Weekly Summary Template

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Tuesday, Feb 16

> **!** TIL
>
> Include a *very brief* summary of what you learnt in this class here.
> Today, I learnt the following concepts in class:
>
> 1. How to make a correlation plot and its interpretation
> 2. Variance inflation
> 3. Step-wise Regression

```
# loading in necessary libraries and datasets
library(ISLR2)
library(dplyr)
```

```
Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag
```

```
The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

```
library(tidyr)
library(purrr)
library(readr)
library(glmnet)
```

```
Loading required package: Matrix
```

```
Attaching package: 'Matrix'
```

```
The following objects are masked from 'package:tidyr':

    expand, pack, unpack
```

```
Loaded glmnet 4.1-6
```

```
library(caret)
```

```
Loading required package: ggplot2
```

```
Loading required package: lattice
```

```
Attaching package: 'caret'
```

```
The following object is masked from 'package:purrr':

    lift
```

```
library(car)
```

```
Loading required package: carData
```

```
Attaching package: 'car'
```

```
The following object is masked from 'package:purrr':

    some

The following object is masked from 'package:dplyr':

    recode
```

```r
df <- Boston
attach(Boston)
```

Correlation Plot

```r
# creates new data frame that outputs correlation table with numeric values
R <- df %>%
  keep(is.numeric) %>%
  cor()
R
```

```
              crim          zn       indus         chas         nox
crim     1.00000000 -0.20046922  0.40658341 -0.055891582  0.42097171
zn      -0.20046922  1.00000000 -0.53382819 -0.042696719 -0.51660371
indus    0.40658341 -0.53382819  1.00000000  0.062938027  0.76365145
chas    -0.05589158 -0.04269672  0.06293803  1.000000000  0.09120281
nox      0.42097171 -0.51660371  0.76365145  0.091202807  1.00000000
rm      -0.21924670  0.31199059 -0.39167585  0.091251225 -0.30218819
age      0.35273425 -0.56953734  0.64477851  0.086517774  0.73147010
dis     -0.37967009  0.66440822 -0.70802699 -0.099175780 -0.76923011
rad      0.62550515 -0.31194783  0.59512927 -0.007368241  0.61144056
tax      0.58276431 -0.31456332  0.72076018 -0.035586518  0.66802320
ptratio  0.28994558 -0.39167855  0.38324756 -0.121515174  0.18893268
lstat    0.45562148 -0.41299457  0.60379972 -0.053929298  0.59087892
medv    -0.38830461  0.36044534 -0.48372516  0.175260177 -0.42732077
                rm         age         dis          rad         tax    ptratio
crim    -0.21924670  0.35273425 -0.37967009  0.625505145  0.58276431  0.2899456
zn       0.31199059 -0.56953734  0.66440822 -0.311947826 -0.31456332 -0.3916785
indus   -0.39167585  0.64477851 -0.70802699  0.595129275  0.72076018  0.3832476
chas     0.09125123  0.08651777 -0.09917578 -0.007368241 -0.03558652 -0.1215152
nox     -0.30218819  0.73147010 -0.76923011  0.611440563  0.66802320  0.1889327
rm       1.00000000 -0.24026493  0.20524621 -0.209846668 -0.29204783 -0.3555015
```

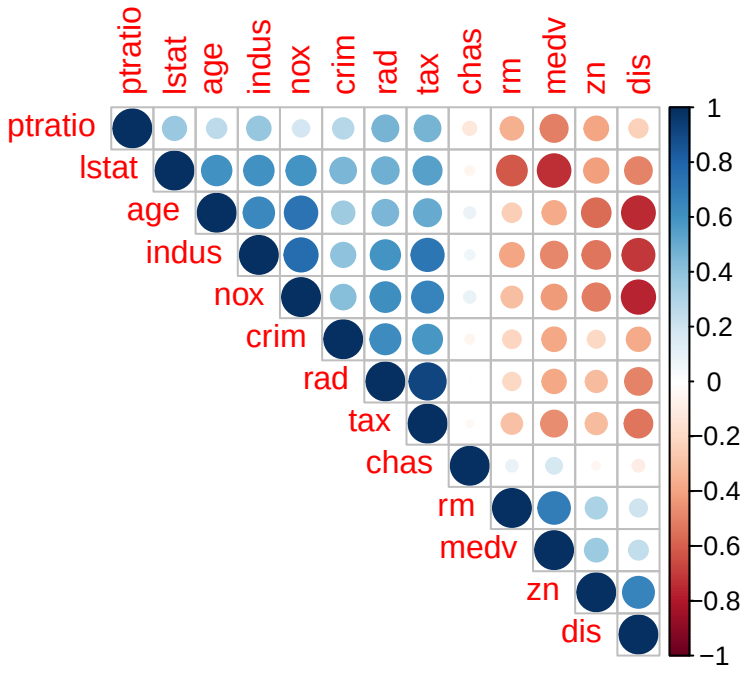
```
age     -0.24026493  1.00000000 -0.74788054  0.456022452  0.50645559  0.2615150
dis      0.20524621 -0.74788054  1.00000000 -0.494587930 -0.53443158 -0.2324705
rad     -0.20984667  0.45602245 -0.49458793  1.000000000  0.91022819  0.4647412
tax     -0.29204783  0.50645559 -0.53443158  0.910228189  1.00000000  0.4608530
ptratio -0.35550149  0.26151501 -0.23247054  0.464741179  0.46085304  1.0000000
lstat   -0.61380827  0.60233853 -0.49699583  0.488676335  0.54399341  0.3740443
medv     0.69535995 -0.37695457  0.24992873 -0.381626231 -0.46853593 -0.5077867
              lstat       medv
crim     0.4556215 -0.3883046
zn      -0.4129946  0.3604453
indus    0.6037997 -0.4837252
chas    -0.0539293  0.1752602
nox      0.5908789 -0.4273208
rm      -0.6138083  0.6953599
age      0.6023385 -0.3769546
dis     -0.4969958  0.2499287
rad      0.4886763 -0.3816262
tax      0.5439934 -0.4685359
ptratio  0.3740443 -0.5077867
lstat    1.0000000 -0.7376627
medv    -0.7376627  1.0000000
```

- Correlation can range between [-1,1]
    1. Close to 1 = strong positive correlation(as one variable increases, the other variable increases)
    2. Close to -1 = strong negative correlation(as one variable increases, the other variable decreases)
    3. Close to 0 = very weak/no correlation between variables
- Can come up with a p-value for a correlation value to see if there is a relationship between 2 variables (see if one is a good predictor of another)

```
# creates correlation plot
library(corrplot)
```

```
corrplot 0.92 loaded
```

```
corrplot(R, type = 'upper', order = 'hclust')
```



- Red = negative correlation
- Blue = positive correlation
- Can't isolate effect of indus and nox as they are related so won't be able to hold one constant while increasing the other (have very high correlation)
- Tax is negatively correlated with indus (total nuberm of business), so if the number of businesses in neighborhood goes up, then the distance from that given house to a business district decreases/goes down

Variance Inflation

```
# creating new model that we can use to investigate variance inflation
new_cols <- colnames(df)[-c(5,13)]
model <- lm(medv ~ ., df %>% select(-c(indus, nox, dis)))
summary(model)
```

```
Call:
lm(formula = medv ~ ., data = df %>% select(-c(indus, nox, dis)))

Residuals:
     Min       1Q   Median       3Q      Max
```

```
-16.9388  -3.0974  -0.7082   1.8472  28.3443

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 21.655695   4.215323   5.137 4.01e-07 ***
crim        -0.091908   0.034722  -2.647 0.008380 **
zn           0.008794   0.012670   0.694 0.487957
chas         2.952830   0.913519   3.232 0.001309 **
rm           4.100202   0.439135   9.337  < 2e-16 ***
age          0.020892   0.012195   1.713 0.087315 .
rad          0.251852   0.067890   3.710 0.000231 ***
tax         -0.012434   0.003469  -3.584 0.000371 ***
ptratio     -0.886594   0.129206  -6.862 2.03e-11 ***
lstat       -0.573951   0.053177 -10.793  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.084 on 496 degrees of freedom
Multiple R-squared:  0.6999,    Adjusted R-squared:  0.6944
F-statistic: 128.5 on 9 and 496 DF,  p-value: < 2.2e-16
```

- Variance inflation = if you have 2 variables that are highly correlated with one another, if you change one variable, then you would expect change in the other variable in the same direction (can't hold that variable constant while increasing the other).

1. variance is used to compute standard errors
2. if standard error goes up, then p-value goes up, so it becomes more significant & less likely to reject the null hypothesis
3. inflating it with sum of other variables
4. high variance inflation = gets very high, so it becomes very insignificant

```r
# inflation variance factor table
library(car)
library(knitr)
library(rmarkdown)
vif_model <- lm(medv ~ ., df)
vif(vif_model) %>% knitr::kable()
```

	x
crim	1.767486
zn	2.298459
indus	3.987181

	x
chas	1.071168
nox	4.369093
rm	1.912532
age	3.088232
dis	3.954037
rad	7.445301
tax	9.002158
ptratio	1.797060
lstat	2.870776

- This table measures the of the amount of multicolinearity in a set of multiple regression variables.
- high inflation factor = anything greater than 2
- low inflation factor = anything less than 2

Stepwise Regression

- can drop a subset of the variables that don't explain enough the variability in the R^2
- by adding more variables, R^2 goes up –> now you can ask what variables leads to the highest increase in R^2 /more significant/good predictors and have low variance inflation

```
# Null model only uses the intercept for the model predicting median house price
null_model <- lm(medv ~ 1,df)
null_model
```

```
Call:
lm(formula = medv ~ 1, data = df)

Coefficients:
(Intercept)
      22.53
```

```
# Full model utilizes all variables in the prediction of median house price
full_model <- lm(medv ~ .,df)
full_model
```

```
Call:
lm(formula = medv ~ ., data = df)
```

```
Coefficients:
(Intercept)         crim           zn        indus         chas          nox
  41.617270    -0.121389     0.046963     0.013468     2.839993   -18.758022
         rm          age          dis          rad          tax      ptratio
   3.658119     0.003611    -1.490754     0.289405    -0.012682    -0.937533
      lstat
  -0.552019
```

Forward Selection

- Starts with no covariates
- Add each covariate 1 by 1 in order of variables importance, increasing R^2

```
# uses step function to run this
forward_model <- step(null_model, direction = 'forward',
                      scope = formula(full_model))
```

```
Start:  AIC=2246.51
medv ~ 1

          Df Sum of Sq   RSS    AIC
+ lstat    1   23243.9 19472 1851.0
+ rm       1   20654.4 22062 1914.2
+ ptratio  1   11014.3 31702 2097.6
+ indus    1    9995.2 32721 2113.6
+ tax      1    9377.3 33339 2123.1
+ nox      1    7800.1 34916 2146.5
+ crim     1    6440.8 36276 2165.8
+ rad      1    6221.1 36495 2168.9
+ age      1    6069.8 36647 2171.0
+ zn       1    5549.7 37167 2178.1
+ dis      1    2668.2 40048 2215.9
+ chas     1    1312.1 41404 2232.7
<none>                 42716 2246.5

Step:  AIC=1851.01
medv ~ lstat

          Df Sum of Sq   RSS    AIC
+ rm       1    4033.1 15439 1735.6
+ ptratio  1    2670.1 16802 1778.4
```

```
+ chas     1     786.3 18686 1832.2
+ dis      1     772.4 18700 1832.5
+ age      1     304.3 19168 1845.0
+ tax      1     274.4 19198 1845.8
+ zn       1     160.3 19312 1848.8
+ crim     1     146.9 19325 1849.2
+ indus    1      98.7 19374 1850.4
<none>                 19472 1851.0
+ rad      1      25.1 19447 1852.4
+ nox      1       4.8 19468 1852.9

Step:  AIC=1735.58
medv ~ lstat + rm

          Df Sum of Sq   RSS    AIC
+ ptratio  1   1711.32 13728 1678.1
+ chas     1    548.53 14891 1719.3
+ tax      1    425.16 15014 1723.5
+ dis      1    351.15 15088 1725.9
+ crim     1    311.42 15128 1727.3
+ rad      1    180.45 15259 1731.6
+ indus    1     61.09 15378 1735.6
<none>                 15439 1735.6
+ zn       1     56.56 15383 1735.7
+ age      1     20.18 15419 1736.9
+ nox      1     14.90 15424 1737.1

Step:  AIC=1678.13
medv ~ lstat + rm + ptratio

        Df Sum of Sq   RSS    AIC
+ dis    1    499.08 13229 1661.4
+ chas   1    377.96 13350 1666.0
+ crim   1    122.52 13606 1675.6
+ age    1     66.24 13662 1677.7
<none>               13728 1678.1
+ tax    1     44.36 13684 1678.5
+ nox    1     24.81 13703 1679.2
+ zn     1     14.96 13713 1679.6
+ rad    1      6.07 13722 1679.9
+ indus  1      0.83 13727 1680.1

Step:  AIC=1661.39
```

```
medv ~ lstat + rm + ptratio + dis

        Df Sum of Sq   RSS    AIC
+ nox    1    759.56 12469 1633.5
+ chas   1    267.43 12962 1653.1
+ indus  1    242.65 12986 1654.0
+ tax    1    240.34 12989 1654.1
+ crim   1    233.54 12995 1654.4
+ zn     1    144.81 13084 1657.8
+ age    1     61.36 13168 1661.0
<none>               13229 1661.4
+ rad    1     22.40 13206 1662.5

Step:  AIC=1633.47
medv ~ lstat + rm + ptratio + dis + nox

        Df Sum of Sq   RSS    AIC
+ chas   1    328.27 12141 1622.0
+ zn     1    151.71 12318 1629.3
+ crim   1    141.43 12328 1629.7
+ rad    1     53.48 12416 1633.3
<none>               12469 1633.5
+ indus  1     17.10 12452 1634.8
+ tax    1     10.50 12459 1635.0
+ age    1      0.25 12469 1635.5

Step:  AIC=1621.97
medv ~ lstat + rm + ptratio + dis + nox + chas

        Df Sum of Sq   RSS    AIC
+ zn     1   164.406 11977 1617.1
+ crim   1   116.330 12025 1619.1
+ rad    1    58.556 12082 1621.5
<none>               12141 1622.0
+ indus  1    26.274 12115 1622.9
+ tax    1     4.187 12137 1623.8
+ age    1     2.331 12139 1623.9

Step:  AIC=1617.07
medv ~ lstat + rm + ptratio + dis + nox + chas + zn

        Df Sum of Sq   RSS    AIC
+ crim   1   170.902 11806 1611.8
```

```
<none>               11977 1617.1
+ tax    1    31.773 11945 1617.7
+ rad    1    28.311 11948 1617.9
+ indus  1    27.377 11949 1617.9
+ age    1     0.071 11977 1619.1

Step:  AIC=1611.8
medv ~ lstat + rm + ptratio + dis + nox + chas + zn + crim

        Df Sum of Sq   RSS    AIC
+ rad    1   155.006 11651 1607.1
<none>               11806 1611.8
+ indus  1    24.957 11781 1612.7
+ tax    1     1.418 11804 1613.7
+ age    1     0.178 11806 1613.8

Step:  AIC=1607.11
medv ~ lstat + rm + ptratio + dis + nox + chas + zn + crim +
    rad

        Df Sum of Sq   RSS    AIC
+ tax    1   298.573 11352 1596.0
<none>               11651 1607.1
+ indus  1    44.346 11606 1607.2
+ age    1     0.581 11650 1609.1

Step:  AIC=1595.98
medv ~ lstat + rm + ptratio + dis + nox + chas + zn + crim +
    rad + tax

        Df Sum of Sq   RSS    AIC
<none>               11352 1596.0
+ age    1    1.6865 11350 1597.9
+ indus  1    1.0784 11351 1597.9
```

```
summary(forward_model)
```

```
Call:
lm(formula = medv ~ lstat + rm + ptratio + dis + nox + chas +
    zn + crim + rad + tax, data = df)
```

```
Residuals:
     Min       1Q   Median       3Q      Max
-15.1814  -2.7625  -0.6243   1.8448  26.3920

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  41.451747   4.903283   8.454 3.18e-16 ***
lstat        -0.546509   0.047442 -11.519  < 2e-16 ***
rm            3.672957   0.409127   8.978  < 2e-16 ***
ptratio      -0.930961   0.130423  -7.138 3.39e-12 ***
dis          -1.515951   0.187675  -8.078 5.08e-15 ***
nox         -18.262427   3.565247  -5.122 4.33e-07 ***
chas          2.871873   0.862591   3.329 0.000935 ***
zn            0.046191   0.013673   3.378 0.000787 ***
crim         -0.121665   0.032919  -3.696 0.000244 ***
rad           0.283932   0.063945   4.440 1.11e-05 ***
tax          -0.012292   0.003407  -3.608 0.000340 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.789 on 495 degrees of freedom
Multiple R-squared:  0.7342,    Adjusted R-squared:  0.7289
F-statistic: 136.8 on 10 and 495 DF,  p-value: < 2.2e-16
```

- The lower the AIC value, the better
- Add the variables that have the result in the lowest AIC value at that point
- The AIC next to each variable, says which variable that would be added next would make the AIC value the lowest
- lstat is first one added as it makes the AIC value the smallest out of all the variables
- forward selection –> keep building model by including variables
- at the end, if you add age or indus, the AIC value increases, which means you should stop before adding those variables (don't use those variables in the model)

Backward Selection

- Start with full model
- Remove variables 1 by 1 to see which results in a decrease in the AIC value

```r
backward_model <- step(full_model, direction = 'backward',
                       scope = formula(null_model))
```

```
Start:  AIC=1599.85
medv ~ crim + zn + indus + chas + nox + rm + age + dis + rad +
```

```
    tax + ptratio + lstat

          Df Sum of Sq   RSS    AIC
- indus    1      1.08 11350 1597.9
- age      1      1.69 11351 1597.9
<none>                 11349 1599.8
- chas     1    245.31 11595 1608.7
- tax      1    256.28 11606 1609.2
- zn       1    263.59 11613 1609.5
- crim     1    311.49 11661 1611.6
- rad      1    430.71 11780 1616.7
- nox      1    546.10 11896 1621.6
- ptratio  1   1157.70 12507 1647.0
- dis      1   1258.52 12608 1651.1
- rm       1   1744.36 13094 1670.2
- lstat    1   2733.54 14083 1707.0

Step:  AIC=1597.9
medv ~ crim + zn + chas + nox + rm + age + dis + rad + tax +
    ptratio + lstat

          Df Sum of Sq   RSS    AIC
- age      1      1.69 11352 1596.0
<none>                 11350 1597.9
- chas     1    251.21 11602 1607.0
- zn       1    262.99 11614 1607.5
- tax      1    299.68 11650 1609.1
- crim     1    313.07 11664 1609.7
- rad      1    453.61 11804 1615.7
- nox      1    574.23 11925 1620.9
- ptratio  1   1168.01 12518 1645.5
- dis      1   1333.19 12684 1652.1
- rm       1   1750.50 13101 1668.5
- lstat    1   2743.21 14094 1705.4

Step:  AIC=1595.98
medv ~ crim + zn + chas + nox + rm + dis + rad + tax + ptratio +
    lstat

          Df Sum of Sq   RSS    AIC
<none>                 11352 1596.0
- chas     1    254.21 11606 1605.2
- zn       1    261.75 11614 1605.5
```

```
- tax      1    298.57 11651 1607.1
- crim     1    313.27 11666 1607.8
- rad      1    452.16 11804 1613.7
- nox      1    601.74 11954 1620.1
- ptratio  1   1168.51 12521 1643.5
- dis      1   1496.35 12848 1656.6
- rm       1   1848.38 13201 1670.3
- lstat    1   3043.23 14395 1714.2
```

```
summary(backward_model)
```

```
Call:
lm(formula = medv ~ crim + zn + chas + nox + rm + dis + rad +
    tax + ptratio + lstat, data = df)

Residuals:
     Min       1Q   Median       3Q      Max
-15.1814  -2.7625  -0.6243   1.8448  26.3920

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  41.451747   4.903283   8.454 3.18e-16 ***
crim         -0.121665   0.032919  -3.696 0.000244 ***
zn            0.046191   0.013673   3.378 0.000787 ***
chas          2.871873   0.862591   3.329 0.000935 ***
nox         -18.262427   3.565247  -5.122 4.33e-07 ***
rm            3.672957   0.409127   8.978  < 2e-16 ***
dis          -1.515951   0.187675  -8.078 5.08e-15 ***
rad           0.283932   0.063945   4.440 1.11e-05 ***
tax          -0.012292   0.003407  -3.608 0.000340 ***
ptratio      -0.930961   0.130423  -7.138 3.39e-12 ***
lstat        -0.546509   0.047442 -11.519  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.789 on 495 degrees of freedom
Multiple R-squared:  0.7342,    Adjusted R-squared:  0.7289
F-statistic: 136.8 on 10 and 495 DF,  p-value: < 2.2e-16
```

- removes variables that would give it a higher AIC until there are no more of that type
- forward selection and backward selection DON'T always give us the same model

Using both selection methods

- use the full model for both and direction as 'both'

```
selected_model <- step(full_model, direction = 'both',
                       scope = formula(full_model))
```

```
Start:  AIC=1599.85
medv ~ crim + zn + indus + chas + nox + rm + age + dis + rad +
    tax + ptratio + lstat

          Df Sum of Sq   RSS    AIC
- indus    1      1.08 11350 1597.9
- age      1      1.69 11351 1597.9
<none>                 11349 1599.8
- chas     1    245.31 11595 1608.7
- tax      1    256.28 11606 1609.2
- zn       1    263.59 11613 1609.5
- crim     1    311.49 11661 1611.6
- rad      1    430.71 11780 1616.7
- nox      1    546.10 11896 1621.6
- ptratio  1   1157.70 12507 1647.0
- dis      1   1258.52 12608 1651.1
- rm       1   1744.36 13094 1670.2
- lstat    1   2733.54 14083 1707.0

Step:  AIC=1597.9
medv ~ crim + zn + chas + nox + rm + age + dis + rad + tax +
    ptratio + lstat

          Df Sum of Sq   RSS    AIC
- age      1      1.69 11352 1596.0
<none>                 11350 1597.9
+ indus    1      1.08 11349 1599.8
- chas     1    251.21 11602 1607.0
- zn       1    262.99 11614 1607.5
- tax      1    299.68 11650 1609.1
- crim     1    313.07 11664 1609.7
- rad      1    453.61 11804 1615.7
- nox      1    574.23 11925 1620.9
- ptratio  1   1168.01 12518 1645.5
- dis      1   1333.19 12684 1652.1
```

```
- rm       1   1750.50 13101 1668.5
- lstat    1   2743.21 14094 1705.4

Step:  AIC=1595.98
medv ~ crim + zn + chas + nox + rm + dis + rad + tax + ptratio +
    lstat

          Df Sum of Sq   RSS    AIC
<none>                 11352 1596.0
+ age      1      1.69 11350 1597.9
+ indus    1      1.08 11351 1597.9
- chas     1    254.21 11606 1605.2
- zn       1    261.75 11614 1605.5
- tax      1    298.57 11651 1607.1
- crim     1    313.27 11666 1607.8
- rad      1    452.16 11804 1613.7
- nox      1    601.74 11954 1620.1
- ptratio  1   1168.51 12521 1643.5
- dis      1   1496.35 12848 1656.6
- rm       1   1848.38 13201 1670.3
- lstat    1   3043.23 14395 1714.2
```

```r
summary(selected_model)
```

```
Call:
lm(formula = medv ~ crim + zn + chas + nox + rm + dis + rad +
    tax + ptratio + lstat, data = df)

Residuals:
     Min       1Q   Median       3Q      Max
-15.1814  -2.7625  -0.6243   1.8448  26.3920

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  41.451747   4.903283   8.454 3.18e-16 ***
crim         -0.121665   0.032919  -3.696 0.000244 ***
zn            0.046191   0.013673   3.378 0.000787 ***
chas          2.871873   0.862591   3.329 0.000935 ***
nox         -18.262427   3.565247  -5.122 4.33e-07 ***
rm            3.672957   0.409127   8.978  < 2e-16 ***
dis          -1.515951   0.187675  -8.078 5.08e-15 ***
```

```
rad           0.283932   0.063945   4.440 1.11e-05 ***
tax          -0.012292   0.003407  -3.608 0.000340 ***
ptratio      -0.930961   0.130423  -7.138 3.39e-12 ***
lstat        -0.546509   0.047442 -11.519  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.789 on 495 degrees of freedom
Multiple R-squared:  0.7342,    Adjusted R-squared:  0.7289
F-statistic: 136.8 on 10 and 495 DF,  p-value: < 2.2e-16
```