

Take Home Examination (Intro To ML)

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01 Aug 2021

Exercise 2.10:

2.10.a

```
## Number of rows in the Boston DataSet : 506
```

```
## Number of columns in the Boston DataSet: 14
```

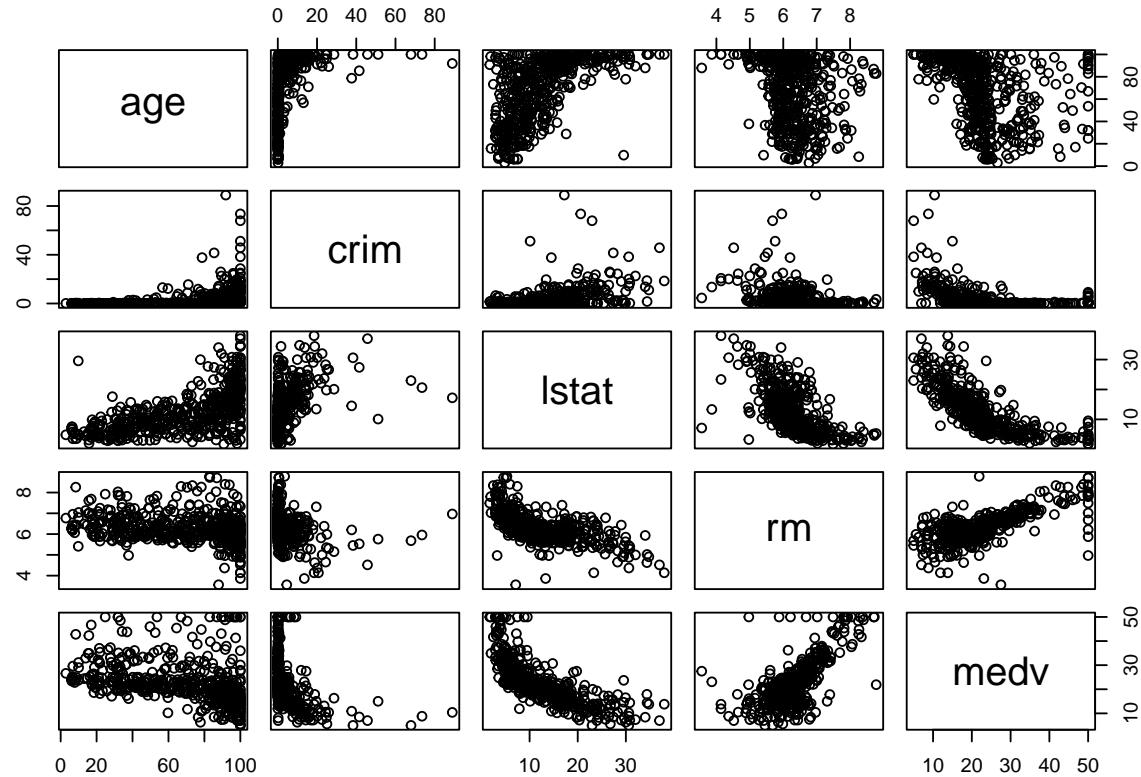
A rows represent observations for each town

The columns represent the following features:

- *crim* : per capita crime rate by town.
- *zn* : proportion of residential land zoned for lots over 25,000 sq.ft.
- *indus* : proportion of non-retail business acres per town.
- *chas* : Charles River dummy variable (= 1 if tract bounds river; 0 otherwise).
- *nox* : nitrogen oxides concentration (parts per 10 million).
- *rm* : average number of rooms per dwelling.
- *age* : proportion of owner-occupied units built prior to 1940.
- *dis* : weighted mean of distances to five Boston employment centres.
- *rad* : index of accessibility to radial highways.
- *tax* : full-value property-tax rate per \$10,000.
- *ptratio*: pupil-teacher ratio by town.
- *black* : $1000(Bk - 0.63)^2$ where Bk is the proportion of blacks by town.
- *lstat* : lower status of the population (percent).
- *medv* : median value of owner-occupied homes in \$1000s.

```
## 'data.frame': 506 obs. of 14 variables:  
##   $ crim    : num  0.00632 0.02731 0.02729 0.03237 0.06905 ...  
##   $ zn      : num  18 0 0 0 0 12.5 12.5 12.5 12.5 ...  
##   $ indus   : num  2.31 7.07 7.07 2.18 2.18 2.18 7.87 7.87 7.87 ...  
##   $ chas    : int  0 0 0 0 0 0 0 0 0 ...  
##   $ nox     : num  0.538 0.469 0.469 0.458 0.458 0.458 0.524 0.524 0.524 ...  
##   $ rm      : num  6.58 6.42 7.18 7 7.15 ...  
##   $ age     : num  65.2 78.9 61.1 45.8 54.2 58.7 66.6 96.1 100 85.9 ...  
##   $ dis     : num  4.09 4.97 4.97 6.06 6.06 ...  
##   $ rad     : int  1 2 2 3 3 3 5 5 5 ...  
##   $ tax     : num  296 242 242 222 222 311 311 311 311 ...  
##   $ ptratio : num  15.3 17.8 17.8 18.7 18.7 18.7 15.2 15.2 15.2 15.2 ...  
##   $ black   : num  397 397 393 395 397 ...  
##   $ lstat   : num  4.98 9.14 4.03 2.94 5.33 ...  
##   $ medv   : num  24 21.6 34.7 33.4 36.2 28.7 22.9 27.1 16.5 18.9 ...
```

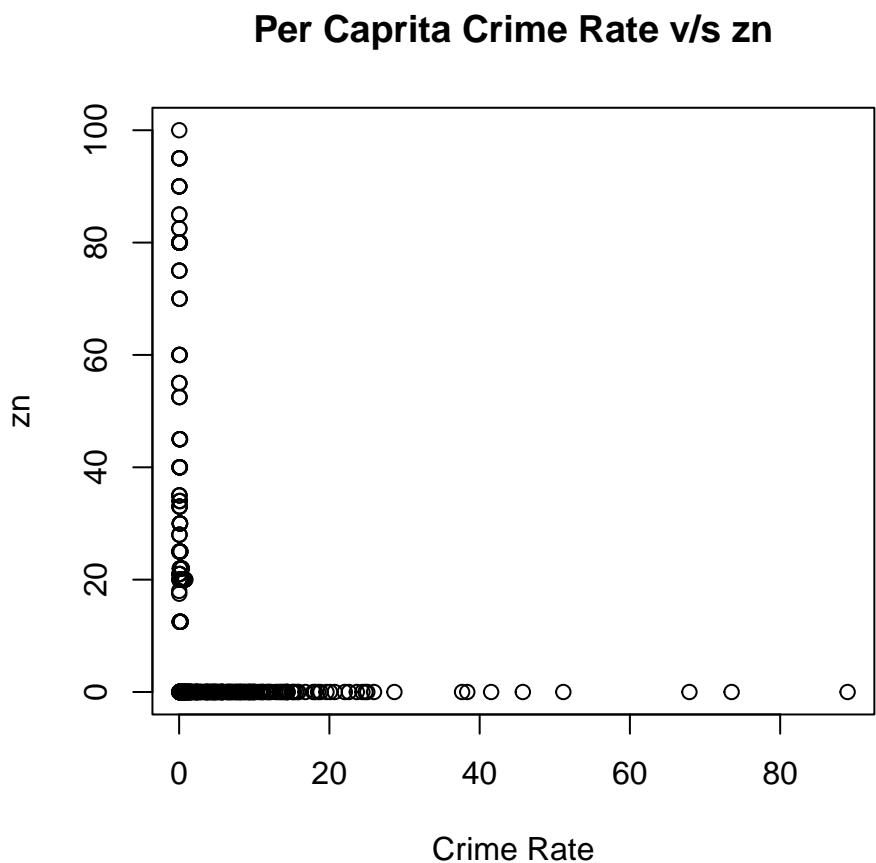
2.10.b



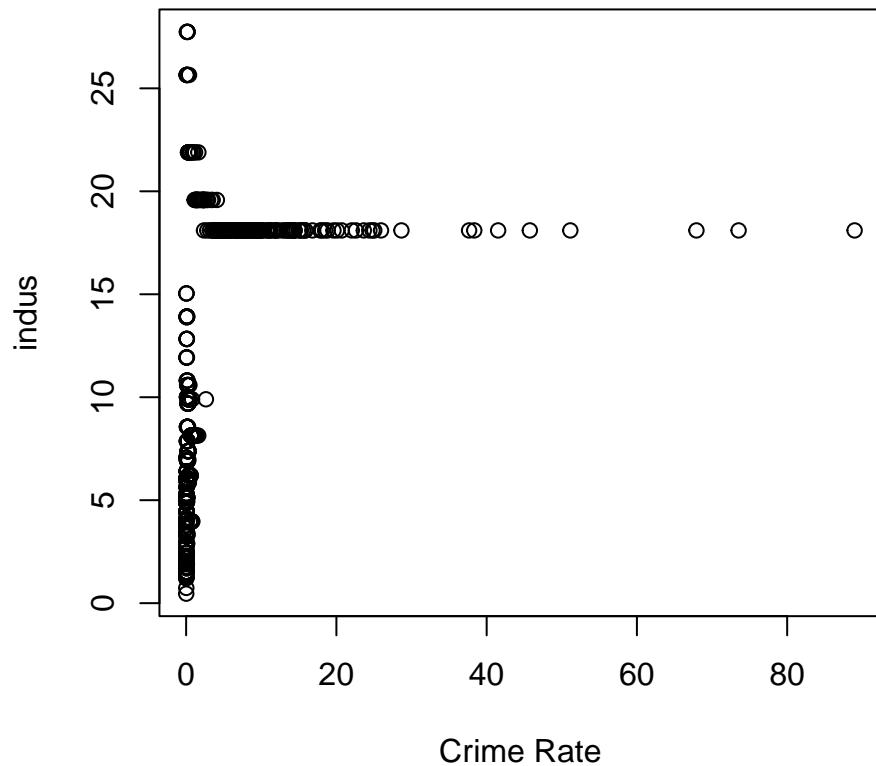
Inference:

- *lstat* is negatively corelated with *medv*
- *lstat* is negatively corelated with *rm*
- very low *medv* usually has higher *crime rate*. But largely, *crime rate* is independent of *locality/medv*
- *lstat* independent of *crime rate*
- *rm* (#Rooms) positively corelated to *medv*
- relationship between *crime rate per capita* and other variables is *non-linear*

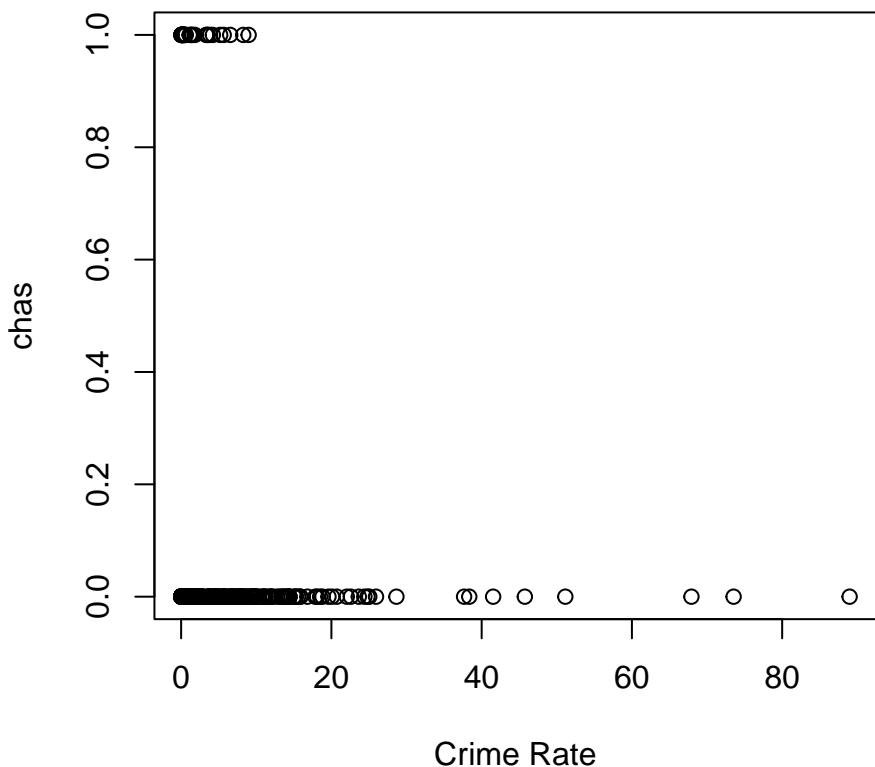
2.10.c



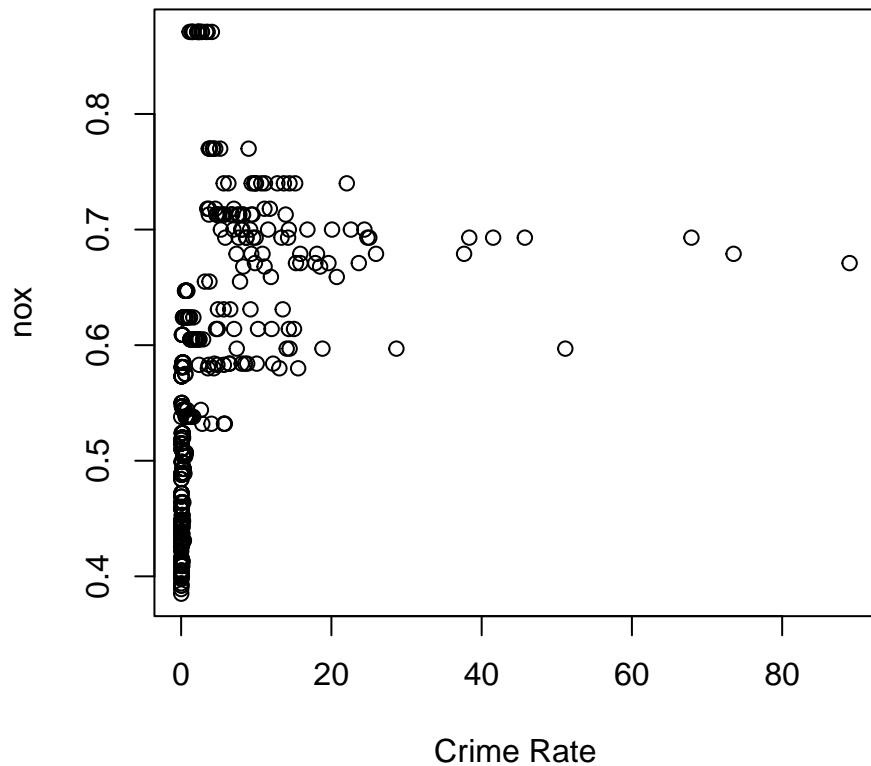
Per Capita Crime Rate v/s indus



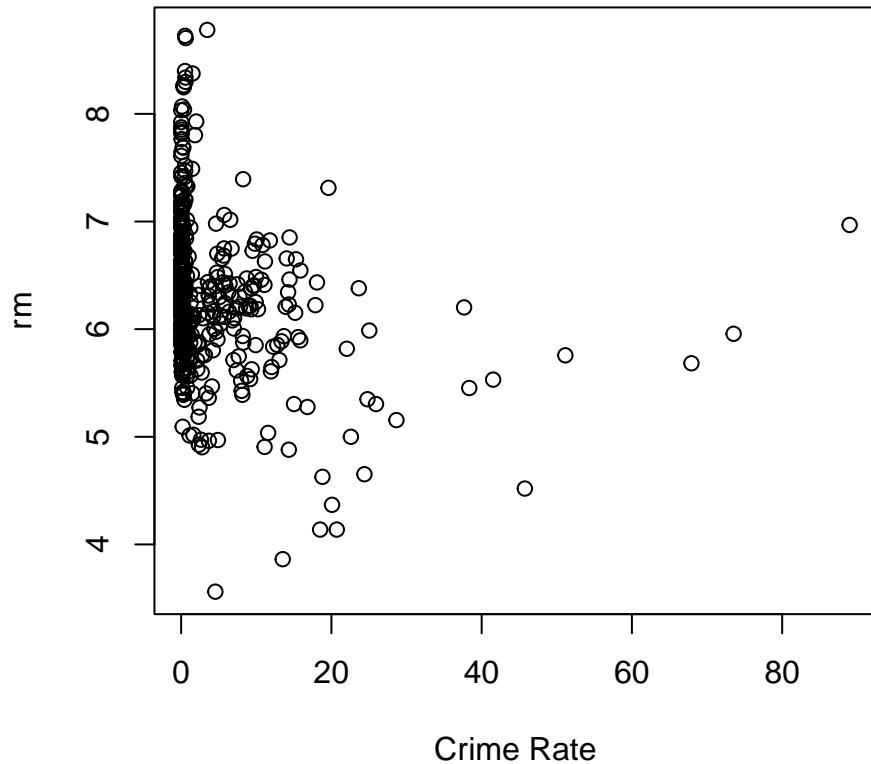
Per Capita Crime Rate v/s chas



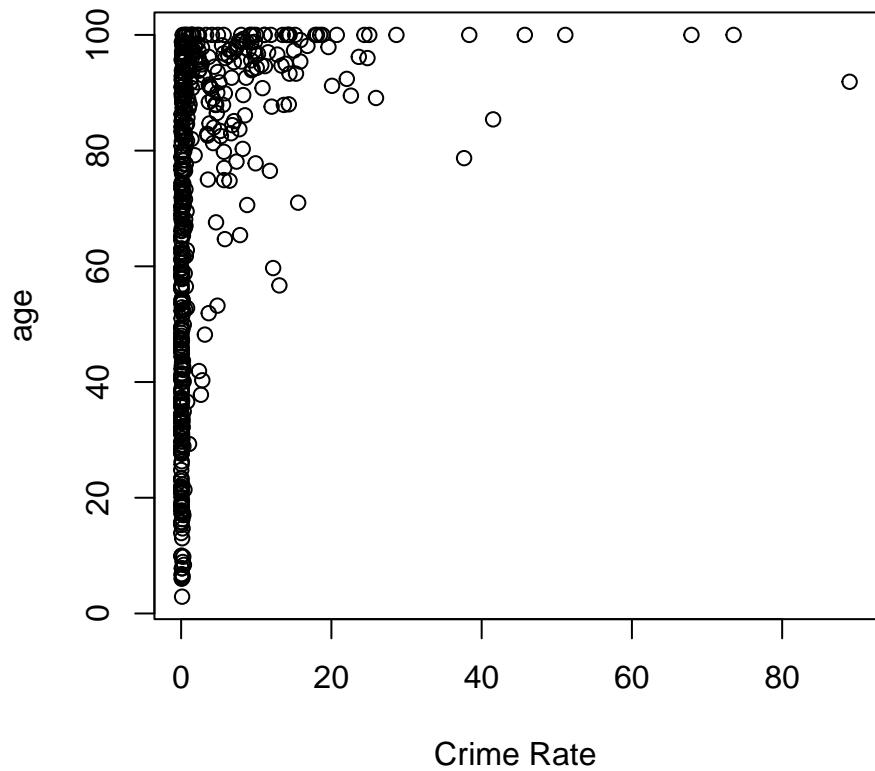
Per Capita Crime Rate v/s nox



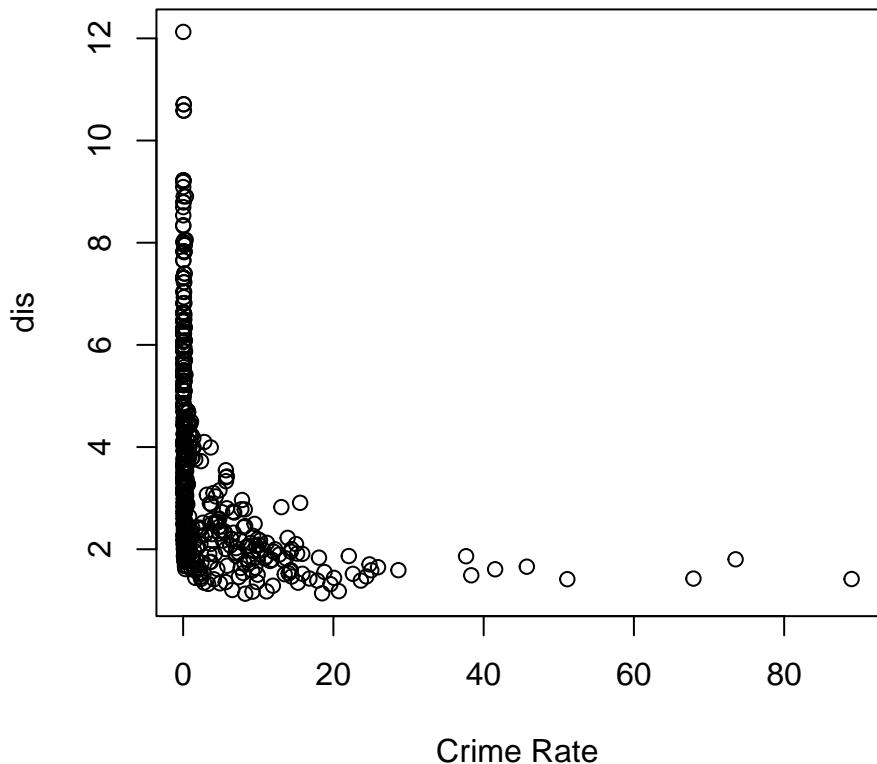
Per Capita Crime Rate v/s rm



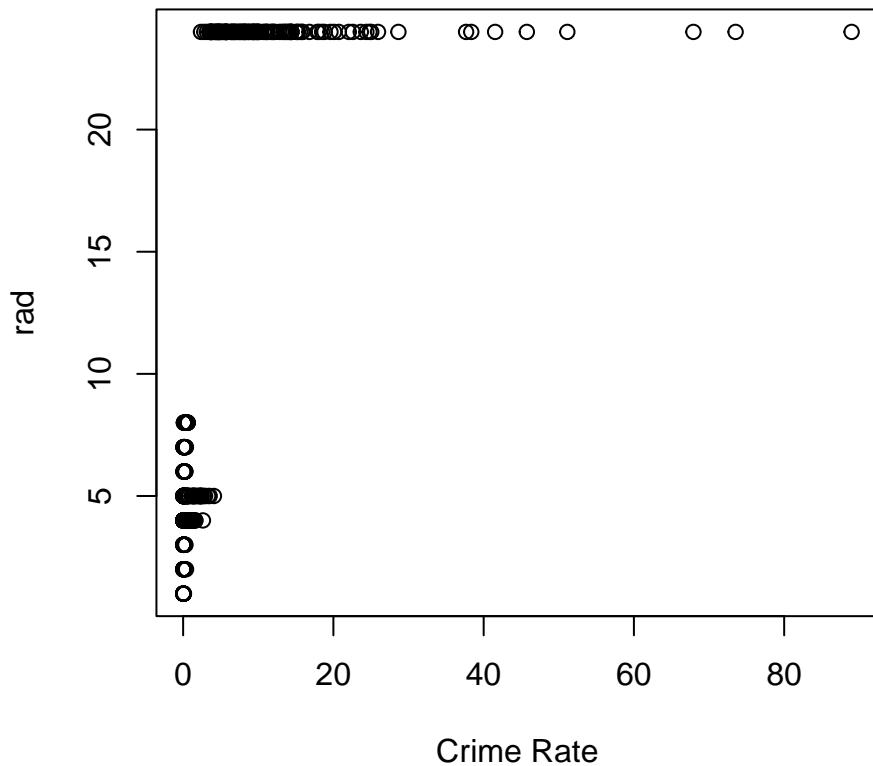
Per Capita Crime Rate v/s age



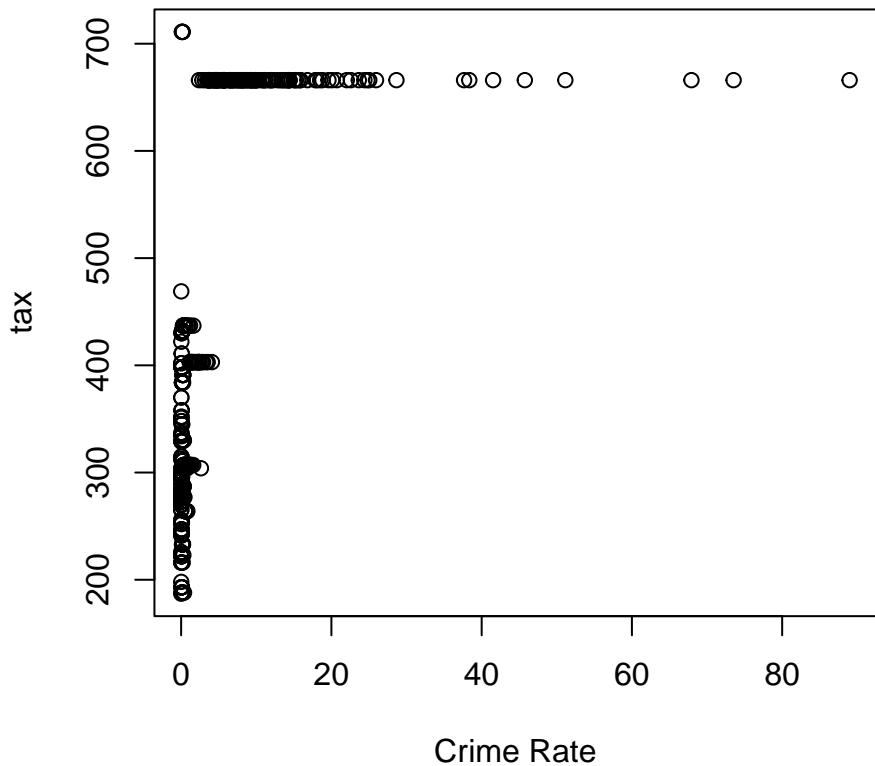
Per Capita Crime Rate v/s dis



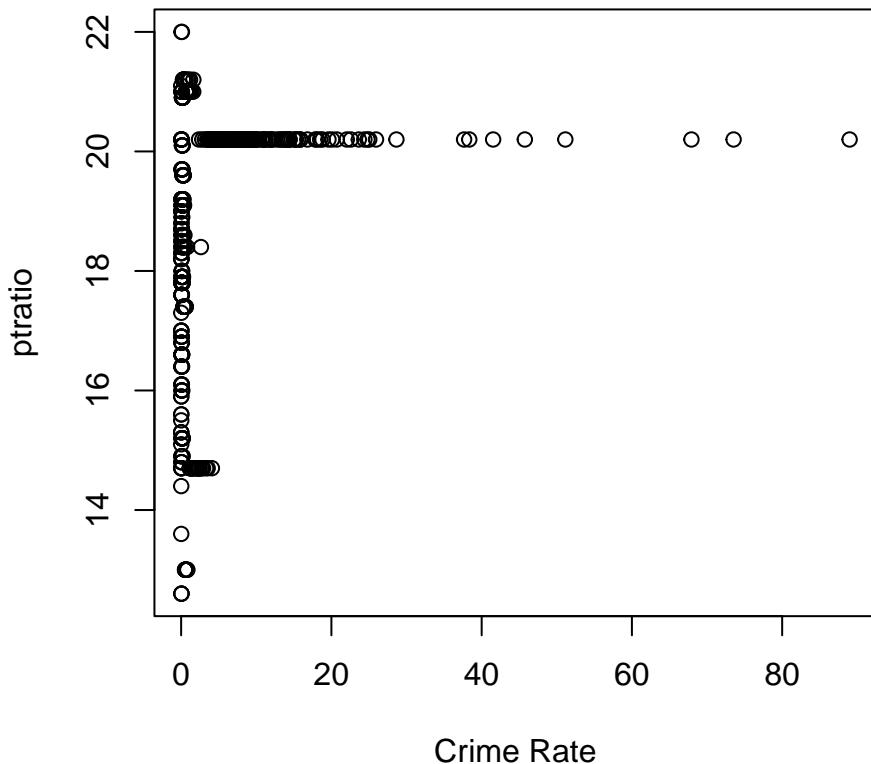
Per Capita Crime Rate v/s rad



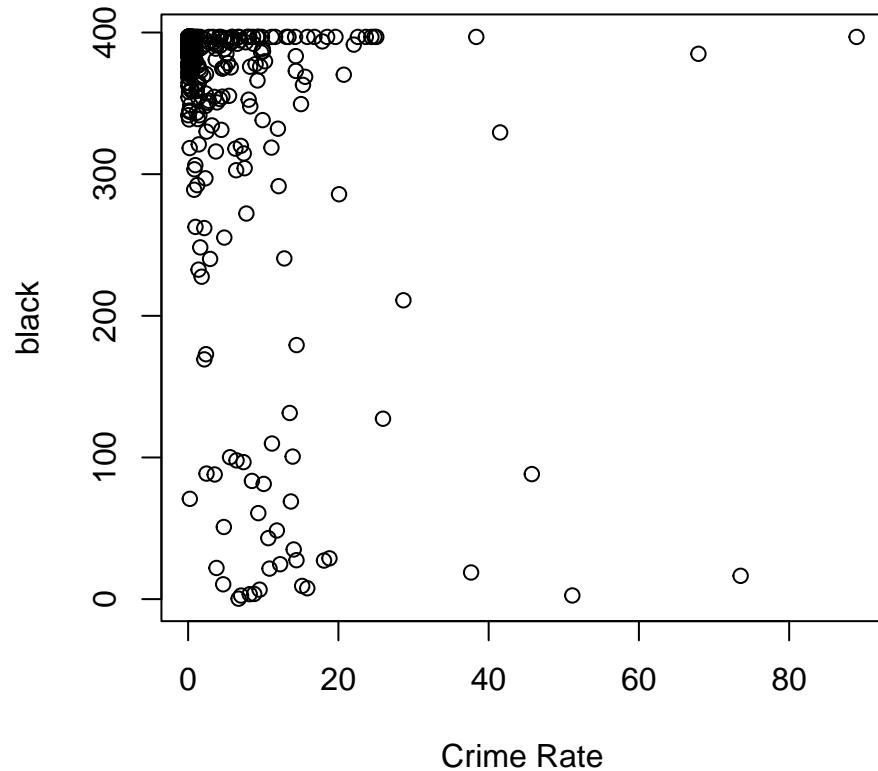
Per Capita Crime Rate v/s tax



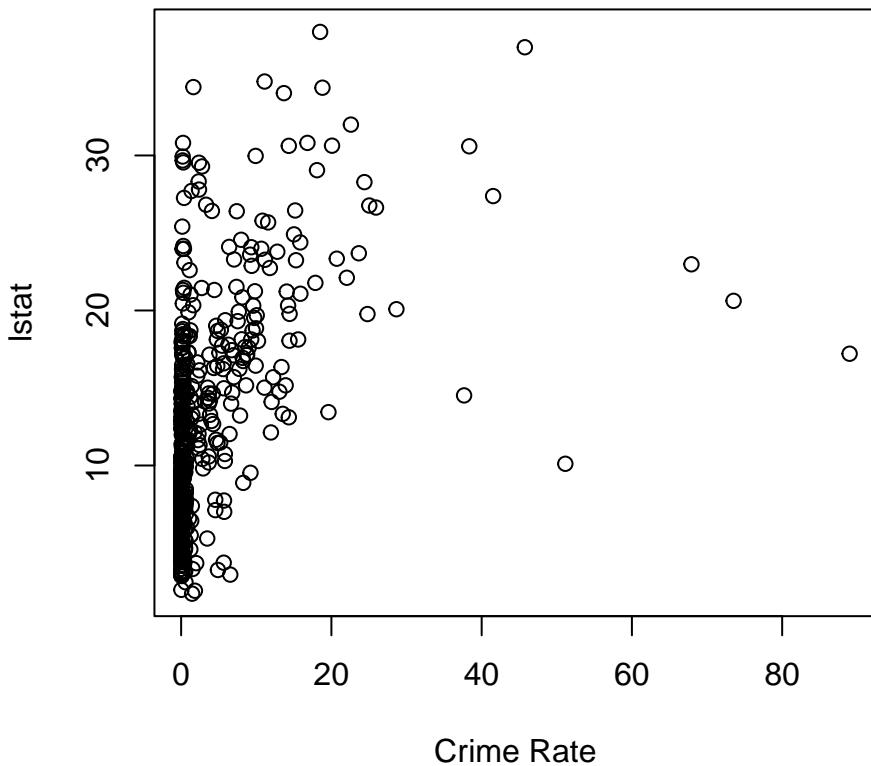
Per Capita Crime Rate v/s ptratio



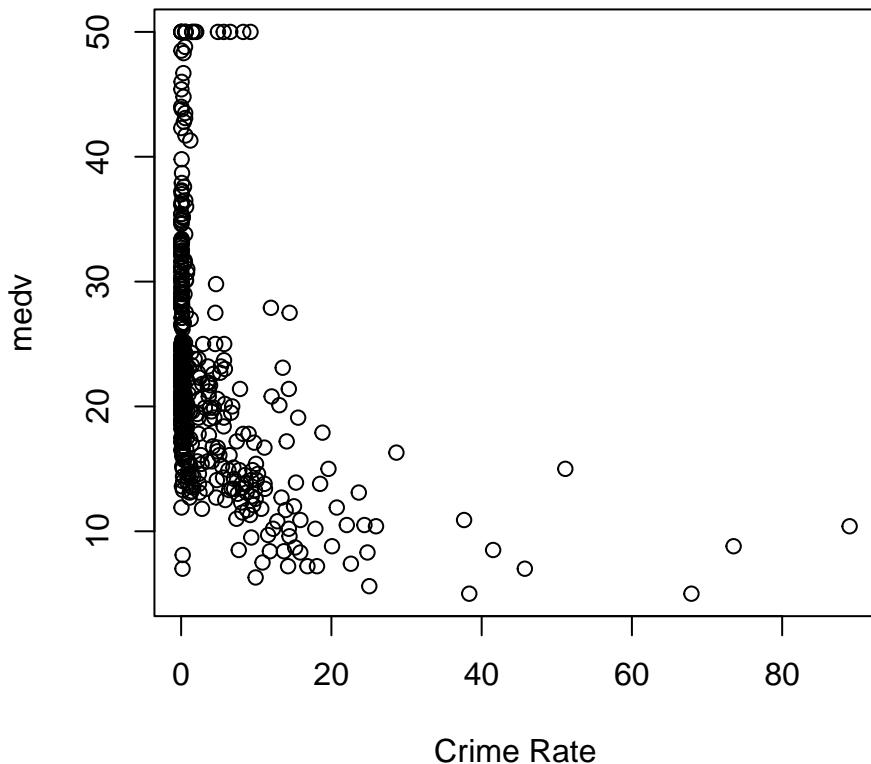
Per Capita Crime Rate v/s black



Per Capita Crime Rate v/s Istat



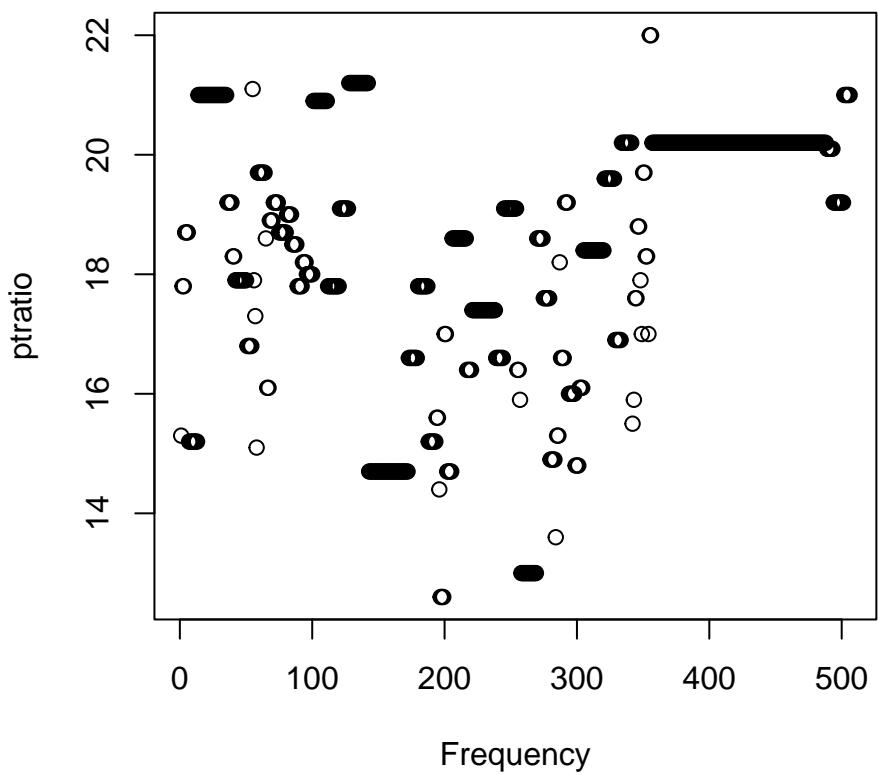
Per Capita Crime Rate v/s medv

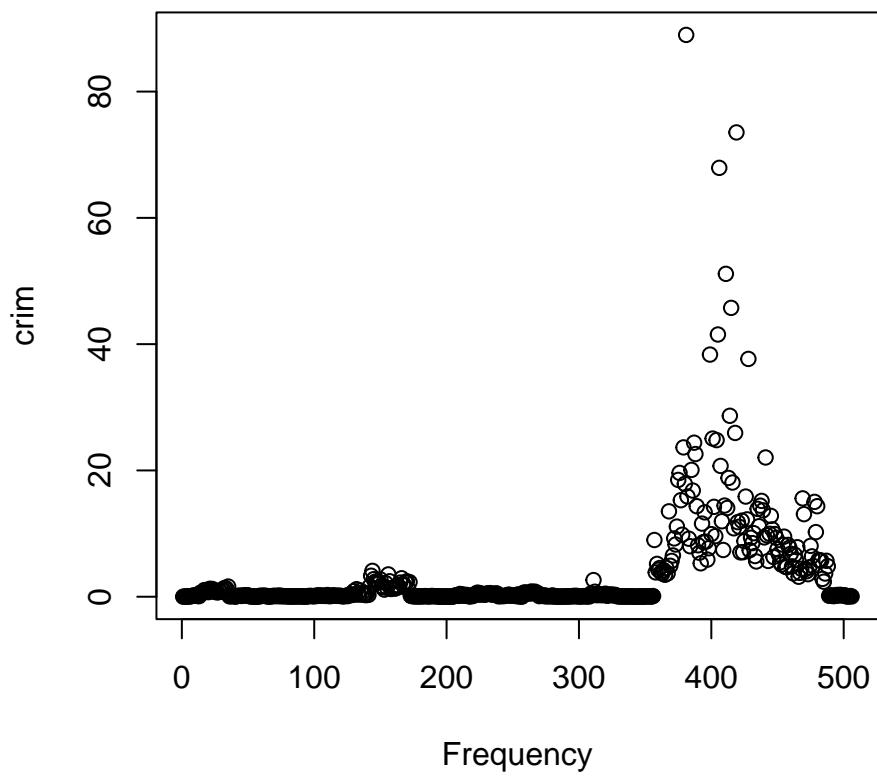


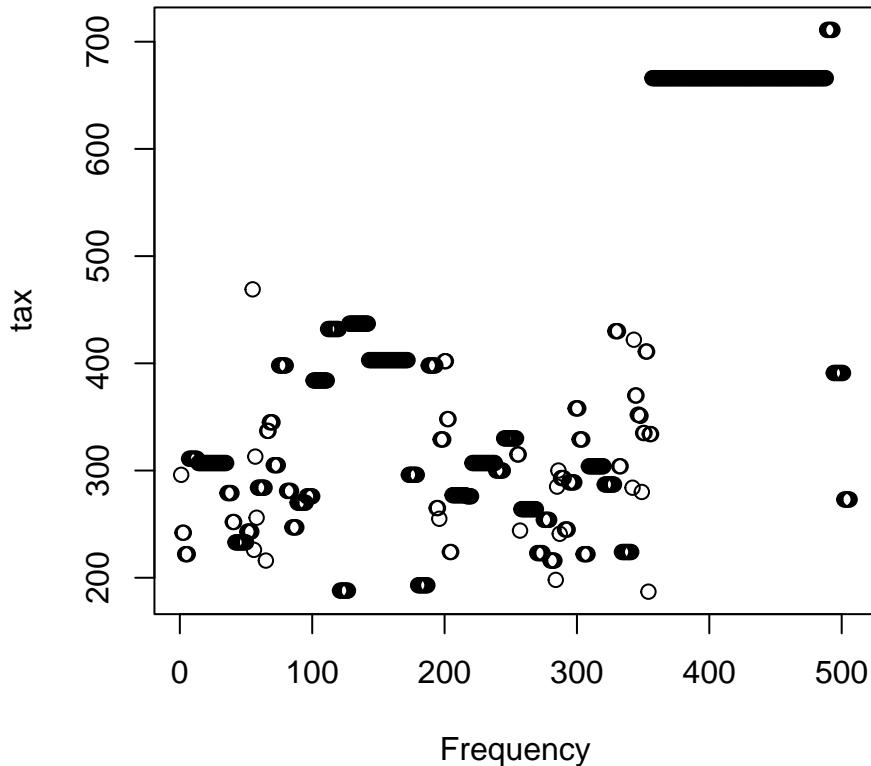
Inference:

- There exists some correlations for *per capita crime rate* with each variable, except *chas*
- *crime rate* seem to spike within certain zones
 - when *rad* is > 20
 - when *tax* is between 600 and 700
 - when *zn* is close to 0
 - when *nox* is between 0.6 and 0.8
- negative correlations with *dis*, *medv* and maybe *black*

2.10.d







Inference

- There exists definite outliers for *crim* and *tax*
- There are no clear outliers for *ptratio*

2.10.e

```
## Number of Towns bound by the Clares river: 35
```

2.10.f

```
## Median Pupil-Teacher Ratio: 19.05
```

2.10.g

```
##      crim   zn  indus  chas    nox     rm age     dis rad tax ptratio  black lstat
## 399 38.3518  0 18.1      0 0.693 5.453 100 1.4896  24 666    20.2 396.90 30.59
## 406 67.9208  0 18.1      0 0.693 5.683 100 1.4254  24 666    20.2 384.97 22.98
##      medv
## 399    5
## 406    5
```

```

##          crim      zn indus chas    nox      rm      age      dis rad tax ptratio
## 0% 0.006320 0.0 0.46 0 0.385 3.5610 2.900 1.129600 1 187 12.60
## 25% 0.082045 0.0 5.19 0 0.449 5.8855 45.025 2.100175 4 279 17.40
## 50% 0.256510 0.0 9.69 0 0.538 6.2085 77.500 3.207450 5 330 19.05
## 75% 3.677083 12.5 18.10 0 0.624 6.6235 94.075 5.188425 24 666 20.20
## 100% 88.976200 100.0 27.74 1 0.871 8.7800 100.000 12.126500 24 711 22.00
##          black lstat medv
## 0% 0.3200 1.730 5.000
## 25% 375.3775 6.950 17.025
## 50% 391.4400 11.360 21.200
## 75% 396.2250 16.955 25.000
## 100% 396.9000 37.970 50.000

```

How the predictors for the minimum *Median Value* compare against the rest:

- *age, rad* at max
- *crim, indus, nox, tax, ptratio, lstat* at or above 75th percentile
- lowest for *zn, rm, dis*

2.10.h

```

## suburbs average >7 rooms per dwelling: 64

## suburbs average >8 rooms per dwelling: 13

## Stats regarding Dwellings with more than 8 bedrooms:

```

```

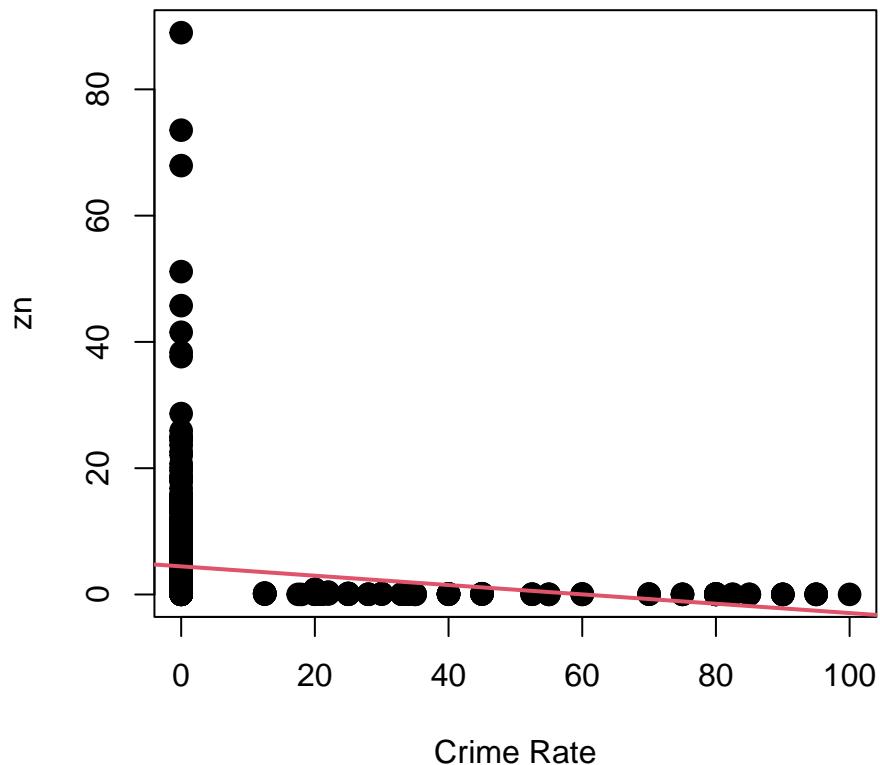
##          crim      zn indus chas    nox      rm      age
## Min. 0.0200900 0.00000 2.680000 0.0000000 0.4161000 8.034000 8.40000
## 1st Qu. 0.3314700 0.00000 3.970000 0.0000000 0.5040000 8.247000 70.40000
## Median 0.5201400 0.00000 6.200000 0.0000000 0.5070000 8.297000 78.30000
## Mean 0.7187954 13.61538 7.078462 0.1538462 0.5392385 8.348538 71.53846
## 3rd Qu. 0.5783400 20.00000 6.200000 0.0000000 0.6050000 8.398000 86.50000
## Max. 3.4742800 95.00000 19.580000 1.0000000 0.7180000 8.780000 93.90000
##          dis      rad      tax      ptratio      black lstat medv
## Min. 1.801000 2.000000 224.0000 13.00000 354.5500 2.47 21.9
## 1st Qu. 2.288500 5.000000 264.0000 14.70000 384.5400 3.32 41.7
## Median 2.894400 7.000000 307.0000 17.40000 386.8600 4.14 48.3
## Mean 3.430192 7.461538 325.0769 16.36154 385.2108 4.31 44.2
## 3rd Qu. 3.651900 8.000000 307.0000 17.40000 389.7000 5.12 50.0
## Max. 8.906700 24.000000 666.0000 20.20000 396.9000 7.44 50.0

```

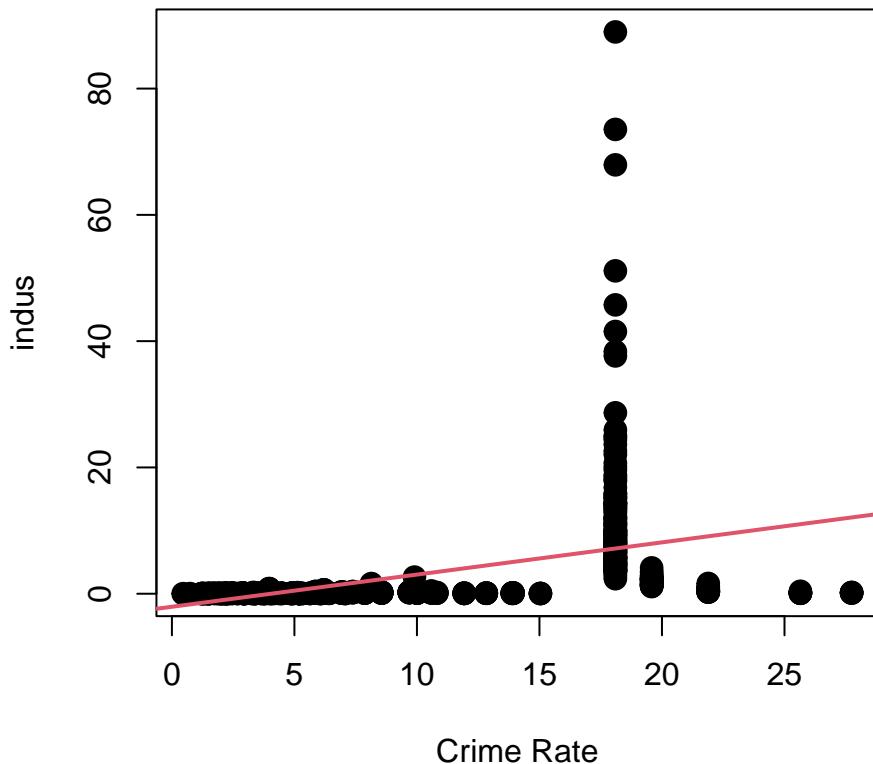
- *crime rates* are higher (*in the 50-75%ile:*)
- higher proportion of 25K sq ft lots
- much lower *lstat* value
- higher *medv* value

EXERCISE 3.15:

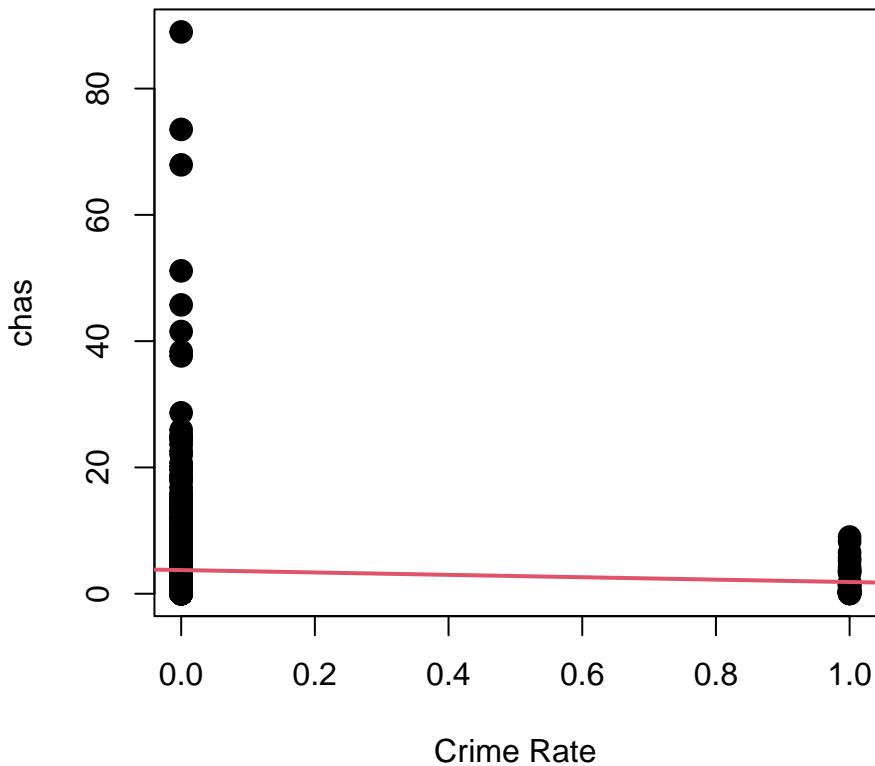
3.15.a



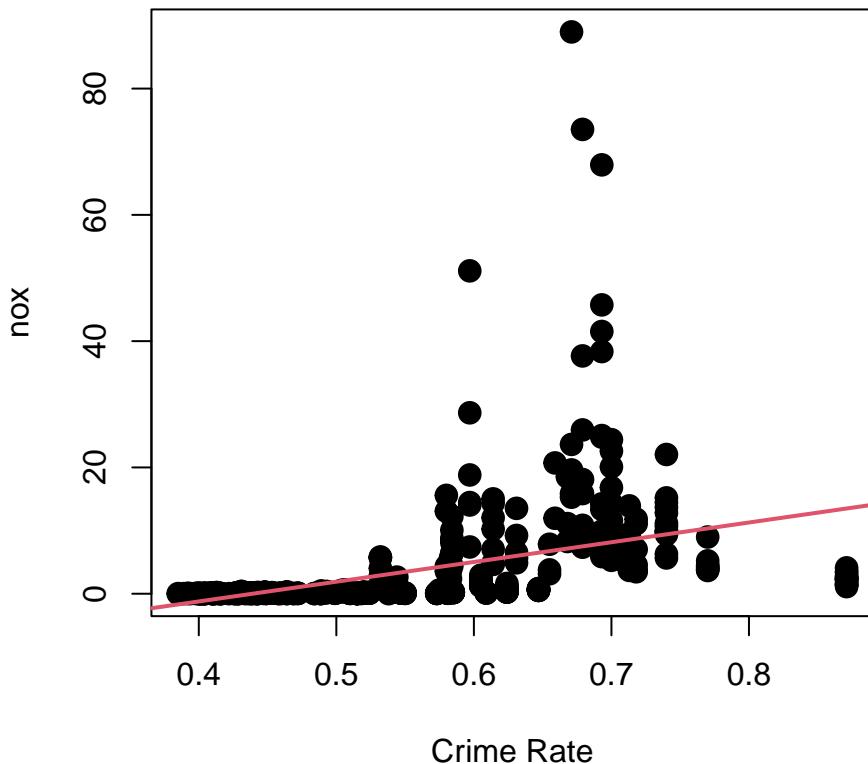
```
## For Predictor : zn
## Co-efficient: -0.0739349774041235
## P-value      : 5.50647210767929e-06
## R^2          : 0.0401879080321107
```



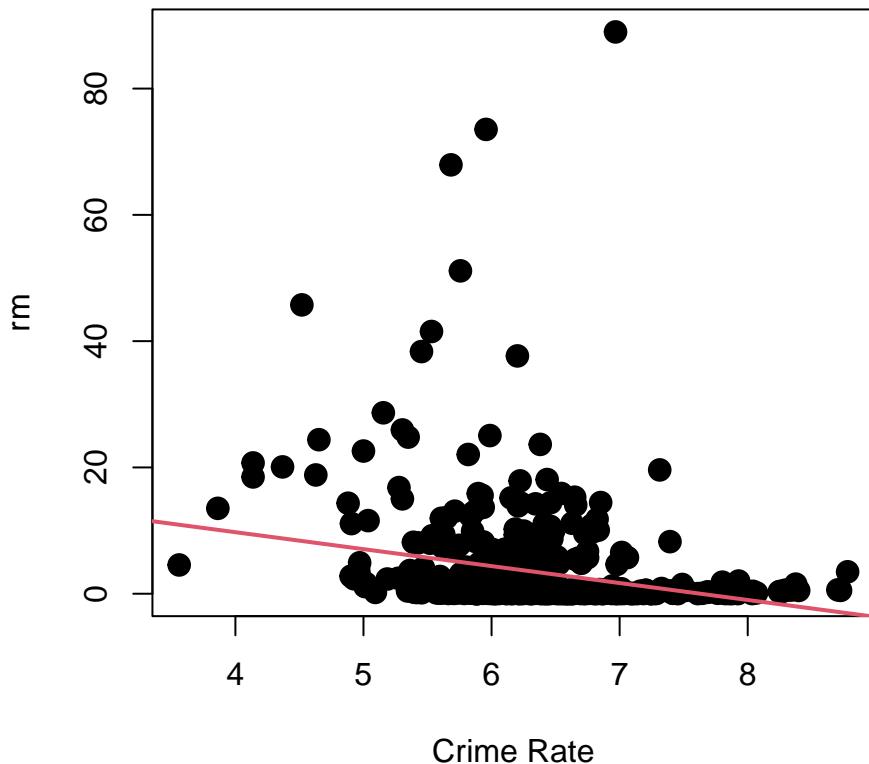
```
## For Predictor : indus
## Co-efficient: 0.509776331104231
## P-value      : 1.45034893302729e-21
## R^2          : 0.165310070430751
```



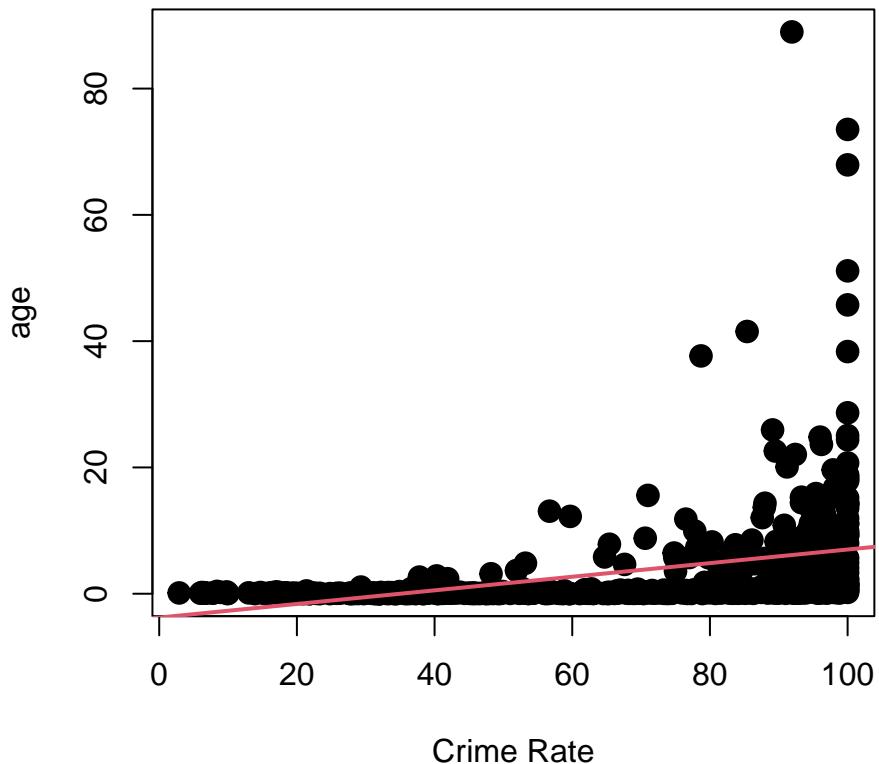
```
## For Predictor : chas
## Co-efficient: -1.89277655080376
## P-value      : 0.2094345015352
## R^2          : 0.00312386896330558
```



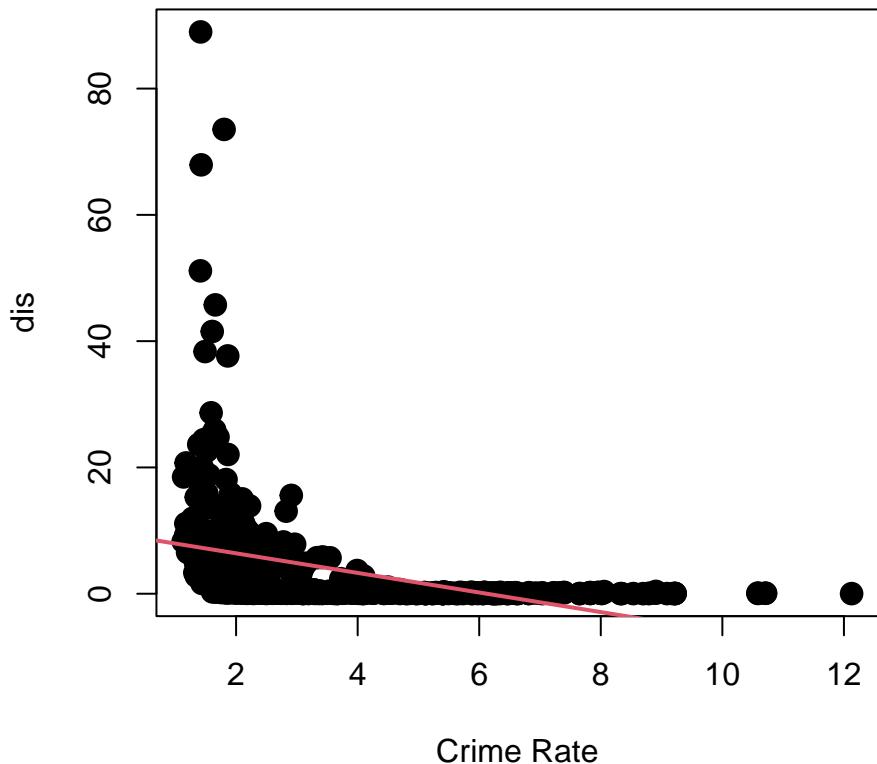
```
## For Predictor : nox
## Co-efficient: 31.2485312011229
## P-value      : 3.7517392603569e-23
## R^2          : 0.177217181792694
```



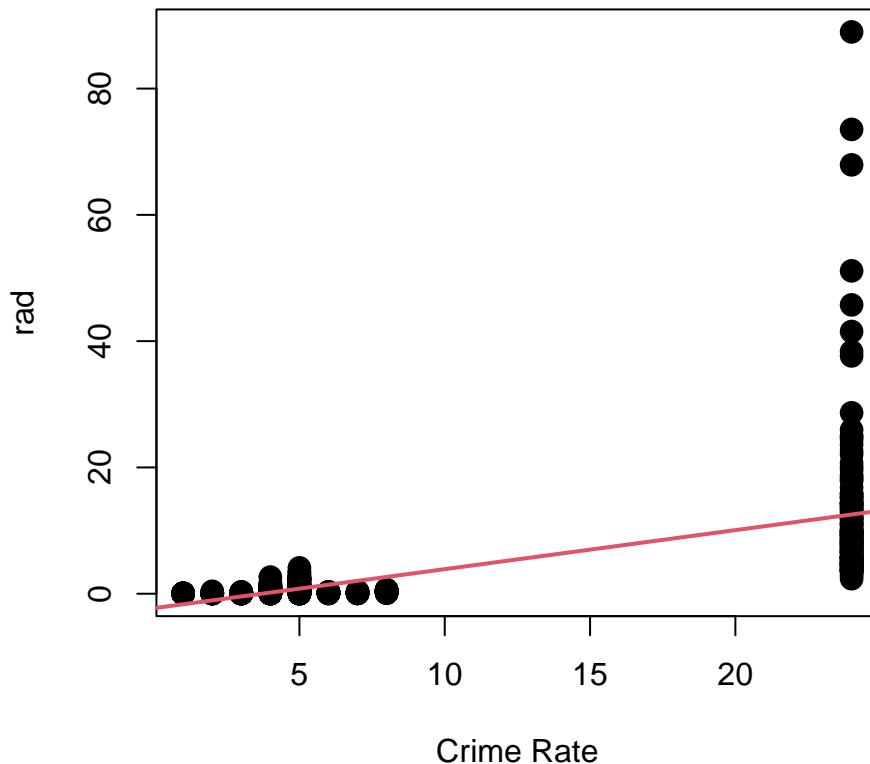
```
## For Predictor : rm
## Co-efficient: -2.68405122411395
## P-value      : 6.34670298468777e-07
## R^2          : 0.0480691167160835
```



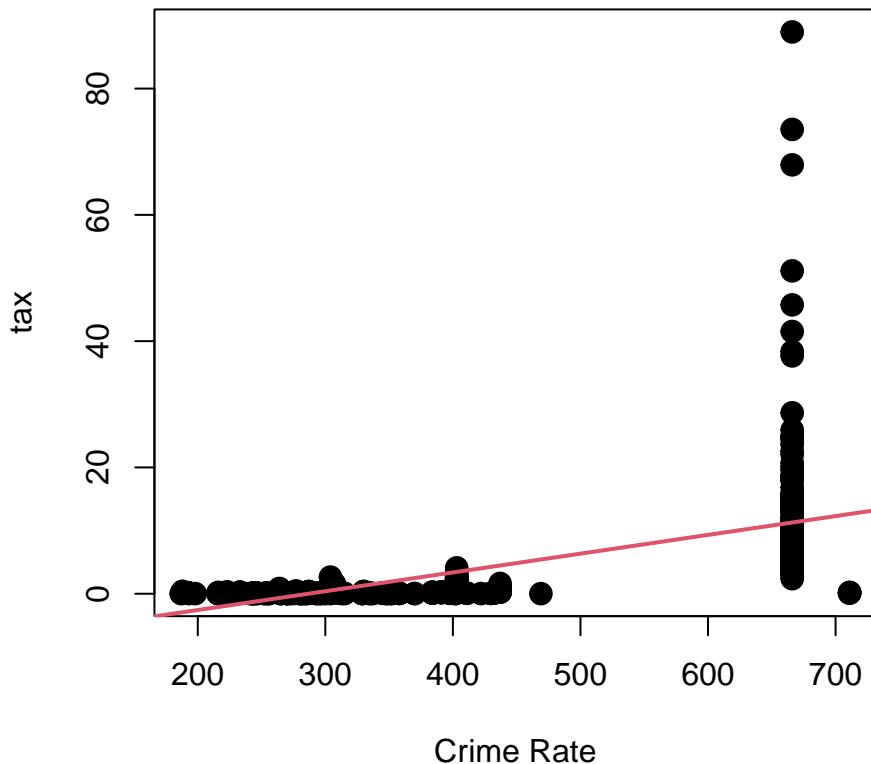
```
## For Predictor : age
## Co-efficient: 0.107786227139533
## P-value      : 2.85486935024418e-16
## R^2          : 0.124421451758946
```



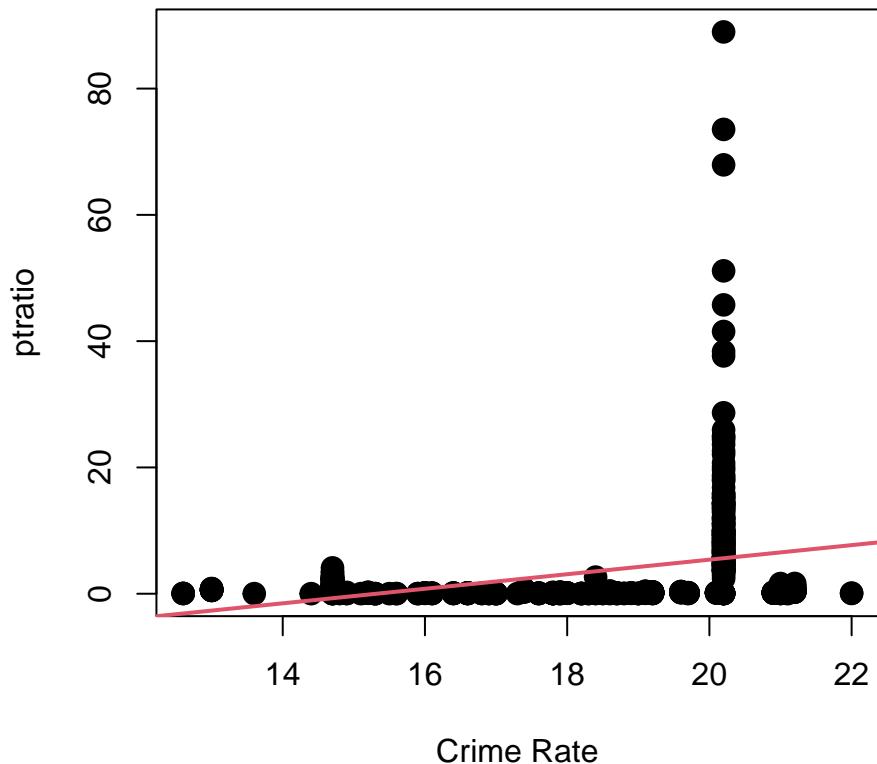
```
## For Predictor : dis
## Co-efficient: -1.5509016824101
## P-value      : 8.51994876692635e-19
## R^2          : 0.144149374925399
```



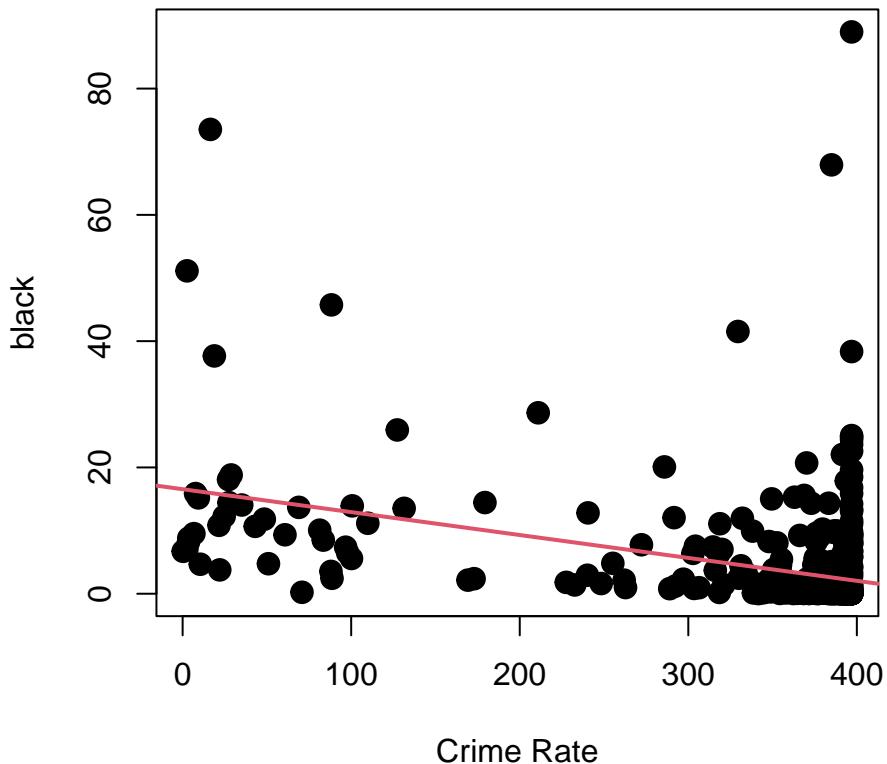
```
## For Predictor : rad
## Co-efficient: 0.617910927327201
## P-value      : 2.69384439818633e-56
## R^2          : 0.391256686749989
```



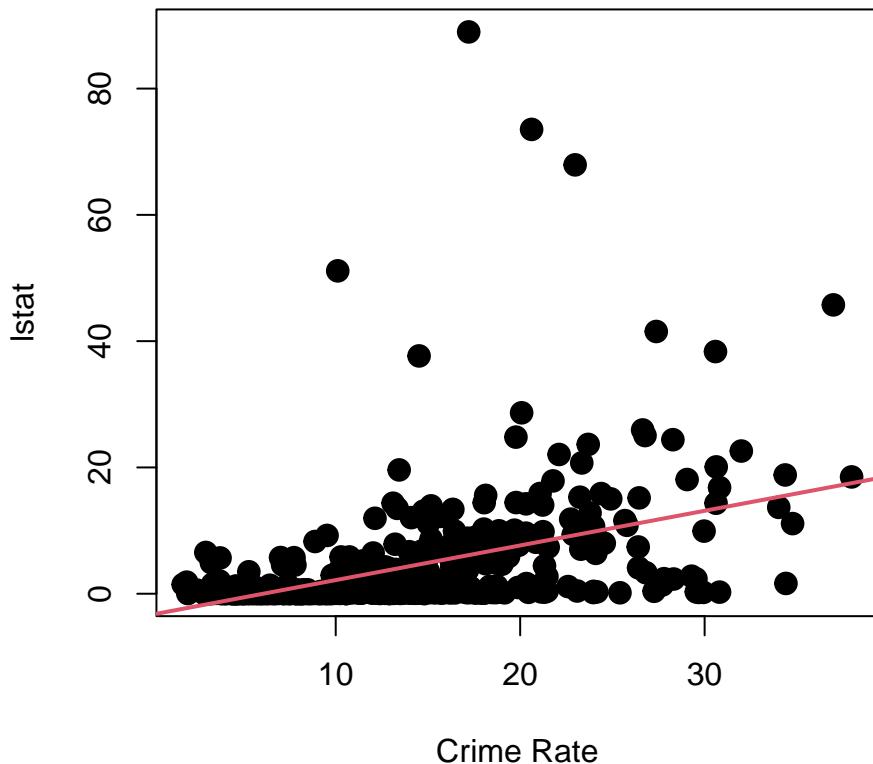
```
## For Predictor : tax
## Co-efficient: 0.0297422528227654
## P-value      : 2.35712683525664e-47
## R^2          : 0.339614243378812
```



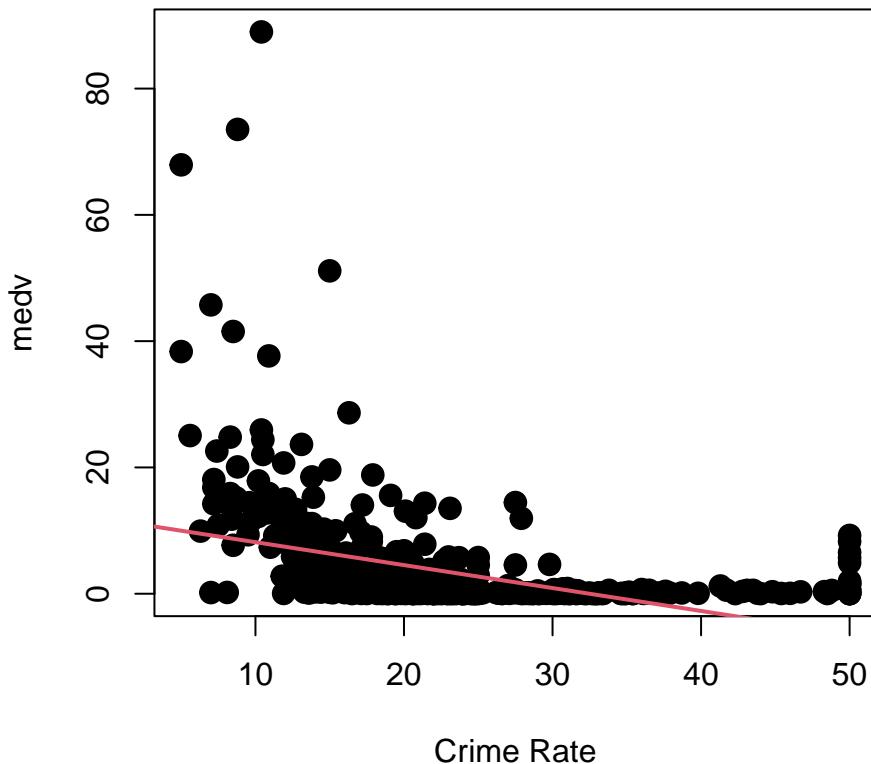
```
## For Predictor : pptratio
## Co-efficient: 1.15198278707058
## P-value      : 2.94292244735985e-11
## R^2          : 0.0840684389437365
```



```
## For Predictor : black
## Co-efficient: -0.0362796405673307
## P-value      : 2.4872739737737e-19
## R^2          : 0.148274239424131
```



```
## For Predictor : lstat
## Co-efficient: 0.548804782062398
## P-value      : 2.65427723147331e-27
## R^2          : 0.207590932534335
```



```

## For Predictor : medv
## Co-efficient: -0.363159922257603
## P-value      : 1.17398708219436e-19
## R^2          : 0.150780469049757

##
## Statistically Significant Variable are:
##  zn  indus  nox  rm  age  dis  rad  tax  ptratio  black  lstat  medv
## because the P value for these are less than 0.05

```

3.15.b

```

## Failing to reject NULL Hypothesis for:

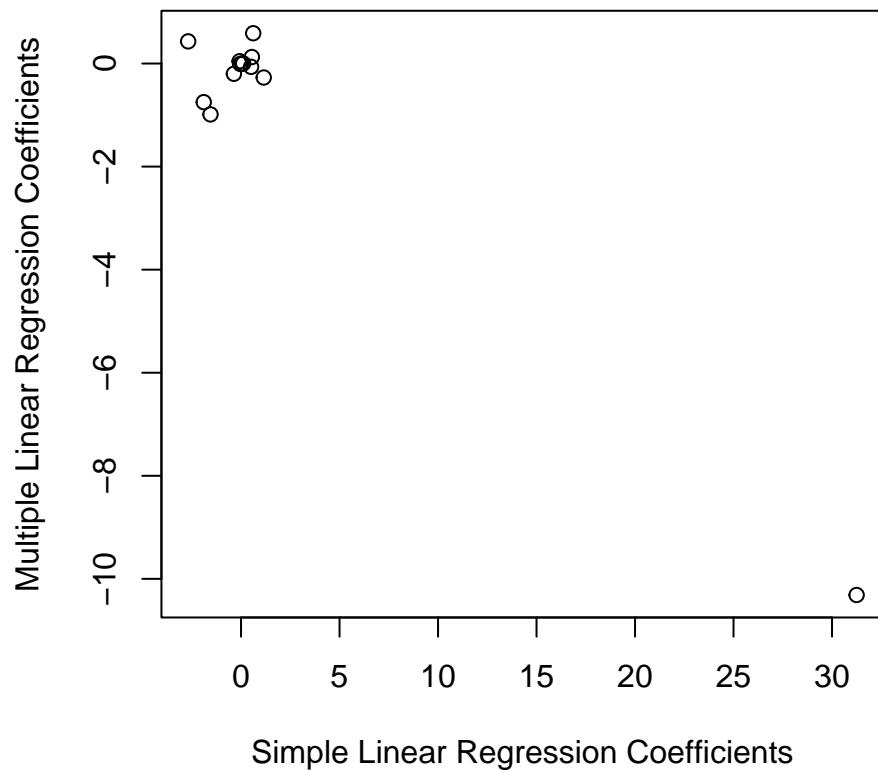
## zn ( 0.0170248914984876 )
## dis ( 0.000502203909227045 )
## rad ( 6.46045147866926e-11 )
## black ( 0.0407023319004137 )
## medv ( 0.00108681009556159 )

## Because Their P-Value is < 0.05

```

3.15.c

Parameter Coefficients Simple v/s Multiple



```
## Coefficients of Simple Linear Regression

##           Coefficient      P-Value          R^2
## zn       -0.07393498 5.506472e-06 0.040187908
## indus     0.50977633 1.450349e-21 0.165310070
## chas    -1.89277655 2.094345e-01 0.003123869
## nox     31.24853120 3.751739e-23 0.177217182
## rm      -2.68405122 6.346703e-07 0.048069117
## age      0.10778623 2.854869e-16 0.124421452
## dis     -1.55090168 8.519949e-19 0.144149375
## rad      0.61791093 2.693844e-56 0.391256687
## tax      0.02974225 2.357127e-47 0.339614243
## ptratio   1.15198279 2.942922e-11 0.084068439
## black    -0.03627964 2.487274e-19 0.148274239
## lstat     0.54880478 2.654277e-27 0.207590933
## medv     -0.36315992 1.173987e-19 0.150780469
```

```
## 
## 
## Coefficients of Multiple Linear Regression
```

```

##               Estimate Std. Error     t value   Pr(>|t|) 
## (Intercept) 17.033227523 7.234903031  2.35431317 1.894909e-02
## zn            0.044855215 0.018734071  2.39431224 1.702489e-02
## indus        -0.063854824 0.083407241 -0.76557890 4.442940e-01
## chas          -0.749133611 1.180146772 -0.63478004 5.258670e-01
## nox           -10.313534912 5.275536315 -1.95497373 5.115200e-02
## rm             0.430130506 0.612830309  0.70187538 4.830888e-01
## age            0.001451643 0.017925128  0.08098372 9.354878e-01
## dis            -0.987175726 0.281817266 -3.50289299 5.022039e-04
## rad             0.588208591 0.088049274  6.68044796 6.460451e-11
## tax             -0.003780016 0.005155587 -0.73318838 4.637927e-01
## ptratio         -0.271080558 0.186450494 -1.45390099 1.466113e-01
## black           -0.007537505 0.003673322 -2.05195893 4.070233e-02
## lstat            0.126211376 0.075724837  1.66671043 9.620842e-02
## medv            -0.198886821 0.060515990 -3.28651687 1.086810e-03

```

From the plot and the tables, we see that most of the predictors are around the same range of values, except **nox**.

- β_{nox} went from 31.25 in the case of Simple Linear Regression to -10.31 in Multiple Linear Regression.
- Similarly, β_{zn} also flipped signs and went from -0.07 to 0.04

3.15.d

```

##          ^1          ^2          ^3
## zn      2.612296e-03 9.375050e-02 2.295386e-01
## indus  5.297064e-05 3.420187e-10 1.196405e-12
## chas   2.094345e-01 2.094345e-01 2.094345e-01
## nox    2.758372e-13 6.811300e-15 6.961110e-16
## rm     2.117564e-01 3.641094e-01 5.085751e-01
## age    1.426608e-01 4.737733e-02 6.679915e-03
## dis    6.374792e-18 4.941214e-12 1.088832e-08
## rad    6.234175e-01 6.130099e-01 4.823138e-01
## tax    1.097075e-01 1.374682e-01 2.438507e-01
## ptratio 3.028663e-03 4.119552e-03 6.300514e-03
## black  1.385871e-01 4.741751e-01 5.436172e-01
## lstat  3.345300e-01 6.458736e-02 1.298906e-01
## medv   2.637707e-28 3.260523e-18 1.046510e-12

```

Thus, from the P-Value, we can conclude that, for a 95% confidence interval, there exists a statistically significant non-linear relationship between crime rate and the following predictors:

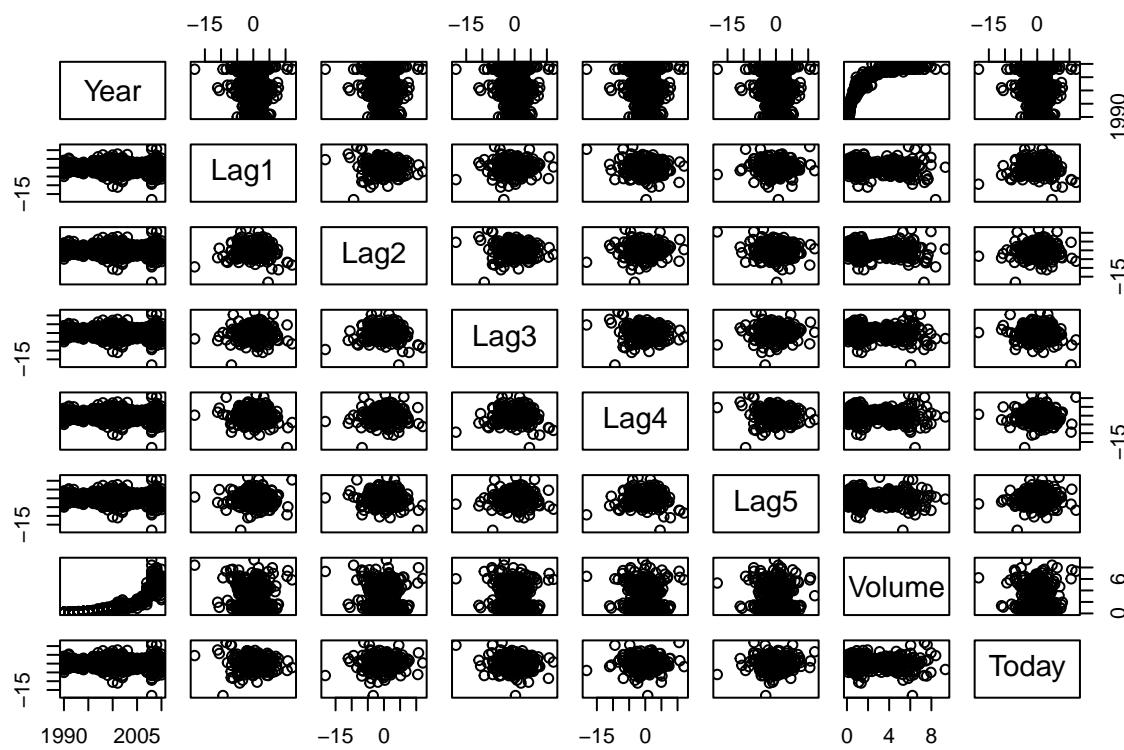
- **zn**
- **indus**
- **nox**
- **age**
- **dis**
- **ptratio**
- **lstat**
- **medv**

EXERCISE 4.10:

4.10.a

```

##      Year      Lag1      Lag2      Lag3
## Min. :1990  Min. :-18.1950  Min. :-18.1950  Min. :-18.1950
## 1st Qu.:1995 1st Qu.: -1.1540  1st Qu.: -1.1540  1st Qu.: -1.1580
## Median :2000 Median : 0.2410  Median : 0.2410  Median : 0.2410
## Mean   :2000  Mean  : 0.1506  Mean  : 0.1511  Mean  : 0.1472
## 3rd Qu.:2005 3rd Qu.: 1.4050  3rd Qu.: 1.4090  3rd Qu.: 1.4090
## Max.  :2010  Max. : 12.0260  Max. : 12.0260  Max. : 12.0260
##      Lag4      Lag5      Volume      Today
## Min. :-18.1950  Min. :-18.1950  Min. :0.08747  Min. :-18.1950
## 1st Qu.: -1.1580 1st Qu.: -1.1660  1st Qu.:0.33202  1st Qu.: -1.1540
## Median : 0.2380  Median : 0.2340  Median :1.00268  Median : 0.2410
## Mean   : 0.1458  Mean   : 0.1399  Mean   :1.57462  Mean   : 0.1499
## 3rd Qu.: 1.4090 3rd Qu.: 1.4050  3rd Qu.:2.05373  3rd Qu.: 1.4050
## Max.  : 12.0260  Max.  : 12.0260  Max. : 9.32821  Max. : 12.0260
## Direction
## Down:484
## Up :605
##
##
```



Positive Correlation between **Year** and **Volume** observed.

4.10.b

```
##  
## Call:  
## glm(formula = Direction ~ ., family = binomial, data = Weekly[,  
##   c(2:7, 9)])  
##  
## Deviance Residuals:  
##      Min       1Q   Median       3Q      Max  
## -1.6949  -1.2565   0.9913   1.0849   1.4579  
##  
## Coefficients:  
##             Estimate Std. Error z value Pr(>|z|)  
## (Intercept) 0.26686   0.08593   3.106   0.0019 **  
## Lag1        -0.04127   0.02641  -1.563   0.1181  
## Lag2         0.05844   0.02686   2.175   0.0296 *  
## Lag3        -0.01606   0.02666  -0.602   0.5469  
## Lag4        -0.02779   0.02646  -1.050   0.2937  
## Lag5        -0.01447   0.02638  -0.549   0.5833  
## Volume     -0.02274   0.03690  -0.616   0.5377  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## (Dispersion parameter for binomial family taken to be 1)  
##  
## Null deviance: 1496.2 on 1088 degrees of freedom  
## Residual deviance: 1486.4 on 1082 degrees of freedom  
## AIC: 1500.4  
##  
## Number of Fisher Scoring iterations: 4
```

To check if a parameter is significant or not, we must check for its **P-Value**.

From the Summary, only Lag2 has a **P-Value** < 0.05. Thus, only Lag2 is statistically significant.

4.10.c

```
##          Reference  
## Prediction Down Up  
##      Down    54  48  
##      Up     430 557  
  
## Accuracy           : 56.11 %  
  
## Recall/Sensitivity : 92.07 %  
  
## Precision          : 56.43 %  
  
## Specificity        : 11.16 %
```

```

## Up Prediction Rate : 56.43 %
## Down Prediction Rate: 52.94 %

## [Logistic Regression] Overall Fraction of Correct Predictions (Accuracy) : 0.62

```

4.10.d

```

##             Reference
## Prediction Down Up
##       Down    9  5
##       Up     34 56

## [Logistic Regression] Overall Fraction of Correct Predictions (Accuracy) : 0.62

```

4.10.g

```

##             Reference
## Prediction Down Up
##       Down   21 30
##       Up     22 31

## [KNN (k = 1)] Overall Fraction of Correct Predictions (Accuracy) : 0.5

```

4.10.h

Considering **only Accuracy** as our metric, we can conclude that *Logistic Regression* outperforms *KNN* (*with k = 1*)

4.10.i

Experimenting with different KNN models:

```

## Predictors: Lag2

## [KNN (k = 30 )] Accuracy : 0.53
## [KNN (k = 130 )] Accuracy : 0.57
## [KNN (k = 230 )] Accuracy : 0.59
## [KNN (k = 330 )] Accuracy : 0.59

## 
## Predictors: Lag2, Lag1

## [KNN (k = 30 )] Accuracy : 0.54
## [KNN (k = 130 )] Accuracy : 0.57
## [KNN (k = 230 )] Accuracy : 0.59
## [KNN (k = 330 )] Accuracy : 0.59

```

```

## 
## Predictors: Lag2^2

## [KNN (k = 30 )] Accuracy : 0.62
## [KNN (k = 130 )] Accuracy : 0.62
## [KNN (k = 230 )] Accuracy : 0.59
## [KNN (k = 330 )] Accuracy : 0.59

## 
## Predictors: Lag2*Lag1

## [KNN (k = 30 )] Accuracy : 0.55
## [KNN (k = 130 )] Accuracy : 0.57
## [KNN (k = 230 )] Accuracy : 0.57
## [KNN (k = 330 )] Accuracy : 0.59

## 
## Predictors: All

## [KNN (k = 30 )] Accuracy : 0.89
## [KNN (k = 130 )] Accuracy : 0.86
## [KNN (k = 230 )] Accuracy : 0.79
## [KNN (k = 330 )] Accuracy : 0.75

```

Considering only **Accuracy**, we can conclude that the following models perform the best:

K= 30, Predictors: All Predictors

```

## Confusion Matrix for K= 130, Predictors: All

##           Reference
## Prediction Down Up
##       Down    35   5
##       Up      8  56

```

Experimenting with different Logistic Regression Models:

```

## Logistic Regression

## 
## [Predictors: Lag2 ] Accuracy : 0.62
## [Predictors: Lag2+Lag1 ] Accuracy : 0.58
## [Predictors: Lag2*Lag1 ] Accuracy : 0.58
## [Predictors: I(Lag2^2) ] Accuracy : 0.59
## [Predictors: All] Accuracy : 1

```

Considering Accuracy, It seems Using **All the Parameters** gives by far the most accurate model with a **100% Accuracy**.

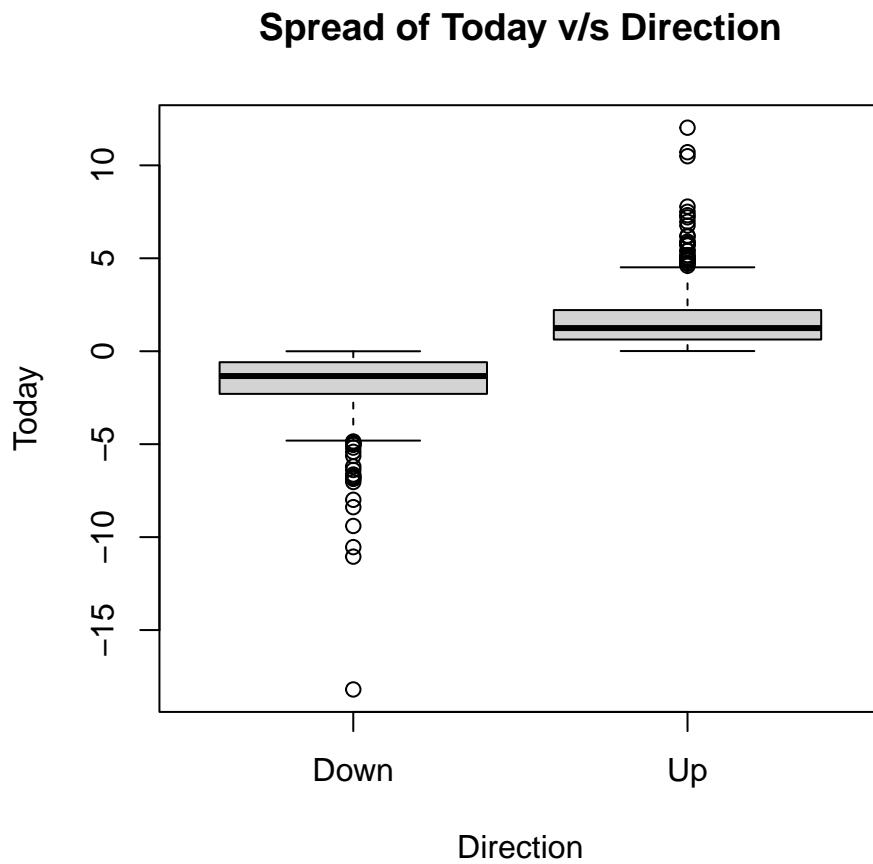
```
## Confusion Matrix for Linear Regression Model with All Predictors:
```

```

##             Reference
## Prediction Down Up
##       Down    43  0
##       Up      0 61

```

*NOTE: This is not surprising because one of the predictors the model trains upon is **Today**. This predictor seems to have a distinct linear boundary when plotted against **Direction***



EXERCISE 6.9:

6.9.a

Creating a **80-20** split between *Train* and *Test* set

```

## Length of College Dataset: 777
## Length of Train Dataset  : 622
## Length of Test Dataset   : 155

```

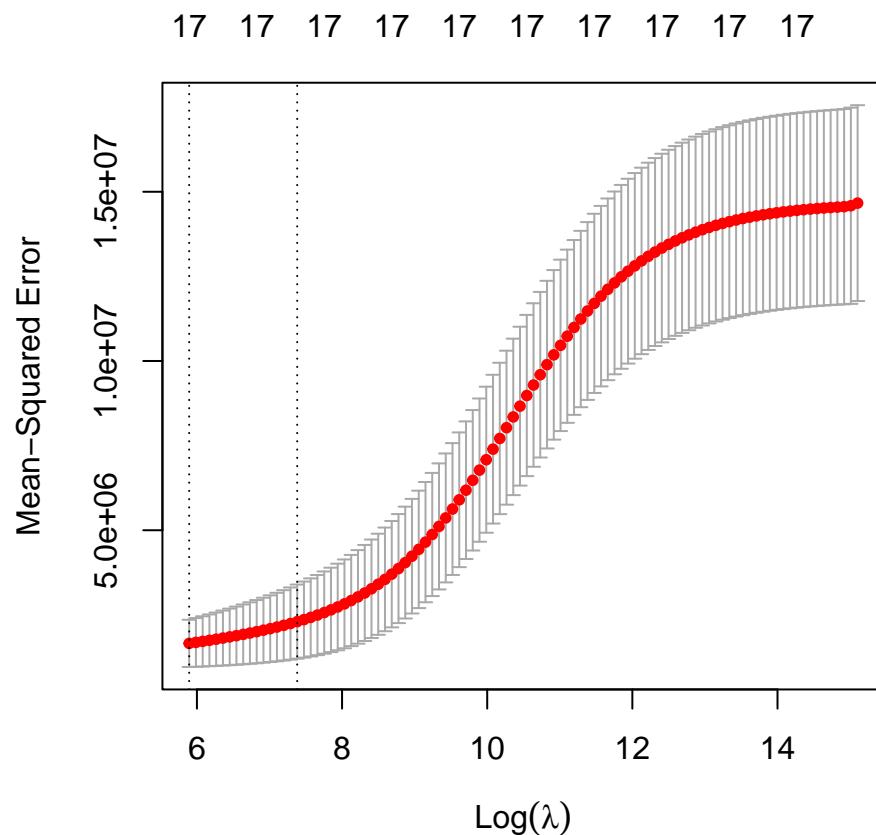
6.9.b

The test error on applying Linear Regression on a Model with All Parameters is:

```
## 1578073.167
```

6.9.c

```
## Optimal Lambda, by 10-fold cross-validation is: 362.660783476255
```

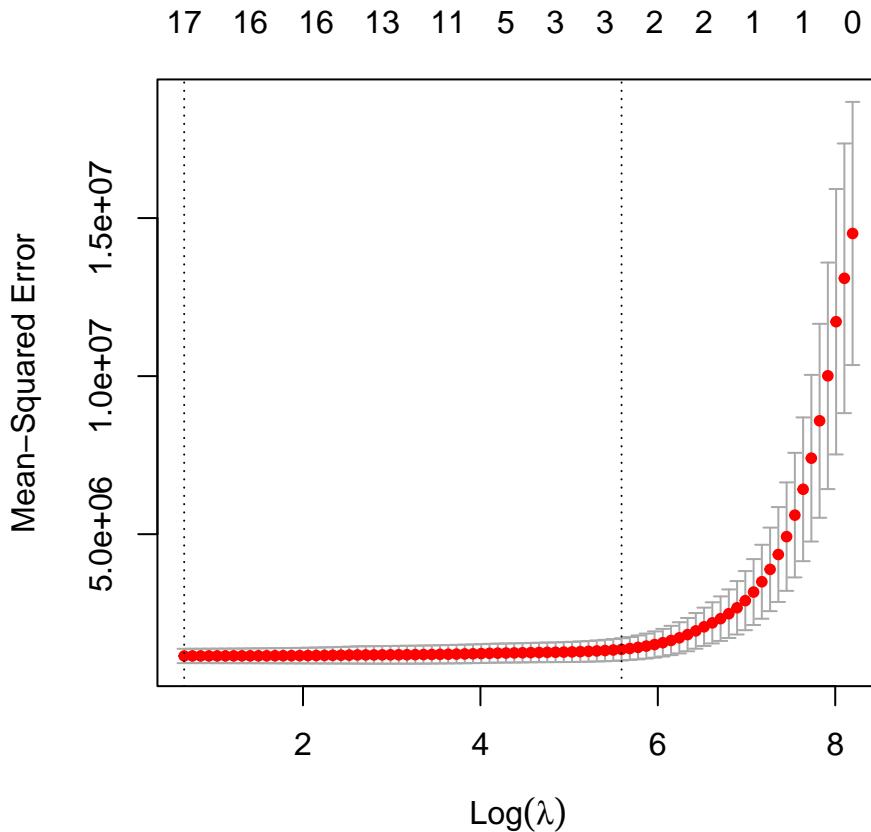


The test error on applying **Ridge-Regression** on a Model with All Parameters is:

```
## 1447148.005
```

6.9.d

```
## Optimal Lambda, by 10-fold cross-validation is: 1.93541152134794
```



The test error on applying **Lasso-Regression** on a Model with All Parameters is:

```
## 1565219.591
```

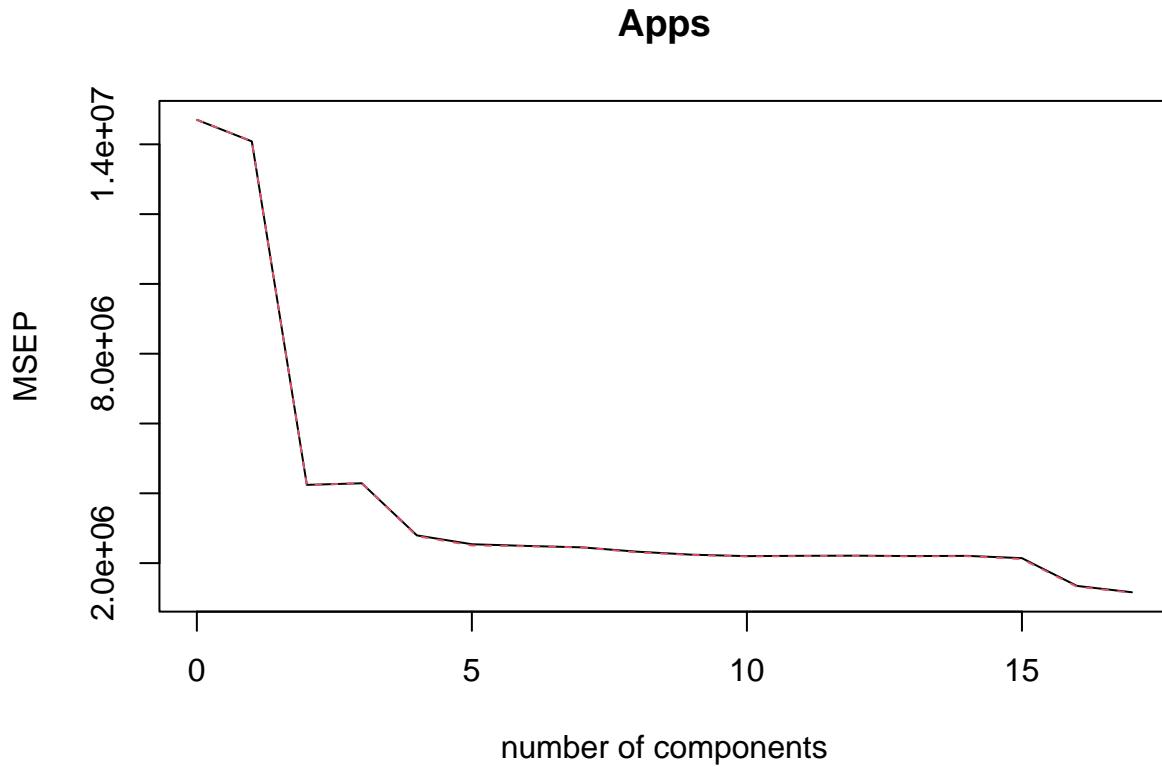
Coefficients of Predictors using the Lasso-Regression method are:

```
##   PrivateYes      Accept      Enroll    Top10perc    Top25perc F.Undergrad
## -381.594455  4108.880244 -1025.359690  864.928922 -247.672551  333.295597
##   P.Undergrad    Outstate   Room.Board     Books    Personal       PhD
##    98.397947 -293.010691   153.190780   32.808299   10.803342 -157.271619
##   Terminal     S.F.Ratio perc.alumni    Expend  Grad.Rate
##    -3.363536    68.276135     7.318633   297.806071    96.507224
```

Thus, Non-Zero Coefficient Estimate Predictors are:

```
## [1] "PrivateYes"  "Accept"       "Enroll"       "Top10perc"    "Top25perc"
## [6] "F.Undergrad" "P.Undergrad"  "Outstate"     "Room.Board"   "Books"
## [11] "Personal"    "PhD"         "Terminal"    "S.F.Ratio"   "perc.alumni"
## [16] "Expend"      "Grad.Rate"
```

6.9.e



```

## Data:      X dimension: 622 17
## Y dimension: 622 1
## Fit method: svdpc
## Number of components considered: 17
##
## VALIDATION: RMSEP
## Cross-validated using 10 random segments.
##          (Intercept) 1 comps 2 comps 3 comps 4 comps 5 comps 6 comps
## CV          3834    3753   2060   2071   1672   1594   1579
## adjCV       3834    3754   2057   2072   1665   1583   1576
##          7 comps 8 comps 9 comps 10 comps 11 comps 12 comps 13 comps
## CV          1566    1526   1497   1483   1486   1488   1484
## adjCV       1565    1519   1494   1481   1484   1485   1481
##          14 comps 15 comps 16 comps 17 comps
## CV          1486    1464   1160   1079
## adjCV       1483    1454   1150   1073
##
## TRAINING: % variance explained
##          1 comps 2 comps 3 comps 4 comps 5 comps 6 comps 7 comps 8 comps
## X          32.019  57.05   64.13   70.01   75.36   80.38   84.09   87.44
## Apps       4.315   72.01   72.02   81.89   83.65   83.73   83.98   85.12
##          9 comps 10 comps 11 comps 12 comps 13 comps 14 comps 15 comps
## X          90.48   92.84   94.92   96.78   97.86   98.72   99.36
## Apps       85.40   85.75   85.75   85.76   85.88   85.94   89.94

```

```

##      16 comps 17 comps
## X       99.83   100.00
## Apps    92.88   93.47

```

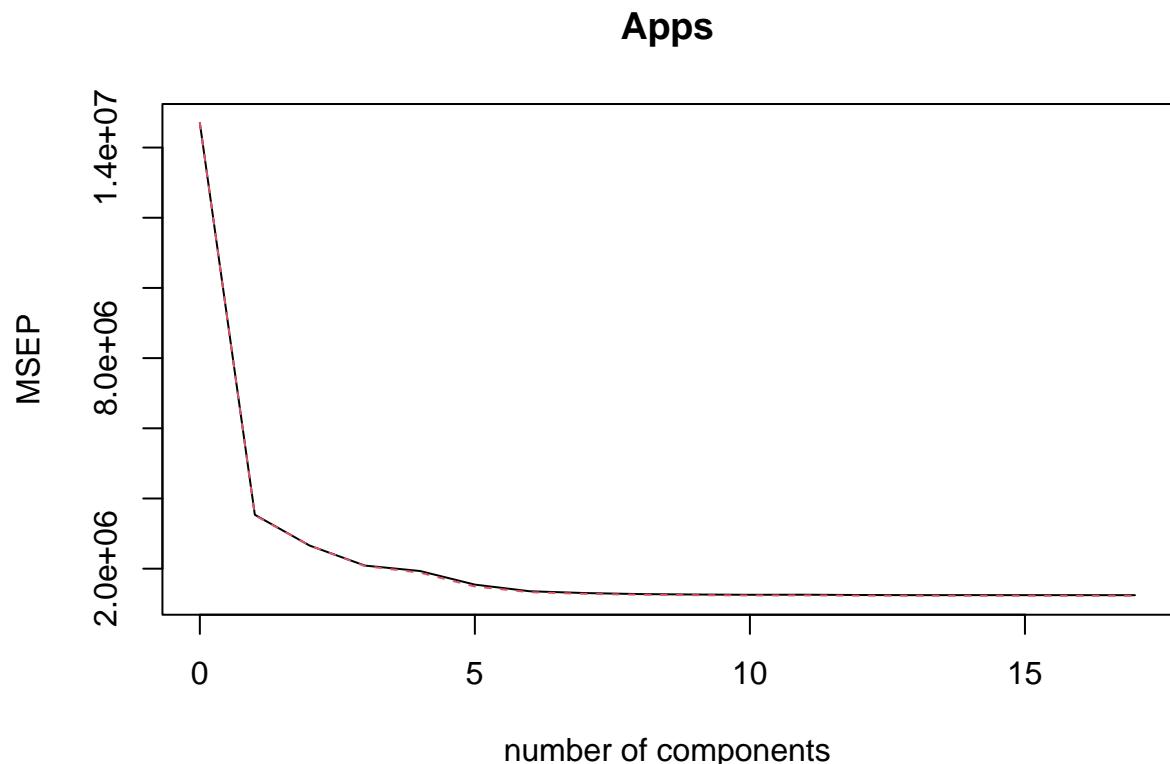
Minimum CV at

Minimum CV at **M = 17**. Thus, using *predict(...,ncomp=17,...)*

The test error on applying **Principal Component Regression** on a Model with All Parameters is:

```
## 1578073.167
```

6.9.f



```

## Data:      X dimension: 622 17
## Y dimension: 622 1
## Fit method: kernelpls
## Number of components considered: 17
##
## VALIDATION: RMSEP
## Cross-validated using 10 random segments.
##          (Intercept) 1 comps 2 comps 3 comps 4 comps 5 comps 6 comps
## CV          3834     1880     1630     1445     1391     1243     1165
## adjCV      3834     1876     1630     1440     1374     1221     1153

```

```

##      7 comps  8 comps  9 comps 10 comps 11 comps 12 comps 13 comps
## CV      1143     1130     1124     1121     1122     1118     1116
## adjCV   1133     1121     1116     1112     1113     1109     1108
##      14 comps 15 comps 16 comps 17 comps
## CV      1116     1116     1116     1116
## adjCV   1108     1108     1108     1108
##
## TRAINING: % variance explained
##      1 comps  2 comps  3 comps  4 comps  5 comps  6 comps  7 comps  8 comps
## X      25.52    45.30    62.57    65.06    67.50    72.05    76.04    80.49
## Apps   77.30    83.58    87.50    90.88    92.89    93.15    93.24    93.31
##      9 comps 10 comps 11 comps 12 comps 13 comps 14 comps 15 comps
## X      82.50    85.41    87.76    91.08    92.72    95.12    96.97
## Apps   93.39    93.42    93.45    93.46    93.46    93.47    93.47
##      16 comps 17 comps
## X      97.98    100.00
## Apps   93.47    93.47

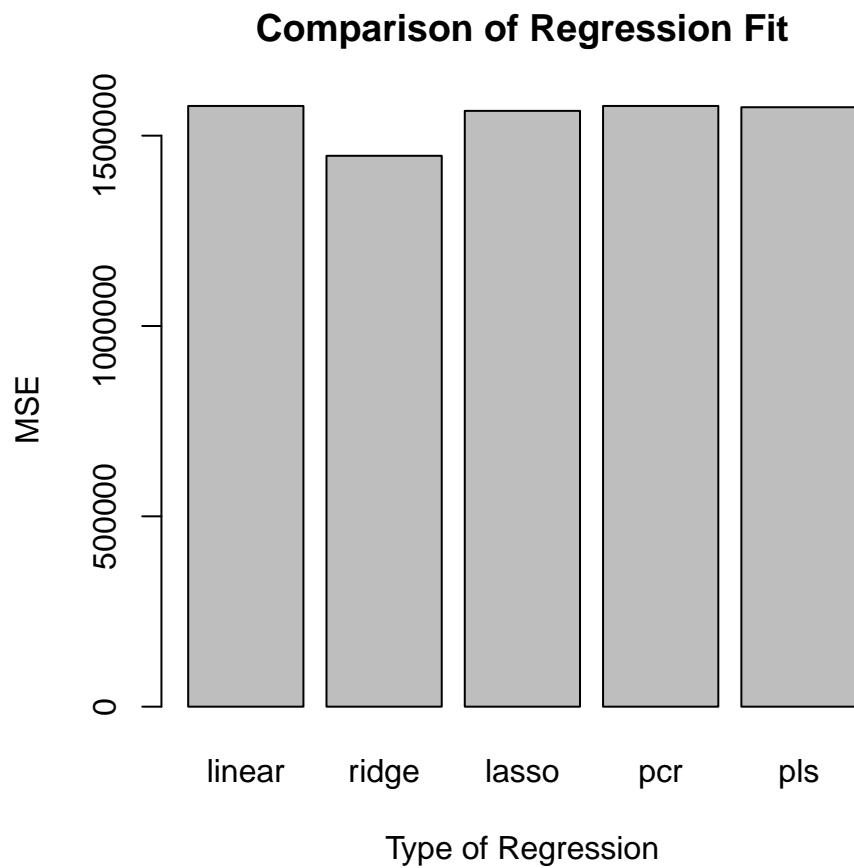
```

Minimum CV at **M = 13**. Thus, using *predict(...,ncomp=13,...)*

The test error on applying **Partial Least Squares Regression** on a Model with All Parameters is:

```
## 1574745.803
```

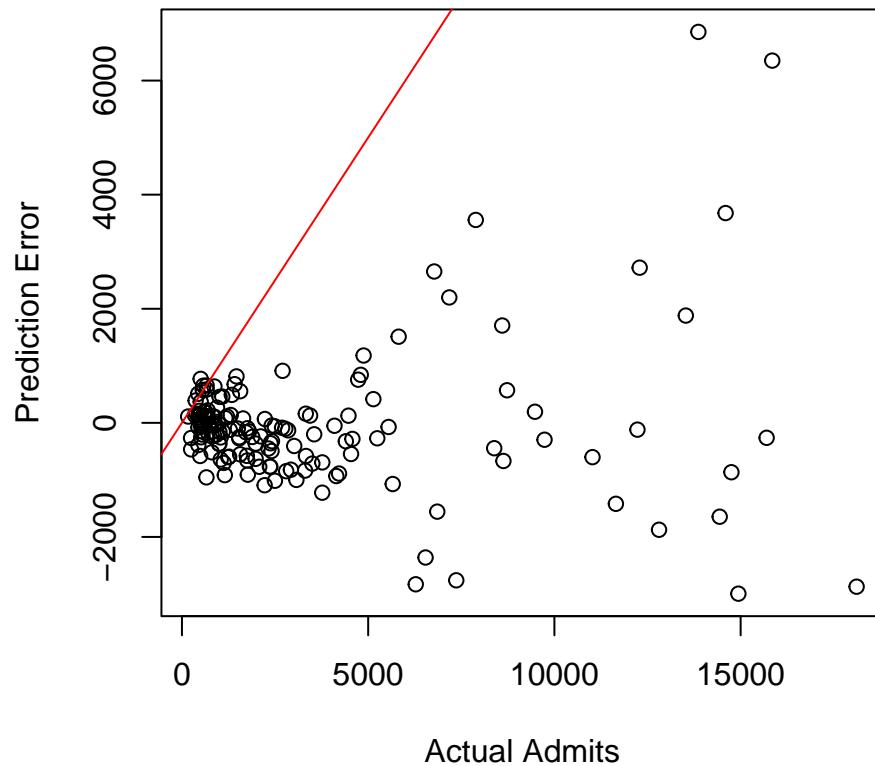
6.9.g



Most of the regression methods ("Linear", "Ridge", "Lasso", "PCR", "PLS") have approximately the same amount of error.

The **Ridge Regression** outperforms others by a slight margin. Its **Test MSE** is: 1447148.005 (*standard deviation = 5319499*)

Residuals in Ridge Regression



EXERCISE 6.11:

6.11.a

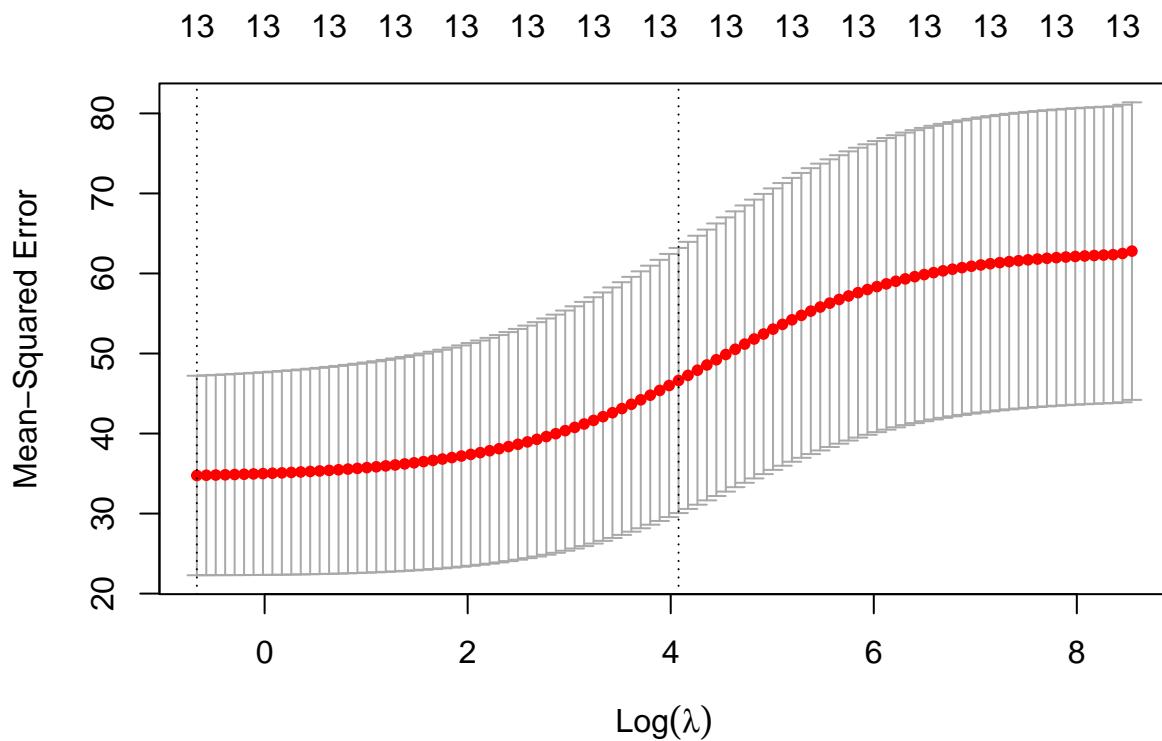
Creating a **80-20** split between *Train* and *Test* set

```
## Length of Boston Dataset: 506
```

```
## Length of Train Dataset : 405
```

```
## Length of Test Dataset : 101
```

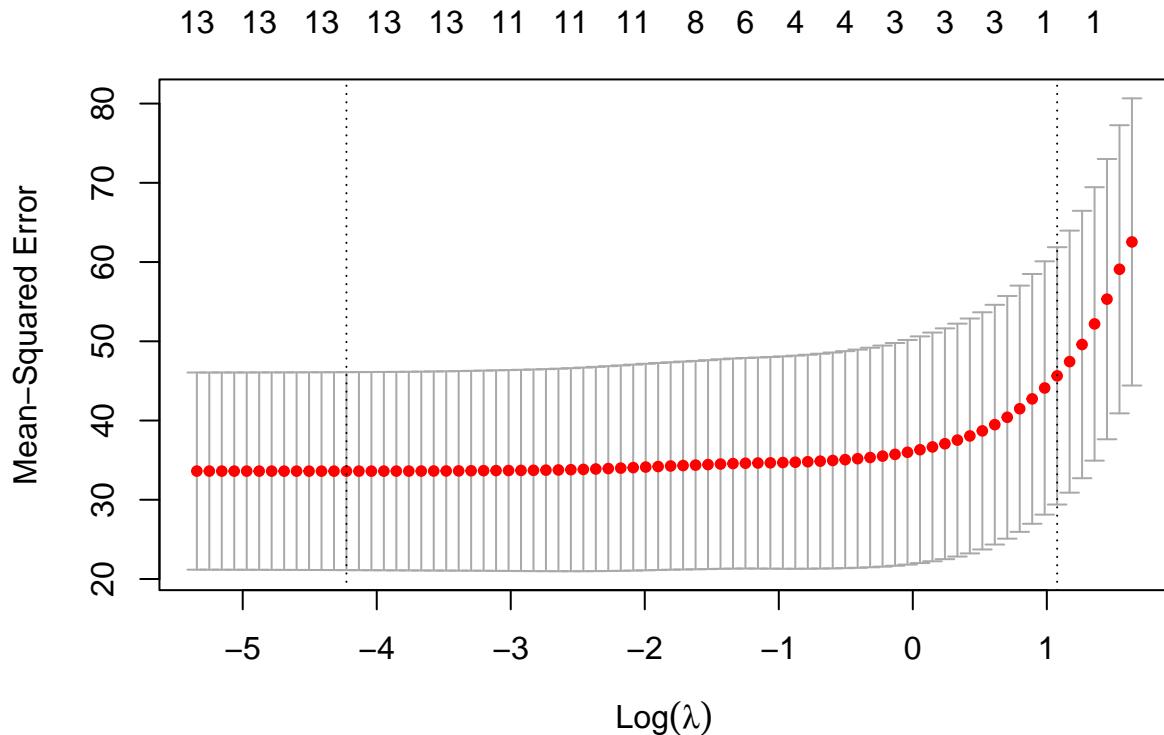
Ridge Regression



```
## Optimal Lambda, by 10-fold cross-validation is: 0.51
```

```
##  
## Test Error of Ridge Regression: 79.45
```

Lasso Regression



```
## Optimal Lambda, by 10-fold cross-validation is: 0.01
```

```
##
## Test Error of Lasso Regression: 78.45
```

Subset Selection (*Forward Selection*)

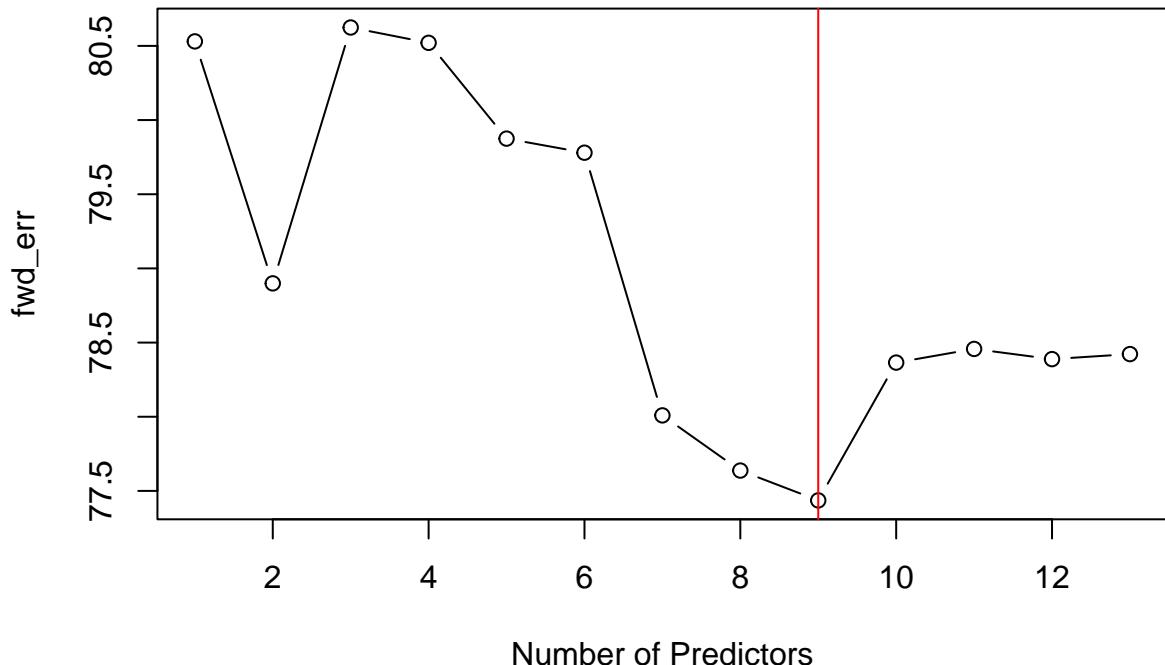
```
## Subset selection object
## Call: regsubsets.formula(crim ~ ., data = train, nvmax = ncol(Boston) -
##     1)
## 13 Variables  (and intercept)
##      Forced in Forced out
## zn          FALSE    FALSE
## indus       FALSE    FALSE
## chas        FALSE    FALSE
## nox         FALSE    FALSE
## rm          FALSE    FALSE
## age         FALSE    FALSE
## dis         FALSE    FALSE
## rad         FALSE    FALSE
## tax         FALSE    FALSE
## ptratio     FALSE    FALSE
## black       FALSE    FALSE
## lstat       FALSE    FALSE
## medv       FALSE    FALSE
```

```

## 1 subsets of each size up to 13
## Selection Algorithm: exhaustive
##          zn  indus chas nox rm  age dis rad tax ptratio black lstat medv
## 1  ( 1 ) " " " " " " " " " " " " " " " " " " " " " " " " " "
## 2  ( 1 ) " " " " " " " " " " " " " " " " " " " " " " " " " "
## 3  ( 1 ) " " " " " " " " " " " " " " " " " " " " " " " " " "
## 4  ( 1 ) "*" " " " " " " " " " " " " " " " " " " " " " " " " "
## 5  ( 1 ) "*" " " " " " " " " " " " " " " " " " " " " " " " " "
## 6  ( 1 ) "*" " " " " " " " " " " " " " " " " " " " " " " " " "
## 7  ( 1 ) "*" " " " " " " " " " " " " " " " " " " " " " " " " "
## 8  ( 1 ) "*" "*" " " " " " " " " " " " " " " " " " " " " " " "
## 9  ( 1 ) "*" " " " " " " " " " " " " " " " " " " " " " " " " "
## 10 ( 1 ) "*" "*" " " " " " " " " " " " " " " " " " " " " " " "
## 11 ( 1 ) "*" "*" " " " " " " " " " " " " " " " " " " " " " " "
## 12 ( 1 ) "*" "*" " " " " " " " " " " " " " " " " " " " " " " "
## 13 ( 1 ) "*" "*" " " " " " " " " " " " " " " " " " " " " " " "

```

Test MSE for Forward Selection

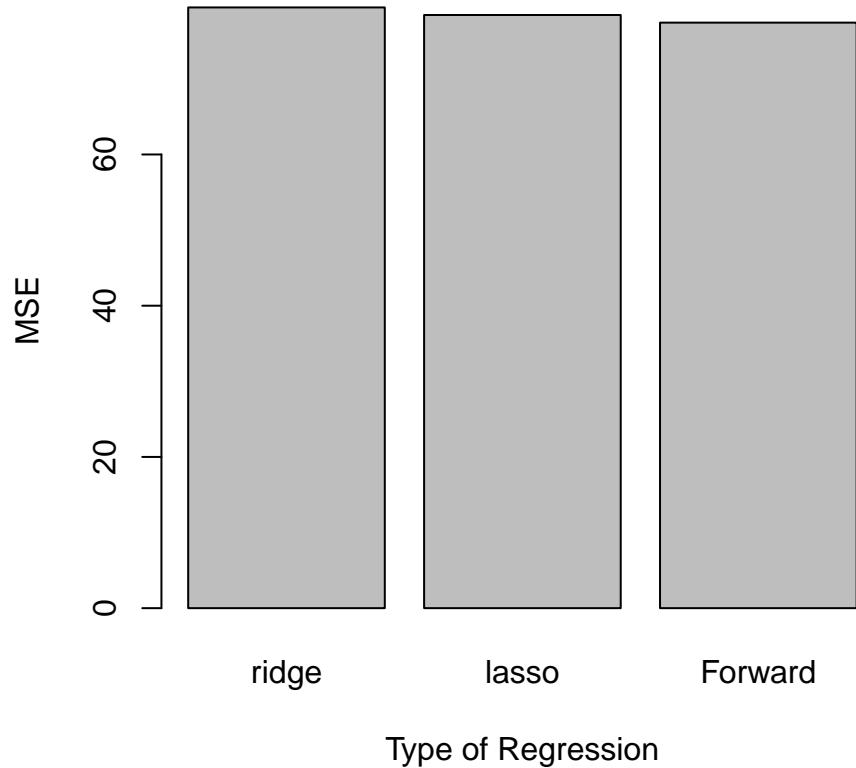


```

##
## Min. Test Error for Forward Selection is: 77.44

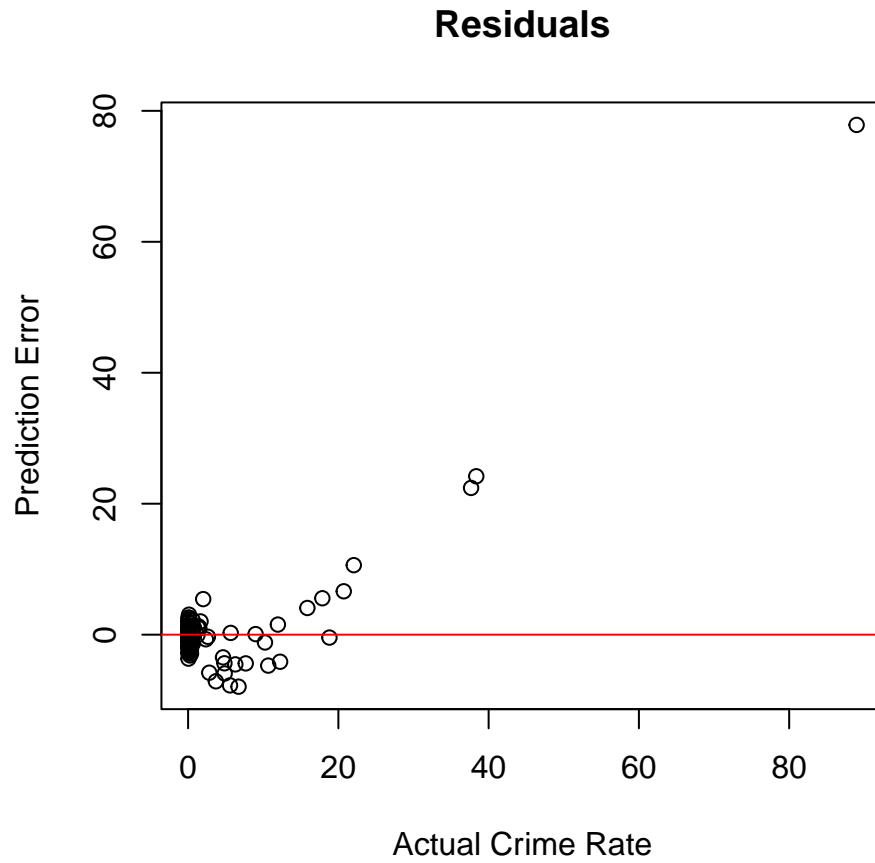
```

Comparison of Regression Fit



The regression methods (“Ridge”, “Lasso”, “Forward Selection”) have approximately the same amount of error.

The **Subset Selection(Forward Selection) Regression** outperforms others by a slight margin. Its **Test MSE** is: 69.55



6.11.b

From the above Test Set Errors, we can reasonably conclude that the 11-parameter Forward selection model is the best fit to the Boston Dataset

6.11.c

No because not all the predictors add much value to the model. Adding more predictors makes the model more complex and computationally expensive. Thus, If a predictor does not increase the amount of variance explained by the model significantly, we can drop it. In our case, We choose the Forward Selection model, which uses just 11 Predictors.

EXERCISE 8.8:

8.8.a

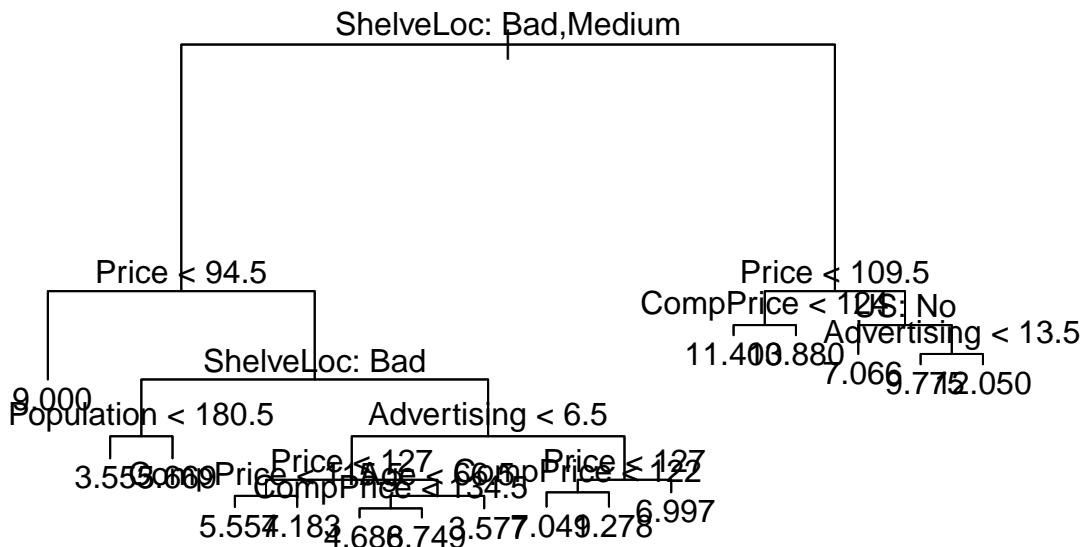
```
## Length of Carseats Dataset: 400
```

```
## Length of Train Dataset : 280
```

```
## Length of Test Dataset : 120
```

8.8.b

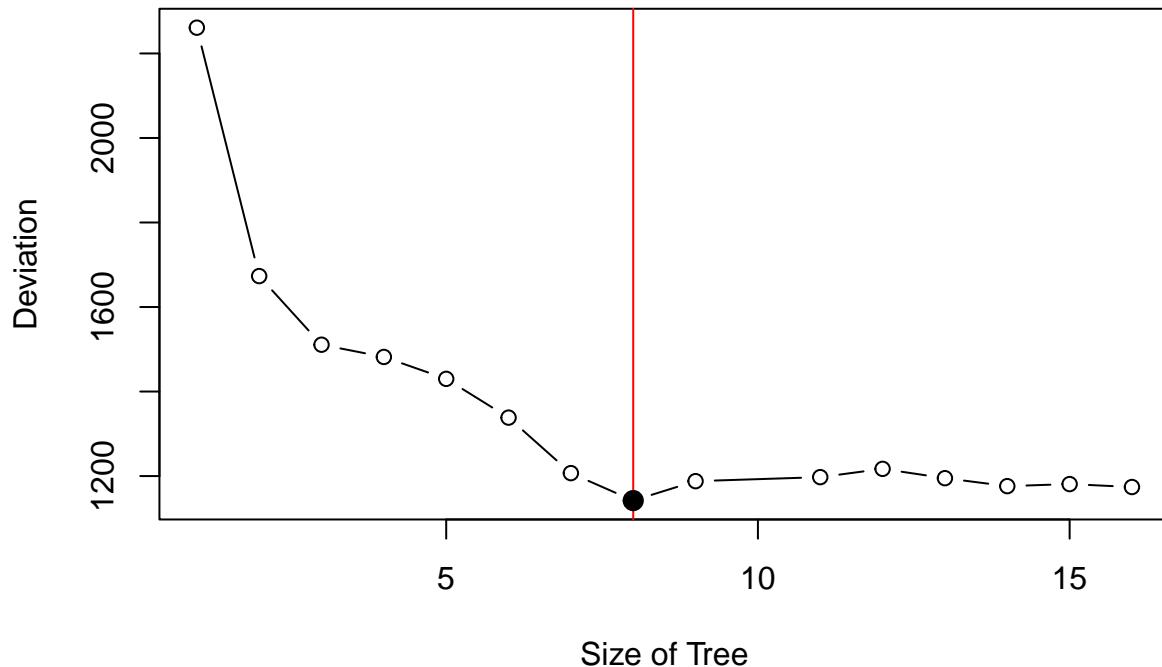
```
##  
## Regression tree:  
## tree(formula = Sales ~ ., data = carseats_train)  
## Variables actually used in tree construction:  
## [1] "ShelveLoc"    "Price"        "Population"   "Advertising" "CompPrice"  
## [6] "Age"          "US"  
## Number of terminal nodes: 16  
## Residual mean deviance: 2.575 = 679.8 / 264  
## Distribution of residuals:  
##      Min. 1st Qu. Median Mean 3rd Qu. Max.  
## -3.5770 -1.0600 -0.2128 0.0000  1.0250  5.1330
```



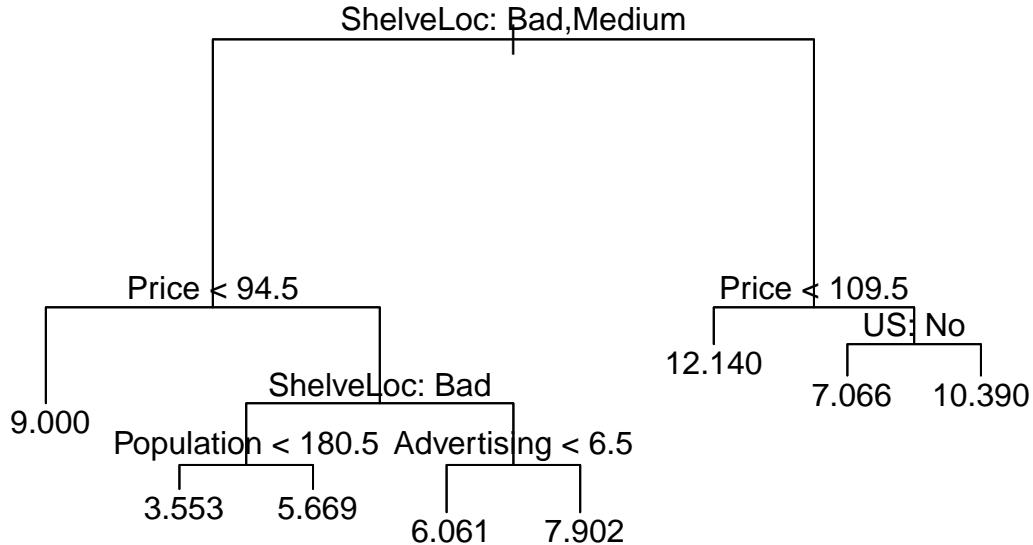
```
## Test MSE for tree is: 4.27687725775323
```

8.8.c

Selecting Tree Size by Cross-Validation



Therefore, Cross-Validation suggests minimum Deviation at tree size of 8. Thus, Pruning the tree to size of 8



```
## Test MSE for Pruned tree is: 5.08898603003723
```

We observe that Test MSE has **increased** to 5.09 after pruning.

8.8.d

For Bagging, Implementing Random Forest with each tree considering all parameters ($mtry = ncol(Carseats) - 1$)

NOTE: Subtracting 1 from $ncol(Carseats)$ because one of the columns in the DataSet is the target column itself

```
## Test MSE for Bagged Model is: 2.44628424130643
```

	%IncMSE	IncNodePurity
## ShelveLoc	78.6084580	748.557677
## Price	62.4450684	591.976064
## CompPrice	32.5703925	217.430548
## Advertising	28.2289858	210.788050
## Age	16.6401794	166.092738
## Income	5.2444968	95.395989
## Population	-0.1787145	82.961943
## Education	3.3273281	63.948412
## US	6.7573125	15.904009
## Urban	-2.5443548	8.609084

From the above table, we see that **ShelveLoc** and **Price** are the most important predictors for *Sales*.

8.8.e

For Random Forest, each tree will consider a subset of parameters

$$m = \sqrt{(p)}$$

Thus: (*mtry = floor(sqrt(ncol(Carseats) -1))*)

NOTE: Subtracting 1 from *ncol(Carseats)* because one of the columns in the DataSet is the target column itself

```
## Test MSE for Random Forest Model is: 2.90107946940021
```

We observe that reducing *m* from 10 (*Bagging*) to 3 (*Random Forest*) increases the Test MSE a little bit.

This increase in MSE can be explained by the fact that in Random Forest, unlike Bagging (wherein each tree is exposed to all the predictors), each tree is exposed to a subset of the predictors.

```
## %IncMSE IncNodePurity
## ShelveLoc 48.4045567 549.59174
## Price     40.2843961 508.51985
## Age       16.7054144 232.84697
## Advertising 19.8861191 211.35524
## CompPrice 12.4875929 185.69329
## Income    1.4748646 152.24336
## Population 0.1294146 150.96879
## Education 1.8102926 99.19403
## US        4.4167507 27.62612
## Urban     -1.7114750 17.57537
```

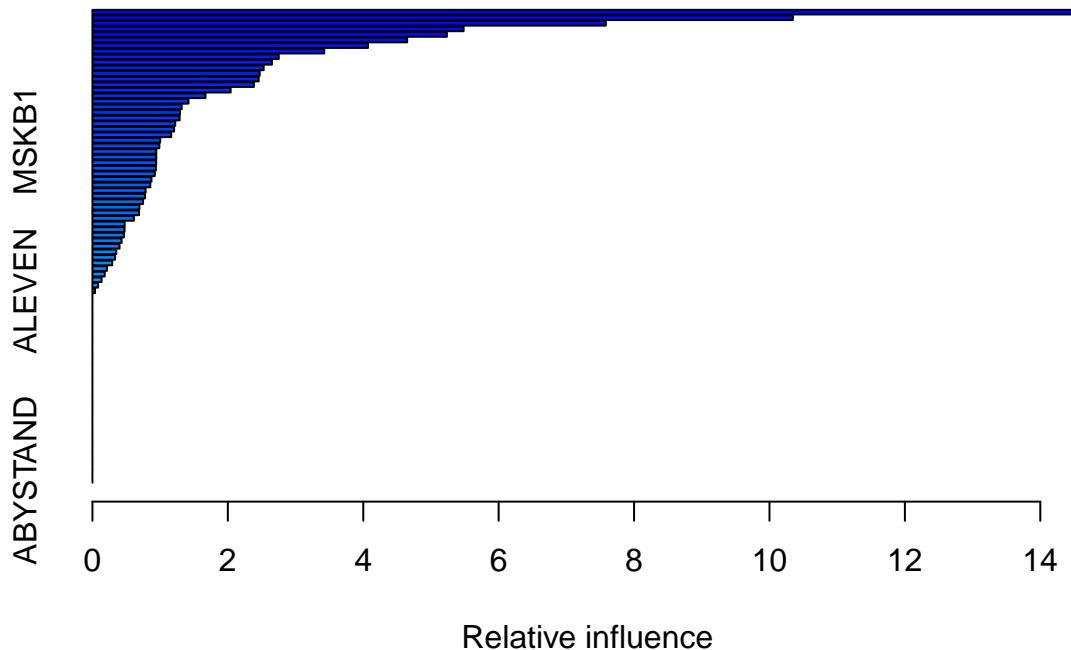
From the above table, we see that **ShelveLoc** and **Price** are still the most important predictors for *Sales*.

EXERCISE 8.11:

8.11.a

```
## Length of Caravan Dataset: 5822
## Length of Train Dataset : 1000
## Length of Test Dataset : 4822
```

8.11.b



```
##           var      rel.inf
## PPERSAUT  PPERSAUT 14.76897821
## MKOOPKLA  MKOOPKLA 10.34608977
## MOPLHOOG MOPLHOOG 7.58276819
## MBERMIDD MBERMIDD 5.48219989
## PBRAND    PBRAND   5.23496596
## ABRAND    ABRAND   4.64846137
## MGODGE    MGODGE   4.07035536
## MINK3045 MINK3045 3.42388385
## MAUT1     MAUT1    2.75186778
## MGODPR    MGODPR   2.65078748
## MOSTYPE   MOSTYPE  2.52899159
## MAUT2     MAUT2    2.47005442
## PWAPART   PWAPART  2.45561187
## MINKGEM   MINKGEM  2.38496124
## MBERARBG MBERARBG 2.04151595
## MSKC      MSKC    1.66946684
## MINK7512 MINK7512 1.41843892
## MRELGE    MRELGE   1.31818732
## MSKA      MSKA    1.29174003
## PBYSTAND  PBYSTAND 1.28796768
## MFWEKIND  MFWEKIND 1.22285160
## MBERHOOG  MBERHOOG 1.20643199
## MGODOV    MGODOV   1.16347453
```

```

## MSKB1      MSKB1  1.00060171
## MHHUUR     MHHUUR  0.98767774
## MBERBOER   MBERBOER 0.94327732
## MFGEKIND   MFGEKIND 0.94278746
## MAUTO      MAUTO  0.94186003
## MGODRK     MGODRK  0.93716929
## MINK4575   MINK4575 0.92108809
## MRELOV     MRELOV  0.87214668
## MSKB2      MSKB2  0.85468878
## MOPLMIDD   MOPLMIDD 0.78499519
## MOSHOOFD   MOSHOOFD 0.77643271
## APERSAUT   APERSAUT 0.74746748
## MSKD       MSKD   0.69351351
## MINKM30    MINKM30  0.68778644
## PLEVEN     PLEVEN  0.61251083
## MBERARBO   MBERARBO 0.47629718
## PMOTSCO    PMOTSCO  0.47452037
## MZPART     MZPART  0.46517256
## MGEMLEEF   MGEMLEEF 0.43011772
## MGEMOMV    MGEMOMV  0.40006320
## MZFONDS   MZFONDS  0.35216196
## MHKOOP     MHKOOP  0.33449542
## MINK123M   MINK123M 0.29175841
## MFALLEEN   MFALLEEN 0.21368001
## MRELSA     MRELSA  0.18161892
## MBERZELF   MBERZELF 0.13498287
## MOPLLAAG   MOPLLAAG 0.08308058
## ALEVEN     ALEVEN  0.03799572
## MAANTHUI   MAANTHUI 0.00000000
## PWABEDR   PWABEDR  0.00000000
## PWALAND   PWALAND  0.00000000
## PBESAUT   PBESAUT  0.00000000
## PVRAAUT   PVRAAUT  0.00000000
## PAANHANG  PAANHANG 0.00000000
## PTRACTOR  PTRACTOR 0.00000000
## PWERKT    PWERKT  0.00000000
## PBROM      PBROM   0.00000000
## PPERSONG  PPERSONG 0.00000000
## PGEZONG   PGEZONG  0.00000000
## PWAOREG   PWAOREG  0.00000000
## PZEILPL   PZEILPL  0.00000000
## PPLEZIER  PPLEZIER 0.00000000
## PFIETS    PFIETS  0.00000000
## PINBOED   PINBOED  0.00000000
## AWAPART   AWAPART  0.00000000
## AWABEDR   AWABEDR  0.00000000
## AWALAND   AWALAND  0.00000000
## ABESAUT   ABESAUT  0.00000000
## AMOTSCO   AMOTSCO  0.00000000
## AVRAAUT   AVRAAUT  0.00000000
## AAANHANG  AAANHANG 0.00000000
## ATRACTOR  ATRACTOR 0.00000000
## AWERKT    AWERKT  0.00000000
## ABROM     ABROM   0.00000000

```

```

## APERSONG APERSONG 0.00000000
## AGEZONG    AGEZONG 0.00000000
## AWAOREG    AWAOREG 0.00000000
## AZEILPL    AZEILPL 0.00000000
## APLEZIER   APLEZIER 0.00000000
## AFIETS     AFIETS  0.00000000
## AINBOED    AINBOED 0.00000000
## ABYSTAND   ABYSTAND 0.00000000

```

From the Table and Graph, we can conclude that the top **Most-Important Predictors** are:

- PPERSAUT
- MKOOPKLA
- MOPLHOOG

8.11.c

Boosting

```

##           Reference
## Prediction 0      1
##            0 4412  255
##            1  121   34

## [Boosting] Fraction of the people predicted to make a purchase who in fact make one: 0.22

```

This value is also called the *Precision*

Logistic Regression

```

##           Reference
## Prediction 0      1
##            0 4183  231
##            1  350   58

## [Logistic Regression]Fraction of the people predicted to make a purchase who in fact make one: 0.14

```

KNN

```

##           2 102 202 302 402
## out_precision_knn 0.08362369 NA  NA  NA  NA

```

Simply applying KNN does not work because the training data is highly skewed. The following is the Summary of **Purchase** in Training Set:

```

## 0 1
## 941 59

```

Thus, the model ends up predicting everything as class-0 or *Not Purchased*. While this achieves a High accuracy, the precision is low.

In order to improve the model, we probably need to *undersample* the majority class in our training data.

Summary: *Boosting* outperforms *Logistic Regression*.

Problem-1 Beauty Pays:

Upon reading the “*BeautyData.csv*” file, we find that the following categorical columns are read as integers:

- female
- lower
- nonenglish
- tenuretrack

Thus converting the same into **factors**.

Summary:

```
##   CourseEvals      BeautyScore      female  lower  nonenglish tenuretrack
##   Min.    :1.944    Min.   :-1.53884   0:268   0:306   0:435     0:102
##   1st Qu.:3.326   1st Qu.:-0.74462   1:195   1:157   1: 28      1:361
##   Median  :3.682   Median  :-0.15636
##   Mean    :3.689   Mean   :-0.08835
##   3rd Qu.:4.067   3rd Qu.: 0.45725
##   Max.    :5.000   Max.   : 1.88167
```

1.1

In order to estimate the effect of “*Beauty*” on a professor’s “*CourseEvaluation*”, taking into account the other determinants, we will fit a Multiple regression model > Model Summary

```
##
## Call:
## lm(formula = CourseEvals ~ ., data = Beauty)
##
## Residuals:
##       Min      1Q      Median      3Q      Max
## -1.31385 -0.30202  0.01011  0.29815  1.04929
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 4.06542   0.05145  79.020 < 2e-16 ***
## BeautyScore 0.30415   0.02543  11.959 < 2e-16 ***
## female1    -0.33199   0.04075  -8.146 3.62e-15 ***
## lower1     -0.34255   0.04282  -7.999 1.04e-14 ***
## nonenglish1 -0.25808   0.08478  -3.044  0.00247 **
## tenuretrack1 -0.09945   0.04888  -2.035  0.04245 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4273 on 457 degrees of freedom
## Multiple R-squared:  0.3471, Adjusted R-squared:  0.3399
## F-statistic: 48.58 on 5 and 457 DF,  p-value: < 2.2e-16
```

From the above model summary, we see that a person’s beauty actually has a statistically significant impact on their course evaluation.

Holding other determinants constant, the ***CourseEval*** is directly proportional to ***BeautyScore*** by a factor of **0.30415**

1.2

Problem-2 Housing Price Structure:

Upon reading the “*MidCity.csv*” file, we find the following:

- **Home:** This is the ID and is same as the row number and hence, can be dropped.
- **Bricks:** This is a categorical Variable and thus need to convert it
- **Nbhd:** This is the Neighbourhood. This is a Categorical Value too and needs to be converted into factors
- **Sqft:** This is the Square Feet area of the House. While the other predictors are in a range of 0-6, Sqft. is way outside. Thus scaling this parameter down will allow for a better regression fit.

Summary:

```
## Nbhd      Offers          SqFt.V1      Brick      Bedrooms
## 1:44    Min. :1.000    Min. :-2.6040137  No :86    Min. :2.000
## 2:45    1st Qu.:2.000   1st Qu.:-0.5716128 Yes:42   1st Qu.:3.000
## 3:39    Median :3.000   Median :-0.0044311           Median :3.000
##          Mean   :2.578   Mean   : 0.0000000           Mean   :3.023
##          3rd Qu.:3.000   3rd Qu.: 0.6572808           3rd Qu.:3.000
##          Max.  :6.000   Max.  : 2.7842120           Max.  :5.000
##      Bathrooms      Price
##      Min.  :2.000   Min.  : 69100
##      1st Qu.:2.000  1st Qu.:111325
##      Median :2.000  Median :125950
##      Mean   :2.445  Mean   :130427
##      3rd Qu.:3.000  3rd Qu.:148250
##      Max.   :4.000  Max.   :211200
```

Each of the Predictors (*Nbhd,Offers,Brick,Bedrooms,Bathrooms*) have similar range, therefore no scaling required.

2.1

To understand the impact of the being a Brick house on Price, all other factors considered, we will fit a Multiple regression model

Model Summary:

```
##
## Call:
## lm(formula = Price ~ ., data = MidCity)
##
## Residuals:
##      Min       1Q     Median      3Q      Max
## -27337.3 -6549.5   -41.7  5803.4 27359.3
##
```

```

## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 108197     6689   16.175 < 2e-16 ***
## Nbhd2       -1561     2397  -0.651  0.51621
## Nbhd3       20681     3149   6.568 1.38e-09 ***
## Offers      -8268     1085  -7.621 6.47e-12 ***
## SqFt        11212     1213   9.242 1.10e-15 ***
## BrickYes    17297     1982   8.729 1.78e-14 ***
## Bedrooms    4247      1598   2.658  0.00894 **
## Bathrooms   7883      2117   3.724  0.00030 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10020 on 120 degrees of freedom
## Multiple R-squared:  0.8686, Adjusted R-squared:  0.861
## F-statistic: 113.3 on 7 and 120 DF, p-value: < 2.2e-16

```

From the above model summary, we see that the parameter: **BrickYes** is statistically significant (*assuming a 95% confidence interval for the hypothesis $\beta_{BrickYes} = 0$*) and has a positive impact on the Price. Thus, holding other factors constant, being a Brick House increases the Price of a house by \$17,297.

In other words, **Premium for a Brick House is estimated to be \$17,297.**

2.2

Yes, There is a premium for a House in Neighbourhood 3

All other factors held constant, a house in Neighbourhood 3 fetches:

- \$20,681 more than the same house in Neighbourhood 1
- \$22,242 more than the same house in Neighbourhood 2

2.3

In order to account for plausible interactions between predictors, a new feature: **Brick_Nbhd3** has to be added. which will be 1 iff the house is a brick house in Neighbourhood 3

```

##
## Call:
## lm(formula = Price ~ ., data = MidCity)
##
## Residuals:
##      Min       1Q       Median      3Q      Max
## -26939.1  -5428.7   -213.9   4519.3  26211.4
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 111190     6668   16.675 < 2e-16 ***
## Nbhd2       -673      2376  -0.283  0.77751
## Nbhd3       17241     3391   5.084 1.39e-06 ***
## Offers      -8401     1064  -7.893 1.62e-12 ***
## SqFt        11439     1192   9.593 < 2e-16 ***
## BrickYes    13826     2406   5.748 7.11e-08 ***

```

```

## Bedrooms      4718      1578    2.991  0.00338 **
## Bathrooms     6463      2154    3.000  0.00329 **
## Brick_Nbhd3Yes 10182      4165    2.444  0.01598 *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9817 on 119 degrees of freedom
## Multiple R-squared:  0.8749, Adjusted R-squared:  0.8665
## F-statistic:   104 on 8 and 119 DF,  p-value: < 2.2e-16

```

From the above model summary, we see that the parameter: **Brick_Nbhd3No** is statistically significant and has a negative impact on the Price. Thus, holding other factors constant, being a Brick House in Neighbourhood 3 increases the Price of a house by \$10,182.

In other words, **Extra Premium for a Brick House in Neighbourhood 3 is estimated to be \$10,182.**

NOTE: *This interaction is only statistically significant if we assume a 95% confidence interval. A less restrictive confidence interval, say 99%, might make the interaction statistically insignificant since the p-value will lie within the non-rejection region of the hypothesis $\beta_{Brick_Nbhd3No} = 0$*

2.4

Yes, we may merge Neighbourhood 2 and 1 into a common “Old” class.

In our models, both **Nbhd1** and **Nbhd2** are statistical significant (*considering a 95% confidence interval for the hypothesis*) $\beta_{Nbhd1} = 0$ and $\beta_{Nbhd2} = 0$ Thus, we fail to reject the hypothesis that Nbhd2 has a 0 coefficient. This implies that belonging to Neighbourhood2 specifically has a significant impact on house price. So, merging Neighbourhood 2 and 1 into a common class would be unwise.

Problem-3 What Causes What??:

3.1

For our models to perform well, we need to ensure that our datasets do not have any inherent biases.

At first sight, it might seem that “*getting data from a few different cities and running the regression of Crime on Police to understand how more cops in the streets affect crime*” is a good idea. However, we need to consider that the density of Police in a city is a policy decision which is taken in response to existing Crime Rates.

Thus, our model will end up reinforcing our bias: “*More Cops reduce Crime.*”

However, to get a good dataset, free of biases, we must **conduct experiments randomly**. One way to achieve this would be by deploying different number of cops across different cities and alert levels over multiple days.

3.2

To obtain their dataset, the researchers from UPENN were able to get the data for an experiment that saw a high volume of police on the streets on high terror alert days.

They observed a low crime rate on high alert days, when more police were deployed on the streets. However, higher police activity was observed on those days to monitor and curb terrorist activities; not for controlling petty crimes.

Similarly, as shown in the table 2, the UPENN researchers considered the metro ridership information, to confirm that low crime rates was not a result of lesser movement of possible criminals or victims.

Nevertheless, there exists an alternate explanation for crime rates being low on high alert days. High alert implies higher probability of a terrorist incident, vis-a-vis being the victim of one. Thus the criminals, like the common man, avoid exposing themselves to this threat by staying indoors. This would mean that the observed lower crime rate are police activity are not directly related but the high alert is an underlying *confounding variable*.

For the purpose of this experiment, as indicated by the table-2, if the ridership is kept constant on high alert days, **more police would reduce crime rate**.

3.3

As mentioned above, METRO ridership had to be controlled to ensure that it was not affecting crime rates. This would help the UPENN researchers establish a more clear relationship between “Police” and “Crime”. Consequently, according to the experiment, it was observed that keeping the metro ridership fixed for high alert days, **more police reduced crime rates**.

3.4

Table 4 has further refined the analysis to check if the effect of high alert days on crime was the same in all areas of town.

Using interactions between *location* and *high alert days* it was observed the effect is only statistically significant (*with a confidence interval of 95%*) in district 1. The effect in the 5 other districts, though still negative, is not statistically significant.

Problem-4 Neural Nets:

Step-1:

First, we split the data-set into **Train**, **Cross-Validation** and **Test** sets

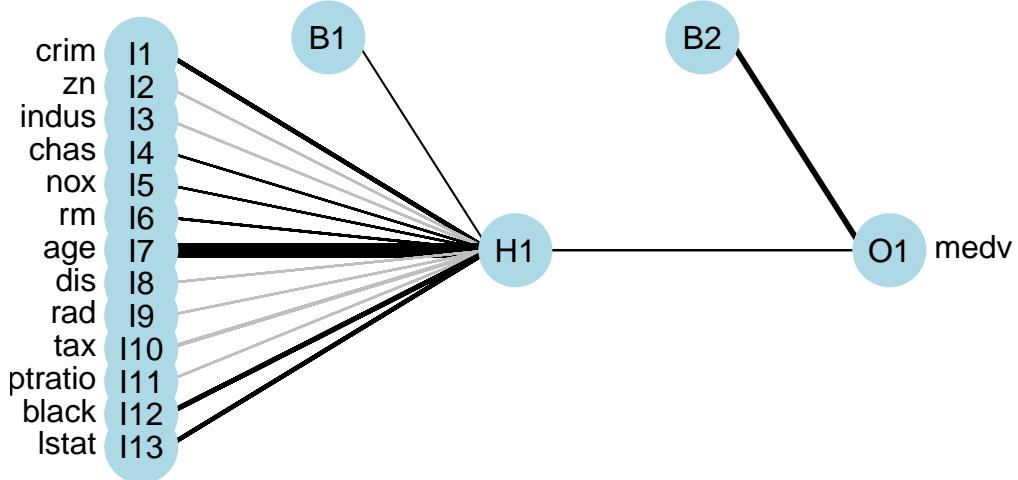
```
## Length of Boston Dataset      : 506
## Length of Train Dataset       : 404
## Length of Cross Validation Dataset : 51
## Length of Test Dataset        : 51
```

Step-2:

Fitting a single layer neural net to predict **medv** based on all other variables in Boston dataset as predictors:

```
## # weights: 29
## initial value 25703914.918253
## iter 10 value 666560.910142
## iter 20 value 8716.661658
## final value 8704.559128
## converged

## a 13-1-1 network with 29 weights
## inputs: crim zn indus chas nox rm age dis rad tax ptratio black lstat
## output(s): medv
## options were - skip-layer connections linear output units
```



```
## RMSE of a single-layer neural network is: 4.852
```

Step-3:

Cross-Validating over different **Size** and **Decay** Parameters:

```
##          0      0.1      0.3      0.01      0.03      0.001      0.003      1e-04
```

```

## 1 5.385722 5.390818 5.445314 5.423088 5.375968 5.361723 5.362722 5.361274
## 2 5.361227 5.430692 4.566297 5.364228 5.629962 5.361531 5.362722 5.149887
## 5 5.379487 4.946790 5.362642 5.266550 4.577101 5.378594 5.446329 5.369206
## 10 5.368180 5.332620 5.489269 5.085475 5.238659 5.458245 5.324589 5.365822
## 20 5.173832 5.316635 5.250776 4.905512 5.336179 8.050774 5.400410 5.378064
## 30 5.676944 5.228055 5.731944 5.746113 5.384913 7.178072 5.363293 5.377685
##      3e-04    1e-05    3e-05
## 1 5.361374 5.361230 5.281073
## 2 4.518849 5.362142 5.298272
## 5 5.382091 5.361231 5.353238
## 10 5.379146 5.284663 5.349404
## 20 5.206584 5.347391 5.449923
## 30 4.916482 5.160412 5.503535

## Minimum Cross-Validation RMSE of 4.51884947159804 achieved with a Neural Net with the following spec
## Size: 2
## Decay: 3e-04

```

Step-4:

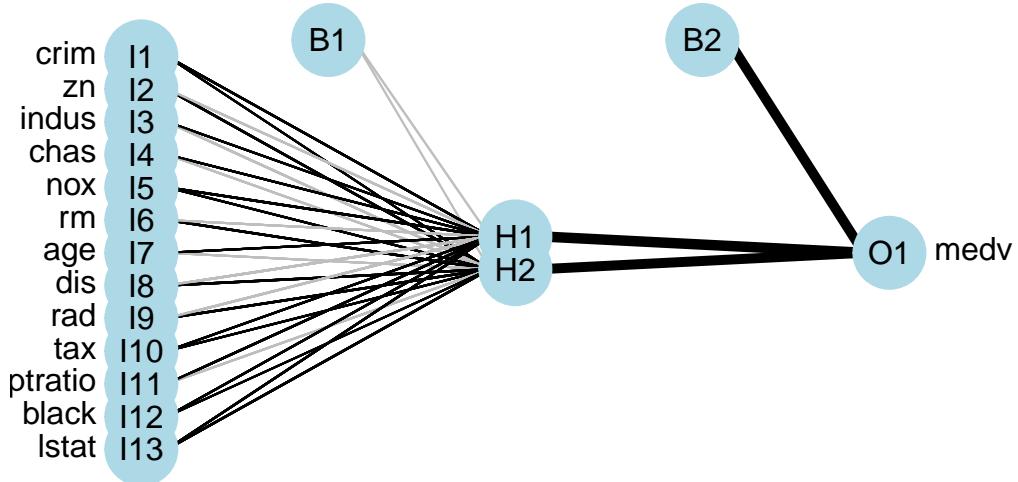
Test Error on the Test Set with the Neural Net chosen from the Cross-Validation set

```

## # weights:  44
## initial  value 35011181.757967
## iter  10 value 1778150.833349
## iter  20 value 8704.832493
## final  value 8704.798073
## converged

## a 13-2-1 network with 44 weights
## inputs: crim zn indus chas nox rm age dis rad tax ptratio black lstat
## output(s): medv
## options were - skip-layer connections  linear output units  decay=3e-04

```



```
##  
##  
## RMSE of a Neural Net of Size: 2 and Decay: 3e-04 is-  
## 4.358
```

Problem-5 Final Project(GROUP-7; Morning Class):

Problem Statement:

What are the important factors in predicting strokes? How can hospitals/public health use this information to prevent strokes and/or help identify them?

For our project, we used a publicly available heart stroke dataset with 11 predictors. We decided to implement a couple of different models and compare them to find the best model.

I chose to implement a KNN model. I also produced several of the key visualisations that was used by my group as reference.

Approach

Right off the bat, I faced the following issues:

Categorical Predictors

7 out of 11 of our database were categorical in nature. Only **Age**, **BMI** and **Average Glucose Level** were numeric.

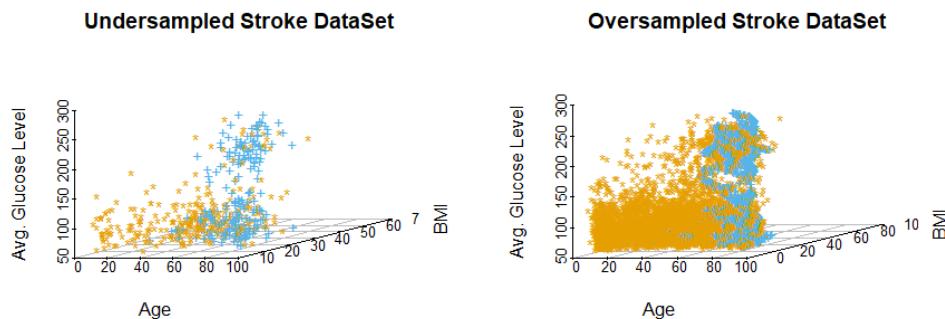
The fundamental mechanism behind KNN is to find the *closest* neighbour. Distances are usually calculated by using a function, usually an order of Minkowski function. However, Distances between categories is not intuitive.

Infact, the model's Adjusted R^2 dropped when I included all the categorical variables v/s when I had just used the aforementioned 3 numeric variables.

Thus, I proceeded with just **Age**, **BMI** and **Average Glucose Level** in my models.

Skewed Data

As is expected with any real world health data, I observed that my dataset was highly skewed with only 5% of the data classified as **Stroke**. The models were achieving high accuracy and 0 Recall (*because everything was being classified as Non-Stroke*) To deal with this imbalance, I chose to *undersample* my data and created a new dataset with a 3:2 ratio of Non-Stroke:Stroke.



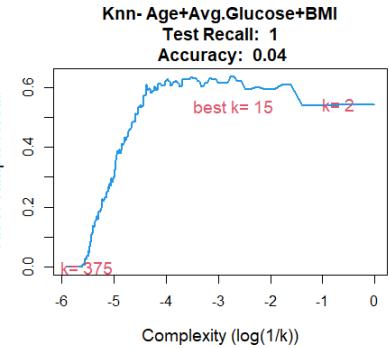
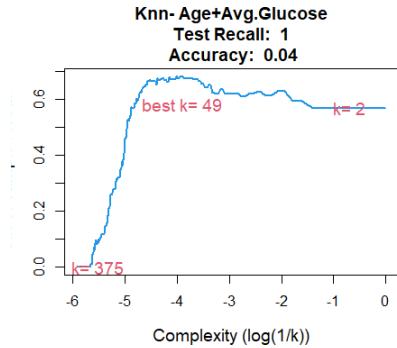
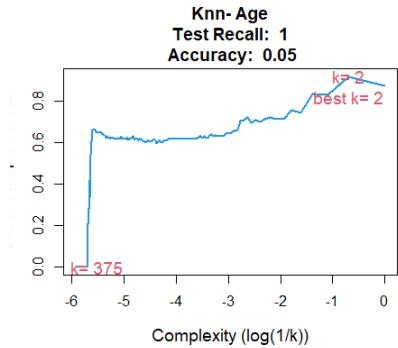
I had also tried **Oversampling** like the rest of my group members but since *SMOTE* produces artificial duplicates of the minority class using KNN itself, the model's were over fitting and performing poorly.

Cross Validation

Since Our's was a classification problem of Heart Stroke prediction, we decided that the **Model Recall is the most important indicator of a Model's Efficacy (With Precision and Accuracy as guardrails)**. I chose to implement **K-Fold Cross Validation** with a K of 10 to select the neighbourhood size (*vis-a-vis complexity*) of my KNN model. I tried doing with different combinations of Predictors like:

- *Age*
- *Age + Average Glucose Level*
- *Age + Average Glucose Level + BMI*

The results are as follows:



As is clear from the model outputs, KNN did a very poor job at classifying Heart Strokes from just the dataset we had. However, It paved the way for more complex models and we were able to work on Bagging, Boosting and Random Forest models which proved to be far more effective in dealing with the categorical predictors.
