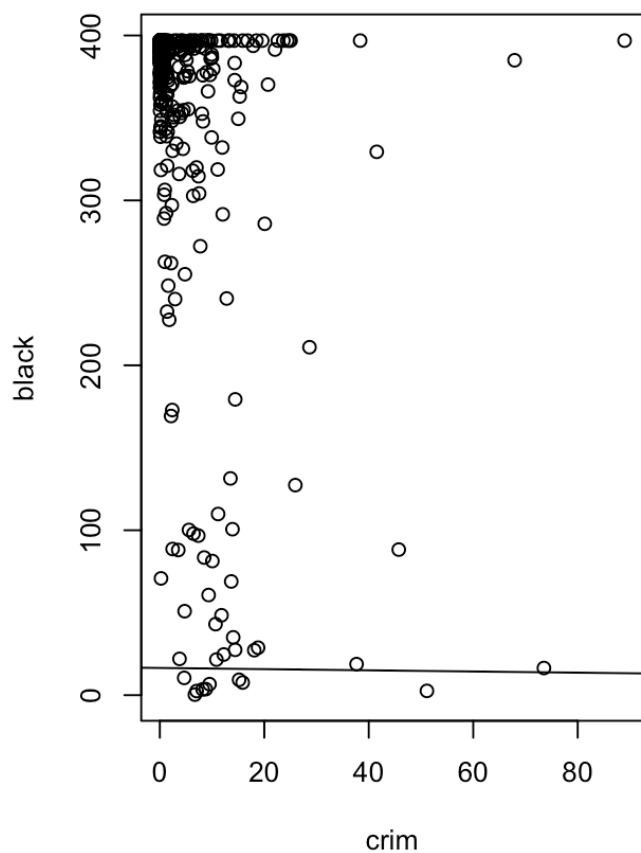
Part B

We can reject the null hypothesis for:

- zn
- dis
- rad
- black
- medv

```
fit = lm( crim ~ ., data=Boston )
summary(fit)
```

```
## 
## Call:
## lm(formula = crim ~ ., data = Boston)
## 
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.924 -2.120 -0.353  1.019 75.051
## 
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  17.033228   7.234903   2.354 0.018949 *
## zn            0.044855   0.018734   2.394 0.017025 *
## indus        -0.063855   0.083407  -0.766 0.444294
## chas         -0.749134   1.180147  -0.635 0.525867
## nox         -10.313535   5.275536  -1.955 0.051152 .
## rm            0.430131   0.612830   0.702 0.483089
## age           0.001452   0.017925   0.081 0.935488
## dis          -0.987176   0.281817  -3.503 0.000502 ***
## rad           0.588209   0.088049   6.680 6.46e-11 ***
## tax          -0.003780   0.005156  -0.733 0.463793
## ptratio      -0.271081   0.186450  -1.454 0.146611
## black        -0.007538   0.003673  -2.052 0.040702 *
## lstat         0.126211   0.075725   1.667 0.096208 .
## medv         -0.198887   0.060516  -3.287 0.001087 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 6.439 on 492 degrees of freedom
## Multiple R-squared:  0.454,  Adjusted R-squared:  0.4396
## F-statistic: 31.47 on 13 and 492 DF,  p-value: < 2.2e-16
```

Part C

Far fewer relationships are marked as "statistically significant" in Part B.

```
univ_coefficnts = c()
for (i in 3:length(Boston) - 1) {
  univ_coefficnts[i - 1] <- summary( lm(crim ~ Boston[,i], data=Boston) )$coeffici
ents[2]
}
print(univ_coefficnts)
```

```
##  [1] -0.07393498  0.50977633 -1.89277655 31.24853120 -2.68405122
##  [6]  0.10778623 -1.55090168  0.61791093  0.02974225  1.15198279
## [11] -0.03627964  0.54880478
```

```
mult_coefficnts = summary(fit)$coefficients[2:13, 1]
print(mult_coefficnts)
```

```
##            zn         indus          chas           nox            rm
##    0.044855215  -0.063854824  -0.749133611 -10.313534912   0.430130506
##           age           dis           rad           tax       ptratio
##    0.001451643  -0.987175726   0.588208591  -0.003780016  -0.271080558
##         black         lstat
##   -0.007537505   0.126211376
```

```
cat(length(univ_coefficnts))
```

```
## 12
```

```
cat(length(mult_coefficnts))
```

```
## 12
```

```
plot(univ_coefficnts, mult_coefficnts)
```
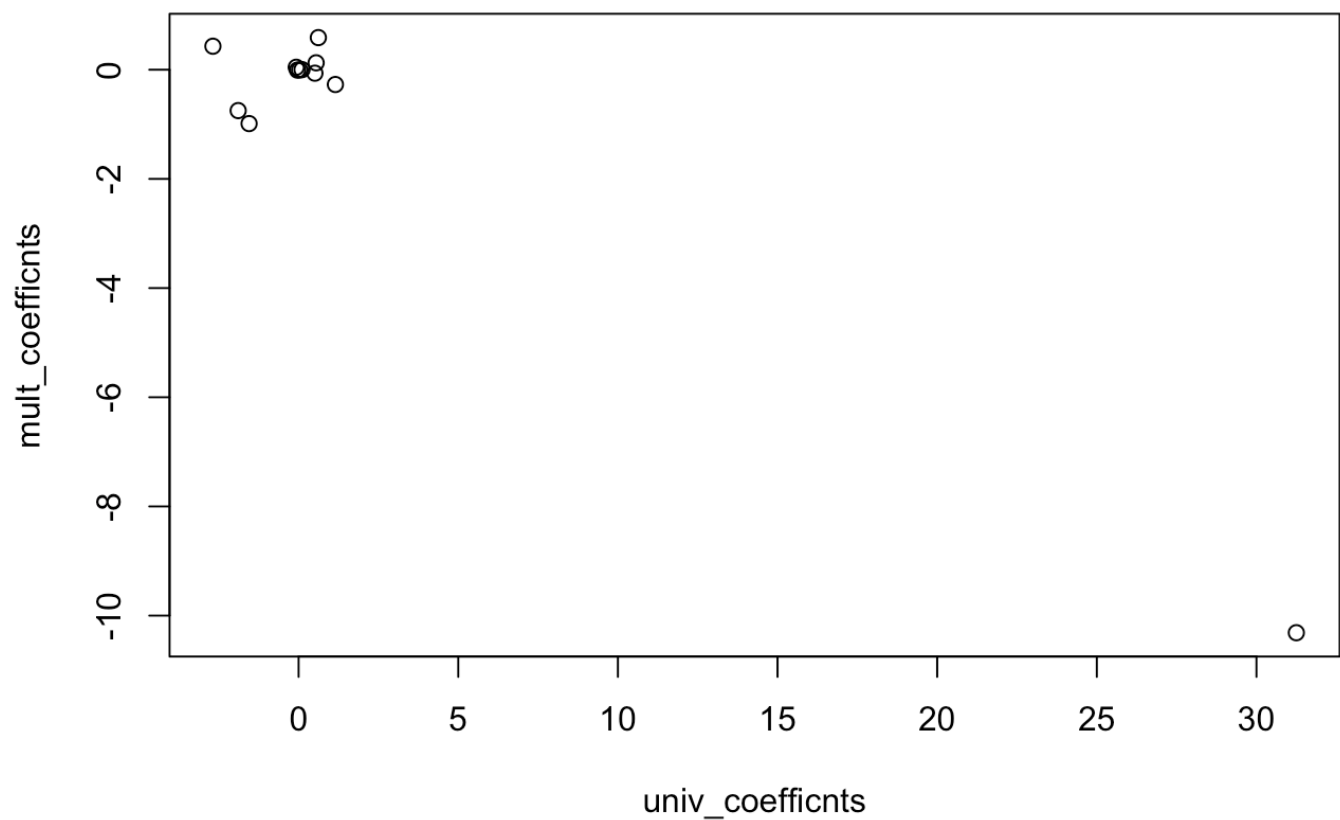
Part D

```
layout(matrix(c(1,2), 2, 2, byrow = TRUE))

for (i in 3:length(Boston) - 1) {
  cat(colnames(Boston)[i])
  cat('\n===================')
  fit = lm(crim ~ poly(Boston[,i], degree=3, raw=TRUE), data=Boston)
  print(summary(fit))
  plot(Boston[,c(1, i)])
  abline(fit)
  predict(fit, data.frame(crim = 0:80))
}
```

```
## zn
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.821 -4.614 -1.294  0.473 84.130
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 4.846e+00  4.330e-01  11.192
## poly(Boston[, i], degree = 3, raw = TRUE)1 -3.322e-01  1.098e-01  -3.025
## poly(Boston[, i], degree = 3, raw = TRUE)2  6.483e-03  3.861e-03   1.679
## poly(Boston[, i], degree = 3, raw = TRUE)3 -3.776e-05  3.139e-05  -1.203
##                                            Pr(>|t|)
## (Intercept)                                 < 2e-16 ***
## poly(Boston[, i], degree = 3, raw = TRUE)1  0.00261 **
## poly(Boston[, i], degree = 3, raw = TRUE)2  0.09375 .
## poly(Boston[, i], degree = 3, raw = TRUE)3  0.22954
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.372 on 502 degrees of freedom
## Multiple R-squared:  0.05824,    Adjusted R-squared:  0.05261
## F-statistic: 10.35 on 3 and 502 DF,  p-value: 1.281e-06
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## indus
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q Median      3Q     Max
## -8.278 -2.514   0.054   0.764 79.713
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 3.6625683  1.5739833   2.327
## poly(Boston[, i], degree = 3, raw = TRUE)1 -1.9652129  0.4819901  -4.077
## poly(Boston[, i], degree = 3, raw = TRUE)2  0.2519373  0.0393221   6.407
## poly(Boston[, i], degree = 3, raw = TRUE)3 -0.0069760  0.0009567  -7.292
##                                            Pr(>|t|)
## (Intercept)                                  0.0204 *
## poly(Boston[, i], degree = 3, raw = TRUE)1 5.30e-05 ***
## poly(Boston[, i], degree = 3, raw = TRUE)2 3.42e-10 ***
## poly(Boston[, i], degree = 3, raw = TRUE)3 1.20e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.423 on 502 degrees of freedom
## Multiple R-squared:  0.2597, Adjusted R-squared:  0.2552
## F-statistic: 58.69 on 3 and 502 DF,  p-value: < 2.2e-16
```
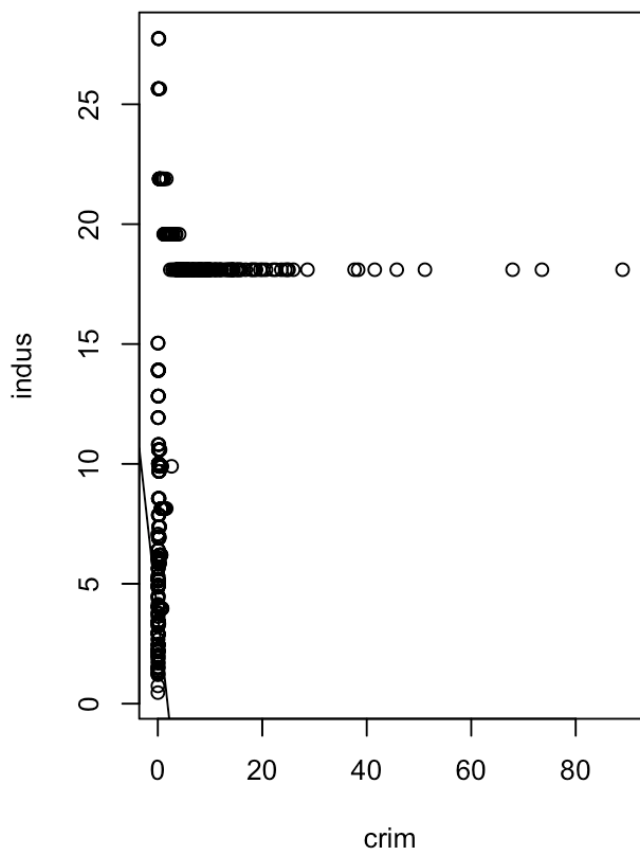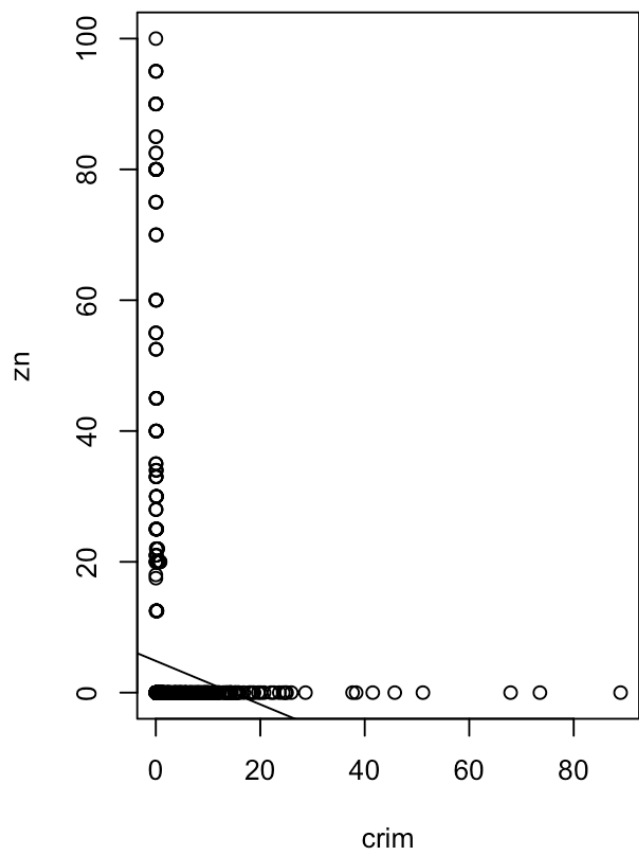
```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## chas
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##      data = Boston)
##
## Residuals:
##     Min      1Q Median      3Q     Max
## -3.738 -3.661 -3.435   0.018 85.232
##
## Coefficients: (2 not defined because of singularities)
##                                              Estimate Std. Error t value
## (Intercept)                                    3.7444     0.3961   9.453
## poly(Boston[, i], degree = 3, raw = TRUE)1    -1.8928     1.5061  -1.257
## poly(Boston[, i], degree = 3, raw = TRUE)2        NA         NA      NA
## poly(Boston[, i], degree = 3, raw = TRUE)3        NA         NA      NA
##                                              Pr(>|t|)
## (Intercept)                                    <2e-16 ***
## poly(Boston[, i], degree = 3, raw = TRUE)1      0.209
## poly(Boston[, i], degree = 3, raw = TRUE)2         NA
## poly(Boston[, i], degree = 3, raw = TRUE)3         NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.597 on 504 degrees of freedom
## Multiple R-squared:  0.003124,   Adjusted R-squared:  0.001146
## F-statistic: 1.579 on 1 and 504 DF,  p-value: 0.2094
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## Warning in predict.lm(fit, data.frame(crim = 0:80)): prediction from a
## rank-deficient fit may be misleading
```

```
## nox
## ===================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.110 -2.068 -0.255  0.739 78.302
##
## Coefficients:
##                                             Estimate Std. Error t value
## (Intercept)                                   233.09      33.64   6.928
## poly(Boston[, i], degree = 3, raw = TRUE)1  -1279.37     170.40  -7.508
## poly(Boston[, i], degree = 3, raw = TRUE)2   2248.54     279.90   8.033
## poly(Boston[, i], degree = 3, raw = TRUE)3  -1245.70     149.28  -8.345
##                                             Pr(>|t|)
## (Intercept)                                 1.31e-11 ***
## poly(Boston[, i], degree = 3, raw = TRUE)1  2.76e-13 ***
## poly(Boston[, i], degree = 3, raw = TRUE)2  6.81e-15 ***
## poly(Boston[, i], degree = 3, raw = TRUE)3  6.96e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.234 on 502 degrees of freedom
## Multiple R-squared:  0.297,  Adjusted R-squared:  0.2928
## F-statistic: 70.69 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```
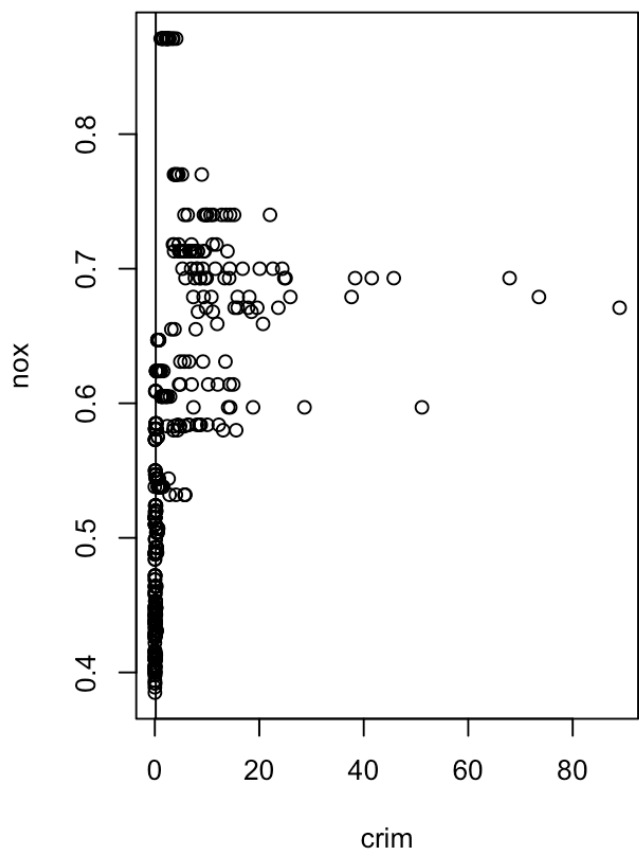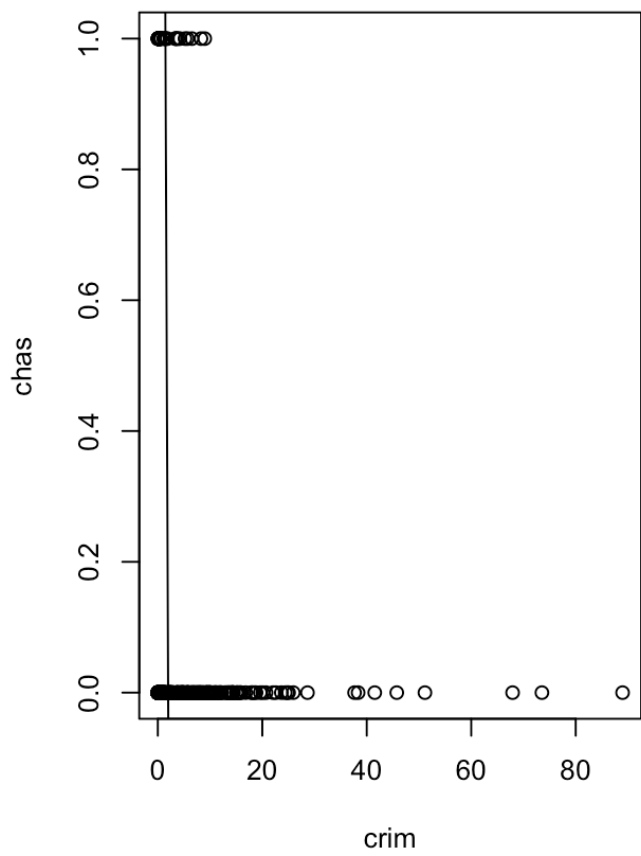
```
## rm
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -18.485  -3.468  -2.221  -0.015  87.219
##
## Coefficients:
##                                            Estimate Std. Error t value
## (Intercept)                                112.6246    64.5172   1.746
## poly(Boston[, i], degree = 3, raw = TRUE)1 -39.1501    31.3115  -1.250
## poly(Boston[, i], degree = 3, raw = TRUE)2   4.5509     5.0099   0.908
## poly(Boston[, i], degree = 3, raw = TRUE)3  -0.1745     0.2637  -0.662
##                                            Pr(>|t|)
## (Intercept)                                  0.0815 .
## poly(Boston[, i], degree = 3, raw = TRUE)1   0.2118
## poly(Boston[, i], degree = 3, raw = TRUE)2   0.3641
## poly(Boston[, i], degree = 3, raw = TRUE)3   0.5086
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.33 on 502 degrees of freedom
## Multiple R-squared:  0.06779,    Adjusted R-squared:  0.06222
## F-statistic: 12.17 on 3 and 502 DF,  p-value: 1.067e-07
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## age
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##      data = Boston)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.762 -2.673 -0.516  0.019 82.842
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 -2.549e+00  2.769e+00  -0.920
## poly(Boston[, i], degree = 3, raw = TRUE)1   2.737e-01  1.864e-01   1.468
## poly(Boston[, i], degree = 3, raw = TRUE)2  -7.230e-03  3.637e-03  -1.988
## poly(Boston[, i], degree = 3, raw = TRUE)3   5.745e-05  2.109e-05   2.724
##                                             Pr(>|t|)
## (Intercept)                                  0.35780
## poly(Boston[, i], degree = 3, raw = TRUE)1   0.14266
## poly(Boston[, i], degree = 3, raw = TRUE)2   0.04738 *
## poly(Boston[, i], degree = 3, raw = TRUE)3   0.00668 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.84 on 502 degrees of freedom
## Multiple R-squared:  0.1742, Adjusted R-squared:  0.1693
## F-statistic: 35.31 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```
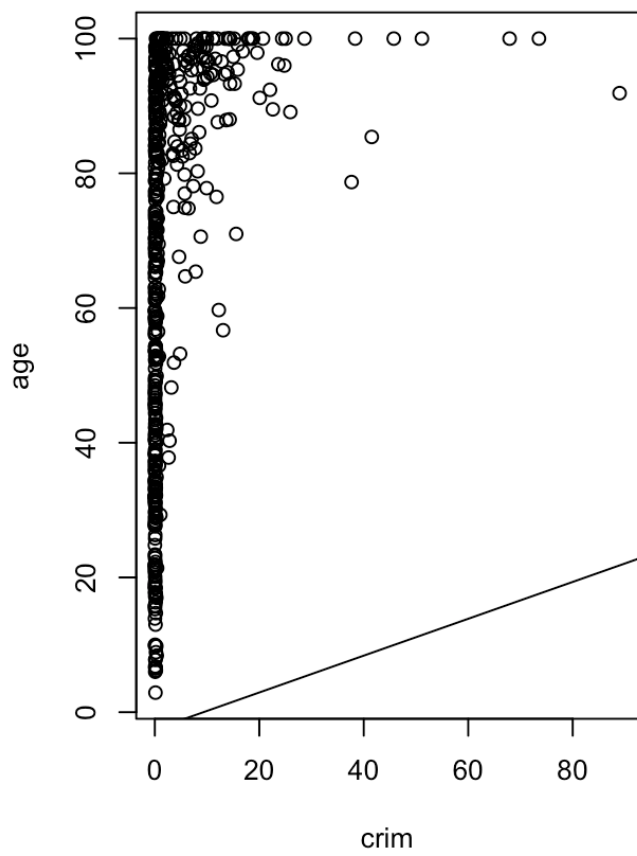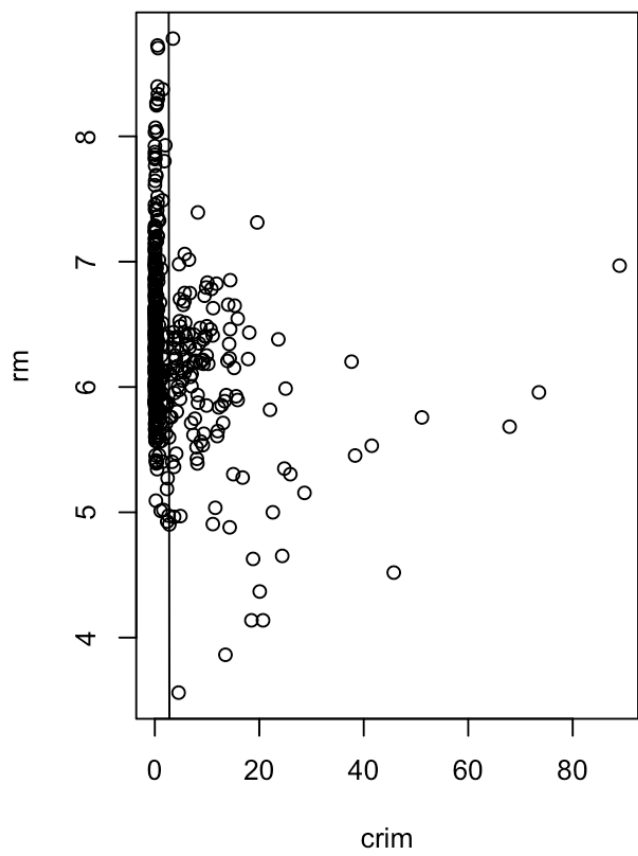
```
## dis
## ===================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.757  -2.588   0.031   1.267  76.378
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                   30.0476     2.4459  12.285
## poly(Boston[, i], degree = 3, raw = TRUE)1   -15.5543     1.7360  -8.960
## poly(Boston[, i], degree = 3, raw = TRUE)2     2.4521     0.3464   7.078
## poly(Boston[, i], degree = 3, raw = TRUE)3    -0.1186     0.0204  -5.814
##                                              Pr(>|t|)
## (Intercept)                                   < 2e-16 ***
## poly(Boston[, i], degree = 3, raw = TRUE)1    < 2e-16 ***
## poly(Boston[, i], degree = 3, raw = TRUE)2   4.94e-12 ***
## poly(Boston[, i], degree = 3, raw = TRUE)3   1.09e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.331 on 502 degrees of freedom
## Multiple R-squared:  0.2778, Adjusted R-squared:  0.2735
## F-statistic: 64.37 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## rad
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.381  -0.412  -0.269   0.179  76.217
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 -0.605545   2.050108  -0.295
## poly(Boston[, i], degree = 3, raw = TRUE)1   0.512736   1.043597   0.491
## poly(Boston[, i], degree = 3, raw = TRUE)2  -0.075177   0.148543  -0.506
## poly(Boston[, i], degree = 3, raw = TRUE)3   0.003209   0.004564   0.703
##                                             Pr(>|t|)
## (Intercept)                                    0.768
## poly(Boston[, i], degree = 3, raw = TRUE)1     0.623
## poly(Boston[, i], degree = 3, raw = TRUE)2     0.613
## poly(Boston[, i], degree = 3, raw = TRUE)3     0.482
##
## Residual standard error: 6.682 on 502 degrees of freedom
## Multiple R-squared:    0.4,  Adjusted R-squared:  0.3965
## F-statistic: 111.6 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```
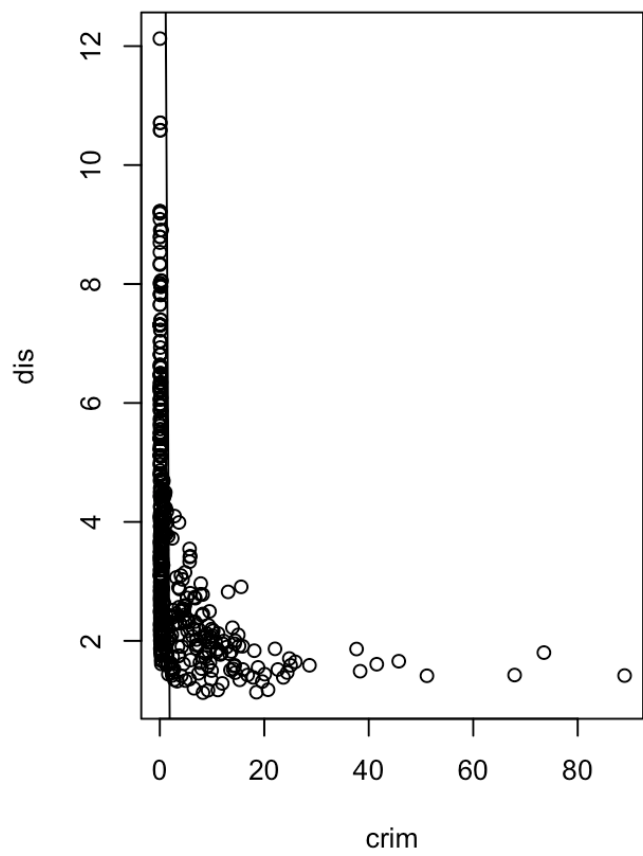
```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```
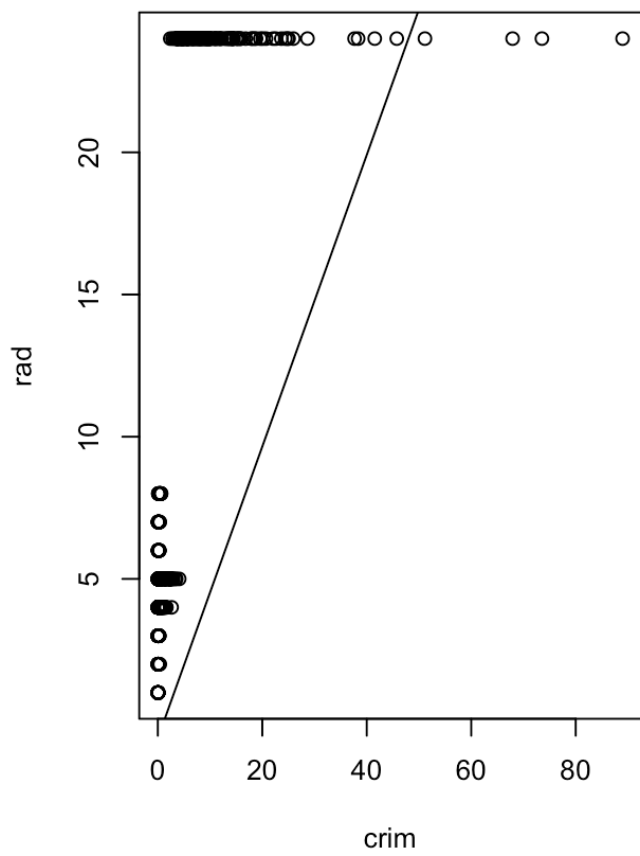
```
## tax
## ===================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -13.273  -1.389   0.046   0.536  76.950
##
## Coefficients:
##                                                 Estimate Std. Error t value
## (Intercept)                                    1.918e+01  1.180e+01   1.626
## poly(Boston[, i], degree = 3, raw = TRUE)1    -1.533e-01  9.568e-02  -1.602
## poly(Boston[, i], degree = 3, raw = TRUE)2     3.608e-04  2.425e-04   1.488
## poly(Boston[, i], degree = 3, raw = TRUE)3    -2.204e-07  1.889e-07  -1.167
##                                                Pr(>|t|)
## (Intercept)                                       0.105
## poly(Boston[, i], degree = 3, raw = TRUE)1        0.110
## poly(Boston[, i], degree = 3, raw = TRUE)2        0.137
## poly(Boston[, i], degree = 3, raw = TRUE)3        0.244
##
## Residual standard error: 6.854 on 502 degrees of freedom
## Multiple R-squared:  0.3689, Adjusted R-squared:  0.3651
## F-statistic:  97.8 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## ptratio
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##      data = Boston)
##
## Residuals:
##     Min     1Q Median     3Q     Max
## -6.833 -4.146 -1.655  1.408 82.697
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                  477.18405  156.79498    3.043
## poly(Boston[, i], degree = 3, raw = TRUE)1   -82.36054   27.64394   -2.979
## poly(Boston[, i], degree = 3, raw = TRUE)2     4.63535    1.60832    2.882
## poly(Boston[, i], degree = 3, raw = TRUE)3    -0.08476    0.03090   -2.743
##                                              Pr(>|t|)
## (Intercept)                                   0.00246 **
## poly(Boston[, i], degree = 3, raw = TRUE)1    0.00303 **
## poly(Boston[, i], degree = 3, raw = TRUE)2    0.00412 **
## poly(Boston[, i], degree = 3, raw = TRUE)3    0.00630 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.122 on 502 degrees of freedom
## Multiple R-squared:  0.1138, Adjusted R-squared:  0.1085
## F-statistic: 21.48 on 3 and 502 DF,  p-value: 4.171e-13
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```
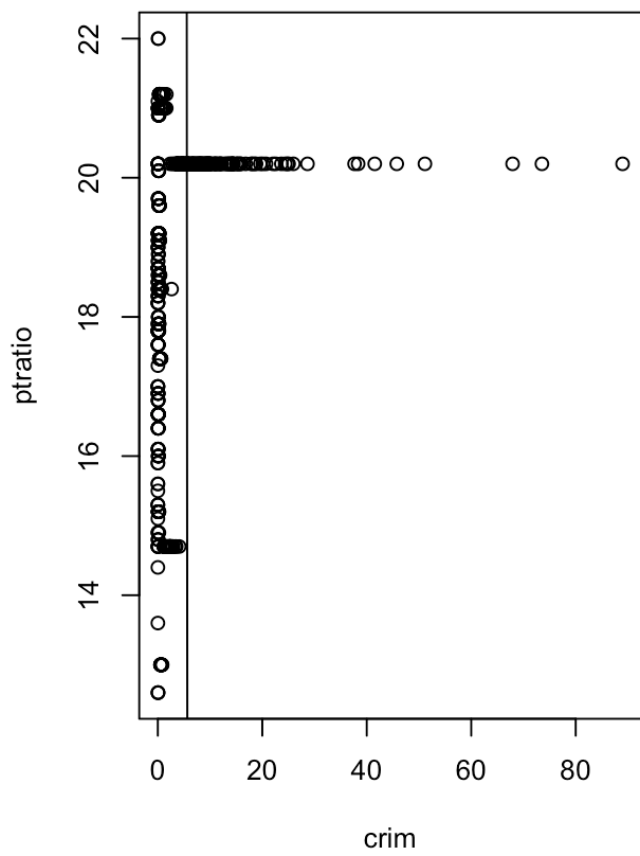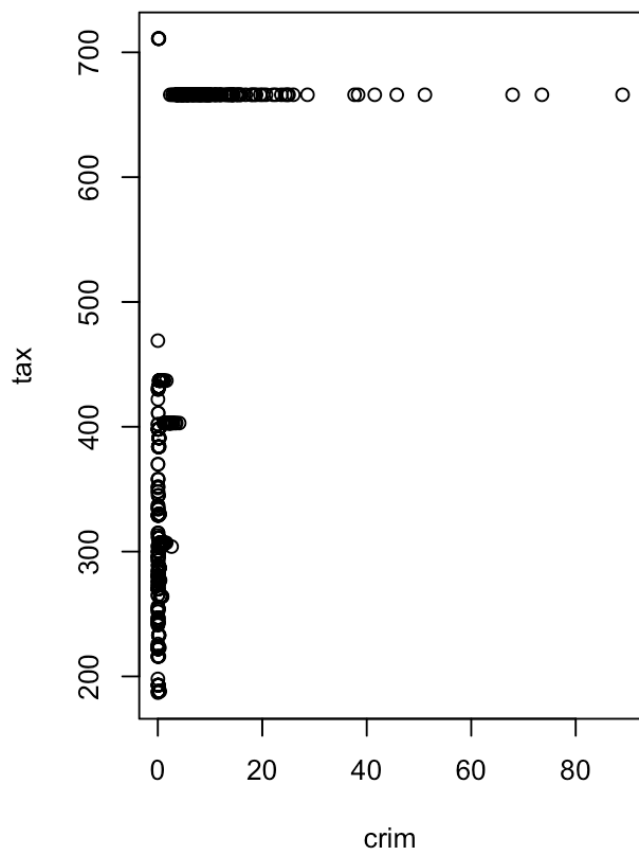
```
## black
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -13.096  -2.343  -2.128  -1.439  86.790
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 1.826e+01  2.305e+00   7.924
## poly(Boston[, i], degree = 3, raw = TRUE)1 -8.356e-02  5.633e-02  -1.483
## poly(Boston[, i], degree = 3, raw = TRUE)2  2.137e-04  2.984e-04   0.716
## poly(Boston[, i], degree = 3, raw = TRUE)3 -2.652e-07  4.364e-07  -0.608
##                                            Pr(>|t|)
## (Intercept)                                 1.5e-14 ***
## poly(Boston[, i], degree = 3, raw = TRUE)1    0.139
## poly(Boston[, i], degree = 3, raw = TRUE)2    0.474
## poly(Boston[, i], degree = 3, raw = TRUE)3    0.544
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.955 on 502 degrees of freedom
## Multiple R-squared:  0.1498, Adjusted R-squared:  0.1448
## F-statistic: 29.49 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```

```
## lstat
## ==================
## Call:
## lm(formula = crim ~ poly(Boston[, i], degree = 3, raw = TRUE),
##     data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.234  -2.151  -0.486   0.066  83.353
##
## Coefficients:
##                                               Estimate Std. Error t value
## (Intercept)                                  1.2009656  2.0286452   0.592
## poly(Boston[, i], degree = 3, raw = TRUE)1 -0.4490656  0.4648911  -0.966
## poly(Boston[, i], degree = 3, raw = TRUE)2  0.0557794  0.0301156   1.852
## poly(Boston[, i], degree = 3, raw = TRUE)3 -0.0008574  0.0005652  -1.517
##                                              Pr(>|t|)
## (Intercept)                                    0.5541
## poly(Boston[, i], degree = 3, raw = TRUE)1     0.3345
## poly(Boston[, i], degree = 3, raw = TRUE)2     0.0646 .
## poly(Boston[, i], degree = 3, raw = TRUE)3     0.1299
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.629 on 502 degrees of freedom
## Multiple R-squared:  0.2179, Adjusted R-squared:  0.2133
## F-statistic: 46.63 on 3 and 502 DF,  p-value: < 2.2e-16
```

```
## Warning in abline(fit): only using the first two of 4 regression
## coefficients
```

```
## Warning: 'newdata' had 81 rows but variables found have 506 rows
```