Assignment: ASSIGNMENT 8, Housing data analysis

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```r
# load readxl library and set directory
# Read the housing data set
library(readxl)
setwd("/Users/mshekhar/Desktop/R Programming/DSC520/stats_for_data_science/stats_for_data_science")
mydata <- read_excel("week-6-housing.xlsx")

# check the structure of data and some basic stats
str(mydata)
```

```
## tibble[,24] [12,865 x 24] (S3: tbl_df/tbl/data.frame)
##  $ Sale Date               : POSIXct[1:12865], format: "2006-01-03" "2006-01-03" ...
##  $ Sale Price              : num [1:12865] 698000 649990 572500 420000 369900 ...
##  $ sale_reason             : num [1:12865] 1 1 1 1 1 1 1 1 1 1 ...
##  $ sale_instrument         : num [1:12865] 3 3 3 3 3 15 3 3 3 3 ...
##  $ sale_warning            : chr [1:12865] NA NA NA NA ...
##  $ sitetype                : chr [1:12865] "R1" "R1" "R1" "R1" ...
##  $ addr_full               : chr [1:12865] "17021 NE 113TH CT" "11927 178TH PL NE" "13315 174TH AVE N
##  $ zip5                    : num [1:12865] 98052 98052 98052 98052 98052 ...
##  $ ctyname                 : chr [1:12865] "REDMOND" "REDMOND" NA "REDMOND" ...
##  $ postalctyn              : chr [1:12865] "REDMOND" "REDMOND" "REDMOND" "REDMOND" ...
##  $ lon                     : num [1:12865] -122 -122 -122 -122 -122 ...
##  $ lat                     : num [1:12865] 47.7 47.7 47.7 47.6 47.7 ...
##  $ building_grade          : num [1:12865] 9 9 8 8 7 7 10 10 9 8 ...
##  $ square_feet_total_living: num [1:12865] 2810 2880 2770 1620 1440 4160 3960 3720 4160 2760 ...
##  $ bedrooms                : num [1:12865] 4 4 4 3 3 4 5 4 4 4 ...
##  $ bath_full_count         : num [1:12865] 2 2 1 1 1 2 3 2 2 1 ...
##  $ bath_half_count         : num [1:12865] 1 0 1 0 0 1 0 1 1 0 ...
##  $ bath_3qtr_count         : num [1:12865] 0 1 1 1 1 1 1 0 1 1 ...
##  $ year_built              : num [1:12865] 2003 2006 1987 1968 1980 ...
##  $ year_renovated          : num [1:12865] 0 0 0 0 0 0 0 0 0 0 ...
##  $ current_zoning          : chr [1:12865] "R4" "R4" "R6" "R4" ...
##  $ sq_ft_lot               : num [1:12865] 6635 5570 8444 9600 7526 ...
##  $ prop_type               : chr [1:12865] "R" "R" "R" "R" ...
##  $ present_use             : num [1:12865] 2 2 2 2 2 2 2 2 2 2 ...
```

```r
summary(mydata)
```

```
##    Sale Date                     Sale Price       sale_reason
##  Min.   :2006-01-03 00:00:00   Min.   :    698   Min.   : 0.00
##  1st Qu.:2008-07-07 00:00:00   1st Qu.: 460000   1st Qu.: 1.00
##  Median :2011-11-17 00:00:00   Median : 593000   Median : 1.00
##  Mean   :2011-07-28 15:07:32   Mean   : 660738   Mean   : 1.55
##  3rd Qu.:2014-06-05 00:00:00   3rd Qu.: 750000   3rd Qu.: 1.00
##  Max.   :2016-12-16 00:00:00   Max.   :4400000   Max.   :19.00
##  sale_instrument  sale_warning         sitetype           addr_full
##  Min.   : 0.000   Length:12865       Length:12865       Length:12865
##  1st Qu.: 3.000   Class :character   Class :character   Class :character
##  Median : 3.000   Mode  :character   Mode  :character   Mode  :character
```

```
##  Mean   : 3.678
##  3rd Qu.: 3.000
##  Max.   :27.000
##       zip5          ctyname           postalctyn             lon
##  Min.   :98052   Length:12865       Length:12865       Min.   :-122.2
##  1st Qu.:98052   Class :character   Class :character   1st Qu.:-122.1
##  Median :98052   Mode  :character   Mode  :character   Median :-122.1
##  Mean   :98053                                         Mean   :-122.1
##  3rd Qu.:98053                                         3rd Qu.:-122.0
##  Max.   :98074                                         Max.   :-121.9
##       lat        building_grade  square_feet_total_living    bedrooms
##  Min.   :47.46   Min.   : 2.00   Min.   :  240             Min.   : 0.000
##  1st Qu.:47.67   1st Qu.: 8.00   1st Qu.: 1820             1st Qu.: 3.000
##  Median :47.69   Median : 8.00   Median : 2420             Median : 4.000
##  Mean   :47.68   Mean   : 8.24   Mean   : 2540             Mean   : 3.479
##  3rd Qu.:47.70   3rd Qu.: 9.00   3rd Qu.: 3110             3rd Qu.: 4.000
##  Max.   :47.73   Max.   :13.00   Max.   :13540             Max.   :11.000
##  bath_full_count  bath_half_count  bath_3qtr_count   year_built
##  Min.   : 0.000   Min.   :0.0000   Min.   :0.000   Min.   :1900
##  1st Qu.: 1.000   1st Qu.:0.0000   1st Qu.:0.000   1st Qu.:1979
##  Median : 2.000   Median :1.0000   Median :0.000   Median :1998
##  Mean   : 1.798   Mean   :0.6134   Mean   :0.494   Mean   :1993
##  3rd Qu.: 2.000   3rd Qu.:1.0000   3rd Qu.:1.000   3rd Qu.:2007
##  Max.   :23.000   Max.   :8.0000   Max.   :8.000   Max.   :2016
##  year_renovated    current_zoning       sq_ft_lot        prop_type
##  Min.   :   0.00   Length:12865       Min.   :    785   Length:12865
##  1st Qu.:   0.00   Class :character   1st Qu.:   5355   Class :character
##  Median :   0.00   Mode  :character   Median :   7965   Mode  :character
##  Mean   :  26.24                      Mean   :  22229
##  3rd Qu.:   0.00                      3rd Qu.:  12632
##  Max.   :2016.00                      Max.   :1631322
##   present_use
##  Min.   :  0.000
##  1st Qu.:  2.000
##  Median :  2.000
##  Mean   :  6.598
##  3rd Qu.:  2.000
##  Max.   :300.000
```

b.i. Explain any transformations or modifications you made to the dataset

```
## -------------- 1. Changed the column name to remove spaces -----------------
# Change the column names to remove spaces
colnames(mydata)[1] <- "Sale_Date"
colnames(mydata)[2] <- "Sale_Price"

## -------------- 2. Checking for NAs in the data ---------------
apply(mydata, 2, function(x) any(is.na(x) | is.infinite(x)))
```

```
##                Sale_Date                Sale_Price               sale_reason
##                    FALSE                     FALSE                     FALSE
##          sale_instrument              sale_warning                  sitetype
```

```
##                   FALSE                    TRUE                   FALSE
##               addr_full                    zip5                 ctyname
##                   FALSE                   FALSE                    TRUE
##              postalctyn                     lon                     lat
##                   FALSE                   FALSE                   FALSE
##          building_grade square_feet_total_living                bedrooms
##                   FALSE                   FALSE                   FALSE
##         bath_full_count         bath_half_count         bath_3qtr_count
##                   FALSE                   FALSE                   FALSE
##              year_built          year_renovated          current_zoning
##                   FALSE                   FALSE                   FALSE
##                sq_ft_lot               prop_type             present_use
##                   FALSE                   FALSE                   FALSE
```

```r
# check if there are any NAs in sale_warning
sum(is.na(mydata$sale_warning))
```

```
## [1] 10568
```

```r
# check if there are any NAs in ctyname
sum(is.na(mydata$ctyname))
```

```
## [1] 6078
```

```r
# We found that sale_warning = 10568 and ctyname = 6078 have NAs
# sale_warning sounds like a bad remark and if it is not present.
# Deriving sale_warning indicator and adding it to the data
mydata <- cbind(mydata, "Sale_Warning_in" = as.numeric(!(is.na(mydata$sale_warning))))
```

```r
# cityname
# Not worried about this field as we have other attributes like zip code,
# latitude, longitude to predict sale price.
# We can ignore this field while model creation

## ---------------- 3. changing categorical variables to factors ------------------
# changing sitetype to factor
# check distinct values
unique(mydata$sitetype)
```

```
## [1] "R1" "R2" "R3" "DV" "A1" "R4" "C1"
```

```r
mydata$sitetype <- factor(mydata$sitetype, labels = c(1,2,3,4,5,6,7))

# changing current zoning to factor
# check current zoning unique values and convert to factor
unique(mydata$current_zoning)
```

```
##  [1] "R4"      "R6"      "URPSO"   "RA5"     "R3"      "R5"      "RA2.5"
##  [8] "RA10"    "R12"     "RA5P"    "R1"      "RA2.5SO" "RA2.5P"  "R4/C"
## [15] "EH"      "R1P"     "BC"      "R8"      "A10"     "R6/C"    "R18"
## [22] "A10SO"   "RA10P"   "GC"
```

```r
mydata$current_zoning <- factor(mydata$current_zoning, labels = c(1:24))

# check unique values in prop_type
unique(mydata$prop_type)
```

```
## [1] "R"
```

```r
# As all the values are R, really this variable won't be a good predictor.
# Ignoring it

# don't need addr_full in the final data set as we have zip, latitude, longitude
# ignoring cityname and postalctyyn for the same reason
```

```r
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
```

```r
# picking only numerical attributes to check correlation to sale_price
hs_data_prcsd_num <- mydata %>% dplyr::select("Sale_Price","sale_reason","Sale_Warning_in",
"sale_instrument","zip5","lon","lat","building_grade",
"square_feet_total_living","bedrooms","bath_full_count",
"bath_half_count","bath_3qtr_count","year_built",
"year_renovated","sq_ft_lot","present_use")
```

```r
# create correlation matrix
cor(hs_data_prcsd_num, method = "pearson", use = "complete.obs")
```

```
##                           Sale_Price  sale_reason Sale_Warning_in
## Sale_Price                1.00000000 -0.116643537     0.083211139
## sale_reason              -0.11664354  1.000000000     0.355583265
## Sale_Warning_in           0.08321114  0.355583265     1.000000000
## sale_instrument          -0.04070601  0.399856649     0.343648065
## zip5                      0.06014866  0.001393069     0.029425761
## lon                       0.04684745 -0.013531540     0.036575404
## lat                       0.02119829 -0.031965818    -0.034812917
## building_grade            0.39122909 -0.078912289    -0.063020490
## square_feet_total_living  0.45458758 -0.065212764    -0.012080335
## bedrooms                  0.22546748 -0.056284214    -0.007526779
## bath_full_count           0.28484899 -0.073127789    -0.015603326
## bath_half_count           0.16582843 -0.051526350    -0.016935167
## bath_3qtr_count           0.03574175 -0.000687221    -0.021751887
## year_built                0.24267127 -0.120238360    -0.052099288
## year_renovated            0.03286429  0.024343886     0.040703002
## sq_ft_lot                 0.11981223  0.034005560     0.086937090
## present_use              -0.02542926 -0.002062742     0.003681498
##                          sale_instrument         zip5         lon         lat
## Sale_Price                  -0.040706012  0.060148664  0.04684745  0.02119829
## sale_reason                  0.399856649  0.001393069 -0.01353154 -0.03196582
## Sale_Warning_in              0.343648065  0.029425761  0.03657540 -0.03481292
## sale_instrument              1.000000000 -0.016103809 -0.02192079 -0.04966602
## zip5                        -0.016103809  1.000000000  0.35337066 -0.13431164
## lon                         -0.021920789  0.353370662  1.00000000 -0.04101493
## lat                         -0.049666024 -0.134311637 -0.04101493  1.00000000
## building_grade              -0.048442696  0.103989081  0.03312593  0.01217953
```

```
## square_feet_total_living    -0.007000713  0.095658773  0.06857118 -0.06383585
## bedrooms                    -0.001834812 -0.036622671 -0.24149623 -0.15481695
## bath_full_count             -0.025098358  0.098244669  0.13139051  0.07757143
## bath_half_count             -0.034397435  0.024996235  0.02574174 -0.04252565
## bath_3qtr_count              0.015641257 -0.074930308 -0.13644355 -0.10044764
## year_built                  -0.096159040  0.100989530  0.34235695  0.37787153
## year_renovated               0.011207272 -0.005762662 -0.02017440 -0.09174116
## sq_ft_lot                    0.124543302  0.089844639  0.20108459 -0.14545622
## present_use                  0.001793940  0.029112870  0.12844704  0.01760738
##                           building_grade square_feet_total_living     bedrooms
## Sale_Price                    0.39122909              0.454587585  0.225467478
## sale_reason                  -0.07891229             -0.065212764 -0.056284214
## Sale_Warning_in              -0.06302049             -0.012080335 -0.007526779
## sale_instrument              -0.04844270             -0.007000713 -0.001834812
## zip5                          0.10398908              0.095658773 -0.036622671
## lon                           0.03312593              0.068571180 -0.241496234
## lat                           0.01217953             -0.063835847 -0.154816948
## building_grade                1.00000000              0.745180518  0.342565614
## square_feet_total_living      0.74518052              1.000000000  0.575347048
## bedrooms                      0.34256561              0.575347048  1.000000000
## bath_full_count               0.45941631              0.517783777  0.304598944
## bath_half_count               0.28076582              0.316856642  0.162334411
## bath_3qtr_count               0.06951439              0.198673964  0.247340383
## year_built                    0.36192968              0.306427289  0.012441913
## year_renovated               -0.01902482              0.043396050  0.014923912
## sq_ft_lot                     0.13843064              0.234104503  0.047173368
## present_use                   0.04472257              0.032493682 -0.038895101
##                           bath_full_count bath_half_count bath_3qtr_count
## Sale_Price                     0.28484899      0.16582843     0.035741748
## sale_reason                   -0.07312779     -0.05152635    -0.000687221
## Sale_Warning_in               -0.01560333     -0.01693517    -0.021751887
## sale_instrument               -0.02509836     -0.03439744     0.015641257
## zip5                           0.09824467      0.02499624    -0.074930308
## lon                            0.13139051      0.02574174    -0.136443549
## lat                            0.07757143     -0.04252565    -0.100447636
## building_grade                 0.45941631      0.28076582     0.069514388
## square_feet_total_living       0.51778378      0.31685664     0.198673964
## bedrooms                       0.30459894      0.16233441     0.247340383
## bath_full_count                1.00000000      0.21731460    -0.379105667
## bath_half_count                0.21731460      1.00000000    -0.315842525
## bath_3qtr_count               -0.37910567     -0.31584253     1.000000000
## year_built                     0.45259966      0.19849009    -0.152354857
## year_renovated                 0.02218095     -0.02665661     0.018358504
## sq_ft_lot                      0.04699255      0.02810463     0.049156430
## present_use                    0.03364950      0.01931299     0.001521253
##                            year_built year_renovated   sq_ft_lot  present_use
## Sale_Price                 0.24267127    0.032864291  0.11981223 -0.025429262
## sale_reason               -0.12023836    0.024343886  0.03400556 -0.002062742
## Sale_Warning_in           -0.05209929    0.040703002  0.08693709  0.003681498
## sale_instrument           -0.09615904    0.011207272  0.12454330  0.001793940
## zip5                       0.10098953   -0.005762662  0.08984464  0.029112870
## lon                        0.34235695   -0.020174395  0.20108459  0.128447040
## lat                        0.37787153   -0.091741159 -0.14545622  0.017607381
## building_grade             0.36192968   -0.019024817  0.13843064  0.044722573
```

```
## square_feet_total_living  0.30642729    0.043396050  0.23410450  0.032493682
## bedrooms                  0.01244191    0.014923912  0.04717337 -0.038895101
## bath_full_count           0.45259966    0.022180945  0.04699255  0.033649501
## bath_half_count           0.19849009   -0.026656615  0.02810463  0.019312989
## bath_3qtr_count          -0.15235486    0.018358504  0.04915643  0.001521253
## year_built                1.00000000   -0.224586183 -0.13491395  0.130783379
## year_renovated           -0.22458618    1.000000000  0.06320824 -0.017558495
## sq_ft_lot                -0.13491395    0.063208244  1.00000000  0.059320852
## present_use               0.13078338   -0.017558495  0.05932085  1.000000000
```

```r
# We can see some of the lowest correlations to sale_price are -
# 1. sale price ~ sale_intrument = -0.040706012
# 2. sale_price ~ zip5 = 0.060148664
# 3. sale_price ~ log = 0.04684745
# 4. sale_price ~ lat = 0.02119829
# 5. sale_price ~ bath_3qtr_count = 0.035741748
# 6. sale_price ~ year_renovated = 0.032864291
# 7. sale_price ~ present_use = -0.025429262
# 8. sale_price ~ sale_warning_in = 0.083211139
```

b. ii. Create two variables; one that will contain the variables Sale Price

and Square Foot of Lot (same variables used from previous assignment on simple

regression) and one that will contain Sale Price and several additional

predictors of your choice. Explain the basis for your additional predictor

selections.

```r
# creating model with just sale price and square feet of the sq_ft_lot
hs_data_smpl_rgr_mdl <- lm(Sale_Price ~ sq_ft_lot, data = mydata)

# creating data set with several additional predictors of my choice
# My choice is purely based on their correlation
# with predicted variable Sale_Price
# Highest correlations are -
# 1. Sale_Price ~ sale_reason = -0.116643537
# 2. Sale_Price ~ building_grade = 0.39122909
# 3. Sale_Price ~ square_feet_total_living = 0.454587585
# 4. Sale_Price ~ bedrooms = 0.225467478
# 5. Sale_Price ~ bath_full_count = 0.28484899
# 6. Sale_Price ~ bath_half_count = 0.16582843
# 7. Sale_Price ~ year_built = 0.24267127
# 8. Sale_Price ~ sq_ft_lot = 0.11981223
```

```
# Checking correlation of Sale_Price with factor variables - sitetype, current_zoning
# applying Kruskal-Wallis chi-squared test as categorical variable is not
# dichotomous
kruskal.test(mydata$Sale_Price~mydata$sitetype)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  mydata$Sale_Price by mydata$sitetype
## Kruskal-Wallis chi-squared = 387.31, df = 6, p-value < 2.2e-16
```

```
kruskal.test(mydata$Sale_Price~mydata$current_zoning)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  mydata$Sale_Price by mydata$current_zoning
## Kruskal-Wallis chi-squared = 1636.5, df = 23, p-value < 2.2e-16
```

```
# Both the variables are highly correlated to Sale_Price and will include
# them as well as the predictor variables

# Run 1 : creating multiple regression model with sale price and several
# other predictors found relevant based on correlation exercise
hs_data_multi_rgr_mdl <- lm(Sale_Price ~ sale_reason+building_grade+
square_feet_total_living+bedrooms+bath_full_count+bath_half_count+
year_built+sq_ft_lot+sitetype+current_zoning, data = mydata)
```

b. iii. Execute a summary() function on two variables defined in the previous

step to compare the model results. What are the R2 and Adjusted R2 statistics?

Explain what these results tell you about the overall model. Did the inclusion

of the additional predictors help explain any large variations found in Sale Price?

```
# check summary of simple regression model
summary(hs_data_smpl_rgr_mdl)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2016064  -194842   -63293    91565  3735109
##
```

```
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 6.418e+05  3.800e+03  168.90   <2e-16 ***
## sq_ft_lot   8.510e-01  6.217e-02   13.69   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 401500 on 12863 degrees of freedom
## Multiple R-squared:  0.01435,    Adjusted R-squared:  0.01428
## F-statistic: 187.3 on 1 and 12863 DF,  p-value: < 2.2e-16
```

```
#Multiple R-squared:  0.01435,  Adjusted R-squared:  0.01428
#F-statistic: 187.3 on 1 and 12863 DF,  p-value: < 2.2e-16

# check summary of multiple regression model
summary(hs_data_multi_rgr_mdl)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bedrooms + bath_full_count + bath_half_count + year_built +
##     sq_ft_lot + sitetype + current_zoning, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2045030  -121627   -41643    47525  3657041
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.848e+06  5.584e+05  -3.310 0.000935 ***
## sale_reason              -1.133e+04  1.165e+03  -9.724  < 2e-16 ***
## building_grade            2.596e+04  4.704e+03   5.520 3.46e-08 ***
## square_feet_total_living  1.456e+02  6.064e+00  24.003  < 2e-16 ***
## bedrooms                 -1.906e+04  4.867e+03  -3.917 9.03e-05 ***
## bath_full_count           1.533e+04  6.027e+03   2.544 0.010973 *
## bath_half_count           1.924e+04  6.348e+03   3.031 0.002445 **
## year_built                1.429e+03  2.725e+02   5.243 1.61e-07 ***
## sq_ft_lot                 2.695e-01  7.200e-02   3.743 0.000182 ***
## sitetype2                 8.307e+04  2.380e+05   0.349 0.727110
## sitetype3                -3.429e+05  1.901e+05  -1.804 0.071244 .
## sitetype4                -2.182e+05  1.244e+05  -1.754 0.079421 .
## sitetype5                -3.186e+05  1.257e+05  -2.536 0.011234 *
## sitetype6                -3.619e+05  1.558e+05  -2.323 0.020185 *
## sitetype7                -3.799e+05  3.712e+05  -1.023 0.306113
## current_zoning2           2.891e+06  3.806e+05   7.596 3.26e-14 ***
## current_zoning3          -3.569e+05  3.746e+05  -0.953 0.340767
## current_zoning4          -7.066e+05  1.436e+05  -4.920 8.77e-07 ***
## current_zoning5          -7.278e+05  3.747e+05  -1.943 0.052094 .
## current_zoning6          -6.597e+05  1.368e+05  -4.824 1.42e-06 ***
## current_zoning7          -7.086e+05  1.363e+05  -5.198 2.04e-07 ***
## current_zoning8          -8.296e+05  1.568e+05  -5.290 1.25e-07 ***
## current_zoning9          -7.010e+05  1.881e+05  -3.727 0.000194 ***
## current_zoning10         -6.526e+05  1.354e+05  -4.821 1.44e-06 ***
## current_zoning11         -6.094e+05  1.343e+05  -4.537 5.76e-06 ***
## current_zoning12         -6.255e+05  1.399e+05  -4.472 7.83e-06 ***
```

```
## current_zoning13         -6.927e+05  1.343e+05  -5.158 2.54e-07 ***
## current_zoning14         -7.019e+05  1.343e+05  -5.225 1.77e-07 ***
## current_zoning15         -1.705e+05  1.509e+05  -1.130 0.258483
## current_zoning16         -2.342e+05  1.430e+05  -1.638 0.101544
## current_zoning17         -7.102e+05  1.406e+05  -5.049 4.49e-07 ***
## current_zoning18         -2.589e+05  2.454e+05  -1.055 0.291434
## current_zoning19         -6.443e+05  1.354e+05  -4.758 1.98e-06 ***
## current_zoning20         -7.247e+05  1.669e+05  -4.343 1.42e-05 ***
## current_zoning21         -6.687e+05  1.462e+05  -4.574 4.83e-06 ***
## current_zoning22         -7.133e+05  1.337e+05  -5.336 9.66e-08 ***
## current_zoning23         -7.711e+05  1.399e+05  -5.512 3.61e-08 ***
## current_zoning24         -6.504e+05  1.346e+05  -4.832 1.37e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 349500 on 12827 degrees of freedom
## Multiple R-squared:  0.255,  Adjusted R-squared:  0.2528
## F-statistic: 118.7 on 37 and 12827 DF,  p-value: < 2.2e-16
```

```r
# Run 2 : Recreating multiple regression model by applying backward elimination
# of non significant variables. sitetype appears non-significant
# with p-values > 0.05
hs_data_multi_rgr_mdl_2 <- lm(Sale_Price ~ sale_reason+building_grade+
square_feet_total_living+bedrooms+bath_full_count+bath_half_count+
year_built+sq_ft_lot+current_zoning, data = mydata)
# check summary of multiple regression model
summary(hs_data_multi_rgr_mdl_2)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bedrooms + bath_full_count + bath_half_count + year_built +
##     sq_ft_lot + current_zoning, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2058754  -122967   -42250    47356  3661440
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.991e+06  5.425e+05  -3.671 0.000243 ***
## sale_reason              -1.147e+04  1.166e+03  -9.835  < 2e-16 ***
## building_grade            2.609e+04  4.699e+03   5.552 2.87e-08 ***
## square_feet_total_living  1.474e+02  6.057e+00  24.328  < 2e-16 ***
## bedrooms                 -1.721e+04  4.853e+03  -3.545 0.000393 ***
## bath_full_count           1.441e+04  6.027e+03   2.390 0.016863 *
## bath_half_count           1.736e+04  6.341e+03   2.737 0.006205 **
## year_built                1.385e+03  2.721e+02   5.089 3.66e-07 ***
## sq_ft_lot                 2.721e-01  7.176e-02   3.792 0.000150 ***
## current_zoning2           2.888e+06  3.810e+05   7.580 3.68e-14 ***
## current_zoning3          -3.542e+05  3.751e+05  -0.945 0.344921
## current_zoning4          -7.344e+05  1.437e+05  -5.111 3.25e-07 ***
## current_zoning5          -7.237e+05  3.751e+05  -1.929 0.053711 .
## current_zoning6          -6.579e+05  1.369e+05  -4.806 1.56e-06 ***
## current_zoning7          -7.115e+05  1.364e+05  -5.215 1.87e-07 ***
```

```
## current_zoning8          -8.201e+05  1.570e+05  -5.223 1.79e-07 ***
## current_zoning9          -6.988e+05  1.883e+05  -3.711 0.000207 ***
## current_zoning10         -6.510e+05  1.355e+05  -4.804 1.58e-06 ***
## current_zoning11         -6.096e+05  1.345e+05  -4.533 5.86e-06 ***
## current_zoning12         -6.238e+05  1.400e+05  -4.455 8.47e-06 ***
## current_zoning13         -6.950e+05  1.344e+05  -5.170 2.38e-07 ***
## current_zoning14         -6.987e+05  1.345e+05  -5.195 2.08e-07 ***
## current_zoning15         -1.692e+05  1.510e+05  -1.120 0.262663
## current_zoning16         -2.335e+05  1.432e+05  -1.630 0.103021
## current_zoning17         -7.061e+05  1.408e+05  -5.015 5.37e-07 ***
## current_zoning18         -2.580e+05  2.457e+05  -1.050 0.293614
## current_zoning19         -6.412e+05  1.356e+05  -4.730 2.27e-06 ***
## current_zoning20         -7.213e+05  1.671e+05  -4.317 1.59e-05 ***
## current_zoning21         -6.596e+05  1.462e+05  -4.512 6.48e-06 ***
## current_zoning22         -7.120e+05  1.338e+05  -5.320 1.05e-07 ***
## current_zoning23         -7.741e+05  1.400e+05  -5.530 3.27e-08 ***
## current_zoning24         -6.495e+05  1.347e+05  -4.820 1.45e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 350000 on 12833 degrees of freedom
## Multiple R-squared:  0.2528, Adjusted R-squared:  0.251
## F-statistic: 140.1 on 31 and 12833 DF,  p-value: < 2.2e-16
```

```r
#Multiple R-squared:  0.2528,   Adjusted R-squared:  0.251
#F-statistic: 140.1 on 31 and 12833 DF,  p-value: < 2.2e-16

# Run 3 : Recreating multiple regression model by applying backward elimination
# of non significant variables. current_zoning appears non-significant with
# some created variables of it having p-values > 0.05
hs_data_multi_rgr_mdl_3 <- lm(Sale_Price ~ sale_reason+building_grade+
square_feet_total_living+bedrooms+bath_full_count+bath_half_count+year_built+sq_ft_lot, data = mydata)
# check summary of multiple regression model
summary(hs_data_multi_rgr_mdl_3)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bedrooms + bath_full_count + bath_half_count + year_built +
##     sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2130758  -119409   -44728    41346  3722325
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -4.238e+06  4.339e+05  -9.767  < 2e-16 ***
## sale_reason              -1.163e+04  1.182e+03  -9.844  < 2e-16 ***
## building_grade            2.985e+04  4.446e+03   6.714 1.97e-11 ***
## square_feet_total_living  1.421e+02  5.957e+00  23.847  < 2e-16 ***
## bedrooms                 -8.170e+03  4.593e+03  -1.779   0.0753 .
## bath_full_count           1.384e+04  6.073e+03   2.279   0.0227 *
## bath_half_count           5.876e+03  6.324e+03   0.929   0.3528
## year_built                2.159e+03  2.202e+02   9.806  < 2e-16 ***
```

```
## sq_ft_lot                 2.972e-01  5.888e-02   5.046 4.56e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 355100 on 12856 degrees of freedom
## Multiple R-squared:  0.2295, Adjusted R-squared:  0.2291
## F-statistic: 478.8 on 8 and 12856 DF,  p-value: < 2.2e-16
```

```r
# Intercept has drastically changed. Also p-values for bedrooms and
# bath_half_count have changed and they no more significant and
# have p-values > 0.05

# Run 4 : Recreating multiple regression model by applying backward elimination
# of non significant variables. bedrooms, bath_half_count appears non-significant
# with p-values > 0.05
hs_data_multi_rgr_mdl_4 <- lm(Sale_Price ~ sale_reason+building_grade+
square_feet_total_living+bath_full_count+year_built+sq_ft_lot, data = mydata)

# check summary of multiple regression model
summary(hs_data_multi_rgr_mdl_4)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bath_full_count + year_built + sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2136788  -119779   -44670    41079  3720748
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -4.477e+06  4.165e+05 -10.749  < 2e-16 ***
## sale_reason              -1.156e+04  1.180e+03  -9.792  < 2e-16 ***
## building_grade            3.106e+04  4.404e+03   7.053 1.84e-12 ***
## square_feet_total_living  1.374e+02  5.083e+00  27.038  < 2e-16 ***
## bath_full_count           1.288e+04  6.040e+03   2.132    0.033 *
## year_built                2.268e+03  2.132e+02  10.640  < 2e-16 ***
## sq_ft_lot                 3.132e-01  5.805e-02   5.395 6.97e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 355100 on 12858 degrees of freedom
## Multiple R-squared:  0.2293, Adjusted R-squared:  0.2289
## F-statistic: 637.6 on 6 and 12858 DF,  p-value: < 2.2e-16
```

```r
# Intercept seems to have stabilized with highly significant p-value
# All remaining predictor variables are highly significant with p-values < 0.05
# F-statistic has significantly improved with highly significant p-value
# Residual standard error: 355100 on 12858 degrees of freedom
# Multiple R-squared:  0.2293,  Adjusted R-squared:  0.2289
# F-statistic: 637.6 on 6 and 12858 DF,  p-value: < 2.2e-16
```

Comparing simple regression to multi regression model

1. Multiple R-squared (variation explained) - In simple regression sq_ft_lot explains only 1.4% of variation in Sale_Price while in final multi regression model 4 predictors together explains almost 23% variation in Sale_Price.
2. Adjusted R-squared - Difference between adjusted R-squared and R-squared in multi regression model is 0.0004 while same difference in simple linear regression is 0.001 which is higher. In ideal world we would like adjusted R-squared to be same as R-squared to say that model can be more genralized and represent population.
3. P-value of predictors - P-values for each predictor in both simple regression and multi regression are highly significant and almost all of them are well below critical value of 0.05.
4. F-statistic - Fscore of multi regression model is almost 4.5 times that of simple regression model. P-value of both models is highly significant. This means that R-squared of multi regression model is more significant than that of simple regression model.
Overall multiple regression model is a much better predictive model for Sale_Price

b. iv. Considering the parameters of the multiple regression model you

have created. What are the standardized betas for each parameter and

what do the values indicate?

Absolute values of beta coeffients of multi regression model are comparatively higher and showing higher strength of the effect of each individual independent variable to the dependent variable. Most of the coefficients are positive showing positive effect on Sale_price.
This mean that unit change in square_feet_total_living will cause Sale_Price to go up by 137.4 units, while keeping effect of all other predictors constant. We can say that effect of sq_feet_tital_living is more compared to sq_ft_lot on Sale_Price when then are seen individually keep other predictors constant. p-values associated with t values of precitors are very significant and well below cut-off value of 0.05 and in most case below 0.01 which would they will be significant in more than 99% cases. With t value of 27.038 and p-value < 0.01

square_feet_total_living is most significant precitor of the model.

```
summary(hs_data_multi_rgr_mdl_4)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bath_full_count + year_built + sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2136788  -119779   -44670    41079  3720748
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -4.477e+06  4.165e+05 -10.749  < 2e-16 ***
## sale_reason              -1.156e+04  1.180e+03  -9.792  < 2e-16 ***
## building_grade            3.106e+04  4.404e+03   7.053 1.84e-12 ***
## square_feet_total_living  1.374e+02  5.083e+00  27.038  < 2e-16 ***
## bath_full_count           1.288e+04  6.040e+03   2.132    0.033 *
## year_built                2.268e+03  2.132e+02  10.640  < 2e-16 ***
## sq_ft_lot                 3.132e-01  5.805e-02   5.395 6.97e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 355100 on 12858 degrees of freedom
## Multiple R-squared:  0.2293, Adjusted R-squared:  0.2289
## F-statistic: 637.6 on 6 and 12858 DF,  p-value: < 2.2e-16
```

Absolute value of beta coeffient of simple regression model is comparatively lower i.e. 0.85 and thus showing weaker strength of the effect of predictor variable to predicted variable. Coefficient is positive showing positive relationship. One unit change in sq_ft_lot will cause 0.85 units of change in Sale_Price. p-value for sq_ft_lot is highly significant and well below 0.01 which means in 99%+ cases this effect will stant true.

```
summary(hs_data_smpl_rgr_mdl)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2016064  -194842   -63293    91565  3735109
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 6.418e+05  3.800e+03  168.90   <2e-16 ***
## sq_ft_lot   8.510e-01  6.217e-02   13.69   <2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 401500 on 12863 degrees of freedom
## Multiple R-squared:  0.01435,    Adjusted R-squared:  0.01428
## F-statistic: 187.3 on 1 and 12863 DF,  p-value: < 2.2e-16
```

We can also get standardized beta estimates using lm.beta() of QuantPsyc package.

```
library(QuantPsyc)
```

```
## Loading required package: boot

## Loading required package: MASS

##
## Attaching package: 'MASS'

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

##
## Attaching package: 'QuantPsyc'

## The following object is masked from 'package:base':
##
##     norm
```

```
lm.beta(hs_data_multi_rgr_mdl_4)
```

```
##              sale_reason           building_grade square_feet_total_living
##              -0.07645294               0.08392564               0.33641067
##          bath_full_count               year_built                sq_ft_lot
##               0.02072611               0.09658661               0.04409583
```

As standardized beta values are calculated in standard deviation units for all predictors they can be easily compared to each other. We can see that for square__feet__total__living standard beta value is 0.33 (one standard deviation unit increase in square__feet__total__living will cause 0.33 standard deviation unit increase in Sale Price) which is much higher than any other predictor's value and thus it indicates highest effect of square__feet__total__living on Sale__Price.

b v. Calculate the confidence intervals for the parameters in your model and

explain what the results indicate.

```
# calculating confidence interval for the parameters of simple regression model
confint(hs_data_smpl_rgr_mdl)
```

```
##                    2.5 %       97.5 %
## (Intercept) 6.343730e+05 6.492698e+05
## sq_ft_lot   7.291208e-01 9.728641e-01
```

```r
# calculating confidence interval for the parameters of multiple regression model 4
confint(hs_data_multi_rgr_mdl_4)
```

```
##                                  2.5 %        97.5 %
## (Intercept)              -5.293246e+06 -3.660485e+06
## sale_reason              -1.386989e+04 -9.243201e+03
## building_grade            2.242855e+04  3.969337e+04
## square_feet_total_living  1.274738e+02  1.474013e+02
## bath_full_count           1.038854e+03  2.471804e+04
## year_built                1.850308e+03  2.685978e+03
## sq_ft_lot                 1.994069e-01  4.269936e-01
```

In simple linear regression model confidence interval is comparatively less wide and thus sample b value of predictor sq_ft_lot is more representative of being closer to beta value in population. In multi regression model, confidence intervals for few variables like bath_full_count, sale_reason, and even building_grade are wider and thus we are comparatively lesser confident about the mean of the future values. It is generally suggested to increase the sample size if CI is too wide, which doesn't seems to be the case in either model. In either model confidence interval does not cross zero for any of the predictors and thus it is indicative that relationships strength is good between predictors and predcited variables and thus model will not be predicting positive in some samples while negative in other samples because of particular predictor.

b. vi. Assess the improvement of the new model compared to your original model

(simple regression model) by testing whether this change is significant by

performing an analysis of variance.

```r
# Running ANOVA for simple regression model
aov(Sale_Price ~ sq_ft_lot, data = mydata)
```

```
## Call:
##    aov(formula = Sale_Price ~ sq_ft_lot, data = mydata)
##
## Terms:
##                    sq_ft_lot    Residuals
## Sum of Squares  3.019674e+13 2.073377e+15
## Deg. of Freedom            1        12863
##
## Residual standard error: 401483.8
## Estimated effects may be unbalanced
```

```r
# Running ANOVA for multiple regression model
aov(Sale_Price ~ sale_reason+building_grade+
square_feet_total_living+bath_full_count+year_built+sq_ft_lot, data = mydata)
```

```
## Call:
##    aov(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bath_full_count + year_built + sq_ft_lot, data = mydata)
##
## Terms:
##                  sale_reason building_grade square_feet_total_living
## Sum of Squares  2.862062e+13   3.089249e+14             1.249171e+14
## Deg. of Freedom            1              1                        1
##                 bath_full_count   year_built    sq_ft_lot    Residuals
## Sum of Squares     4.206324e+12 1.202280e+13 3.669902e+12 1.621212e+15
## Deg. of Freedom               1            1            1        12858
##
## Residual standard error: 355085.7
## Estimated effects may be unbalanced
```

We can observe that Residual standard error in case of simple linear regression is higher than that of multi regression model and thus there is more unexplained variation in data by simple regression model predictor that multi regression model predictors together. In other words multi regression model is better model to explain variation in the data.

b. vii. Perform casewise diagnostics to identify outliers and/or influential cases,

storing each function's output in a dataframe assigned to a unique variable name.

Statistics to identify outliers in the data by checking residuals using resid(), standard residuals using rstandard() and studentized residual using rstudent().

Identifying influencial cases -

1. Cook's distance - Access overall influence of a single case on the model.

Cook and Weisberg (1982) have suggested that values greater than 1 may be cause for concern. If a point is a significant outlier on Y, but its Cook's distance is $<$ 1, there is no real need to delete that point since it does not have a large effect on the regression analysis. Using cooks.distance()

2. Hat value (leverage) - Value of 0 would mean that case has no influence, while value of 1 would indicate that case has complete influence over prediction. If no cases exert undue influence over the model then we would expect all of the leverage values to be close to the average value ((k + 1)/ n). Using hatvalues().

3. DFFit & DFbeta - It is the difference between the predicted value for a

case when the model is fitted including that case and when the model is fitted excluding that case. Using dffits() and DFBeta using dfbeta().

adding variables to check each of above case level statistics to original data frames.

```
# adding case level residual/outlier and influencial stats for multi regression model
mydata$residuals <- resid(hs_data_multi_rgr_mdl_4)
mydata$standardized.residuals <- rstandard(hs_data_multi_rgr_mdl_4)
mydata$studentized.residuals <- rstudent(hs_data_multi_rgr_mdl_4)
mydata$cooks.distance <- cooks.distance(hs_data_multi_rgr_mdl_4)
mydata$dfbeta <- dfbeta(hs_data_multi_rgr_mdl_4)
mydata$dffit <- dffits(hs_data_multi_rgr_mdl_4)
mydata$leverage <- hatvalues(hs_data_multi_rgr_mdl_4)
mydata$covariance.ratios <- covratio(hs_data_multi_rgr_mdl_4)
# looking at the data
# mydata
# writing the saved stats for each case into a table
write.table(mydata, "House Sales With Diagnostics.dat", sep = "\t", row.names = FALSE)
# nrow(mydata) -- 12865
# check if about 5% of cases (<= 643 cases) have standardized residual within +-2.
sum(mydata$standardized.residuals > 2 | mydata$standardized.residuals < -2)
```

```
## [1] 329
```

```
# As only 329 cases are outside range or have large residuals, we are well within the range of 5% outli

# To exactly identify outliers we can add a variable called large.residual in the data frame to save th
mydata$large.residual <- mydata$standardized.residuals > 2 | mydata$standardized.residuals < -2
# we can now select the outlier cases by select rows with large.residual = TRUE
# model is fairly accurate

# check how many cases have standard residuals > 3 which may be we can investigate further
sum(mydata$standardized.residuals > 3 | mydata$standardized.residuals < -3)
```

```
## [1] 213
```

```
# create a variable to flag cases with very large residual
mydata$very.large.residual <- mydata$standardized.residuals > 3 | mydata$standardized.residuals < -3
# 213 cases out of 12865 -- about 1.65%

# Let's look at the leverage (hat value), cook's distance, and covariance ratio
# for cases with large.residual = TRUE
mydata[mydata$large.residual, c("cooks.distance","leverage","covariance.ratios")]
```

```
##       cooks.distance     leverage covariance.ratios
## 25      0.0010257923 0.0011869228         0.9984429
## 108     0.0033044011 0.0042136523         1.0017920
## 115     0.0024117590 0.0018063670         0.9972755
## 178     0.0011465389 0.0012854582         0.9984365
## 239     0.0001090031 0.0001668056         0.9982225
## 246     0.0031564325 0.0017464582         0.9954241
## 287     0.0006893490 0.0007933254         0.9980305
## 295     0.2396277578 0.1188300220         1.1278061
## 300     0.0075267399 0.0043854071         0.9984257
```

```
## 341      0.0004487567 0.0006708699         0.9986685
## 344      0.0057351762 0.0089305205         1.0071144
## 359      0.0017397504 0.0014731451         0.9975264
## 385      0.0025307845 0.0015599477         0.9959382
## 396      0.0014805940 0.0014632775         0.9981591
## 475      0.0006986847 0.0009934765         0.9988611
## 482      0.0031738517 0.0039360295         1.0014278
## 508      0.0033052073 0.0053950353         1.0036382
## 528      0.0010875245 0.0016248737         0.9996238
## 576      0.0008319101 0.0013155085         0.9994538
## 661      0.0027968265 0.0028437415         0.9996540
## 670      0.0016660191 0.0005997724         0.9906016
## 679      0.0070450303 0.0036509393         0.9968763
## 742      0.0004484261 0.0007724219         0.9991065
## 784      0.0019524886 0.0023320386         0.9996953
## 802      0.0010311108 0.0015000453         0.9994297
## 811      0.0035835198 0.0009199438         0.9867072
## 852      0.0009102800 0.0015231355         0.9997943
## 853      0.0004455858 0.0007137136         0.9988811
## 877      0.0016204219 0.0014373881         0.9976943
## 916      0.0045527934 0.0030400158         0.9978991
## 1009     0.0002877654 0.0004295533         0.9984230
## 1099     0.0009422438 0.0015341461         0.9997424
## 1119     0.0020112581 0.0015651144         0.9972234
## 1142     0.0011810063 0.0010314525         0.9972200
## 1155     0.0149292319 0.0095001048         1.0041643
## 1305     0.0011346071 0.0016966438         0.9996980
## 1345     0.0002542520 0.0004161686         0.9986340
## 1368     0.0007075141 0.0011555917         0.9993700
## 1380     0.0003101548 0.0004637808         0.9984617
## 1442     0.0016275507 0.0015502173         0.9981018
## 1492     0.0010091685 0.0012623284         0.9987649
## 1504     0.0048822856 0.0030902960         0.9976377
## 1543     0.0010641713 0.0017134567         0.9998962
## 1550     0.0008218085 0.0008187770         0.9975437
## 1633     0.0001621965 0.0002170445         0.9979159
## 1650     0.0135138750 0.0062910557         0.9987168
## 1716     0.0009970945 0.0007971874         0.9965835
## 1745     0.0009432943 0.0007656760         0.9966233
## 1870     0.0074126080 0.0066798036         1.0030493
## 1962     0.0024740915 0.0014260536         0.9953770
## 1963     0.0006106903 0.0007478570         0.9981840
## 1964     0.0008404656 0.0004465255         0.9938367
## 1976     0.0013242658 0.0003997737         0.9883823
## 1977     0.0006853792 0.0001884214         0.9869458
## 1978     0.0012447634 0.0003547031         0.9875953
## 1979     0.0006774109 0.0001869084         0.9869939
## 1980     0.0012740900 0.0003552299         0.9873042
## 1981     0.0014775095 0.0004630181         0.9889040
## 1982     0.0012863954 0.0003793806         0.9880669
## 2022     0.0013424594 0.0009537856         0.9961454
## 2099     0.0005363480 0.0006876495         0.9982629
## 2137     0.0005589791 0.0003740237         0.9952344
## 2157     0.0005565648 0.0005217858         0.9970069
```

```
## 2264    0.0031592360 0.0015138722          0.9941316
## 2302    0.0017626301 0.0024168498          1.0001911
## 2360    0.0005459138 0.0005608369          0.9974005
## 2361    0.0024410539 0.0009953756          0.9922280
## 2469    0.0004473775 0.0003714912          0.9963336
## 2684    0.0015598153 0.0004735320          0.9885261
## 2685    0.0012316856 0.0003774574          0.9885464
## 2686    0.0014329427 0.0005141746          0.9904813
## 2687    0.0012141040 0.0003613572          0.9881655
## 2688    0.0011725802 0.0003451790          0.9880091
## 2689    0.0013120914 0.0004579103          0.9901284
## 2690    0.0013092871 0.0004699203          0.9904396
## 2699    0.0340776069 0.0254130949          1.0215325
## 2708    0.0013991091 0.0008301737          0.9949675
## 2709    0.0012136735 0.0008456224          0.9959317
## 2710    0.0017277029 0.0010943362          0.9956365
## 2717    0.0030168291 0.0015203003          0.9945262
## 2742    0.0005096100 0.0004644780          0.9968336
## 2852    0.0323551464 0.0084297003          0.9945063
## 2934    0.0009961450 0.0007971874          0.9965880
## 2937    0.0009613303 0.0007971874          0.9967538
## 3097    0.0026676183 0.0014175848          0.9948117
## 3102    0.0007357039 0.0006850037          0.9971425
## 3110    0.0008237369 0.0008555478          0.9977359
## 3111    0.0003968700 0.0005785581          0.9985112
## 3168    0.0039875726 0.0004821071          0.9699125
## 3169    0.0033779971 0.0004123887          0.9701391
## 3170    0.0029576959 0.0003738115          0.9711367
## 3171    0.0027292290 0.0003492111          0.9714720
## 3172    0.0027537800 0.0003513317          0.9713897
## 3173    0.0027317318 0.0003496169          0.9714795
## 3174    0.0027533928 0.0003512709          0.9713887
## 3175    0.0030548353 0.0003796849          0.9706469
## 3176    0.0027749988 0.0003587433          0.9717792
## 3177    0.0026791022 0.0003464883          0.9717788
## 3178    0.0026799098 0.0003466282          0.9717818
## 3179    0.0028631251 0.0003611646          0.9710675
## 3180    0.0026810696 0.0003468243          0.9717859
## 3181    0.0028623150 0.0003610450          0.9710660
## 3182    0.0039884401 0.0004822319          0.9699139
## 3183    0.0039868755 0.0004820066          0.9699114
## 3184    0.0039868755 0.0004820066          0.9699114
## 3185    0.0039885428 0.0004822466          0.9699141
## 3186    0.0039875726 0.0004821071          0.9699125
## 3187    0.0039875726 0.0004821071          0.9699125
## 3188    0.0033853118 0.0004134073          0.9701493
## 3189    0.0030536527 0.0003795151          0.9706449
## 3190    0.0027516005 0.0003509865          0.9713838
## 3191    0.0030531822 0.0003794474          0.9706441
## 3192    0.0027294619 0.0003492496          0.9714728
## 3193    0.0027512095 0.0003509237          0.9713827
## 3194    0.0027509545 0.0003508825          0.9713819
## 3195    0.0026794947 0.0003465567          0.9717803
## 3196    0.0026803440 0.0003467022          0.9717834
```

```
## 3197     0.0027812390 0.0003597503          0.9717962
## 3198     0.0039902426 0.0004824902          0.9699168
## 3199     0.0039900914 0.0004824686          0.9699165
## 3200     0.0039868755 0.0004820066          0.9699114
## 3201     0.0039868755 0.0004820066          0.9699114
## 3202     0.0039868755 0.0004820066          0.9699114
## 3424     0.0024495202 0.0040292686          1.0022766
## 3464     0.0029958323 0.0003794015          0.9712020
## 3465     0.0028920607 0.0003723198          0.9716726
## 3466     0.0026276922 0.0003464232          0.9723251
## 3467     0.0026294974 0.0003467421          0.9723320
## 3468     0.0029970621 0.0003795821          0.9712041
## 3469     0.0028044725 0.0003604398          0.9716123
## 3470     0.0026272739 0.0003463465          0.9723233
## 3471     0.0028929496 0.0003724558          0.9716744
## 3472     0.0026776797 0.0003492414          0.9720233
## 3473     0.0027005098 0.0003511464          0.9719381
## 3474     0.0029999885 0.0003800094          0.9712089
## 3475     0.0026801737 0.0003496534          0.9720308
## 3476     0.0037772871 0.0004924125          0.9721523
## 3477     0.0026793022 0.0003495111          0.9720283
## 3478     0.0039134029 0.0004820066          0.9704772
## 3479     0.0039134029 0.0004820066          0.9704772
## 3480     0.0039134029 0.0004820066          0.9704772
## 3481     0.0039134029 0.0004820066          0.9704772
## 3482     0.0039134029 0.0004820066          0.9704772
## 3483     0.0039134076 0.0004820073          0.9704772
## 3484     0.0033146796 0.0004122789          0.9707011
## 3485     0.0028051885 0.0003710987          0.9724468
## 3486     0.0028040584 0.0003603760          0.9716114
## 3487     0.0027138345 0.0003583941          0.9723855
## 3488     0.0026989172 0.0003508860          0.9719335
## 3489     0.0026767519 0.0003490836          0.9720201
## 3490     0.0027005680 0.0003511558          0.9719383
## 3491     0.0037826809 0.0004935759          0.9721801
## 3492     0.0028922054 0.0003723420          0.9716729
## 3493     0.0026280542 0.0003464886          0.9723266
## 3494     0.0029973689 0.0003796270          0.9712046
## 3495     0.0039134076 0.0004820073          0.9704772
## 3496     0.0039134076 0.0004820073          0.9704772
## 3497     0.0039134076 0.0004820073          0.9704772
## 3523     0.0026507975 0.0015849983          0.9957735
## 3837     0.0006838252 0.0007383763          0.9977580
## 3918     0.0012625486 0.0015651144          0.9990412
## 3919     0.0007652759 0.0010314525          0.9987521
## 4055     0.0014804592 0.0011854653          0.9969800
## 4056     0.0045005009 0.0013619354          0.9893770
## 4248     0.0007189969 0.0012086223          0.9994892
## 4391     0.0011440636 0.0019973401          1.0003650
## 4435     0.0003501356 0.0004602009          0.9981078
## 4648     0.1052345743 0.0102109306          0.9722188
## 4649     0.6906373336 0.0441092700          0.9884534
## 4671     0.0033942707 0.0042189274          1.0017201
## 4695     0.0015209988 0.0004222043          0.9873116
```

```
## 4696    0.0012415938 0.0008215703           0.9956192
## 4740    0.0003991572 0.0006797623           0.9989884
## 4821    0.0018888427 0.0015127881           0.9973094
## 4834    0.0011454391 0.0009537856           0.9969297
## 4840    0.0156021509 0.0095001048           1.0038956
## 4934    0.0009536065 0.0009580187           0.9977148
## 5083    0.0901980470 0.0309037562           1.0213738
## 5491    0.0001204817 0.0001827619           0.9982166
## 5494    0.0001184603 0.0001828554           0.9982600
## 5495    0.0001210330 0.0001833950           0.9982144
## 5496    0.0001205418 0.0001828299           0.9982163
## 5497    0.0002495714 0.0003894789           0.9984937
## 5549    0.0007267978 0.0011075487           0.9991545
## 5935    0.0013552866 0.0010634637           0.9967606
## 6055    0.0009548636 0.0013018514           0.9990555
## 6230    0.0016927822 0.0003674489           0.9834783
## 6231    0.0016557276 0.0003716195           0.9840513
## 6232    0.0018284484 0.0004261427           0.9847252
## 6233    0.0018688703 0.0003973082           0.9831440
## 6234    0.0016795075 0.0003655666           0.9835237
## 6235    0.0016921418 0.0003673263           0.9834790
## 6236    0.0016791110 0.0003654903           0.9835241
## 6237    0.0017228537 0.0003748257           0.9835249
## 6238    0.0019715318 0.0004140669           0.9829447
## 6239    0.0016560923 0.0003716927           0.9840510
## 6429    0.0051922484 0.0003579187           0.9468824
## 6430    0.0028656656 0.0001849280           0.9431183
## 6431    0.0034505351 0.0002283094           0.9445494
## 6432    0.0040677930 0.0002746190           0.9456881
## 6433    0.0044944781 0.0003068287           0.9463174
## 6434    0.0048150696 0.0003295367           0.9464729
## 6435    0.0087269903 0.0006216813           0.9488530
## 6436    0.0035389281 0.0002355183           0.9448734
## 6437    0.0028910251 0.0001879459           0.9435341
## 6438    0.0030345974 0.0001959032           0.9431503
## 6439    0.0044687097 0.0003045868           0.9462308
## 6440    0.0050615201 0.0003607200           0.9486138
## 6441    0.0072029810 0.0004873128           0.9460152
## 6442    0.0044465560 0.0003022794           0.9460878
## 6443    0.0062548245 0.0004833333           0.9527154
## 6444    0.0065752820 0.0005214943           0.9539694
## 6445    0.0066645597 0.0004997116           0.9512863
## 6446    0.0063454767 0.0004937736           0.9530550
## 6447    0.0071497350 0.0005789957           0.9549787
## 6448    0.0026806822 0.0002002402           0.9508024
## 6449    0.0059395065 0.0004822235           0.9549975
## 6450    0.0077410779 0.0006442085           0.9562607
## 6451    0.0065804276 0.0004930996           0.9512497
## 6452    0.0063582774 0.0004955632           0.9531320
## 6453    0.0076861191 0.0006311932           0.9556587
## 6454    0.0067255502 0.0005369915           0.9542924
## 6455    0.0062439332 0.0004799401           0.9524606
## 6456    0.0029151760 0.0002198457           0.9512864
## 6457    0.0047098882 0.0003741964           0.9539020
```

```
## 6512      0.0027687042 0.0013074985           0.9938082
## 6527      0.0011439540 0.0014878729           0.9991076
## 6739      0.0010574400 0.0010579402           0.9977993
## 6796      0.0002679505 0.0004499813           0.9987267
## 6938      0.0008439725 0.0003966984           0.9928578
## 6939      0.0012674214 0.0006937685           0.9942942
## 6940      0.0005499315 0.0002296020           0.9916774
## 6941      0.0005484610 0.0002296106           0.9917020
## 6942      0.0011257892 0.0005881841           0.9938582
## 6943      0.0021717622 0.0011535140           0.9945433
## 6944      0.0015445694 0.0008612923           0.9945893
## 6945      0.0008439725 0.0003966984           0.9928578
## 6946      0.0005520202 0.0002309316           0.9916967
## 6947      0.0005282048 0.0002164612           0.9914939
## 6948      0.0005193341 0.0002109403           0.9914059
## 7039      0.0008794222 0.0013133248           0.9993099
## 7147      0.0008071568 0.0008465522           0.9977625
## 7167      0.0040556743 0.0007040698           0.9794912
## 7210      0.0034382281 0.0013317753           0.9920764
## 7211      0.0049454782 0.0015271078           0.9897918
## 7446      0.0019642756 0.0002300190           0.9686643
## 7447      0.0019171957 0.0002216273           0.9682447
## 7448      0.0019661194 0.0002303729           0.9686836
## 7449      0.0019179172 0.0002216866           0.9682413
## 7450      0.0019172881 0.0002215034           0.9682251
## 7451      0.0019167196 0.0002213281           0.9682090
## 7452      0.0019168567 0.0002216008           0.9682465
## 7453      0.0018489967 0.0002157551           0.9685378
## 7454      0.0018541697 0.0002165786           0.9685709
## 7455      0.0018138062 0.0002095564           0.9682144
## 7456      0.0019172478 0.0002216315           0.9682445
## 7457      0.0019590073 0.0002291654           0.9686307
## 7458      0.0019156108 0.0002212414           0.9682150
## 7459      0.0019175169 0.0002199960           0.9679999
## 7460      0.0019172881 0.0002215034           0.9682251
## 7461      0.0019152975 0.0002203961           0.9680963
## 7462      0.0019160039 0.0002201497           0.9680481
## 7463      0.0019152776 0.0002203946           0.9680964
## 7507      0.0023158182 0.0024123317           0.9993094
## 7649      0.0006917948 0.0011398730           0.9993746
## 7650      0.0006918818 0.0011402519           0.9993754
## 7683      0.0103781570 0.0159671542           1.0143040
## 7791      0.0010461800 0.0015224008           0.9994529
## 7871      0.0046273592 0.0030157643           0.9977352
## 8154      0.0002961755 0.0004439867           0.9984482
## 8232      0.0024292806 0.0023320386           0.9989182
## 8262      0.0253133456 0.0181771335           1.0137703
## 8320      0.0064410706 0.0050596919           1.0007889
## 8377      0.3807445906 0.0644221375           1.0471077
## 8457      0.0005906999 0.0007478570           0.9982856
## 8458      0.0008222984 0.0004465255           0.9939909
## 8535      0.0003569741 0.0005152238           0.9984215
## 8541      0.0001631968 0.0002170445           0.9978983
## 8698      0.0002796865 0.0003719032           0.9980529
```

```
## 8710     0.0022473554 0.0007041959         0.9891443
## 8763     0.0005216706 0.0006359458         0.9980577
## 8887     0.0129194672 0.0027836422         0.9857741
## 8911     0.0013009607 0.0019755686         1.0000169
## 8946     0.0013009607 0.0019755686         1.0000169
## 9215     0.0024188561 0.0026122144         0.9996397
## 9293     0.0011160547 0.0016248737         0.9995570
## 9369     0.0013616896 0.0021917458         1.0003758
## 9420     0.0060749032 0.0073714500         1.0048367
## 9453     0.0005106974 0.0007971874         0.9989027
## 9528     0.0056161190 0.0022635893         0.9933926
## 9546     0.0006538835 0.0007383763         0.9979122
## 9722     0.0007277701 0.0006797623         0.9971501
## 10125    0.0052324495 0.0048478089         1.0013104
## 10318    0.0133567782 0.0224122117         1.0212129
## 10371    0.0021064306 0.0028288247         1.0005472
## 10418    0.0015299893 0.0023617801         1.0004458
## 10478    0.0004579563 0.0007820097         0.9990968
## 10623    0.0004269388 0.0006254808         0.9985711
## 10707    0.0001299349 0.0002014687         0.9982897
## 10723    0.0004312082 0.0006878271         0.9988453
## 10741    0.0002559881 0.0004202566         0.9986450
## 10787    0.0027445767 0.0014033335         0.9945172
## 10844    0.0016949044 0.0021391104         0.9996722
## 10958    0.0004796424 0.0004712638         0.9971420
## 10995    0.0030409613 0.0051210076         1.0034327
## 11165    0.0013206888 0.0014774990         0.9986218
## 11289    0.0006334948 0.0002389100         0.9907170
## 11413    0.0027417091 0.0012059380         0.9931160
## 11558    0.0042468752 0.0009956524         0.9853908
## 11586    0.0016574128 0.0011102733         0.9959786
## 11728    0.0068990834 0.0047846693         0.9998698
## 11758    0.0022656737 0.0028288247         1.0003331
## 11772    0.0120241217 0.0018168689         0.9774022
## 11822    0.0025447045 0.0006655231         0.9867224
## 11898    0.0327527392 0.0348098650         1.0330472
## 11899    0.0767419624 0.0375479305         1.0318106
## 11982    0.0086379247 0.0030400158         0.9928114
## 11992    0.0732808662 0.0046287603         0.9463640
## 12212    0.0020701946 0.0019228612         0.9983743
## 12255    0.0041240793 0.0022774808         0.9959444
## 12256    0.0011712201 0.0011821940         0.9979574
## 12392    0.0008750702 0.0010714059         0.9985077
## 12472    0.0042021297 0.0013192567         0.9897842
## 12487    0.0110948252 0.0046009420         0.9960107
## 12577    0.0039696302 0.0014696028         0.9917631
## 12582    0.0186385515 0.0024805710         0.9747313
## 12643    0.0160063267 0.0019543570         0.9716895
## 12686    0.0001473875 0.0002401013         0.9984466
## 12764    0.0054974616 0.0021949561         0.9932346
```

```r
# check if any outlier cases have cook's distance > 1
sum(mydata[mydata$large.residual, c("cooks.distance")] > 1)
```

```
## [1] 0
```

```r
# None of the cases have cooks distance > 1, so none of the cases have undue
# influence on the model

# calculate average leverage using formula = (k+1/n)
avg_leverage <- (6+1)/12865
# three times average leverage
times_3_leverage <- avg_leverage*3
# check if there are outlier cases with levarage > 3 times the average leverage
sum(mydata[mydata$large.residual, c("levarage")] > times_3_leverage)
```

```
## [1] 0
```

```r
# There are none
```

b. viii. Calculate the standardized residuals using the appropriate command,

specifying those that are +-2, storing the results of large residuals in a

variable you create.

Answered this question as part of analyis in last question. Below is the

command used. Variable is already added to the data frame mydata

- mydata$large.residual < -mydata$**standardized.residuals > 2 | mydata$standardized.residuals < -2 -**

b. ix. Use the appropriate function to show the sum of large residuals.

Answered in b. vii. as part of analysis of residual and influence.

```r
# nrow(mydata) -- 12865
# check if about 5% of cases (<= 643 cases) have standardized residual within +-2.
sum(mydata$standardized.residuals > 2 | mydata$standardized.residuals < -2)
```

```
## [1] 329
```

```r
# As only 329 cases are outside range or have large residuals, we are well
# within the range of 5% outliers.
```

b. x. Which specific variables have large residuals (only cases that evaluate

as TRUE)?

```r
mydata[mydata$large.residual == TRUE, c("Sale_Date","Sale_Price","sale_reason",
                                        "sale_instrument","sale_warning",
                                        "sitetype","addr_full","zip5",
```

```
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                                          "square_feet_total_living","bedrooms",
                                          "bath_full_count","year_built","year_renovated",
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## 1633   2007-02-27       5000           1               3           16        4
## 1650   2007-03-02     349999           1               3         <NA>        4
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## 1745   2007-03-29    2235000           1               3         <NA>        4
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## 108     3230 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0972 47.63926
## 115                19656 NE REDMOND RD 98053      <NA> -122.0772 47.69595
## 178   13414 WOODINVILLE REDMOND RD NE 98052      <NA> -122.1343 47.72058
## 239                  24103 NE 122ND ST 98053      <NA> -122.0192 47.70719
## 246     3068 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0953 47.63820
## 287                   28218 NE 40TH ST 98053      <NA> -121.9611 47.64355
## 295                   5806 249TH CT NE 98053      <NA> -122.0053 47.65706
## 300                  8015 228TH AVE NE 98053      <NA> -122.0364 47.67546
## 341                  11650 154TH PL NE 98052   REDMOND -122.1328 47.70418
## 344                  1520 268TH AVE NE 98053      <NA> -121.9787 47.62110
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## 385                   20424 NE 64TH PL 98053      <NA> -122.0685 47.66419
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## 1979                 14005 NE 85TH CT 98052   REDMOND -122.1532 47.67926
## 1980                 14006 NE 85TH CT 98052   REDMOND -122.1532 47.67940
## 1981                 14018 NE 85TH CT 98052   REDMOND -122.1527 47.67959
## 1982                 14022 NE 85TH CT 98052   REDMOND -122.1527 47.67941
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## 6235                  17256 NE 46TH CT 98052   REDMOND -122.1100 47.65079
## 6236                  17260 NE 46TH CT 98052   REDMOND -122.1098 47.65079
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## 6239                  17384 NE 46TH CT 98052   REDMOND -122.1088 47.65062
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## 6430                 11818 171ST PL NE 98052   REDMOND -122.1119 47.70639
## 6431                17011 NE 118TH WAY 98052   REDMOND -122.1134 47.70580
## 6432                16943 NE 118TH WAY 98052   REDMOND -122.1138 47.70579
## 6433                16944 NE 118TH WAY 98052   REDMOND -122.1138 47.70624
## 6434                 16909 NE 120TH ST 98052   REDMOND -122.1145 47.70694
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## 8541                8490 138TH LN NE 98052   REDMOND -122.1554 47.67857
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## 8710    3244 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0973 47.63979
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## 9528                20338 NE 85TH ST 98053      <NA> -122.0692 47.68341
## 9546               22465 NE 111TH LN 98053      <NA> -122.0384 47.69732
## 9722    2850 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0927 47.63610
## 10125               20015 NE 85TH ST 98053      <NA> -122.0729 47.67825
## 10318             8565 261ST AVE NE 98053      <NA> -121.9914 47.67951
## 10371   22016 NE REDMOND FALL CITY RD 98053      <NA> -122.0448 47.65178
## 10418            19841 NE REDMOND RD 98053      <NA> -122.0716 47.69623
## 10478               5715 251ST CT NE 98053      <NA> -122.0034 47.65602
## 10623               25621 NE 42ND PL 98053      <NA> -121.9967 47.64604
## 10707               16410 NE 43RD CT 98052   REDMOND -122.1208 47.64847
## 10723              15339 NE 106TH CT 98052   REDMOND -122.1350 47.69446
## 10741              6228 224TH AVE NE 98053      <NA> -122.0407 47.66293
## 10787   3230 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0972 47.63926
## 10844               15430 NE 51ST ST 98052   REDMOND -122.1341 47.65443
## 10958               24143 NE 58TH PL 98053      <NA> -122.0174 47.65712
## 10995              8513 255TH AVE NE 98053      <NA> -121.9994 47.67765
## 11165   2410 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0878 47.63155
## 11289   3260 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0978 47.64009
## 11413              8071 208TH AVE NE 98053      <NA> -122.0640 47.67567
## 11558             11004 132ND AVE NE 98052   REDMOND -122.1642 47.69914
## 11586   2864 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0929 47.63633
## 11728              21031 NE 122ND ST 98053      <NA> -122.0590 47.70618
## 11758   22016 NE REDMOND FALL CITY RD 98053      <NA> -122.0448 47.65178
```

```
## 11772   2808 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0915 47.63512
## 11822   2420 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0879 47.63179
## 11898              11207 248TH AVE NE 98053      <NA> -122.0090 47.69878
## 11899              11207 248TH AVE NE 98053      <NA> -122.0090 47.69878
## 11982                7350 259TH PL NE 98053      <NA> -121.9927 47.66975
## 11992               17656 NE 116TH ST 98052   REDMOND -122.1036 47.70440
## 12212                25205 NE 80TH ST 98053      <NA> -122.0020 47.67283
## 12255               19610 NE 116TH ST 98053      <NA> -122.0784 47.70355
## 12256               19610 NE 116TH ST 98053      <NA> -122.0784 47.70355
## 12392              11220 196TH AVE NE 98053      <NA> -122.0778 47.69907
## 12472   3020 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0945 47.63747
## 12487   2656 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0911 47.63458
## 12577               7702 196TH AVE NE 98053      <NA> -122.0751 47.67266
## 12582   2942 W LAKE SAMMAMISH PKWY NE 98052   REDMOND -122.0932 47.63718
## 12643               7917 219TH AVE NE 98053      <NA> -122.0480 47.67454
## 12686          3851 E AMES LAKE DR NE 98053      <NA> -121.9549 47.64393
## 12764               18025 NE 136TH ST 98052      <NA> -122.0988 47.72113
##       building_grade square_feet_total_living bedrooms bath_full_count
## 25                10                     4920        4               4
## 108                9                     4640        5               2
## 115                6                      660        0               1
## 178               11                     5800        5               4
## 239                9                     3360        2               2
## 246                6                      900        2               1
## 287                9                     4710        4               2
## 295               11                     5060        4              23
## 300               10                     6880        5               1
## 341               11                     4490        4               2
## 344                7                     2700        3               1
## 359               11                     5140        4               2
## 385               11                     6310        4               2
## 396               12                     5080        4               3
## 475               10                     3320        4               1
## 482               12                     6380        6               6
## 508                9                     3700        4               3
## 528                9                     5830        5               3
## 576               10                     4320        4               3
## 661               12                     8090        4               3
## 670               10                     4710        4               2
## 679               11                     8490        7               3
## 742               11                     4577        4               2
## 784               10                     5150        4               1
## 802               11                     4380        4               3
## 811               11                     5270        4               2
## 852               10                     3630        4               2
## 853                9                     3470        3               2
## 877               11                     4640        4               3
## 916               12                     7640        5               5
## 1009               9                     4040        4               3
## 1099              11                     4250        4               2
## 1119              11                     6340        4               4
## 1142              11                     5980        4               3
## 1155               8                     4740        6               5
## 1305               8                     2800        4               2
```

```
## 1345                10                  3990         5            3
## 1368                10                  4550         4            3
## 1380                 8                  3660         3            2
## 1442                 4                   340         0            0
## 1492                11                  4610         4            4
## 1504                12                  7780         5            3
## 1543                11                  4310         4            3
## 1550                11                  5380         4            3
## 1633                 9                  3130         5            2
## 1650                10                  9360         4            3
## 1716                 9                  4610         4            2
## 1745                11                  5360         4            3
## 1870                12                 10630         5            4
## 1962                12                  5300         4            3
## 1963                10                  3090         3            1
## 1964                 7                   550         1            1
## 1976                 9                  3830         5            3
## 1977                 9                  3330         4            2
## 1978                 9                  3480         4            3
## 1979                 9                  3370         4            2
## 1980                 9                  3350         4            3
## 1981                 9                  4080         6            3
## 1982                 9                  3690         5            3
## 2022                 7                   900         1            1
## 2099                11                  5020         4            3
## 2137                 8                  2820         3            1
## 2157                 9                  3130         4            2
## 2264                 5                  1540         3            1
## 2302                 9                  6340        10            2
## 2360                 9                  3200         3            1
## 2361                 5                   310         0            0
## 2469                 8                  2980         3            1
## 2684                10                  3410         5            3
## 2685                 9                  3660         4            3
## 2686                10                  4500         5            2
## 2687                 9                  3480         4            3
## 2688                10                  3310         4            2
## 2689                10                  4340         5            2
## 2690                10                  4390         5            3
## 2699                 9                  5270         4            3
## 2708                 9                  4710         5            3
## 2709                10                  5100         4            3
## 2710                 9                  4910         4            3
## 2717                12                  5390         4            3
## 2742                10                  3950         4            3
## 2852                13                 11810         7            4
## 2934                 9                  4610         4            2
## 2937                 9                  4610         4            2
## 3097                12                  5320         4            3
## 3102                11                  4790         4            3
## 3110                 6                  1290         2            0
## 3111                 7                  1920         5            2
## 3168                 7                  1290         2            1
## 3169                 7                  1290         2            2
```

```
## 3170      7      1600   3      2
## 3171      7      1740   3      2
## 3172      7      1710   3      2
## 3173      7      1740   3      2
## 3174      7      1710   3      2
## 3175      7      1460   3      2
## 3176      7      1820   3      2
## 3177      7      1840   3      2
## 3178      7      1840   3      2
## 3179      7      1600   3      2
## 3180      7      1840   3      2
## 3181      7      1600   3      2
## 3182      7      1290   2      1
## 3183      7      1290   2      1
## 3184      7      1290   2      1
## 3185      7      1290   2      1
## 3186      7      1290   2      1
## 3187      7      1290   2      1
## 3188      7      1290   2      2
## 3189      7      1460   3      2
## 3190      7      1710   3      2
## 3191      7      1460   3      2
## 3192      7      1740   3      2
## 3193      7      1710   3      2
## 3194      7      1710   3      2
## 3195      7      1840   3      2
## 3196      7      1840   3      2
## 3197      7      1820   3      2
## 3198      7      1290   2      1
## 3199      7      1290   2      1
## 3200      7      1290   2      1
## 3201      7      1290   2      1
## 3202      7      1290   2      1
## 3424      8      4290   4      3
## 3464      7      1460   3      2
## 3465      7      1600   3      2
## 3466      7      1840   3      2
## 3467      7      1840   3      2
## 3468      7      1460   3      2
## 3469      7      1600   3      2
## 3470      7      1840   3      2
## 3471      7      1600   3      2
## 3472      7      1740   3      2
## 3473      7      1710   3      2
## 3474      7      1460   3      2
## 3475      7      1740   3      2
## 3476      7      1830   3      1
## 3477      7      1740   3      2
## 3478      7      1290   2      1
## 3479      7      1290   2      1
## 3480      7      1290   2      1
## 3481      7      1290   2      1
## 3482      7      1290   2      1
## 3483      7      1290   2      1
```

```
## 3484                    7                                        1290          2                  2
## 3485                    7                                        1840          3                  2
## 3486                    7                                        1600          3                  2
## 3487                    7                                        1840          3                  2
## 3488                    7                                        1710          3                  2
## 3489                    7                                        1740          3                  2
## 3490                    7                                        1710          3                  2
## 3491                    7                                        1840          4                  1
## 3492                    7                                        1600          3                  2
## 3493                    7                                        1840          3                  2
## 3494                    7                                        1460          3                  2
## 3495                    7                                        1290          2                  1
## 3496                    7                                        1290          2                  1
## 3497                    7                                        1290          2                  1
## 3523                    8                                        3980          4                  3
## 3837                    9                                        4480          4                  2
## 3918                   11                                        6340          4                  4
## 3919                   11                                        5980          4                  3
## 4055                   11                                        4110          4                  1
## 4056                    8                                         900          1                  1
## 4248                    8                                        2610          3                  2
## 4391                    8                                        3140          2                  2
## 4435                   10                                        4330          4                  2
## 4648                   11                                        5790          3                  2
## 4649                    6                                        2410          3                  1
## 4671                   11                                        7810          5                  5
## 4695                    8                                        1430          2                  1
## 4696                   10                                        5330          4                  3
## 4740                   10                                        2900          3                  2
## 4821                    9                                         890          1                  1
## 4834                    7                                         900          1                  1
## 4840                    8                                        4740          6                  5
## 4934                    9                                        4210          4                  2
## 5083                   12                                        5830          4                  4
## 5491                    9                                        2960          4                  2
## 5494                    9                                        3010          4                  2
## 5495                    9                                        2960          4                  2
## 5496                    9                                        2960          4                  2
## 5497                    9                                        2950          5                  3
## 5549                   10                                        4130          3                  1
## 5935                   10                                        5640          3                  3
## 6055                    9                                        3500          4                  2
## 6230                   10                                        3320          4                  2
## 6231                   10                                        3530          4                  2
## 6232                   10                                        3720          4                  3
## 6233                   10                                        3150          4                  2
## 6234                   10                                        3340          5                  2
## 6235                   10                                        3320          5                  2
## 6236                   10                                        3340          5                  2
## 6237                   10                                        3320          5                  2
## 6238                   10                                        3060          4                  2
## 6239                   10                                        3530          4                  2
## 6429                    8                                        3290          4                  2
## 6430                    8                                        2450          4                  2
```

```
## 6431          8        2750   4      2
## 6432          8        3010   4      2
## 6433          8        3200   5      2
## 6434          8        3200   5      2
## 6435          8        3620   5      3
## 6436          8        2810   4      2
## 6437          8        2550   4      2
## 6438          8        2440   3      2
## 6439          8        3160   4      2
## 6440          9        3400   4      3
## 6441          8        2960   4      3
## 6442          8        3110   4      2
## 6443          8        2900   5      3
## 6444          8        3220   5      3
## 6445          8        2510   4      3
## 6446          8        2970   4      3
## 6447          8        3470   5      3
## 6448          8        2580   4      2
## 6449          8        3590   5      2
## 6450          8        3890   5      2
## 6451          8        2520   4      3
## 6452          8        2990   4      3
## 6453          8        3620   5      3
## 6454          8        3300   5      3
## 6455          8        2830   5      3
## 6456          8        2680   4      2
## 6457          8        3330   5      2
## 6512         12        5040   4      3
## 6527         10        5050   5      1
## 6739         10        3850   3      4
## 6796          9        4000   4      3
## 6938          9        3970   4      2
## 6939          9        4610   4      3
## 6940          9        3360   4      2
## 6941          9        3370   4      2
## 6942          9        4390   5      3
## 6943          9        4380   5      4
## 6944          9        4790   5      2
## 6945          9        3970   4      2
## 6946          9        3370   4      2
## 6947          9        3260   4      2
## 6948          9        3210   4      2
## 7039         11        5320   4      3
## 7147         10        5370   5      3
## 7167         10        4460   4      2
## 7210          9        4460   4      3
## 7211          7        3640   5      3
## 7446          8        2650   4      2
## 7447          8        2520   4      2
## 7448          8        2655   4      2
## 7449          8        2520   3      2
## 7450          8        2515   3      2
## 7451          8        2510   3      2
## 7452          8        2520   4      2
```

```
## 7453               8                      2630       4           2
## 7454               8                      2640       4           2
## 7455               8                      2530       4           2
## 7456               8                      2520       4           2
## 7457               8                      2640       4           2
## 7458               8                      2510       3           2
## 7459               8                      2445       4           2
## 7460               8                      2515       3           2
## 7461               8                      2475       4           2
## 7462               8                      2460       4           2
## 7463               8                      2475       4           2
## 7507              10                      5150       4           1
## 7649               9                      4350       4           4
## 7650               9                      4350       4           4
## 7683              12                     13210       4           2
## 7791              11                      5620       3           3
## 7871              12                      6650       4           3
## 8154               9                      3960       4           3
## 8232              10                      5150       4           1
## 8262              12                     13540       7           1
## 8320              10                      5820       3           2
## 8377              12                      8750       5           2
## 8457              10                      3090       3           1
## 8458               7                       550       1           1
## 8535              10                      4420       5           2
## 8541               9                      3130       5           2
## 8698              10                      3380       4           2
## 8710              10                      4950       5           3
## 8763              10                      3460       5           2
## 8887              10                      6360       4           5
## 8911              13                      6280       5           4
## 8946              13                      6280       5           4
## 9215               7                      1650       4           1
## 9293               9                      5830       5           3
## 9369               8                      3240       3           2
## 9420               9                      4800       4           0
## 9453               9                      4610       4           2
## 9528              11                      7110       4           3
## 9546               9                      4480       4           2
## 9722              10                      2900       3           2
## 10125             12                      6680       4           3
## 10318             11                      5150       4           3
## 10371             10                      4930       4           0
## 10418              8                      4770       3           3
## 10478             11                      4400       4           2
## 10623             10                      4570       4           3
## 10707              9                      2630       4           2
## 10723             11                      4790       4           3
## 10741             10                      4200       4           3
## 10787              9                      4640       5           2
## 10844              7                      1800       4           2
## 10958             10                      4010       5           2
## 10995             11                      9070       6           5
## 11165             11                      4140       4           4
```

```
## 11289          9              3310        4           2
## 11413          8              2610        3           1
## 11558          5               730        2           1
## 11586          8              2770        4           1
## 11728          8              2280        2           1
## 11758         10              4930        4           0
## 11772         11              6600        4           2
## 11822         11              4240        3           2
## 11898         11              3690        4           2
## 11899          9              1230        1           1
## 11982         12              7640        5           5
## 11992          8              1670        3           1
## 12212          5               820        2           1
## 12255          5              1650        2           1
## 12256          8              3260        4           2
## 12392          7              2140        3           1
## 12472          8              3150        3           3
## 12487          9              5000        4           1
## 12577         10              5030        3           2
## 12582         12              7070        5           3
## 12643         13              4690        3           2
## 12686          9              3720        3           2
## 12764         12              6990        5           3
##       year_built year_renovated current_zoning sq_ft_lot
## 25          2007              0             22    112650
## 108         1952           2004             11     19173
## 115         1955              0             22    225640
## 178         2008              0             21     63162
## 239         2005              0             24      8752
## 246         1918              0             11     14043
## 287         2014              0             22     18498
## 295         2016              0             22     89734
## 300         2008              0             22    288367
## 341         2008              0             11     55303
## 344         2003              0             22    574992
## 359         2008              0             22    212572
## 385         2005              0             22     36362
## 396         2005              0             22    180774
## 475         1963           1989             11     10247
## 482         2007              0             11     15021
## 508         2010              0             22    305173
## 528         2014              0             11     10454
## 576         2008              0             22    223898
## 661         2006              0             22    176418
## 670         1992              0             11     15167
## 679         2008              0             22    118483
## 742         2011              0             22     98881
## 784         2015              0             22    221720
## 802         2008              0             22    221720
## 811         2001              0             11     18045
## 852         2007              0             22    243176
## 853         1985           2001             22    182516
## 877         2008              0             22    220413
## 916         2007              0             22    144683
```

```
## 1009          2005         0          22    35042
## 1099          2007         0          22   223027
## 1119          2007         0          22    45302
## 1142          2007         0          22    55756
## 1155          2007         0          22   544199
## 1305          1929      1993          11    10046
## 1345          2008         0          11    11842
## 1368          2010         0          22   204732
## 1380          2008         0          22    14820
## 1442          1954         0          22    29933
## 1492          2007         0          22   106722
## 1504          2008         0          17   266152
## 1543          2008         0          22   240855
## 1550          2007         0          22   106722
## 1633          2014         0          13     5930
## 1650          2009         0          21    45738
## 1716          2015         0          22    95989
## 1745          2006         0          19    46609
## 1870          2003         0          22   207781
## 1962          2006         0          22   179031
## 1963          1978         0          11    17715
## 1964          1979         0          11    17715
## 1976          2009         0          13     9480
## 1977          2009         0          13     7399
## 1978          2008         0          13    10309
## 1979          2008         0          13     7457
## 1980          2008         0          13     5788
## 1981          2008         0          13     8371
## 1982          2009         0          13     6731
## 2022          1940         0          11    18102
## 2099          2004         0          22    59677
## 2137          1972         0          11    17995
## 2157          1965      1997          11    13634
## 2264          1938         0          11    28183
## 2302          2009         0          11    17328
## 2360          1968         0          11    19556
## 2361          1964      1992          11    19556
## 2469          1980         0          11    19110
## 2684          2008         0          15     5794
## 2685          2010         0          15     5833
## 2686          2008         0          15     5169
## 2687          2010         0          15     5035
## 2688          2008         0          15     5650
## 2689          2008         0          15     5086
## 2690          2009         0          15     5476
## 2699          2015         0          23  1008414
## 2708          2015         0          22   108542
## 2709          2016         0          22   131301
## 2710          2015         0          22   146779
## 2717          2007         0          22   193842
## 2742          2013         0          22    78844
## 2852          2000         0          21   139392
## 2934          2015         0          22    95989
## 2937          2015         0          22    95989
```

```
## 3097              2007                    0                    22    178160
## 3102              2008                    0                    12      7701
## 3110              1961                    0                    11     18792
## 3111              1961                    0                    11     18792
## 3168              2008                    0                    24      2628
## 3169              2008                    0                    24      2628
## 3170              2009                    0                    24      6451
## 3171              2008                    0                    24      3833
## 3172              2008                    0                    24      4846
## 3173              2008                    0                    24      4862
## 3174              2008                    0                    24      4710
## 3175              2008                    0                    24      4350
## 3176              2009                    0                    24      4622
## 3177              2008                    0                    24      4697
## 3178              2008                    0                    24      5125
## 3179              2008                    0                    24      5481
## 3180              2008                    0                    24      5680
## 3181              2008                    0                    24      5277
## 3182              2008                    0                    24      2807
## 3183              2008                    0                    24      2482
## 3184              2008                    0                    24      2482
## 3185              2008                    0                    24      2828
## 3186              2008                    0                    24      2628
## 3187              2008                    0                    24      2628
## 3188              2008                    0                    24      3940
## 3189              2008                    0                    24      4093
## 3190              2008                    0                    24      4041
## 3191              2008                    0                    24      3989
## 3192              2008                    0                    24      3937
## 3193              2008                    0                    24      3885
## 3194              2008                    0                    24      3781
## 3195              2008                    0                    24      4910
## 3196              2008                    0                    24      5340
## 3197              2009                    0                    24      6952
## 3198              2008                    0                    24      3170
## 3199              2008                    0                    24      3140
## 3200              2008                    0                    24      2482
## 3201              2008                    0                    24      2482
## 3202              2008                    0                    24      2482
## 3424              2008                    0                    13     10922
## 3464              2008                    0                    24      3918
## 3465              2009                    0                    24      4036
## 3466              2008                    0                    24      4487
## 3467              2008                    0                    24      5453
## 3468              2008                    0                    24      4195
## 3469              2008                    0                    24      4179
## 3470              2008                    0                    24      4229
## 3471              2009                    0                    24      4279
## 3472              2008                    0                    24      3915
## 3473              2008                    0                    24      4424
## 3474              2008                    0                    24      4827
## 3475              2008                    0                    24      4948
## 3476              2008                    0                    24      4646
## 3477              2008                    0                    24      4607
```

```
## 3478          2008            0          24       2482
## 3479          2008            0          24       2482
## 3480          2008            0          24       2482
## 3481          2008            0          24       2482
## 3482          2008            0          24       2482
## 3483          2008            0          24       2483
## 3484          2008            0          24       2479
## 3485          2010            0          24       4408
## 3486          2008            0          24       4056
## 3487          2009            0          24       4424
## 3488          2008            0          24       3790
## 3489          2008            0          24       3476
## 3490          2008            0          24       4446
## 3491          2008            0          24       4140
## 3492          2009            0          24       4076
## 3493          2008            0          24       4698
## 3494          2008            0          24       4263
## 3495          2008            0          24       2483
## 3496          2008            0          24       2483
## 3497          2008            0          24       2483
## 3523          1955         1991          11      22545
## 3837          2014            0          23     104688
## 3918          2007            0          22      45302
## 3919          2007            0          22      55756
## 4055          1991            0          11      14388
## 4056          1937         1991          11      14388
## 4248          1988            0          22     228690
## 4391          2015            0          22     260488
## 4435          2011            0          13      11325
## 4648          1999            0           1     657816
## 4649          1935            0           2    1327090
## 4671          2011            0          22     277286
## 4695          2003            0          11      16105
## 4696          2005            0          11      16105
## 4740          1974            0          11      15188
## 4821          1999            0          13       7599
## 4834          1940            0          11      18102
## 4840          2007            0          22     544199
## 4934          1959         1989          11      15353
## 5083          1969            0          23    1127205
## 5491          2011            0          11       7743
## 5494          2011            0          11       6932
## 5495          2011            0          11       6396
## 5496          2011            0          11       7588
## 5497          2011            0          11       5815
## 5549          2013            0          22     104544
## 5935          2012            0          23     127591
## 6055          2013            0          22     223027
## 6230          2012            0          16       5000
## 6231          2014            0          16       5037
## 6232          2013            0          16       6237
## 6233          2013            0          16       5163
## 6234          2012            0          16       5013
## 6235          2012            0          16       5143
```

```
## 6236          2012            0             16      5100
## 6237          2013            0             16      5100
## 6238          2013            0             16      5103
## 6239          2014            0             16      4963
## 6429          2012            0             11      6712
## 6430          2010            0             11      4749
## 6431          2012            0             11      5816
## 6432          2012            0             11      8908
## 6433          2010            0             11      4584
## 6434          2012            0             11      4681
## 6435          2012            0             11      9901
## 6436          2012            0             11     13289
## 6437          2010            0             11      4368
## 6438          2011            0             11      4244
## 6439          2011            0             11      5778
## 6440          2012            0             11      6740
## 6441          2012            0             11      4451
## 6442          2012            0             11      5310
## 6443          2012            0             11      4647
## 6444          2012            0             11      4080
## 6445          2013            0             11      5032
## 6446          2013            0             11      4383
## 6447          2012            0             11      5326
## 6448          2011            0             11      5913
## 6449          2012            0             11      6254
## 6450          2012            0             11      5441
## 6451          2012            0             11      4442
## 6452          2013            0             11      4234
## 6453          2013            0             11      6168
## 6454          2012            0             11      4676
## 6455          2012            0             11      6695
## 6456          2012            0             11      7271
## 6457          2012            0             11      4596
## 6512          1990            0             11     17417
## 6527          2012            0             13     15681
## 6739          2013            0             22     62726
## 6796          2014            0             11     11780
## 6938          2013            0             11      6260
## 6939          2013            0             11      6260
## 6940          2013            0             11      6200
## 6941          2013            0             11      8108
## 6942          2013            0             11      6858
## 6943          2013            0             11      6475
## 6944          2013            0             11      6438
## 6945          2013            0             11      6260
## 6946          2013            0             11      6418
## 6947          2013            0             11      6594
## 6948          2013            0             11      7617
## 7039          1976         1998             19    151153
## 7147          2014            0             13     11718
## 7167          1975         2000             11     20119
## 7210          1978         2005             19    202387
## 7211          1982            0             19    155074
## 7446          2013            0             24      4644
```

```
## 7447           2013                 0                24        4887
## 7448           2013                 0                24        5078
## 7449           2013                 0                24        4409
## 7450           2013                 0                24        4400
## 7451           2013                 0                24        4408
## 7452           2013                 0                24        5140
## 7453           2012                 0                24        5021
## 7454           2012                 0                24        5099
## 7455           2012                 0                24        5127
## 7456           2013                 0                24        4850
## 7457           2013                 0                24        4499
## 7458           2013                 0                24        5232
## 7459           2013                 0                24        4400
## 7460           2013                 0                24        4400
## 7461           2013                 0                24        4400
## 7462           2013                 0                24        4403
## 7463           2013                 0                24        4416
## 7507           2015                 0                22      221720
## 7649           2014                 0                14        8038
## 7650           2014                 0                14        7796
## 7683           2008                 0                11       29728
## 7791           2015                 0                17      218439
## 7871           2015                 0                22      319294
## 8154           2014                 0                22       54014
## 8232           2015                 0                22      221720
## 8262           1999                 0                17      307752
## 8320           2016                 0                18      436507
## 8377           1996                 0                22     1631322
## 8457           1978                 0                11       17715
## 8458           1979                 0                11       17715
## 8535           2014                 0                14       10000
## 8541           2014                 0                13        5930
## 8698           2014                 0                11       16190
## 8710           1996                 0                11       14444
## 8763           1972              2007                11       10861
## 8887           2008                 0                11       21010
## 8911           2003                 0                 6       83813
## 8946           2003                 0                 6       83813
## 9215           1954                 0                 1      316245
## 9293           2014                 0                11       10454
## 9369           2015                 0                22      279219
## 9420           2015                 0                22      464350
## 9453           2015                 0                22       95989
## 9528           2006                 0                22      209088
## 9546           2014                 0                23      104688
## 9722           1974                 0                11       15188
## 10125          1998                 0                22      167270
## 10318          1997                 0                17      963702
## 10371          2016                 0                22      111950
## 10418          2003                 0                22      261795
## 10478          2015                 0                22       93654
## 10623          2016                 0                22      112384
## 10707          1987                 0                11        9705
## 10723          2008                 0                12        6451
```

```
## 10741        2015             0              22     30475
## 10787        1952          2004              11     19173
## 10844        1918             0              13     41789
## 10958        1997             0              19    117454
## 10995        2005             0              22    186525
## 11165        1995             0              11     14041
## 11289        1982             0              11     10532
## 11413        1948             0              22    192099
## 11558        1952             0              11     13260
## 11586        1938             0              11     13170
## 11728        1981             0              22    439956
## 11758        2016             0              22    111950
## 11772        2001             0              11     41217
## 11822        2005             0              11     15368
## 11898        1999             0              18   1166246
## 11899        1999             0              18   1166246
## 11982        2007             0              22    144683
## 11992        1964             0              11    425145
## 12212        1932             0              22    167838
## 12255        1980             0              22    227383
## 12256        1980             0              22    227383
## 12392        1987             0              22    188614
## 12472        1955             0              11     30894
## 12487        1962          1980              11      9600
## 12577        2005             0              22    227818
## 12582        1974          2003              11     29494
## 12643        2009             0              22     77418
## 12686        2006             0              22     19290
## 12764        2006             0              22    226512
```

b. xi. Investigate further by calculating the leverage, cooks distance, and

covariance rations. Comment on all cases that are problematics.

```
# nrow(mydata) -- 12865

# Let's look at the leverage (hat value), cook's distance, and covariance ratio
# for cases with large.residual = TRUE
mydata[mydata$large.residual, c("cooks.distance","leverage","covariance.ratios")]
```

```
##       cooks.distance     leverage covariance.ratios
## 25      0.0010257923 0.0011869228         0.9984429
## 108     0.0033044011 0.0042136523         1.0017920
## 115     0.0024117590 0.0018063670         0.9972755
## 178     0.0011465389 0.0012854582         0.9984365
## 239     0.0001090031 0.0001668056         0.9982225
## 246     0.0031564325 0.0017464582         0.9954241
## 287     0.0006893490 0.0007933254         0.9980305
## 295     0.2396277578 0.1188300220         1.1278061
## 300     0.0075267399 0.0043854071         0.9984257
## 341     0.0004487567 0.0006708699         0.9986685
```

```
## 344      0.0057351762 0.0089305205          1.0071144
## 359      0.0017397504 0.0014731451          0.9975264
## 385      0.0025307845 0.0015599477          0.9959382
## 396      0.0014805940 0.0014632775          0.9981591
## 475      0.0006986847 0.0009934765          0.9988611
## 482      0.0031738517 0.0039360295          1.0014278
## 508      0.0033052073 0.0053950353          1.0036382
## 528      0.0010875245 0.0016248737          0.9996238
## 576      0.0008319101 0.0013155085          0.9994538
## 661      0.0027968265 0.0028437415          0.9996540
## 670      0.0016660191 0.0005997724          0.9906016
## 679      0.0070450303 0.0036509393          0.9968763
## 742      0.0004484261 0.0007724219          0.9991065
## 784      0.0019524886 0.0023320386          0.9996953
## 802      0.0010311108 0.0015000453          0.9994297
## 811      0.0035835198 0.0009199438          0.9867072
## 852      0.0009102800 0.0015231355          0.9997943
## 853      0.0004455858 0.0007137136          0.9988811
## 877      0.0016204219 0.0014373881          0.9976943
## 916      0.0045527934 0.0030400158          0.9978991
## 1009     0.0002877654 0.0004295533          0.9984230
## 1099     0.0009422438 0.0015341461          0.9997424
## 1119     0.0020112581 0.0015651144          0.9972234
## 1142     0.0011810063 0.0010314525          0.9972200
## 1155     0.0149292319 0.0095001048          1.0041643
## 1305     0.0011346071 0.0016966438          0.9996980
## 1345     0.0002542520 0.0004161686          0.9986340
## 1368     0.0007075141 0.0011555917          0.9993700
## 1380     0.0003101548 0.0004637808          0.9984617
## 1442     0.0016275507 0.0015502173          0.9981018
## 1492     0.0010091685 0.0012623284          0.9987649
## 1504     0.0048822856 0.0030902960          0.9976377
## 1543     0.0010641713 0.0017134567          0.9998962
## 1550     0.0008218085 0.0008187770          0.9975437
## 1633     0.0001621965 0.0002170445          0.9979159
## 1650     0.0135138750 0.0062910557          0.9987168
## 1716     0.0009970945 0.0007971874          0.9965835
## 1745     0.0009432943 0.0007656760          0.9966233
## 1870     0.0074126080 0.0066798036          1.0030493
## 1962     0.0024740915 0.0014260536          0.9953770
## 1963     0.0006106903 0.0007478570          0.9981840
## 1964     0.0008404656 0.0004465255          0.9938367
## 1976     0.0013242658 0.0003997737          0.9883823
## 1977     0.0006853792 0.0001884214          0.9869458
## 1978     0.0012447634 0.0003547031          0.9875953
## 1979     0.0006774109 0.0001869084          0.9869939
## 1980     0.0012740900 0.0003552299          0.9873042
## 1981     0.0014775095 0.0004630181          0.9889040
## 1982     0.0012863954 0.0003793806          0.9880669
## 2022     0.0013424594 0.0009537856          0.9961454
## 2099     0.0005363480 0.0006876495          0.9982629
## 2137     0.0005589791 0.0003740237          0.9952344
## 2157     0.0005565648 0.0005217858          0.9970069
## 2264     0.0031592360 0.0015138722          0.9941316
```

```
## 2302    0.0017626301 0.0024168498          1.0001911
## 2360    0.0005459138 0.0005608369          0.9974005
## 2361    0.0024410539 0.0009953756          0.9922280
## 2469    0.0004473775 0.0003714912          0.9963336
## 2684    0.0015598153 0.0004735320          0.9885261
## 2685    0.0012316856 0.0003774574          0.9885464
## 2686    0.0014329427 0.0005141746          0.9904813
## 2687    0.0012141040 0.0003613572          0.9881655
## 2688    0.0011725802 0.0003451790          0.9880091
## 2689    0.0013120914 0.0004579103          0.9901284
## 2690    0.0013092871 0.0004699203          0.9904396
## 2699    0.0340776069 0.0254130949          1.0215325
## 2708    0.0013991091 0.0008301737          0.9949675
## 2709    0.0012136735 0.0008456224          0.9959317
## 2710    0.0017277029 0.0010943362          0.9956365
## 2717    0.0030168291 0.0015203003          0.9945262
## 2742    0.0005096100 0.0004644780          0.9968336
## 2852    0.0323551464 0.0084297003          0.9945063
## 2934    0.0009961450 0.0007971874          0.9965880
## 2937    0.0009613303 0.0007971874          0.9967538
## 3097    0.0026676183 0.0014175848          0.9948117
## 3102    0.0007357039 0.0006850037          0.9971425
## 3110    0.0008237369 0.0008555478          0.9977359
## 3111    0.0003968700 0.0005785581          0.9985112
## 3168    0.0039875726 0.0004821071          0.9699125
## 3169    0.0033779971 0.0004123887          0.9701391
## 3170    0.0029576959 0.0003738115          0.9711367
## 3171    0.0027292290 0.0003492111          0.9714720
## 3172    0.0027537800 0.0003513317          0.9713897
## 3173    0.0027317318 0.0003496169          0.9714795
## 3174    0.0027533928 0.0003512709          0.9713887
## 3175    0.0030548353 0.0003796849          0.9706469
## 3176    0.0027749988 0.0003587433          0.9717792
## 3177    0.0026791022 0.0003464883          0.9717788
## 3178    0.0026799098 0.0003466282          0.9717818
## 3179    0.0028631251 0.0003611646          0.9710675
## 3180    0.0026810696 0.0003468243          0.9717859
## 3181    0.0028623150 0.0003610450          0.9710660
## 3182    0.0039884401 0.0004822319          0.9699139
## 3183    0.0039868755 0.0004820066          0.9699114
## 3184    0.0039868755 0.0004820066          0.9699114
## 3185    0.0039885428 0.0004822466          0.9699141
## 3186    0.0039875726 0.0004821071          0.9699125
## 3187    0.0039875726 0.0004821071          0.9699125
## 3188    0.0033853118 0.0004134073          0.9701493
## 3189    0.0030536527 0.0003795151          0.9706449
## 3190    0.0027516005 0.0003509865          0.9713838
## 3191    0.0030531822 0.0003794474          0.9706441
## 3192    0.0027294619 0.0003492496          0.9714728
## 3193    0.0027512095 0.0003509237          0.9713827
## 3194    0.0027509545 0.0003508825          0.9713819
## 3195    0.0026794947 0.0003465567          0.9717803
## 3196    0.0026803440 0.0003467022          0.9717834
## 3197    0.0027812390 0.0003597503          0.9717962
```

```
## 3198     0.0039902426 0.0004824902          0.9699168
## 3199     0.0039900914 0.0004824686          0.9699165
## 3200     0.0039868755 0.0004820066          0.9699114
## 3201     0.0039868755 0.0004820066          0.9699114
## 3202     0.0039868755 0.0004820066          0.9699114
## 3424     0.0024495202 0.0040292686          1.0022766
## 3464     0.0029958323 0.0003794015          0.9712020
## 3465     0.0028920607 0.0003723198          0.9716726
## 3466     0.0026276922 0.0003464232          0.9723251
## 3467     0.0026294974 0.0003467421          0.9723320
## 3468     0.0029970621 0.0003795821          0.9712041
## 3469     0.0028044725 0.0003604398          0.9716123
## 3470     0.0026272739 0.0003463465          0.9723233
## 3471     0.0028929496 0.0003724558          0.9716744
## 3472     0.0026776797 0.0003492414          0.9720233
## 3473     0.0027005098 0.0003511464          0.9719381
## 3474     0.0029999885 0.0003800094          0.9712089
## 3475     0.0026801737 0.0003496534          0.9720308
## 3476     0.0037772871 0.0004924125          0.9721523
## 3477     0.0026793022 0.0003495111          0.9720283
## 3478     0.0039134029 0.0004820066          0.9704772
## 3479     0.0039134029 0.0004820066          0.9704772
## 3480     0.0039134029 0.0004820066          0.9704772
## 3481     0.0039134029 0.0004820066          0.9704772
## 3482     0.0039134029 0.0004820066          0.9704772
## 3483     0.0039134076 0.0004820073          0.9704772
## 3484     0.0033146796 0.0004122789          0.9707011
## 3485     0.0028051885 0.0003710987          0.9724468
## 3486     0.0028040584 0.0003603760          0.9716114
## 3487     0.0027138345 0.0003583941          0.9723855
## 3488     0.0026989172 0.0003508860          0.9719335
## 3489     0.0026767519 0.0003490836          0.9720201
## 3490     0.0027005680 0.0003511558          0.9719383
## 3491     0.0037826809 0.0004935759          0.9721801
## 3492     0.0028922054 0.0003723420          0.9716729
## 3493     0.0026280542 0.0003464886          0.9723266
## 3494     0.0029973689 0.0003796270          0.9712046
## 3495     0.0039134076 0.0004820073          0.9704772
## 3496     0.0039134076 0.0004820073          0.9704772
## 3497     0.0039134076 0.0004820073          0.9704772
## 3523     0.0026507975 0.0015849983          0.9957735
## 3837     0.0006838252 0.0007383763          0.9977580
## 3918     0.0012625486 0.0015651144          0.9990412
## 3919     0.0007652759 0.0010314525          0.9987521
## 4055     0.0014804592 0.0011854653          0.9969800
## 4056     0.0045005009 0.0013619354          0.9893770
## 4248     0.0007189969 0.0012086223          0.9994892
## 4391     0.0011440636 0.0019973401          1.0003650
## 4435     0.0003501356 0.0004602009          0.9981078
## 4648     0.1052345743 0.0102109306          0.9722188
## 4649     0.6906373336 0.0441092700          0.9884534
## 4671     0.0033942707 0.0042189274          1.0017201
## 4695     0.0015209988 0.0004222043          0.9873116
## 4696     0.0012415938 0.0008215703          0.9956192
```

```
## 4740    0.0003991572 0.0006797623          0.9989884
## 4821    0.0018888427 0.0015127881          0.9973094
## 4834    0.0011454391 0.0009537856          0.9969297
## 4840    0.0156021509 0.0095001048          1.0038956
## 4934    0.0009536065 0.0009580187          0.9977148
## 5083    0.0901980470 0.0309037562          1.0213738
## 5491    0.0001204817 0.0001827619          0.9982166
## 5494    0.0001184603 0.0001828554          0.9982600
## 5495    0.0001210330 0.0001833950          0.9982144
## 5496    0.0001205418 0.0001828299          0.9982163
## 5497    0.0002495714 0.0003894789          0.9984937
## 5549    0.0007267978 0.0011075487          0.9991545
## 5935    0.0013552866 0.0010634637          0.9967606
## 6055    0.0009548636 0.0013018514          0.9990555
## 6230    0.0016927822 0.0003674489          0.9834783
## 6231    0.0016557276 0.0003716195          0.9840513
## 6232    0.0018284484 0.0004261427          0.9847252
## 6233    0.0018688703 0.0003973082          0.9831440
## 6234    0.0016795075 0.0003655666          0.9835237
## 6235    0.0016921418 0.0003673263          0.9834790
## 6236    0.0016791110 0.0003654903          0.9835241
## 6237    0.0017228537 0.0003748257          0.9835249
## 6238    0.0019715318 0.0004140669          0.9829447
## 6239    0.0016560923 0.0003716927          0.9840510
## 6429    0.0051922484 0.0003579187          0.9468824
## 6430    0.0028656656 0.0001849280          0.9431183
## 6431    0.0034505351 0.0002283094          0.9445494
## 6432    0.0040677930 0.0002746190          0.9456881
## 6433    0.0044944781 0.0003068287          0.9463174
## 6434    0.0048150696 0.0003295367          0.9464729
## 6435    0.0087269903 0.0006216813          0.9488530
## 6436    0.0035389281 0.0002355183          0.9448734
## 6437    0.0028910251 0.0001879459          0.9435341
## 6438    0.0030345974 0.0001959032          0.9431503
## 6439    0.0044687097 0.0003045868          0.9462308
## 6440    0.0050615201 0.0003607200          0.9486138
## 6441    0.0072029810 0.0004873128          0.9460152
## 6442    0.0044465560 0.0003022794          0.9460878
## 6443    0.0062548245 0.0004833333          0.9527154
## 6444    0.0065752820 0.0005214943          0.9539694
## 6445    0.0066645597 0.0004997116          0.9512863
## 6446    0.0063454767 0.0004937736          0.9530550
## 6447    0.0071497350 0.0005789957          0.9549787
## 6448    0.0026806822 0.0002002402          0.9508024
## 6449    0.0059395065 0.0004822235          0.9549975
## 6450    0.0077410779 0.0006442085          0.9562607
## 6451    0.0065804276 0.0004930996          0.9512497
## 6452    0.0063582774 0.0004955632          0.9531320
## 6453    0.0076861191 0.0006311932          0.9556587
## 6454    0.0067255502 0.0005369915          0.9542924
## 6455    0.0062439332 0.0004799401          0.9524606
## 6456    0.0029151760 0.0002198457          0.9512864
## 6457    0.0047098882 0.0003741964          0.9539020
## 6512    0.0027687042 0.0013074985          0.9938082
```

```
## 6527     0.0011439540 0.0014878729          0.9991076
## 6739     0.0010574400 0.0010579402          0.9977993
## 6796     0.0002679505 0.0004499813          0.9987267
## 6938     0.0008439725 0.0003966984          0.9928578
## 6939     0.0012674214 0.0006937685          0.9942942
## 6940     0.0005499315 0.0002296020          0.9916774
## 6941     0.0005484610 0.0002296106          0.9917020
## 6942     0.0011257892 0.0005881841          0.9938582
## 6943     0.0021717622 0.0011535140          0.9945433
## 6944     0.0015445694 0.0008612923          0.9945893
## 6945     0.0008439725 0.0003966984          0.9928578
## 6946     0.0005520202 0.0002309316          0.9916967
## 6947     0.0005282048 0.0002164612          0.9914939
## 6948     0.0005193341 0.0002109403          0.9914059
## 7039     0.0008794222 0.0013133248          0.9993099
## 7147     0.0008071568 0.0008465522          0.9977625
## 7167     0.0040556743 0.0007040698          0.9794912
## 7210     0.0034382281 0.0013317753          0.9920764
## 7211     0.0049454782 0.0015271078          0.9897918
## 7446     0.0019642756 0.0002300190          0.9686643
## 7447     0.0019171957 0.0002216273          0.9682447
## 7448     0.0019661194 0.0002303729          0.9686836
## 7449     0.0019179172 0.0002216866          0.9682413
## 7450     0.0019172881 0.0002215034          0.9682251
## 7451     0.0019167196 0.0002213281          0.9682090
## 7452     0.0019168567 0.0002216008          0.9682465
## 7453     0.0018489967 0.0002157551          0.9685378
## 7454     0.0018541697 0.0002165786          0.9685709
## 7455     0.0018138062 0.0002095564          0.9682144
## 7456     0.0019172478 0.0002216315          0.9682445
## 7457     0.0019590073 0.0002291654          0.9686307
## 7458     0.0019156108 0.0002212414          0.9682150
## 7459     0.0019175169 0.0002199960          0.9679999
## 7460     0.0019172881 0.0002215034          0.9682251
## 7461     0.0019152975 0.0002203961          0.9680963
## 7462     0.0019160039 0.0002201497          0.9680481
## 7463     0.0019152776 0.0002203946          0.9680964
## 7507     0.0023158182 0.0024123317          0.9993094
## 7649     0.0006917948 0.0011398730          0.9993746
## 7650     0.0006918818 0.0011402519          0.9993754
## 7683     0.0103781570 0.0159671542          1.0143040
## 7791     0.0010461800 0.0015224008          0.9994529
## 7871     0.0046273592 0.0030157643          0.9977352
## 8154     0.0002961755 0.0004439867          0.9984482
## 8232     0.0024292806 0.0023320386          0.9989182
## 8262     0.0253133456 0.0181771335          1.0137703
## 8320     0.0064410706 0.0050596919          1.0007889
## 8377     0.3807445906 0.0644221375          1.0471077
## 8457     0.0005906999 0.0007478570          0.9982856
## 8458     0.0008222984 0.0004465255          0.9939909
## 8535     0.0003569741 0.0005152238          0.9984215
## 8541     0.0001631968 0.0002170445          0.9978983
## 8698     0.0002796865 0.0003719032          0.9980529
## 8710     0.0022473554 0.0007041959          0.9891443
```

```
## 8763     0.0005216706 0.0006359458         0.9980577
## 8887     0.0129194672 0.0027836422         0.9857741
## 8911     0.0013009607 0.0019755686         1.0000169
## 8946     0.0013009607 0.0019755686         1.0000169
## 9215     0.0024188561 0.0026122144         0.9996397
## 9293     0.0011160547 0.0016248737         0.9995570
## 9369     0.0013616896 0.0021917458         1.0003758
## 9420     0.0060749032 0.0073714500         1.0048367
## 9453     0.0005106974 0.0007971874         0.9989027
## 9528     0.0056161190 0.0022635893         0.9933926
## 9546     0.0006538835 0.0007383763         0.9979122
## 9722     0.0007277701 0.0006797623         0.9971501
## 10125    0.0052324495 0.0048478089         1.0013104
## 10318    0.0133567782 0.0224122117         1.0212129
## 10371    0.0021064306 0.0028288247         1.0005472
## 10418    0.0015299893 0.0023617801         1.0004458
## 10478    0.0004579563 0.0007820097         0.9990968
## 10623    0.0004269388 0.0006254808         0.9985711
## 10707    0.0001299349 0.0002014687         0.9982897
## 10723    0.0004312082 0.0006878271         0.9988453
## 10741    0.0002559881 0.0004202566         0.9986450
## 10787    0.0027445767 0.0014033335         0.9945172
## 10844    0.0016949044 0.0021391104         0.9996722
## 10958    0.0004796424 0.0004712638         0.9971420
## 10995    0.0030409613 0.0051210076         1.0034327
## 11165    0.0013206888 0.0014774990         0.9986218
## 11289    0.0006334948 0.0002389100         0.9907170
## 11413    0.0027417091 0.0012059380         0.9931160
## 11558    0.0042468752 0.0009956524         0.9853908
## 11586    0.0016574128 0.0011102733         0.9959786
## 11728    0.0068990834 0.0047846693         0.9998698
## 11758    0.0022656737 0.0028288247         1.0003331
## 11772    0.0120241217 0.0018168689         0.9774022
## 11822    0.0025447045 0.0006655231         0.9867224
## 11898    0.0327527392 0.0348098650         1.0330472
## 11899    0.0767419624 0.0375479305         1.0318106
## 11982    0.0086379247 0.0030400158         0.9928114
## 11992    0.0732808662 0.0046287603         0.9463640
## 12212    0.0020701946 0.0019228612         0.9983743
## 12255    0.0041240793 0.0022774808         0.9959444
## 12256    0.0011712201 0.0011821940         0.9979574
## 12392    0.0008750702 0.0010714059         0.9985077
## 12472    0.0042021297 0.0013192567         0.9897842
## 12487    0.0110948252 0.0046009420         0.9960107
## 12577    0.0039696302 0.0014696028         0.9917631
## 12582    0.0186385515 0.0024805710         0.9747313
## 12643    0.0160063267 0.0019543570         0.9716895
## 12686    0.0001473875 0.0002401013         0.9984466
## 12764    0.0054974616 0.0021949561         0.9932346
```

```r
# check if any outlier cases have cook's distance > 1
sum(mydata[mydata$large.residual, c("cooks.distance")] > 1)
```

```
## [1] 0
```

```r
sum(mydata[, c("cooks.distance")] > 1)
```

```
## [1] 0
```

```r
# None of the cases have cooks distance > 1, so none of the cases have undue
# influence on the model

# calculate average leverage using formula = (k+1/n)
avg_leverage <- (6+1)/12865
# twice the average leverage
times_2_leverage <- avg_leverage*2
# three times average leverage
times_3_leverage <- avg_leverage*3
# check if there are outlier cases with levarage > 3 times the average leverage
sum(mydata[mydata$large.residual, c("levarage")] >= times_3_leverage)
```

```
## [1] 0
```

```r
# There are none. All the cases are within the range of three times the average.
sum(mydata[mydata$large.residual, c("levarage")] >= times_2_leverage)
```

```
## [1] 0
```

```r
# There are none. All the cases are within the range of two times the average.

# check the minimum and maximum covariance ratios
# calculate the covariance minimum and maximum range
cov_ratio_min <- 1-(3*7/12865) # 1-[3(k+1)/n]
cov_ratio_max <- 1+(3*7/12865) # 1+[3(k+1)/n]
# checking covariance ratios
min(mydata[mydata$large.residual, c("covariance.ratios")])
```

```
## [1] 0.9431183
```

```r
# 0.94 which is less that calculated minimum
max(mydata[mydata$large.residual, c("covariance.ratios")])
```

```
## [1] 1.127806
```

```r
# 1.127 which is greater than calculated maximum
# check cook's distance for out of range covariance ratio cases
mydata$outside.covariance.ratios <- mydata$covariance.ratios > cov_ratio_max | mydata$covariance.ratios
# check cook's distance for out of range covariance ratios
sum(mydata[mydata$outside.covariance.ratios, c("cooks.distance")] > 1)
```

```
## [1] 0
```

```r
# As there are no cases with cook's distance > 1 they are not alarming
```

b. xii. Perform the necessary calculations to assess the assumption of

independence and state if the condition is met or not.

```r
# execute Durbin-Watson test to assess the assumption of independent error
library(car)
```

```
## Loading required package: carData

##
## Attaching package: 'car'

## The following object is masked from 'package:boot':
##
##     logit

## The following object is masked from 'package:dplyr':
##
##     recode
```

```
durbinWatsonTest(hs_data_multi_rgr_mdl_4)
```

```
##  lag Autocorrelation D-W Statistic p-value
##    1       0.7302629     0.5394659       0
##  Alternative hypothesis: rho != 0
```

```
# Value is < 1 i.e. 0.539 and p-value is 0 which is < 0.05
# Result of the test conclude the residuals in the regression are positively
# correlated and thus fails the assumption of independence or errors.
library(lmtest)
```

```
## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
dwtest(hs_data_multi_rgr_mdl_4)
```

```
##
##  Durbin-Watson test
##
## data:  hs_data_multi_rgr_mdl_4
## DW = 0.53947, p-value < 2.2e-16
## alternative hypothesis: true autocorrelation is greater than 0
```

```
# Alternative hypothesis is true and thus error terms or residuals are
# auto correlated.
```

b. xiii. Perform the necessary calculations to assess the assumption of no multicollinearity and state if the condition is met or not.

```
# calculating mean vif
mean(vif(hs_data_multi_rgr_mdl_4))
```

```
## [1] 1.671316
```

```
# calculating vif
vif(hs_data_multi_rgr_mdl_4)
```

```
##              sale_reason           building_grade square_feet_total_living
##                 1.017011                 2.362311                 2.582797
##          bath_full_count               year_built                sq_ft_lot
```

```
##                1.576506                1.374726                1.114547
```

```
# calculating tolerance
1/vif(hs_data_multi_rgr_mdl_4)
```

```
##              sale_reason          building_grade square_feet_total_living
##                0.9832737               0.4233143                0.3871772
##          bath_full_count              year_built                sq_ft_lot
##                0.6343139               0.7274178                0.8972257
```

```
# Observations
# 1. There is no vif greater than 10
# 2. Average vif is > 1, though not substantially and thus there may be some
# bias in the model (not significant). Value of vif is way below 5 and near 1.
# 3. None of the tolerance is below 0.1, no we do not have any serious problem
# with the model
# 4. None of the tolerance is below 0.2
# looking at above observation we can say that no multi-collinearity assumption
# is met.
```

b. xiv. Visually check the assumptions related to the residuals using the plot()

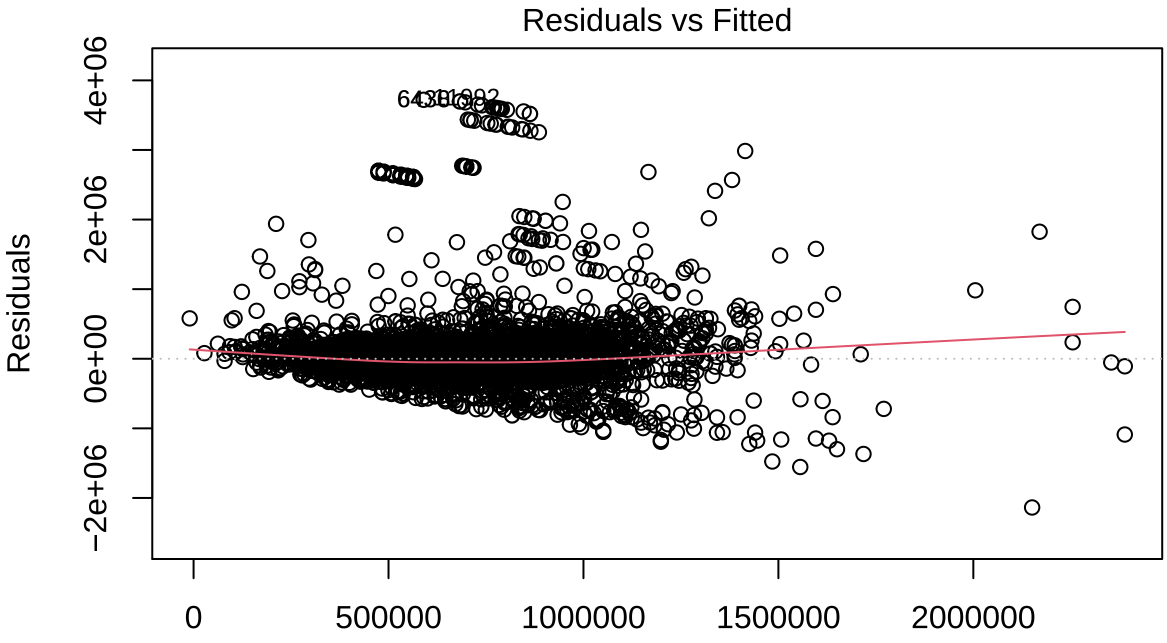
and hist() functions. Summarize what each graph is informing you of and if any

anomalies are present.

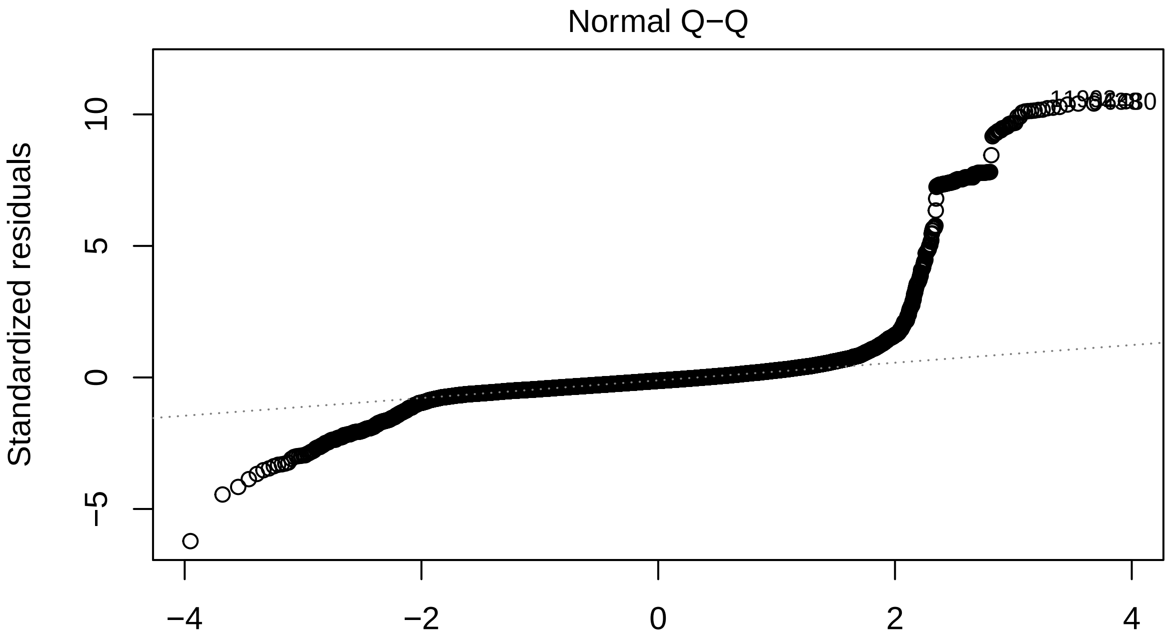
```
# Plotting standardized residual on y-axis and predicted values on x-axis.
# Plot is useful to determine if assumptions of random errors or homoscedasticity
# have been met.
# save fitted.values or predicted values as a variable in mydata data frame
mydata$fitted <- hs_data_multi_rgr_mdl_4$fitted.values

library(ggplot2)
library(qqplotr)
```

```
##
## Attaching package: 'qqplotr'

## The following objects are masked from 'package:ggplot2':
##
##     stat_qq_line, StatQqLine
```

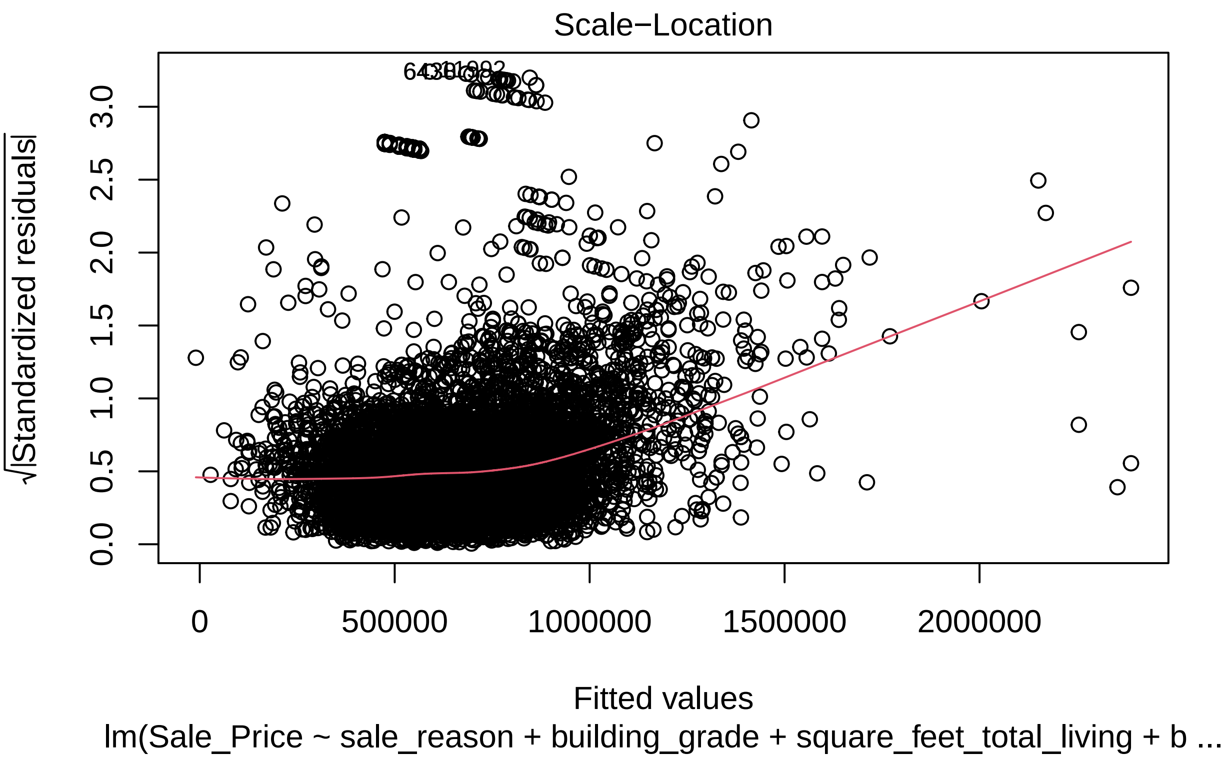
```
plot(hs_data_multi_rgr_mdl_4)
```

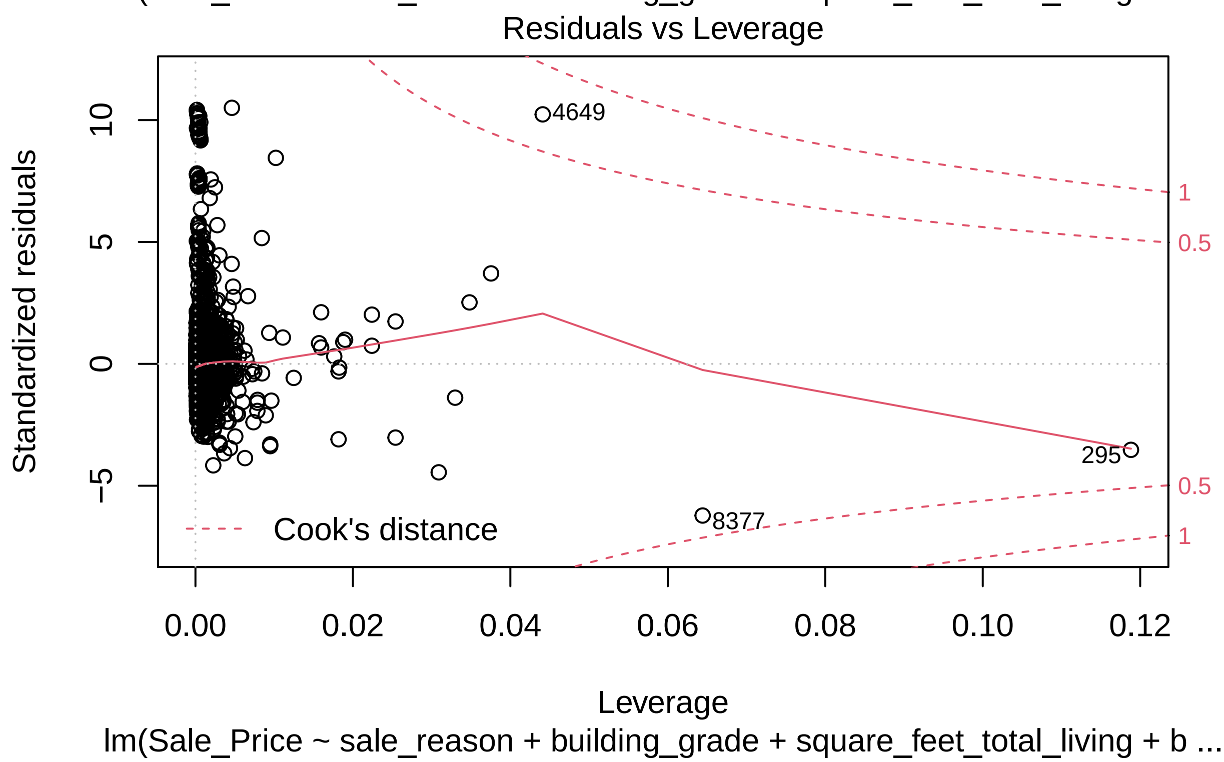


lm(Sale_Price ~ sale_reason + building_grade + square_feet_total_living + b ...



lm(Sale_Price ~ sale_reason + building_grade + square_feet_total_living + b ...

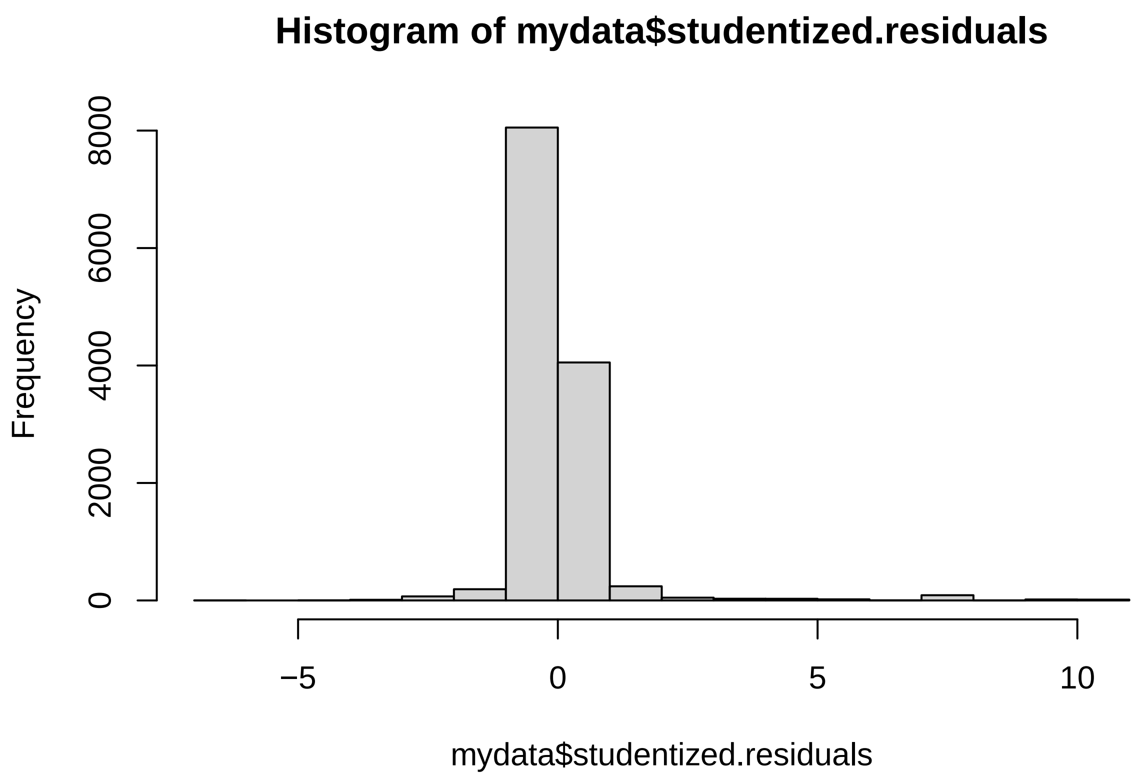




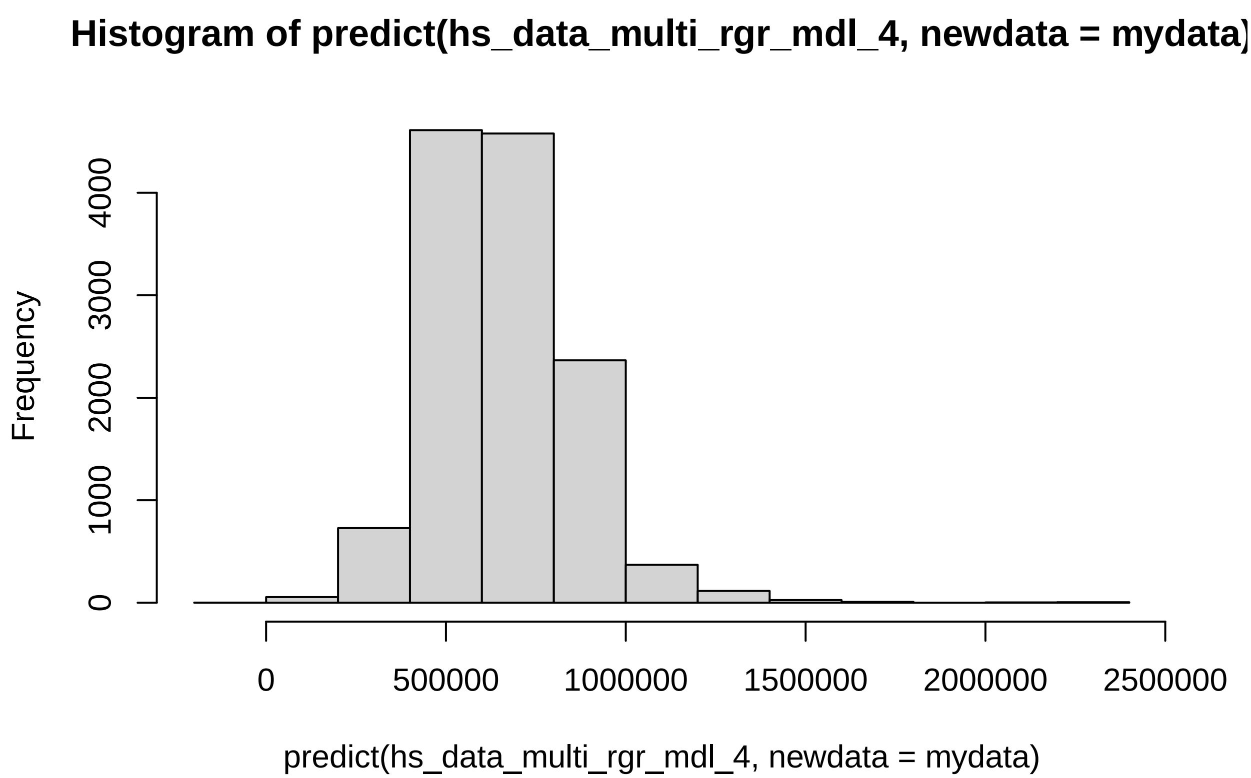

```
# Plot 1 - Scatterplot (Residual vs Fitted) - Access linearity of data
# Ideally, the residual plot will show no fitted pattern. That is, the red
# line should be approximately horizontal at zero. The presence of a pattern may
# indicate a problem with some aspect of the linear model. In our example,
# there is no pattern in the residual plot. This suggests that we can assume
# linear relationship between the predictors and the outcome variables.
```

```
# Plot 2 = QQ plot of residuals - Access normality of residuals
# It can be used to visually check the normality assumption. The normal
# probability plot of residuals should approximately follow a straight line.
# In our example, half of the points fall exactly on the reference line which
# about half does not. We cannot assume normality of residuals in our case.

# Plot 3 - It's also called Spread-Location or scale-location plot.
# It is to evaluate Homogeneity of variance. This plot shows if residuals
# are spread equally along the ranges of predictors. It's good if you see a
# horizontal line with equally spread points. In our example, while majority
# of points are concentrated together and maintains the straight horizontal
# red line, few observations on right exist with higher residuals that are
# changes the red line from being horizontal to slant. I will still say overall
# data satisfies Homogeneity of variance because majority of points are randomly
# distributed and keeping the red line almost horizontal. If assumption is
# failed, a possible solution to reduce the heteroscedasticity problem is to
# use a log or square root transformation of the outcome variable (y).
# For e.g. model2 <- lm(log(sales) ~ youtube, data = marketing)

# Plot 4 - Residuals vs Leverage - outliers and high leverage points.
# Outliers - An outlier is a point that has an extreme outcome variable value.
# The presence of outliers may affect the interpretation of the model,
# because it increases the RSE. Outliers can be identified by examining the
# standardized residual (or studentized residual), which is the residual
# divided by its estimated standard error. Standardized residuals can be
# interpreted as the number of standard errors away from the regression line. Observations whose standa
# High leverage points - A data point has high leverage, if it has extreme
# predictor x values. This can be detected by examining the leverage statistic
# or the hat-value. A value of this statistic above 2(k + 1)/n indicates an
# observation with high leverage, where k is the number of predictors and n
# is the number of observations.
# Influencial values - An influential value is a value, which inclusion or
# exclusion can alter the results of the regression analysis. Such a value is
# associated with a large residual. Not all outliers (or extreme data points)
# are influential in linear regression analysis. Statisticians have developed
# a metric called Cook's distance to determine the influence of a value.
# This metric defines influence as a combination of leverage and residual size.
# Outliers and high leverage points can be identified by inspecting the
# Residuals vs Leverage plot.
# In our example, the plot highlights the top 3 most extreme points
# (#295, #4649 and #8377) with (-4,10,-5) approx standard residuals respectively.
# These are > 3 in absolute values and thus should be considered possible outliers.
# There are no points with higher leverage i.e. with leverage > than 2 times avg(leverage).
# The Residuals vs Leverage plot can help us to find influential observations if any.
# On this plot, outlying values are generally located at the upper right corner
# or at the lower right corner. Those spots are the places where data points
# can be influential against a regression line. We do not really have any
# points on the other side red dotted lines with Cook's distance >= 1.
# None on top right corner or bottom right corner. Thus, we do not see any
# outliers that are influential enough to change the regression line.


# plotting histograms of studentized.residuals and predicted values using hist()
```

```r
hist(mydata$studentized.residuals)
```




```r
hist(predict(hs_data_multi_rgr_mdl_4, newdata = mydata))
```



```
# as the histogram of residuals and predicted values have almost same shape,
# we can conclude that the residuals are normally distributed.
```

b. xv. Overall, is this regression model unbiased? If an unbiased regression model,

what does this tell us about the sample vs. the entire population model?

```
# 1. Utilizing vif values to gauge model bias
# When we check multi collinearity we check for vif score
vif(hs_data_multi_rgr_mdl_4)
```

```
##              sale_reason           building_grade square_feet_total_living
##                 1.017011                 2.362311                 2.582797
##          bath_full_count               year_built                sq_ft_lot
##                 1.576506                 1.374726                 1.114547
```

```
# None of the vif scores are near 5 or greater and thus predictors does not
# have any significant multi collinearity. Multi collinearity problems consist of
# including, in the model, different variables that have a similar predictive
# relationship with the outcome.

# Average vif
mean(vif(hs_data_multi_rgr_mdl_4))
```

```
## [1] 1.671316
```

```
# Average vif is >1 but nowhere close to 5 or greater. Model does not appear to have significant proof

# 2. We can also check bias by checking the impact of adding predictors on
# coefficient of first chosen predictor (in case of housing data - sq_ft_lot).
# If the coefficient of sq_ft_lot gets impacted much by addition of new predictors
# that means addition may cause bias.

# Coefficient of sq_ft_lot in simple regression model as base to compare
summary(hs_data_smpl_rgr_mdl)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2016064  -194842   -63293    91565  3735109
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 6.418e+05  3.800e+03  168.90   <2e-16 ***
## sq_ft_lot   8.510e-01  6.217e-02   13.69   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 401500 on 12863 degrees of freedom
## Multiple R-squared:  0.01435,    Adjusted R-squared:  0.01428
## F-statistic: 187.3 on 1 and 12863 DF,  p-value: < 2.2e-16
```

```
#             Estimate Std. Error t value Pr(>|t|)
#(Intercept) 6.418e+05  3.800e+03  168.90   <2e-16 ***
#sq_ft_lot   8.510e-01  6.217e-02   13.69   <2e-16 ***

# Trying to create models with one chosen variable at a time and observe change in coefficient of sq_ft
hs_data_multi_rgr_mdl_5 <- lm(Sale_Price ~ sq_ft_lot+square_feet_total_living, data = mydata)

summary(hs_data_multi_rgr_mdl_5)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot + square_feet_total_living,
##     data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1953643  -119763   -41295    44410  3770022
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)              1.903e+05  8.771e+03  21.697   <2e-16 ***
## sq_ft_lot                1.006e-01  5.737e-02   1.754   0.0795 .
## square_feet_total_living 1.844e+02  3.300e+00  55.869   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 360200 on 12862 degrees of freedom
## Multiple R-squared:  0.2068, Adjusted R-squared:  0.2067
## F-statistic:  1677 on 2 and 12862 DF,  p-value: < 2.2e-16
```

```
#(Intercept)              1.903e+05  8.771e+03  21.697   <2e-16 ***
#sq_ft_lot                1.006e-01  5.737e-02   1.754   0.0795 .
#square_feet_total_living 1.844e+02  3.300e+00  55.869   <2e-16 ***
## difference caused in coefficient of sq_ft_lot (from simple regression) = 0.75

hs_data_multi_rgr_mdl_6 <- lm(Sale_Price ~ sq_ft_lot+building_grade, data = mydata)

summary(hs_data_multi_rgr_mdl_6)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot + building_grade, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1943227  -135853   -48001    53756  3762342
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -5.147e+05  2.499e+04 -20.595  < 2e-16 ***
## sq_ft_lot       4.754e-01  5.805e-02   8.191 2.84e-16 ***
```

```
## building_grade  1.414e+05  3.025e+03  46.739  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 371200 on 12862 degrees of freedom
## Multiple R-squared:  0.1575, Adjusted R-squared:  0.1573
## F-statistic:  1202 on 2 and 12862 DF,  p-value: < 2.2e-16
```

```
# (Intercept)    -5.147e+05  2.499e+04 -20.595  < 2e-16 ***
# sq_ft_lot       4.754e-01  5.805e-02   8.191 2.84e-16 ***
# building_grade  1.414e+05  3.025e+03  46.739  < 2e-16 ***
## difference caused in coefficient of sq_ft_lot (from simple regression) = 0.375

hs_data_multi_rgr_mdl_7 <- lm(Sale_Price ~ sq_ft_lot+bath_full_count, data = mydata)

summary(hs_data_multi_rgr_mdl_7)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot + bath_full_count, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4128410  -161910   -49329    72518  3698383
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     3.312e+05  1.002e+04   33.05   <2e-16 ***
## sq_ft_lot       7.576e-01  5.973e-02   12.68   <2e-16 ***
## bath_full_count 1.739e+05  5.225e+03   33.28   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 385300 on 12862 degrees of freedom
## Multiple R-squared:  0.09249,    Adjusted R-squared:  0.09235
## F-statistic: 655.4 on 2 and 12862 DF,  p-value: < 2.2e-16
```

```
# (Intercept)     3.312e+05  1.002e+04   33.05   <2e-16 ***
# sq_ft_lot       7.576e-01  5.973e-02   12.68   <2e-16 ***
# bath_full_count 1.739e+05  5.225e+03   33.28   <2e-16 ***
# difference caused in coefficient of sq_ft_lot (from simple regression) = 0.1

hs_data_multi_rgr_mdl_8 <- lm(Sale_Price ~ sq_ft_lot+year_built, data = mydata)

summary(hs_data_multi_rgr_mdl_8)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot + year_built, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2441124  -166193   -48805    74921  3634286
##
## Coefficients:
```

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.170e+07  3.991e+05  -29.32   <2e-16 ***
## sq_ft_lot    1.104e+00  6.054e-02   18.23   <2e-16 ***
## year_built   6.191e+03  2.002e+02   30.93   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 387400 on 12862 degrees of freedom
## Multiple R-squared:  0.08259,    Adjusted R-squared:  0.08245
## F-statistic:   579 on 2 and 12862 DF,  p-value: < 2.2e-16
```

```
# (Intercept) -1.170e+07  3.991e+05  -29.32   <2e-16 ***
# sq_ft_lot    1.104e+00  6.054e-02   18.23   <2e-16 ***
# year_built   6.191e+03  2.002e+02   30.93   <2e-16 ***
# difference caused in coefficient of sq_ft_lot (from simple regression) = -.25

hs_data_multi_rgr_mdl_9 <- lm(Sale_Price ~ sq_ft_lot+sale_reason, data = mydata)

summary(hs_data_multi_rgr_mdl_9)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sq_ft_lot + sale_reason, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2073083  -194249   -65029    86963  3725586
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  6.695e+05  4.265e+03  156.98   <2e-16 ***
## sq_ft_lot    8.802e-01  6.175e-02   14.25   <2e-16 ***
## sale_reason -1.827e+04  1.314e+03  -13.90   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 398500 on 12862 degrees of freedom
## Multiple R-squared:  0.02894,    Adjusted R-squared:  0.02879
## F-statistic: 191.7 on 2 and 12862 DF,  p-value: < 2.2e-16
```

```
# (Intercept)  6.695e+05  4.265e+03  156.98   <2e-16 ***
# sq_ft_lot    8.802e-01  6.175e-02   14.25   <2e-16 ***
# sale_reason -1.827e+04  1.314e+03  -13.90   <2e-16 ***
# difference caused in coefficient of sq_ft_lot (from simple regression) = -0.03

summary(hs_data_multi_rgr_mdl_4)
```

```
##
## Call:
## lm(formula = Sale_Price ~ sale_reason + building_grade + square_feet_total_living +
##     bath_full_count + year_built + sq_ft_lot, data = mydata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2136788  -119779   -44670    41079  3720748
```

```
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)             -4.477e+06  4.165e+05 -10.749  < 2e-16 ***
## sale_reason             -1.156e+04  1.180e+03  -9.792  < 2e-16 ***
## building_grade           3.106e+04  4.404e+03   7.053 1.84e-12 ***
## square_feet_total_living  1.374e+02  5.083e+00  27.038  < 2e-16 ***
## bath_full_count          1.288e+04  6.040e+03   2.132    0.033 *
## year_built               2.268e+03  2.132e+02  10.640  < 2e-16 ***
## sq_ft_lot                3.132e-01  5.805e-02   5.395 6.97e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 355100 on 12858 degrees of freedom
## Multiple R-squared:  0.2293, Adjusted R-squared:  0.2289
## F-statistic: 637.6 on 6 and 12858 DF,  p-value: < 2.2e-16
```

```
#(Intercept)             -4.477e+06  4.165e+05 -10.749  < 2e-16 ***
#sale_reason             -1.156e+04  1.180e+03  -9.792  < 2e-16 ***
#building_grade           3.106e+04  4.404e+03   7.053 1.84e-12 ***
#square_feet_total_living  1.374e+02  5.083e+00  27.038  < 2e-16 ***
#bath_full_count          1.288e+04  6.040e+03   2.132    0.033 *
#year_built               2.268e+03  2.132e+02  10.640  < 2e-16 ***
#sq_ft_lot                3.132e-01  5.805e-02   5.395 6.97e-08 ***
# difference caused in coefficient of sq_ft_lot (from simple regression) = 0.54

# As we can see that most difference caused to the coefficient of sq_ft_lot
# was when we added square_feet_total_living. Difference was 0.75. There may
# be some bias in the model because of this observation but it needs further
# analysis.

# 3. We can also observe correlation between variables of the model,
# specially checking correlation between sq_ft_lot and every other
# variable individually
cor(mydata[,c("sale_reason","building_grade","square_feet_total_living",
              "bath_full_count","year_built","sq_ft_lot")], method = "pearson")
```

```
##                          sale_reason building_grade square_feet_total_living
## sale_reason               1.00000000    -0.07891229              -0.06521276
## building_grade           -0.07891229     1.00000000               0.74518052
## square_feet_total_living -0.06521276     0.74518052               1.00000000
## bath_full_count          -0.07312779     0.45941631               0.51778378
## year_built               -0.12023836     0.36192968               0.30642729
## sq_ft_lot                 0.03400556     0.13843064               0.23410450
##                          bath_full_count year_built   sq_ft_lot
## sale_reason                  -0.07312779 -0.1202384  0.03400556
## building_grade                0.45941631  0.3619297  0.13843064
## square_feet_total_living      0.51778378  0.3064273  0.23410450
## bath_full_count               1.00000000  0.4525997  0.04699255
## year_built                    0.45259966  1.0000000 -0.13491395
## sq_ft_lot                     0.04699255 -0.1349139  1.00000000
```

```
# We see that there is some correlation positive correlation between
# sq_ft_lot and square_feet_total_living. We observed that addition of
# square_feet_total_living caused most change in the coefficient of sq_ft_lot as well.
```

```
# To conclude there may be little bias in the model because of correlation
# between sq_ft_lot and square_feet_total_living. But as we see the results of
# vif stats it is not significant enough.
```