

Kaggle - House Price Prediction

MSDS6371 Class Project

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I. Introduction

This project is focused on the Ames Housing dataset on Kaggle. We will first explore how the sales price of a home is influenced by the home's living area square footage in three different neighborhoods. We will then build different models aimed at accurately predicts a home's sales price based off of many different features of the home.

II. Data Description

The data comes from the Ames Housing dataset which describes the sale price of property in Ames, Iowa from the years 2006 to 2010. This includes 80 distinct variables, all of which help describe a property and may influence the price of a home. We looked at all the observations included in the dataset (2930) and used a mixture of these variables to build models that can aid in predicting a home's sale price.

III. Analysis 1

a. Restate the problem

The Century 21 Ames real estate company has hired us to analyze how square footage of living area of house(GrLivArea) is related to its sales price in the three neighborhoods they sell homes in (NAmes, BrkSide, and Edward neighborhoods).

b. Build and Fit

i. Model 1

1. $SalesPrice = \beta_0 + \beta_1 SquareFootage$
 - a. **model1** = `lm(SalePrice~GrLivArea, data = data1)`
2. Check Assumptions (see Appendix 1.1, 1.2, 1.3, 1.4)
 - a. Linearity: According to *Plot 1.1* the general trend follows linear relationship between Square Foot of Living Area and Sale Price, however there are few outliers that may work against this trend
 - b. Normality: Q-Q *Plot(1.4)* presents a general normal trend, although there are few outliers at either end of the plot
 - c. Equal SD: Observations 169 and 190 both have standardized residuals greater than 4 - outliers
 - d. Independence: We will assume observations are independent
 - e. Outliers: Observation 339 has a Cook's Distance larger than 5.6 while observation 131 has a Cook's Distance larger than 1.
 - i. These may be due to some unique cases

3. Decision: Since our sample is sufficiently large, and these four outliers may come from a different population of interest than the one we are trying to set up, so we decided to remove these four outliers for further analysis. (Adjusted R-squared = 0.3406)

ii. Model 2

1. $SalesPrice = \beta_0 + \beta_1 SquareFootage$
 - a. **model2** = `lm(SalePrice~GrlivArea, data = data2)`
 - b. Model2 = model1 run without outliers
2. Check Assumptions (*Appendix 1.5, 1.6, 1.7, 1.8*)
 - a. Linearity: *Plot 1.5* shows linear relationship between square foot of living area and sales price
 - b. Normality: Q-Q Plot shows normal distribution
 - c. Equal SD: standardized residuals show all data within 2.5 range, so this assumption is met
 - d. Independence: Assume our observations are independent.
 - e. Outliers: All observations have a Cook's D less than 0.01, so no high leverage and high residual point.
3. All assumptions are met with this model, however we are interested in adding in the neighborhood factors. So we will go on building out Model 3 and see if the Neighborhood is significant in our analysis. (Adjusted R-squared= 0.449)

iii. Model 3

1. $SalesPrice = \beta_0 + \beta_1 SquareFootage + \beta_2 (N1) + \beta_3 (N2) + \beta_4 (N1)SquareFootage + \beta_5 (N2)SquareFootage$
 - a. **model3** = `lm(SalePrice~GrlivArea + Neighborhood + GrlivArea * Neighborhood, data = data2)`
 - b. Model3 is run with neighborhood data added in.
2. Check Assumptions (*Appendix 1.9, 1.10, 1.11, 1.12*)
 - a. Linearity: As we seen from *Plot 1.9*, each neighborhood follows a linear relationship between square foot of living area and sales price
 - b. Normality: QQ-Plot shows normal distribution of our model
 - c. Equal SD: Standardized residual plot shows about 5% of data is beyond residual value of 2. So this assumption is met.
 - d. Independence: We will assume all observations are independent.
 - e. Outliers: observations have a Cook's D less than 0.20, so no major high leverage or high residual point.
3. Conclusion: Adjusted R-squared = 0.5165, which is higher than model 2, by adding in Neighborhoods, our model is better explained. So we will move forward to interpret Model 3.

c. The Analysis

- i. Using model 3 we can generate separate models(one for each neighborhood)

1. Overall Model:
 - a. $SalesPrice = 19971.514 + 87.163SquareFootage + 17128.908(Edwards) + 60354.199(NAmes) + -17.004(Edwards)SquareFootage + -37.601(Ames)SquareFootage$
2. BrkSide Model:
 - a. $SalesPrice = 19971.514 + 87.163 * SquareFootage$
3. Edwards Model:
 - a. $SalesPrice = 37100.422 + 70.159 * SquareFootage$
4. NAmes Model:
 - a. $SalesPrice = 80325.739 + 49.562 * SquareFootage$
- ii. Analyze the plot and assumptions
 1. Linearity, Normality, Equal SD, Independence and outliers are checked with section above.
 2. There is no evidence to suggest any major outliers that will need to be accounted for as the residuals appear in a random cloud. All assumptions are met, we will move on to interpret our findings.
- d. **Conclusion**
 - i. There is sufficient evidence to suggest that Model 3 is a good fit for the data (p-value < 0.0001).
 - ii. We can interpret each sub-model of model 3 as follows
 1. Given that the Neighborhood is BrkSide, it is predicted that the Sales price of the house will increase by \$8716.3 for every 100 square feet added to the house. We are 95% confident this increase will be between 7152.22 and 10380.29.
 2. Given that the Neighborhood is Edwards, it is predicted that the Sales Price of the house will increase by \$7015.9 for every 100 square feet added to the house. We are 95% confident this increase will be between 5618.25 and 8413.43
 3. Given that the neighborhood is NAmes, it is predicted that the Sales Price of the house will increase by \$4956.2 for every 10 square feet added to the house. We are 95% confident this increase will be between 4150.50 and 5761.75
 - iii. Scope: Because this an observational study we cannot draw any causal inference. Not knowing if this data set is randomly drawn from a bigger population from the entire sales data from 2006-2010, any inference to the population needs to remain speculative.

IV. Analysis 2

- a. **Restate the Problem**
 - i. Select from all the variables available to us, and build a model that can accurately predict the sales price of a home in Ames, Iowa between 2006 and 2010.

- ii. We will first explore the Stepwise, Forward, and Backward models and use our findings to create a more accurate model.

b. Clean-up and selection

- i. We will first look at each variable and convert specific variables that are levels to factors so we can use them as categorical variable for linear regression.
- ii. We plotted each continuous variable vs the sales price of the house to look for correlation and independence. From there we will begin to assemble a list of variables with strong correlation that may be good predictors in our regression model. (See *plot 2.1 – 2.12*)
- iii. 31 of the 80 variables were selected for our models
 - 1. We used the pool area variable that is available to create a new predictor(*poolYN*) that tells us Yes or No to a house having a pool.
- iv. After selection we decided to look closely at our selected variables that contained N/A and transform those values to useable factors such as None for quality rankings. We then replotted these variables to confirm that there was still strong correlation.
- v. After plotting the residuals, we decided to use a log transform on the sales price to help normalize or data better.

c. Build and Fit Models

- i. Stepwise
 - 1. Using R and our selected variables we created a model using stepwise AIC to choose the optimal variables/model among the variables we have narrowed down above, it is further verified by internal 10-fold cross validation.
 - 2. Checking Assumptions
 - a. Linearity: this has been checked by pair wise *plots 2.1-2.12*
 - b. Normality: see Q-Q *plot 2.13*, normality is roughly met, although there are some outliers at the ends
 - c. Equal SD: see Standardized Residuals *plot 2.14*, some outliers are outside of 2.5 range, however due to the size of our sample data, it should not cause major concern. We will assume this assumption met and move on.
 - d. Independence: Assume all of our observations are independent
 - e. Outliers: Looking at the Cook's D *plot 2.15*, there is one data point went over 1.5, comparing to our sample size, it should not have a huge impact on our model. So we will keep this observation and move on.
 - 3. Conclusions: The Stepwise model has selected following predictors (see *plot 2.16*): *MSSubClass*, *MSZoning*, *LotArea*, *LotConfig*, *Neighborhood*, *HouseStyle*, *OverallQual*, *YearBuilt*, *YearRemodAdd*, *ExterCond*, *Foundation*, *BsmtQual*, *BsmtCond*, *TotalBsmtSF*, *Heating*, *CentralAir*, *GrLivArea*, *FullBath*, *KitchenQual*, *Fireplaces*, *GarageType*, *GarageCars*, *PolIYN*, *MoSold*, *YrSold*, among the 31 variables we feed to the model. And it give us RMSE of 0.149 and follow performance:

- a. Final Results
 - i. Kaggle Score = 0.15372
 - ii. CV Press = 0.1494
 - iii. Adjusted R-squared = 0.8975
- ii. Forward Selection
 1. Using R and our selected variables we created another model using Forward selection by AIC to choose the optimal variables/model among the variables we have narrowed down above, it is further verified by creating our own cross validation.
 2. Checking Assumptions:
 - a. Linearity: this has been checked by pair wise *plotting 2.1-2.12*
 - b. Normality: see Q-Q *plot 2.17*, normality is roughly met, although there are some outliers at the ends
 - c. Equal SD: see Standardized Residuals *plot 2.18*, some outliers are outside of 2.5 range, however due to the size of our sample data, it should not cause major concern. We will assume this assumption met and move on.
 - d. Independence: Assume all of our observations are independent
 - e. Outliers: Looking at the Cook's D *plot 2.19*, there is one data point went over 1.25, comparing to our sample size, it should not have a huge impact on our model. So we will keep this observation and move on.
 3. Conclusion: The Forward Selection has chosen the following predictors(see *plots 2.20, 2.21*): OverallQual, Neighborhood, GrLivArea, MSSubClass, OverallCond, GarageCars, YearBuilt, Fireplaces, BsmtQual, MSZoning, Heating, LotArea, YearRemodAdd, CentralAir, KitchenQual, GarageType, TotalBsmtSF, PoolYN, BsmtCond, LotConfig, FullBath among the 31 variables we fed to the automatic model selection. It gives us the following performance for prediction and Cross validation.
 - a. Kaggle Score = 0.15432
 - b. CV Press = 0.14199
 - c. Adjusted R-Squared = 0.89575
- iii. Backward Selection
 1. Using R and our selected variables we created the next model using Backward selection by AIC to choose the optimal variables/model among the variables we have narrowed down above, it is further verified by creating our own cross validation.
 2. Checking Assumptions:
 - a. Linearity: this has been checked by pair wise *plotting 2.1-2.12*
 - b. Normality: see Q-Q *plot 2.22*, normality is roughly met, although there are some outliers at the ends
 - c. Equal SD: see Standardized Residuals *plot 2.23*, some outliers are outside of 2.5 range, however due to the size of our sample

data, it should not cause major concern. We will assume this assumption met and move on.

- d. Independence: Assume all of our observations are independent
- e. Outliers: Looking at the Cook's D *plot* 2.24, there is one data point went over 1.25, comparing to our sample size, it should not have a huge impact on our model. So we will keep this observation and move on.

- 3. Conclusion: The Backward Selection has chosen the following predictors(see *plots* 2.25, 2.26): MSSubClass, MSZoning, LotArea, LotConfig, Neighborhood, OverallQual, YearRemodAdd, BsmtQual, TotalBsmtSF, Heating, CentralAir, GrLivArea, FullBath, KitchenQual, Fireplaces, GarageType, GarageCars, PoolYN, among the 31 variables we fed to the automatic model selection. It gives us the following performance for prediction and Cross validation.

- a. Kaggle Score = 0.15432
- b. CV Press = 0.148
- c. Adjusted R-Squared = 0.89575

iv. Custom Model:

- 1. To design our optimal custom model, we used following steps:

- a. Reimport the training dataset, use predictive mean matching to fill in missing continuous variables (use best estimate and keep original distribution of each variable.)
- b. Log transformation on SalePrice and GrLivArea to increase linearity relationship.
- c. Divide all 80 variables available to us into different subgroups
- d. Run best subset selection to pick out the best predictors within each subgroup
- e. Convert Categorical variables with NA to None or Others.
- f. Use all predictors selected under each subgroup to run a stepwise AIC to choose the optimal variables/model
- g. Further verified model by internal 10-fold cross validation.

- 2. Checking Assumptions:

- a. Linearity: this has been checked by pair wise *plotting* 2.1-2.12
- b. Normality: see Q-Q *plot* 2.27, normality is roughly met, although there are some outliers at the ends
- c. Equal SD: see Standardized Residuals *plot* 2.28, some outliers are outside of 2.5 range, however due to the size of our sample data, it should not cause major concern. We will assume this assumption met and move on.
- d. Independence: Assume all of our observations are independent
- e. Outliers: Looking at the Cook's D *plot* 2.29, there are two data points went around 0.6. This should not be a problem considering our sample size.

3. Conclusion: The Custom model has chosen the following predictors(see *plots 2.30, 2.31*): MSSubClass, MSZoning, LotArea, LotConfig, Neighborhood, Condition2, BldgType, OverallQual, YearBuilt, YearRemodAdd, RoofStyle, RoofMatl, Exterior1st, Exterior2nd, MasVnrType, Foundation, BsmtQual, BsmtFinType1, TotalBsmt, Heating, HeatingQC, CentralAir, Electrical, X2ndFlr, GrLivArea, BsmtFullBath, FullBath, BedroomAbvGr, KitchenAbvGr, KitchenQual, Fireplaces, GarageCars, GarageArea, PavedDrive, WoodDeckSF, ScreenPorch, MoSold, YrSold. It gives us the following performance for prediction and Cross validation.
 - a. Kaggle Score = 0.14773
 - b. CV Press = 0.1649
 - c. Adjusted R-Squared = 0.9207

d. Overall Conclusion:

After running and comparing the four models we built, see table below, the Custom model gives us the best Adjusted R-Squared score (highest) and best Kaggle Score(Lowest). After all, we choose custom model as our best model.

Predictive Models	Adjusted R2	CV PRESS	Kaggle Score
Forward	0.89575	0.14199	0.15432
Backward	0.89575	0.148	0.15432
Stepwise	0.8975	0.1494	0.15372
CUSTOM	0.9207	0.1649	0.14773

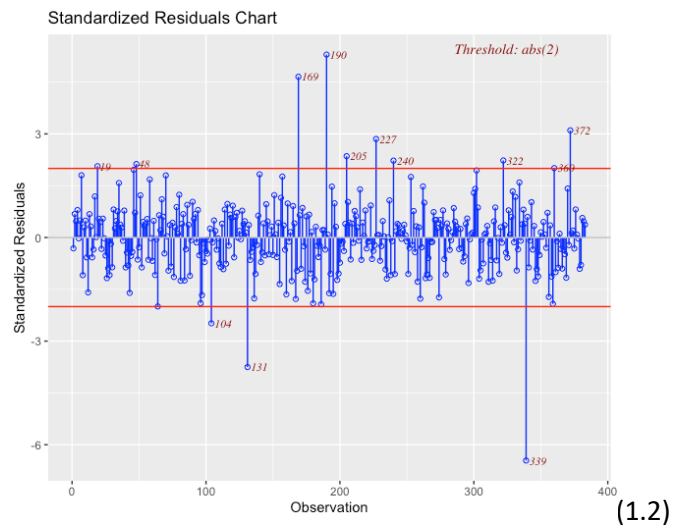
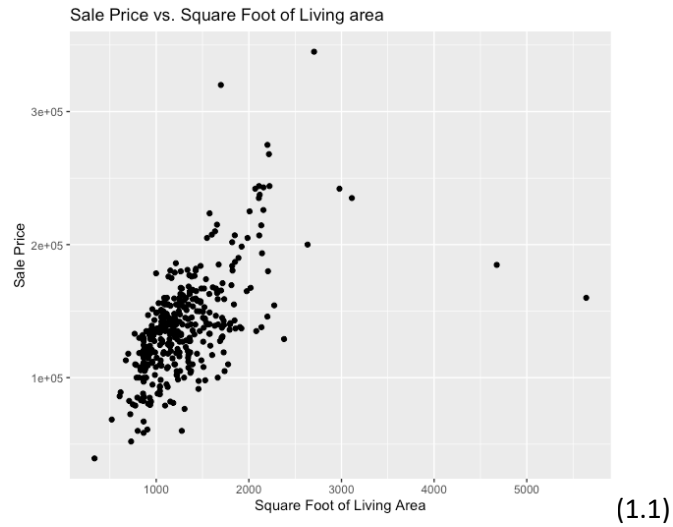
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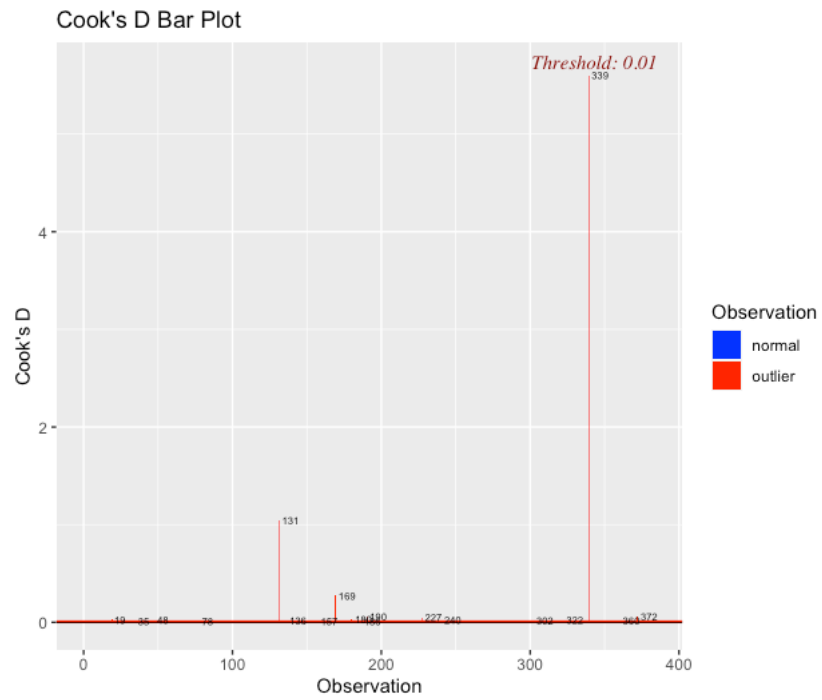
- a. MSDS 6371 Project Description.docx – see details at <https://github.com/nickmingyang/MSDS6371Project>
- b. Kaggle Competition – Data description, training and testing Data source, and other data details: <https://www.kaggle.com/c/house-prices-advanced-regression-techniques>
- c. Project source code used for analysis and results: MSDS6371Project.Rmd under: <https://github.com/nickmingyang/MSDS6371Project>
- d. Custom Model test set prediction—custom_model_Miller_YU.csv under: <https://github.com/nickmingyang/MSDS6371Project>
- e. Stepwise AIC model: <http://www.sthda.com/english/articles/37-model-selection-essentials-in-r/154-stepwise-regression-essentials-in-r/>

- f. Other models result labeled csv files under:
<https://github.com/nickmingyang/MSDS6371Project>

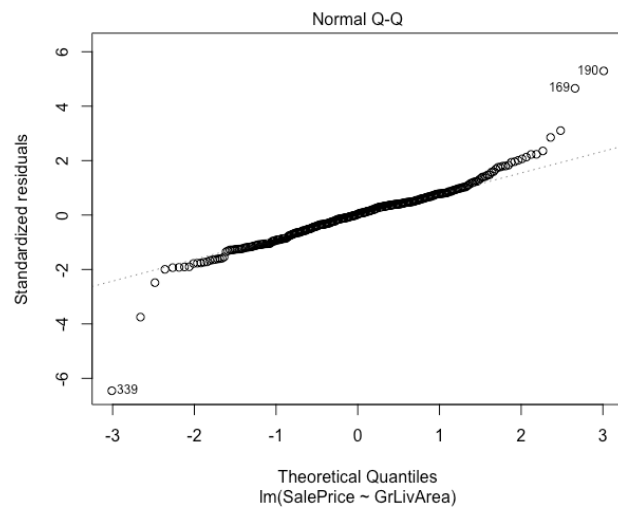
VI. Appendix

- a. Analysis 1
i. Model 1





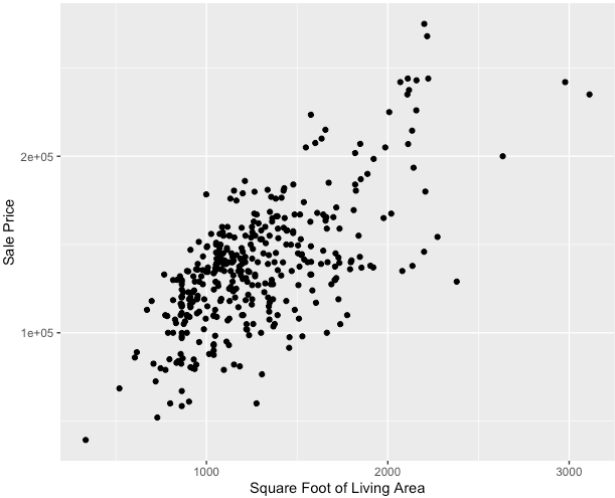
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(1.4)

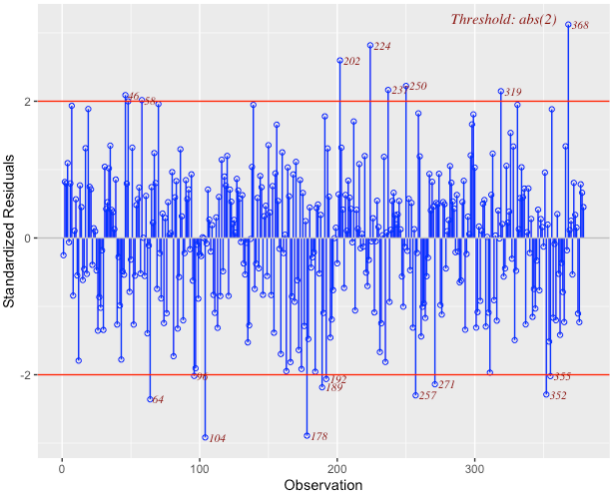
ii. Model 2

Sale Price vs. Square Foot of Living area

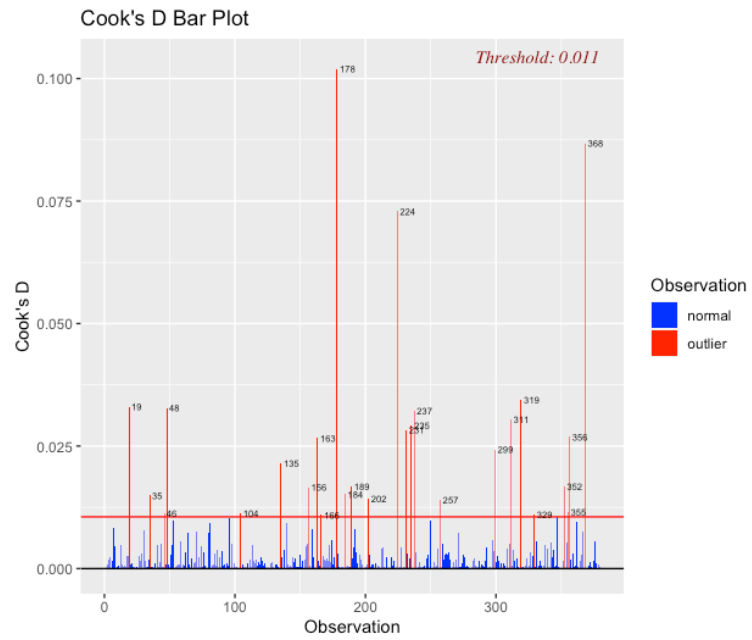


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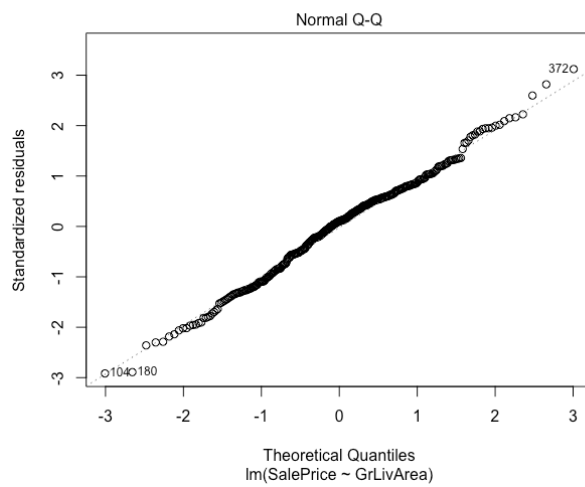
Standardized Residuals Chart



(1.6)



(1.7)

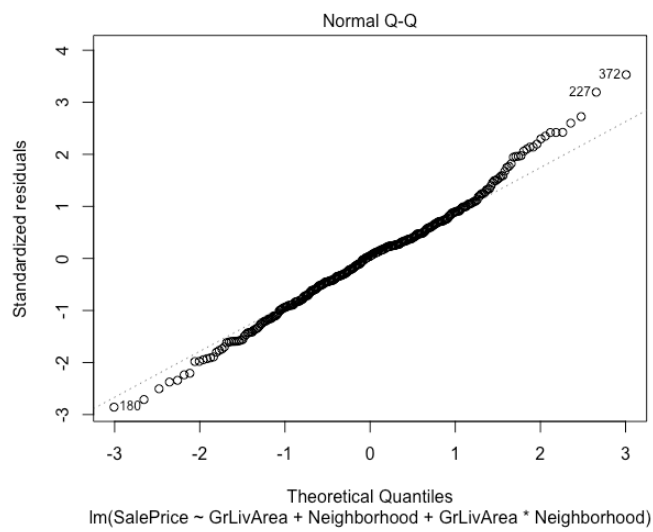


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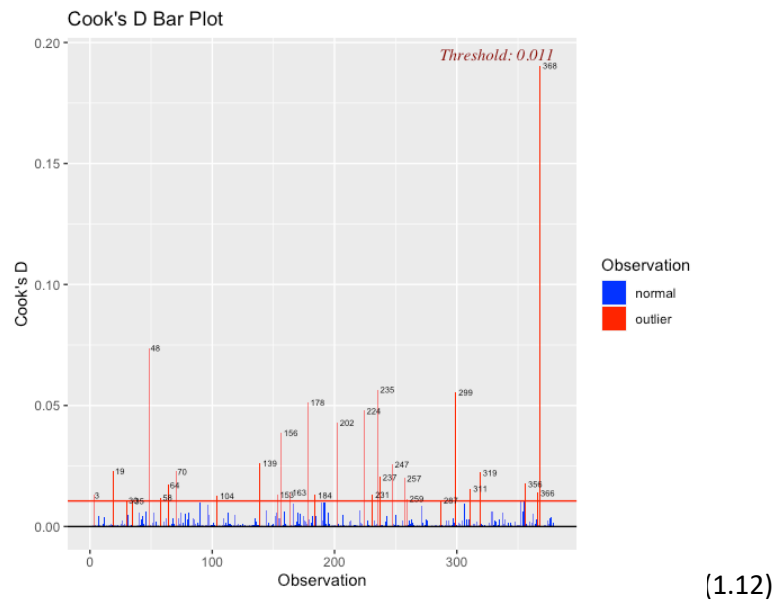
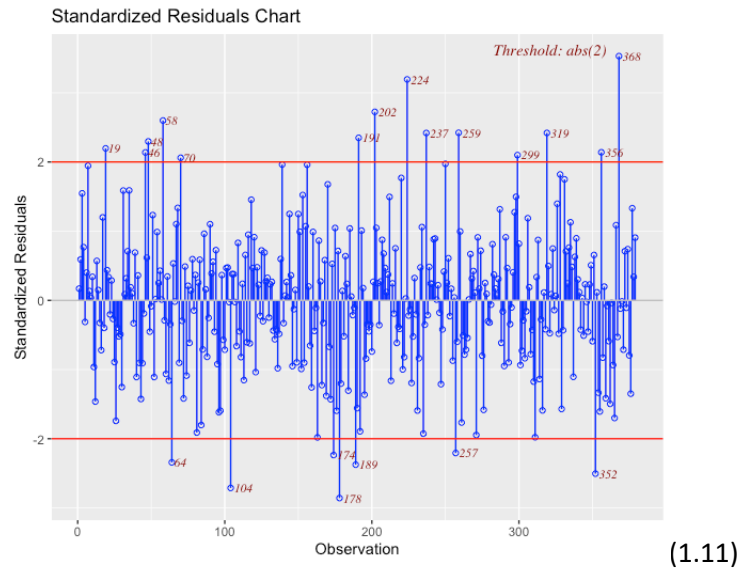
iii. Model 3



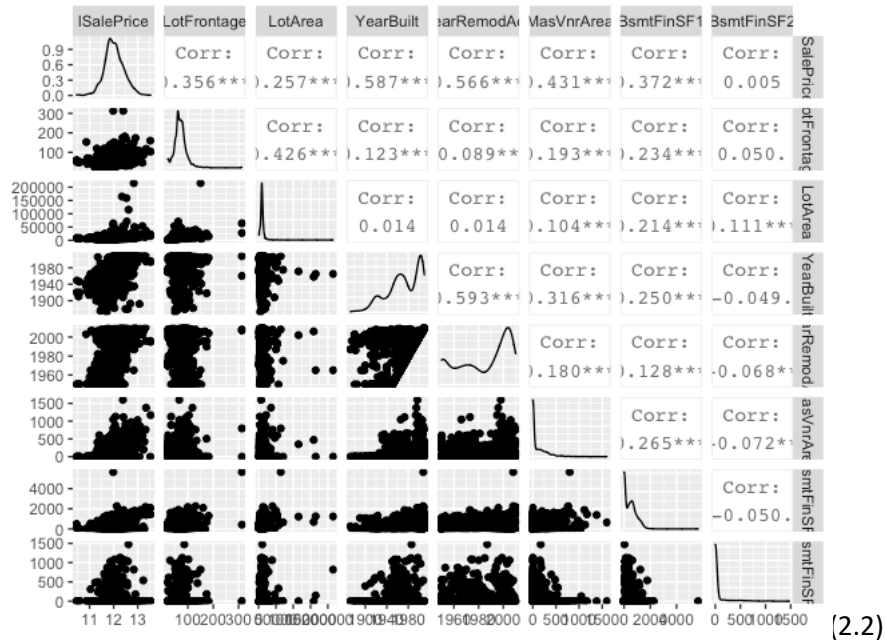
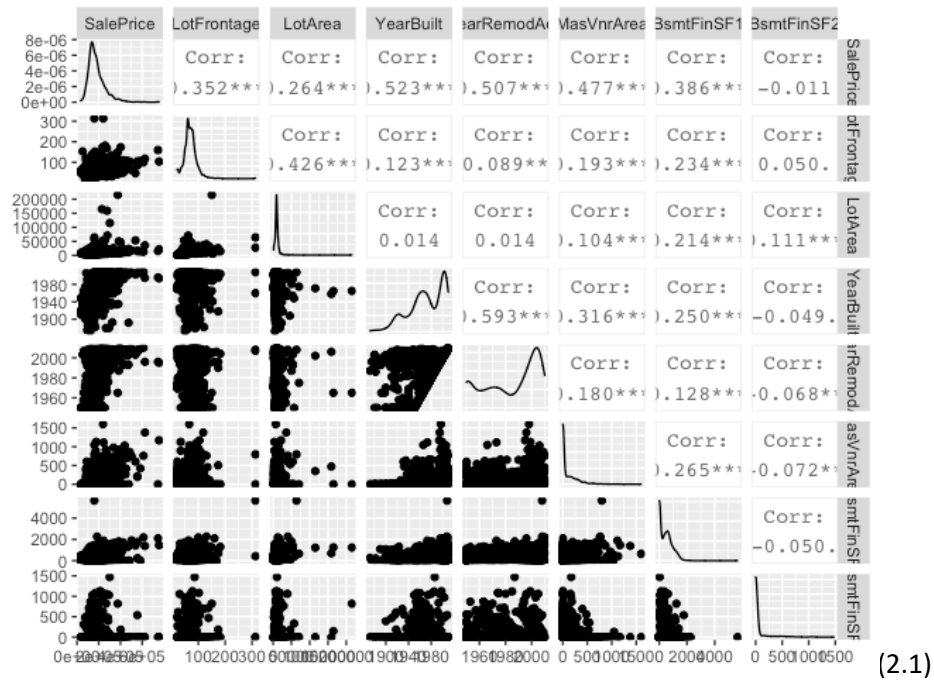
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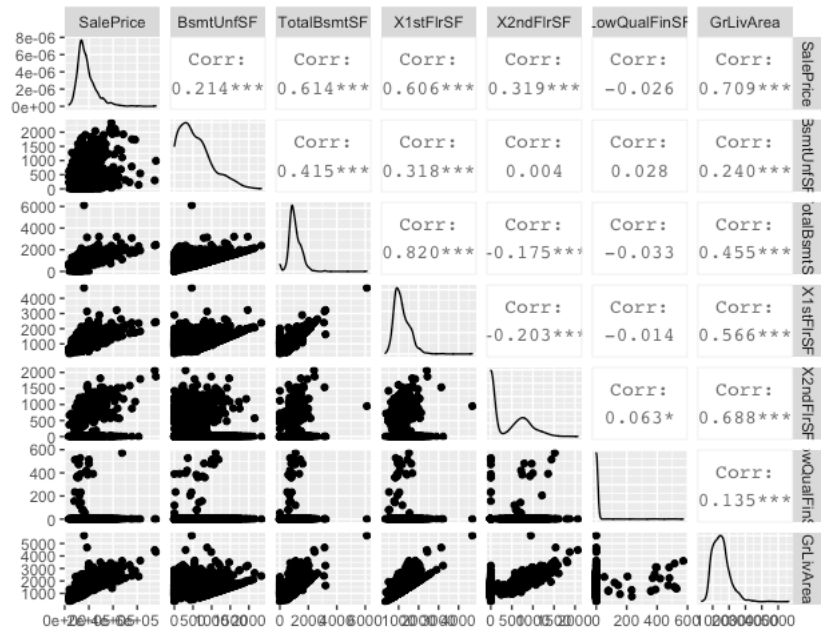


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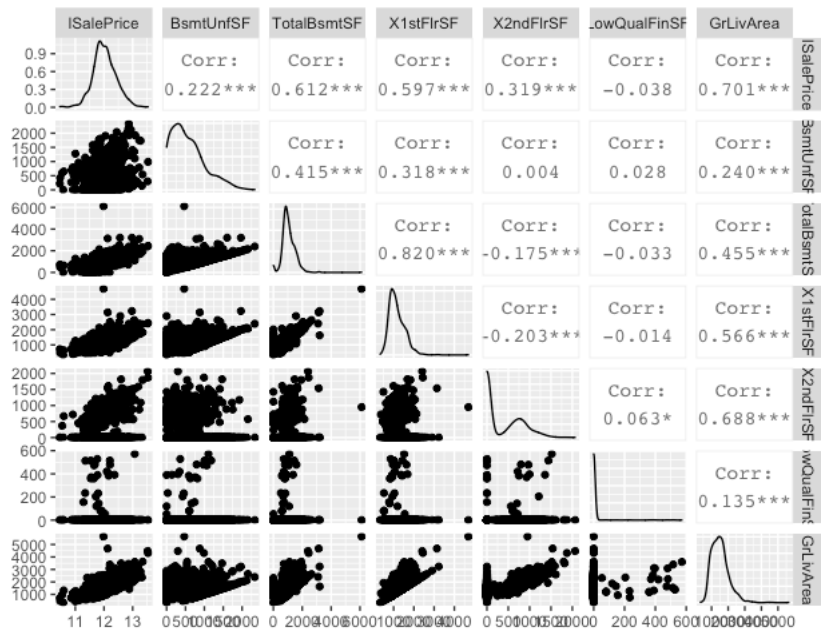


b. Analysis 2

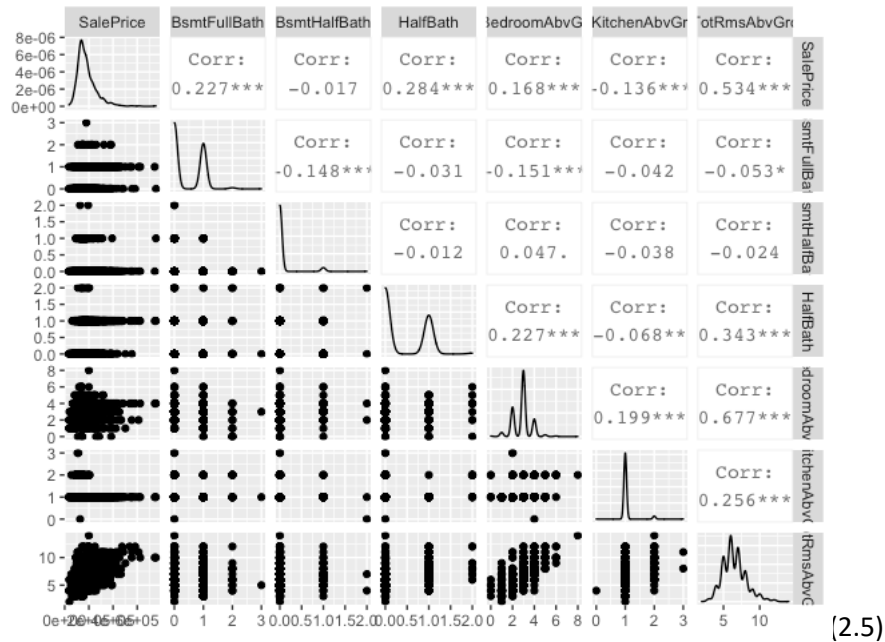




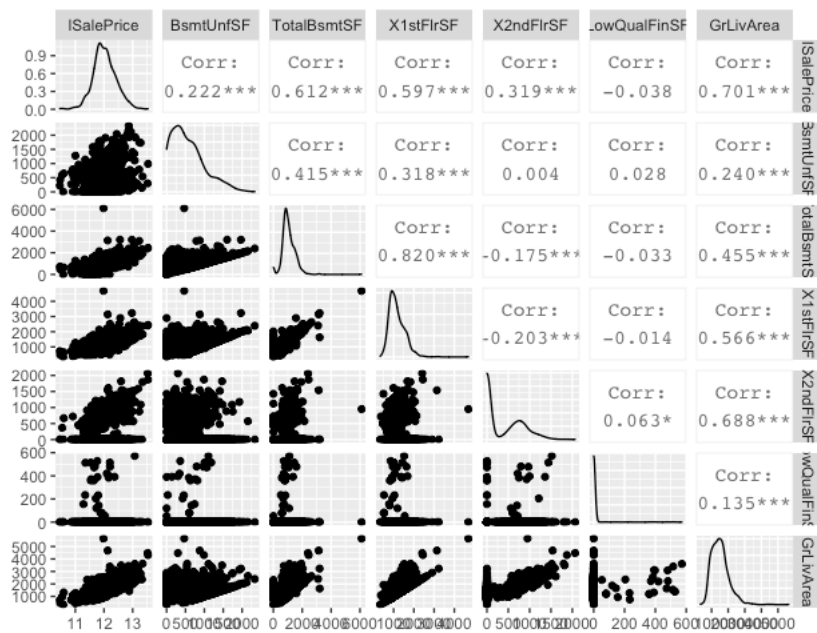
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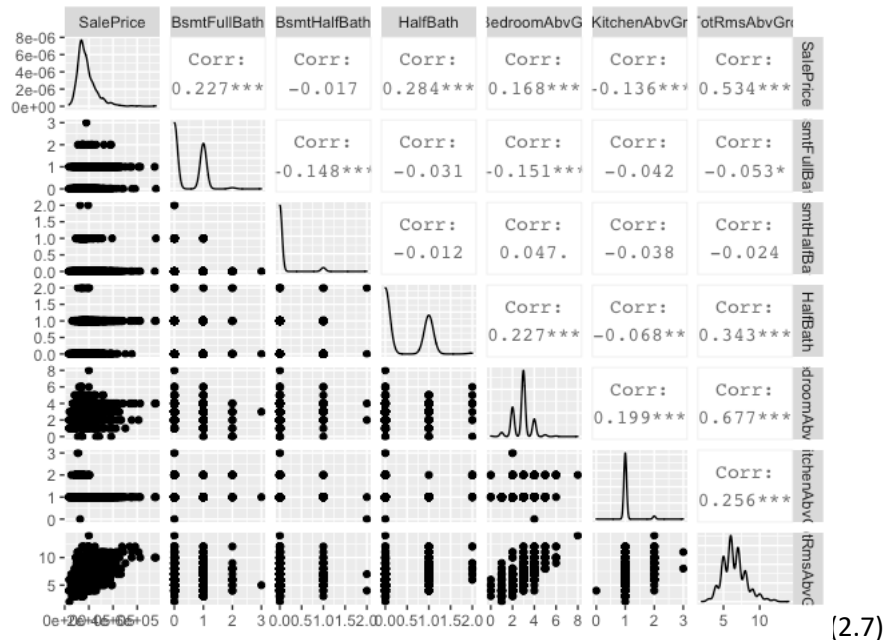
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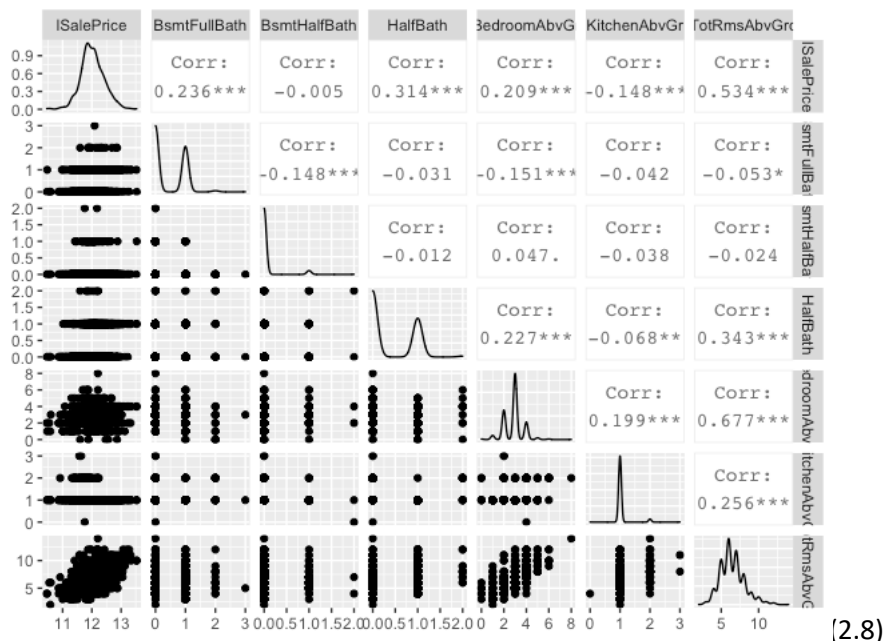
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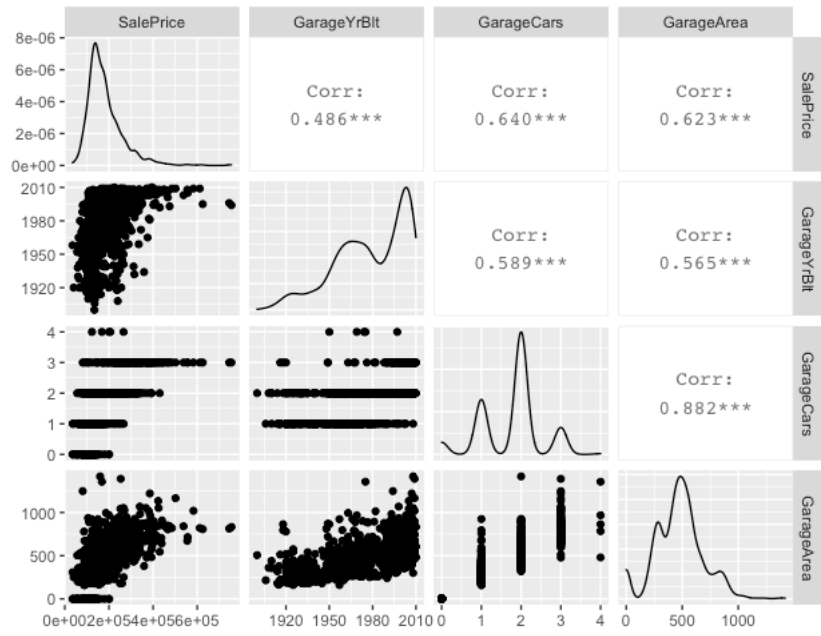
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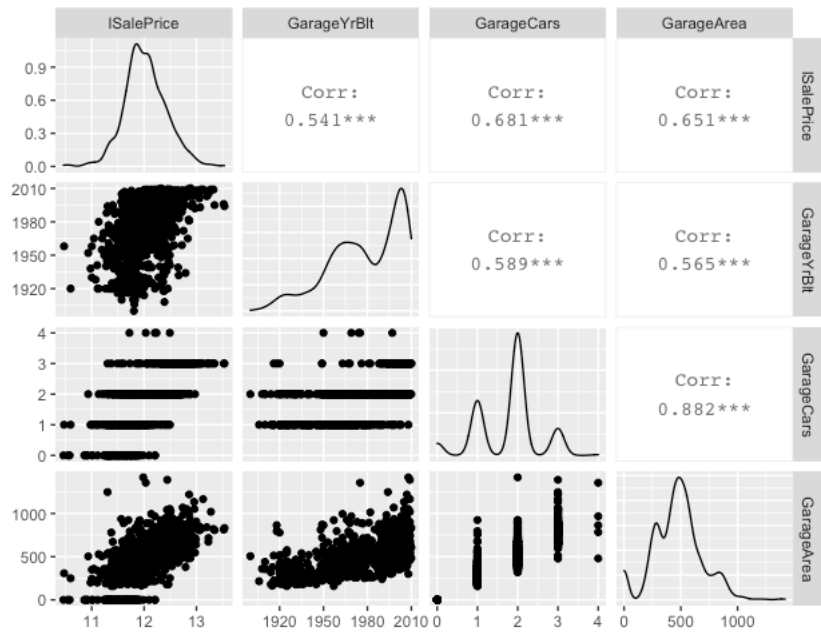
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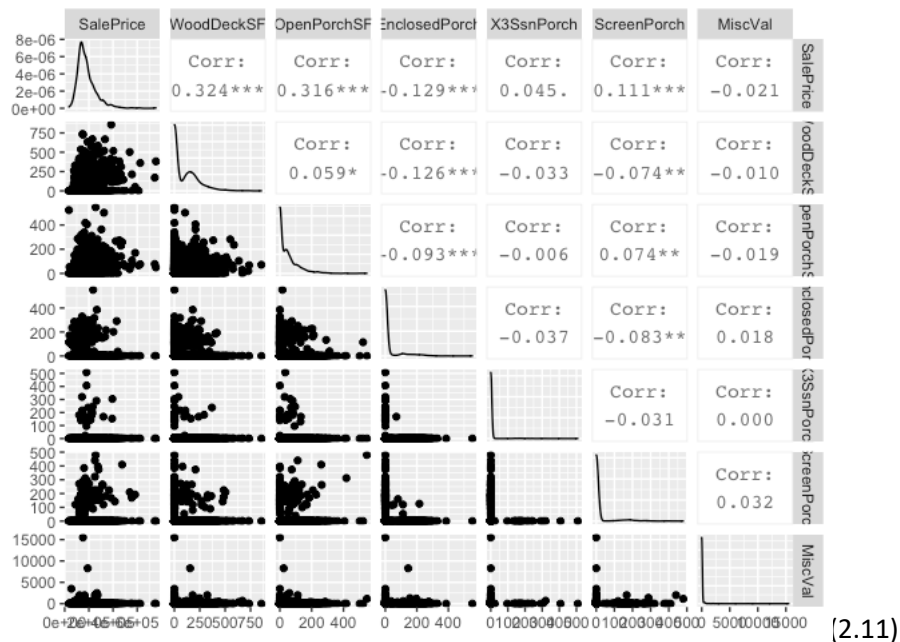
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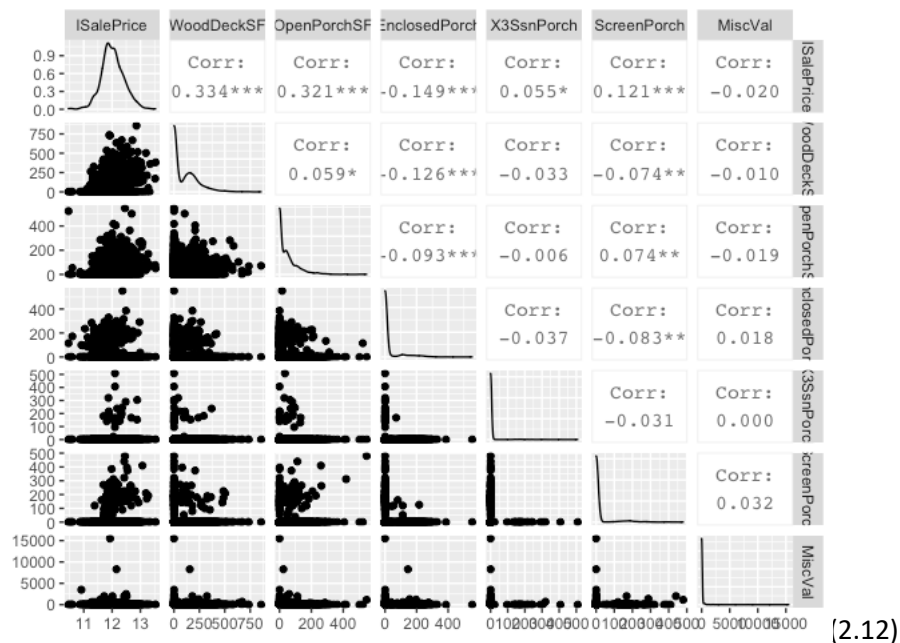
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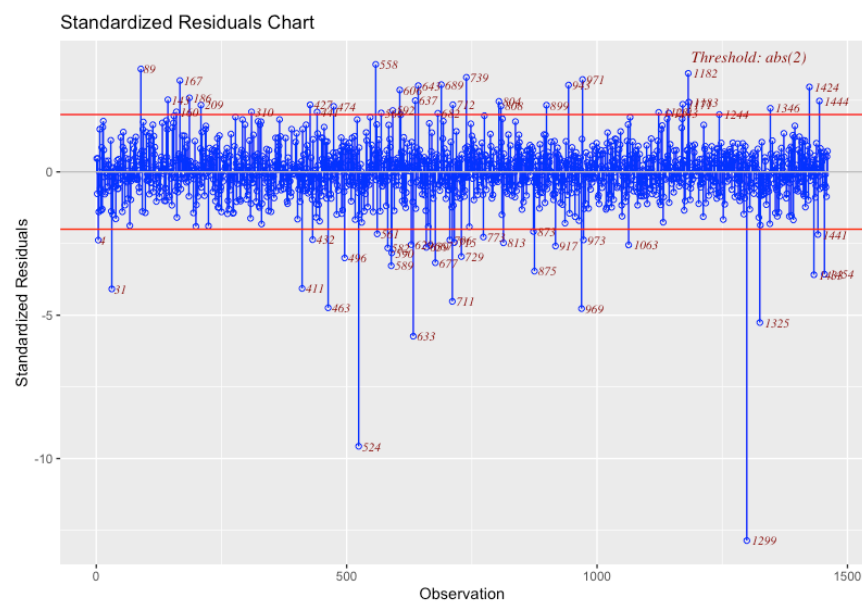
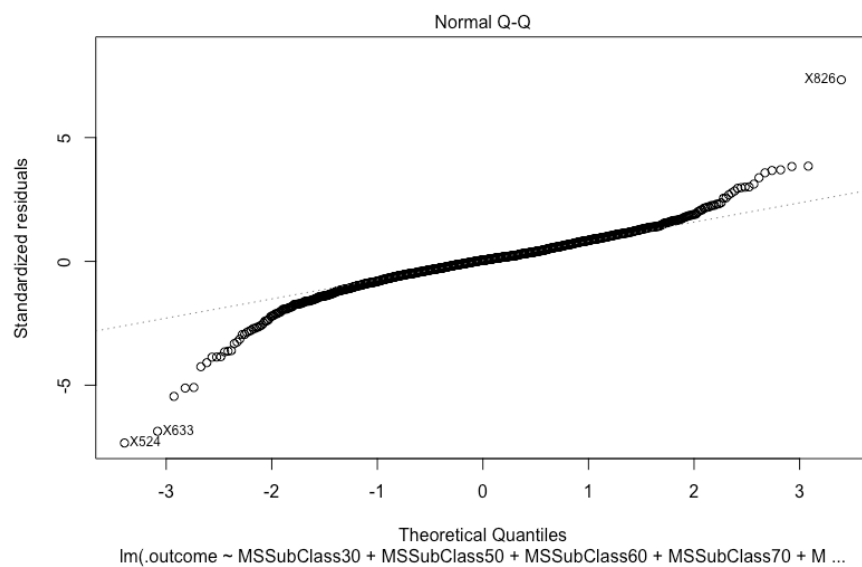
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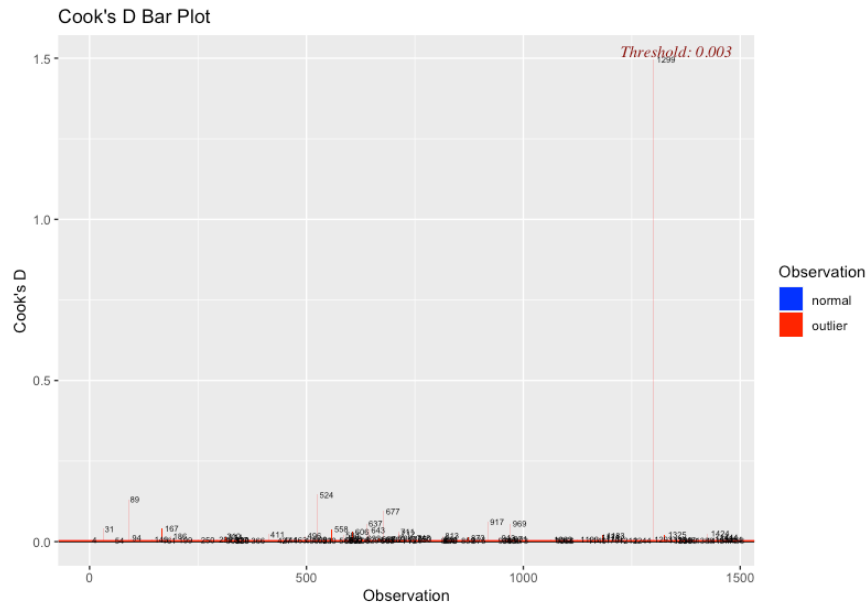


(2.11)



(2.12)



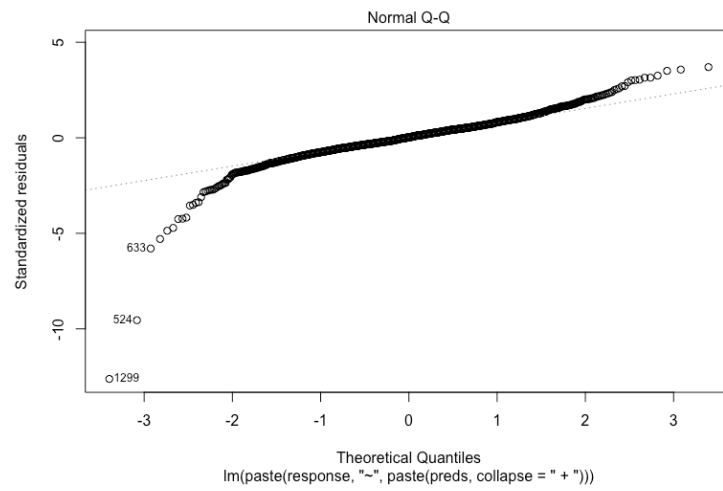


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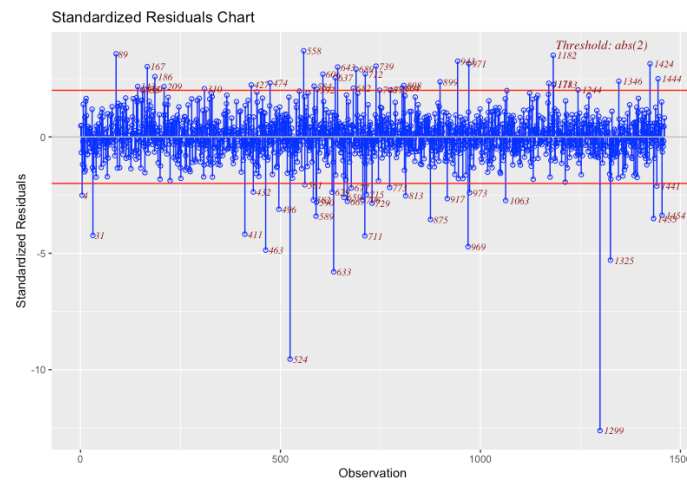
Call:

```
lm(formula = .outcome ~ MSSubClass30 + MSSubClass75 + MSSubClass90 +
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  NeighborhoodClearCr + NeighborhoodCollgCr + NeighborhoodCrawfor +
  NeighborhoodIDOTRR + NeighborhoodMeadowV + NeighborhoodNames +
  NeighborhoodNoRidge + NeighborhoodNridgHt + NeighborhoodSawyerW +
  NeighborhoodSomerst + NeighborhoodStoneBr + NeighborhoodSWISU +
  NeighborhoodTimber + NeighborhoodVeenker + HouseStyle1Story +
  HouseStyleSFoyer + HouseStyleSLvl + OverallQual2 + OverallQual3 +
  OverallQual4 + OverallQual5 + OverallQual6 + OverallQual7 +
  OverallQual8 + OverallQual9 + OverallQual10 + OverallCond2 +
  OverallCond3 + OverallCond4 + OverallCond5 + OverallCond6 +
  OverallCond7 + OverallCond8 + OverallCond9 + YearBuilt +
  YearRemodAdd + ExterCondFa + ExterCondGd + ExterCondPo +
  ExterCondTA + FoundationPConc + FoundationStone + BsmtQualFa +
  BsmtQualGd + BsmtQualNONE + BsmtQualTA + BsmtCondGd + BsmtCondPo +
  BsmtCondTA + TotalBsmtSF + HeatingGasA + HeatingGasW + HeatingWall +
  CentralAirY + GrLivArea + FullBath1 + KitchenQualFa + KitchenQualGd +
  KitchenQualTA + Fireplaces1 + Fireplaces2 + Fireplaces3 +
  GarageTypeAttchd + GarageTypeBasement + GarageTypeBuiltIn +
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  MoSold5 + MoSold7 + YrSold2007 + YrSold2009, data = dat)
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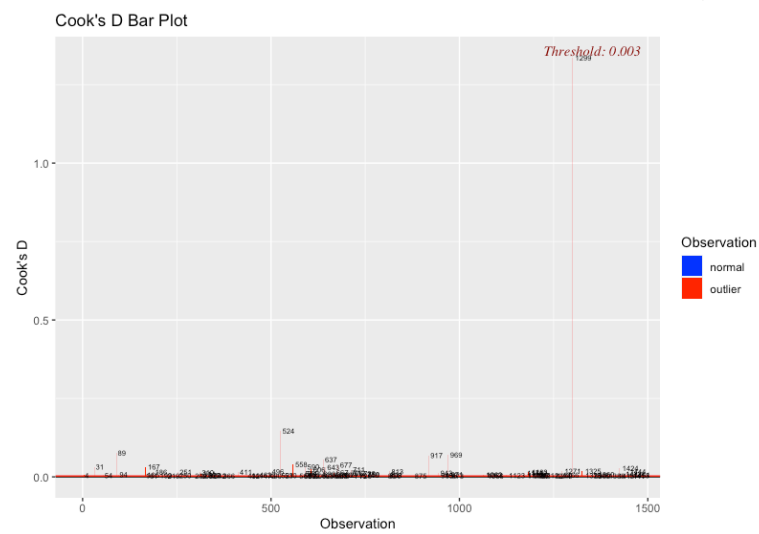
(2.16)



(2.17)



(2.18)



(2.19)

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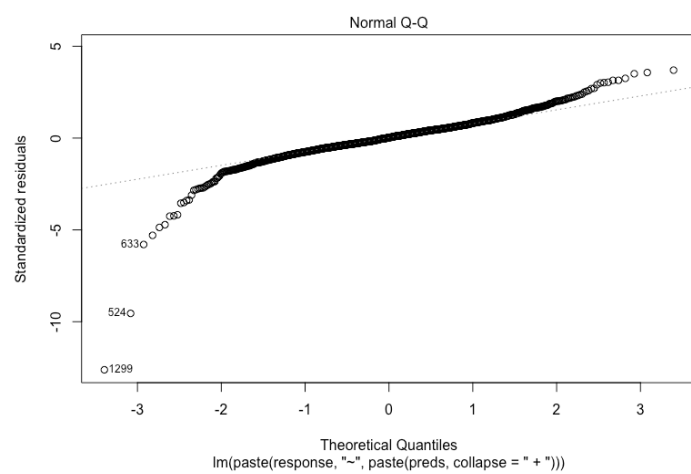
Selection Summary					
Variable	AIC	Sum Sq	RSS	R-Sq	Adj. R-Sq
OverallQual	-148.980	156.765	76.036	0.67339	0.67136
Neighborhood	-561.285	177.326	55.475	0.76171	0.75619
GrLivArea	-1007.859	192.001	40.800	0.82474	0.82056
MSSubClass	-1147.798	196.434	36.367	0.84379	0.83847
OverallCond	-1260.060	199.492	33.308	0.85692	0.85121
GarageCars	-1383.757	202.240	30.561	0.86873	0.86339
YearBuilt	-1462.629	203.887	28.914	0.87580	0.87066
Fireplaces	-1545.292	205.590	27.210	0.88312	0.87802
BsmtQual	-1596.682	206.675	26.126	0.88778	0.88254
MSZoning	-1649.430	207.740	25.061	0.89235	0.88701
Heating	-1665.340	208.181	24.620	0.89424	0.88859
LotArea	-1679.711	208.455	24.346	0.89542	0.88976
YearRemodAdd	-1694.524	208.734	24.067	0.89662	0.89094
CentralAir	-1704.251	208.926	23.874	0.89745	0.89173
KitchenQual	-1713.070	209.168	23.633	0.89848	0.89259
GarageType	-1723.201	209.523	23.278	0.90001	0.89375
TotalBsmtSF	-1728.437	209.638	23.163	0.90050	0.89420
PoolYN	-1732.705	209.737	23.063	0.90093	0.89457
BsmtCond	-1735.000	209.899	22.901	0.90163	0.89508
LotConfig	-1737.196	210.059	22.742	0.90231	0.89551
FullBath	-1737.841	210.162	22.639	0.90276	0.89575

(2.20)

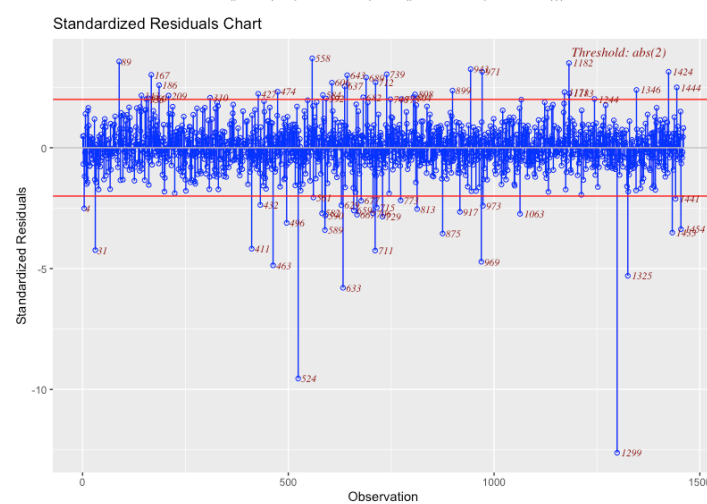
```
Call:
lm(formula = paste(response, "~", paste(preds, collapse = " + ")),
    data = 1)
```

```
Coefficients:
(Intercept) OverallQual2 OverallQual3 OverallQual4 OverallQual5 OverallQual6
5.649e+00 2.645e-01 3.628e-01 4.272e-01 4.612e-01 5.009e-01
OverallQual7 OverallQual8 OverallQual9 OverallQual10 NeighborhoodBlueste NeighborhoodBrDale
5.595e-01 6.336e-01 7.236e-01 6.408e-01 5.196e-03 9.981e-03
NeighborhoodBrkSide NeighborhoodClearCr NeighborhoodCollgCr NeighborhoodCrawfor NeighborhoodEdwards NeighborhoodGilbert
5.949e-02 1.189e-01 4.747e-02 1.553e-01 2.326e-02 1.872e-02
NeighborhoodIDOTRR NeighborhoodMeadow NeighborhoodMitchel NeighborhoodNames NeighborhoodNaRidge NeighborhoodNPkVill
2.647e-02 -1.026e-01 2.140e-03 1.177e-02 1.555e-01 4.217e-03
NeighborhoodNridgHt NeighborhoodNWames NeighborhoodOldTown NeighborhoodSawyer NeighborhoodSawyerW NeighborhoodSomerst
1.464e-01 -1.521e-02 -3.865e-02 -1.230e-02 2.994e-02 6.066e-02
NeighborhoodStoneBr NeighborhoodWISU NeighborhoodTimber NeighborhoodVeenker GrLivArea MSSubClass30
1.904e-01 3.167e-02 5.488e-02 1.268e-01 2.186e-04 -1.096e-01
MSSubClass40 MSSubClass45 MSSubClass50 MSSubClass60 MSSubClass70 MSSubClass75
-5.785e-02 -6.695e-02 -3.817e-02 -3.119e-02 -2.327e-02 2.353e-02
MSSubClass80 MSSubClass85 MSSubClass90 MSSubClass120 MSSubClass160 MSSubClass180
6.449e-03 -5.114e-03 -4.499e-02 -5.784e-02 -1.632e-01 -6.969e-02
MSSubClass190 OverallCond2 OverallCond3 OverallCond4 OverallCond5 OverallCond6
-1.020e-02 -5.522e-01 -7.127e-01 -5.766e-01 -5.563e-01 -4.980e-01
OverallCond7 OverallCond8 OverallCond9 GarageCars YearBuilt Fireplaces1
-4.640e-01 -4.582e-01 -4.183e-01 6.669e-02 1.732e-03 4.782e-02
Fireplaces2 Fireplaces3 BsmtQualFa BsmtQualGd BsmtQualNONE BsmtQualTA
1.096e-01 -2.226e-01 -8.312e-02 -6.225e-02 -1.477e-01 -8.411e-02
MSZoningFV MSZoningRH MSZoningRL MSZoningRM HeatingGasA HeatingGasW
4.646e-01 3.969e-01 3.990e-01 3.585e-01 1.461e-01 2.409e-01
HeatingGrav HeatingOthW HeatingWall LotArea YearRemodAdd CentralAirY
2.396e-03 1.252e-01 2.416e-01 1.322e-06 8.993e-04 7.172e-02
KitchenQualFa KitchenQualGd KitchenQualTA GarageTypeAttchd GarageTypeBasment GarageTypeBuiltIn
-1.012e-01 -6.480e-02 -8.604e-02 1.519e-01 1.234e-01 1.239e-01
GarageTypeCarPort GarageTypeDetchd GarageTypeNONE TotalBsmtSF PoolYNYE5 BsmtCondGd
4.918e-02 1.223e-01 1.127e-01 5.080e-05 1.268e-01 5.486e-02
BsmtCondNONE BsmtCondPo BsmtCondTA LotConfigCulDSac LotConfigFR2 LotConfigFR3
NA -3.020e-01 5.092e-02 4.251e-02 -2.469e-02 -3.641e-02
LotConfigInside FullBath1 FullBath2 FullBath3
2.258e-03 -3.228e-02 -9.387e-03 3.234e-02
```

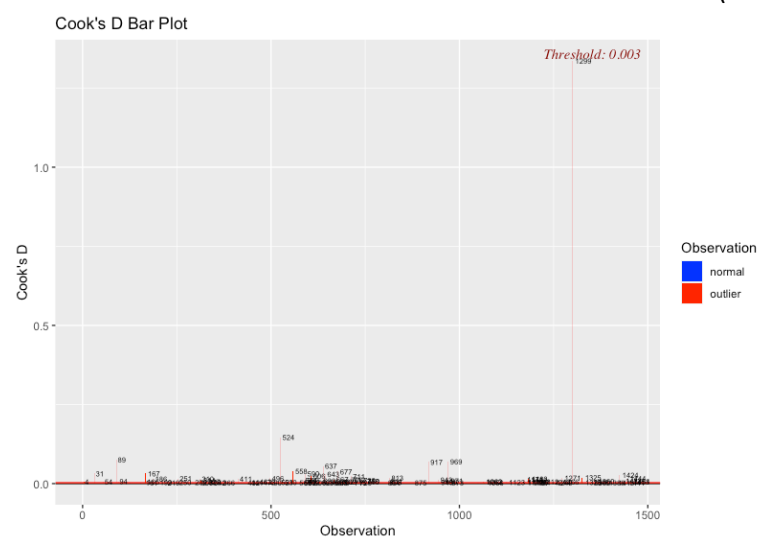
(2.21)



(2.22)



(2.23)



(2.24)


```
> backward.model
```

Backward Elimination Summary

Variable	AIC	RSS	Sum Sq	R-Sq	Adj. R-Sq
Full Model	-1700.261	22.081	210.720	0.90515	0.89548
MoSold	-1712.833	22.224	210.577	0.90454	0.89567
HouseStyle	-1720.795	22.316	210.485	0.90414	0.89578
ExterQual	-1726.111	22.326	210.474	0.90410	0.89597
Foundation	-1730.239	22.416	210.384	0.90371	0.89594
MasVnrArea	-1732.233	22.417	210.384	0.90371	0.89601
X1stFlrSF	-1734.123	22.418	210.382	0.90370	0.89608
TotRmsAbvGrd	-1735.787	22.423	210.377	0.90368	0.89613
YrSold	-1737.090	22.526	210.274	0.90324	0.89596
ExterCond	-1737.841	22.639	210.162	0.90276	0.89575

(2.25)

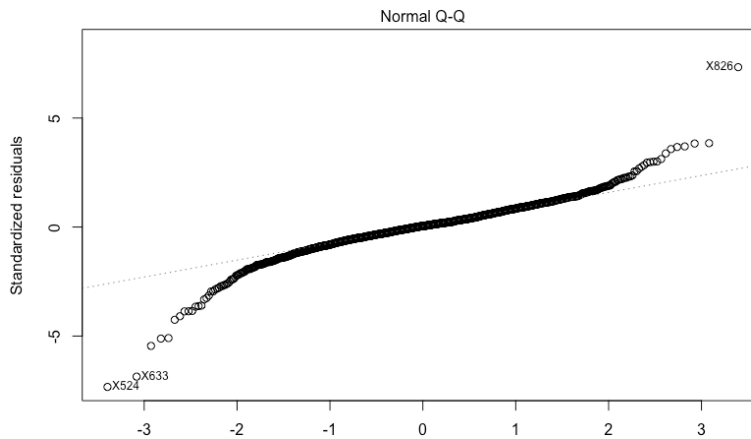
```
> backward.model$model
```

```
Call:
lm(formula = paste(response, "~", paste(preds, collapse = " + ")),
    data = l)
```

Coefficients:

```
(Intercept)      MSSubClass30      MSSubClass40      MSSubClass45      MSSubClass50      MSSubClass60
 5.649e+00      -1.096e-01      -5.785e-02      -6.695e-02      -3.817e-02      -3.119e-02
MSSubClass70      MSSubClass75      MSSubClass80      MSSubClass85      MSSubClass90      MSSubClass120
-2.327e-02      2.353e-02      6.449e-03      -5.114e-03      -4.499e-02      -5.784e-02
MSSubClass160      MSSubClass180      MSSubClass190      MSZoningFV      MSZoningRH      MSZoningRL
-1.632e-01      -6.969e-02      -1.020e-02      4.646e-01      3.969e-01      3.990e-01
MSZoningRM      LotArea      LotConfigCulDSac      LotConfigFR2      LotConfigFR3      LotConfigInside
 3.585e-01      1.322e-06      4.251e-02      -2.469e-02      -3.641e-02      2.258e-03
NeighborhoodBlueste      NeighborhoodBrkSide      NeighborhoodClearCr      NeighborhoodCollgCr      NeighborhoodCrawfor
-5.196e-03      9.901e-03      5.949e-02      1.189e-01      4.747e-02      1.553e-01
NeighborhoodEdwards      NeighborhoodGilbert      NeighborhoodIDOTRR      NeighborhoodMeadowV      NeighborhoodMitchel
-2.326e-02      1.872e-02      2.647e-02      -1.026e-01      2.140e-03      1.177e-02
NeighborhoodNoRidge      NeighborhoodNPkVill      NeighborhoodNridgHt      NeighborhoodNWAmes      NeighborhoodOldTown
 1.555e-01      4.217e-03      1.464e-01      -1.521e-02      -3.865e-02      -1.230e-02
NeighborhoodSawyerW      NeighborhoodSomerst      NeighborhoodStoneBr      NeighborhoodSWISU      NeighborhoodTimber
 2.994e-02      6.066e-02      1.904e-01      3.167e-02      5.488e-02      1.268e-01
OverallQual12      OverallQual13      OverallQual14      OverallQual15      OverallQual16      OverallQual17
 2.645e-01      3.628e-01      4.272e-01      4.612e-01      5.009e-01      5.595e-01
OverallQual18      OverallQual19      OverallQual10      OverallCond2      OverallCond3      OverallCond4
 6.336e-01      7.236e-01      6.408e-01      -5.522e-01      -7.127e-01      -5.766e-01
OverallCond5      OverallCond6      OverallCond7      OverallCond8      OverallCond9      YearBuilt
-5.563e-01      -4.980e-01      -4.640e-01      -4.582e-01      -4.183e-01      1.732e-03
YearRemodAdd      BsmtQualFa      BsmtQualGd      BsmtQualNONE      BsmtQualTA      BsmtCondGd
 8.993e-04      -8.312e-02      -6.225e-02      -1.477e-01      -8.411e-02      5.486e-02
BsmtCondNONE      BsmtCondPo      BsmtCondTA      TotalBsmtSF      HeatingGasA      HeatingGasW
  NA      -3.020e-01      5.092e-02      5.080e-05      1.461e-01      2.409e-01
HeatingGrav      HeatingOthW      HeatingWall      CentralAirY      GrLivArea      FullBath1
 2.396e-03      1.252e-01      2.416e-01      7.172e-02      2.186e-04      -3.228e-02
FullBath2      FullBath3      KitchenQualFa      KitchenQualGd      KitchenQualTA      Fireplaces1
-9.387e-03      3.234e-02      -1.012e-01      -6.480e-02      -8.604e-02      4.782e-02
Fireplaces2      Fireplaces3      GarageTypeAttchd      GarageTypeBasement      GarageTypeBuiltIn      GarageTypeCarPort
 1.096e-01      -2.226e-01      1.519e-01      1.234e-01      1.239e-01      4.918e-02
GarageTypeDetchd      GarageTypeNONE      GarageCars      PoolYNYES
 1.223e-01      1.127e-01      6.669e-02      -1.268e-01
```

(2.26)

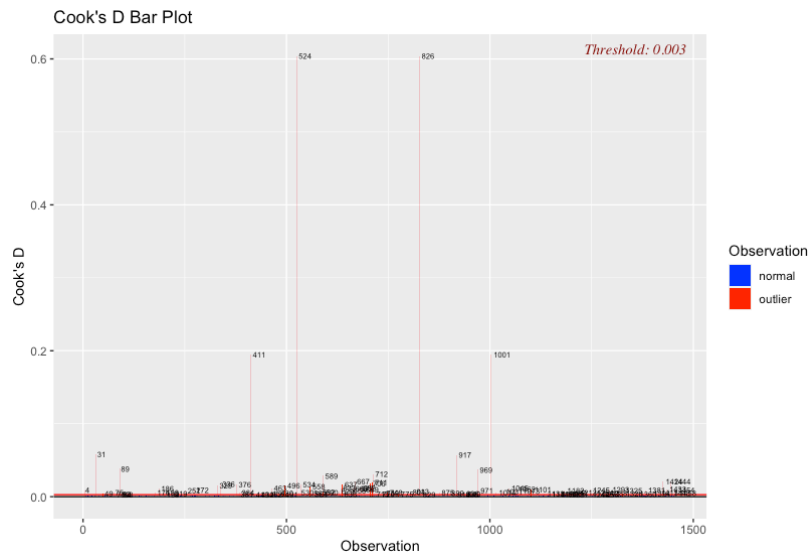


lm(outcome ~ MSSubClass30 + MSSubClass50 + MSSubClass60 + MSSubClass70 + M ...

(2.27)



(2.28)



(2.29)

```
> custom.model$finalModel
```

Call:

```
lm(formula = .outcome ~ MSSubClass30 + MSSubClass50 + MSSubClass60 +
  MSSubClass70 + MSSubClass120 + MSSubClass160 + MSZoningFV +
  MSZoningRH + MSZoningRL + MSZoningRM + LotArea + LotConfigCulDSac +
  LotConfigFR2 + LotConfigFR3 + LotConfigInside + NeighborhoodBrkSide +
  NeighborhoodCrawfor + NeighborhoodEdwards + NeighborhoodMeadowV +
  NeighborhoodMitchel + NeighborhoodNames + NeighborhoodNoRidge +
  NeighborhoodNridgHt + NeighborhoodOldTown + NeighborhoodSawyer +
  NeighborhoodStoneBr + NeighborhoodVeenker + Condition2PosN +
  BldgTypeTwnhs + OverallQual2 + OverallQual3 + OverallQual4 +
  OverallQual5 + OverallQual6 + OverallQual7 + OverallQual8 +
  OverallQual9 + OverallQual10 + YearBuilt + YearRemodAdd +
  RoofStyleGable + RoofMatlCompShg + RoofMatlMembran + RoofMatlMetal +
  RoofMatlRoll + `RoofMatlTar&Grv` + RoofMatlWdShake + RoofMatlWdShngl +
  Exterior1stBrkComm + Exterior1stBrkFace + Exterior1stStucco +
  `Exterior1stWd Sdng` + `Exterior2ndBrk Cmn` + Exterior2ndBrkFace +
  Exterior2ndCmentBd + Exterior2ndMetalSd + Exterior2ndStucco +
  `Exterior2ndWd Sdng` + `Exterior2ndWd Shng` + MasVnrTypeBrkFace +
  MasVnrTypeNone + MasVnrTypeStone + FoundationPConc + FoundationStone +
  BsmtQualFa + BsmtQualGd + BsmtQualTA + BsmtFinType1LwQ +
  BsmtFinType1Unf + TotalBsmtSF + HeatingGasA + HeatingGasW +
  HeatingWall + HeatingQCFA + HeatingQCGd + HeatingQCTA + CentralAirY +
  ElectricalMix + X2ndFlrSF + GrLivArea + BsmtFullBath + FullBath2 +
  FullBath3 + HalfBath + BedroomAbvGr + KitchenAbvGr + KitchenQualFa +
  KitchenQualGd + KitchenQualTA + Fireplaces1 + Fireplaces2 +
  Fireplaces3 + GarageCars + GarageArea + PavedDriveP + PavedDriveY +
  WoodDeckSF + ScreenPorch + MoSold5 + MoSold6 + MoSold7 +
  YrSold2009, data = dat)
```

(2.30)

```
Coefficients:
(Intercept)      MSSubClass30      MSSubClass50      MSSubClass60      MSSubClass70      MSSubClass120
1.278e+00      -7.853e-02      -5.284e-02      -5.970e-02      -3.530e-02      -6.273e-02
MSSubClass160      MSZoningFV      MSZoningRH      MSZoningRL      MSZoningRM      LotArea
-1.881e-01      4.924e-01      4.100e-01      4.212e-01      3.842e-01      2.184e-06
LotConfigCulDSac      LotConfigFR2      LotConfigFR3      LotConfigInside      NeighborhoodBrkSide      NeighborhoodCrawfor
3.638e-02      -3.969e-02      -9.211e-02      -1.161e-02      5.490e-02      1.497e-01
NeighborhoodEdwards      NeighborhoodMeadowV      NeighborhoodMitchel      NeighborhoodNames      NeighborhoodNoRidge      NeighborhoodNridgHt
-6.039e-02      -1.337e-01      -3.791e-02      -2.354e-02      7.730e-02      8.145e-02
NeighborhoodOldTown      NeighborhoodSawyer      NeighborhoodStoneBr      NeighborhoodVeenker      Condition2PosN      BldgTypeTwnhs
-3.898e-02      -3.065e-02      1.195e-01      8.597e-02      -7.737e-01      -3.992e-02
OverallQual2      OverallQual3      OverallQual4      OverallQual5      OverallQual6      OverallQual7
2.162e-01      2.813e-01      3.804e-01      4.258e-01      4.670e-01      5.112e-01
OverallQual8      OverallQual9      OverallQual10      YearBuilt      YearRemodAdd      RoofStyleGable
5.758e-01      6.494e-01      7.429e-01      1.012e-03      1.721e-03      -1.473e-02
RoofMatlCompShg      RoofMatlMembran      RoofMatlMetal      RoofMatlRoll      `RoofMatlTar&Grv`      RoofMatlWdShake
1.965e+00      2.133e+00      2.067e+00      1.867e+00      2.002e+00      2.021e+00
RoofMatlWdShngl      Exterior1stBrkComm      Exterior1stBrkFace      Exterior1stStucco      `Exterior1stWd Sdng`      `Exterior2ndBrk Cmn`
2.066e+00      -4.717e-01      8.557e-02      6.966e-02      -3.493e-02      1.039e-01
Exterior2ndBrkFace      Exterior2ndCmentBd      Exterior2ndMetalSd      Exterior2ndStucco      `Exterior2ndWd Sdng`      `Exterior2ndWd Shng`
-4.911e-02      3.236e-02      1.788e-02      -6.451e-02      3.934e-02      -3.657e-02
MasVnrTypeBrkFace      MasVnrTypeNone      MasVnrTypeStone      FoundationPConc      FoundationStone      BsmtQualFa
7.977e-02      7.325e-02      1.039e-01      1.705e-02      1.515e-01      -4.066e-02
BsmtQualGd      BsmtQualTA      BsmtFinType1LwQ      BsmtFinType1Unf      TotalBsmtSF      HeatingGasA
-4.308e-02      -4.360e-02      -3.800e-02      -5.903e-02      1.212e-04      1.346e-01
HeatingGasW      HeatingWall      HeatingQCFA      HeatingQCGd      HeatingQCTA      CentralAirY
1.982e-01      2.326e-01      -3.391e-02      -1.525e-02      -3.306e-02      7.757e-02
ElectricalMix      X2ndFlrSF      GrLivArea      BsmtFullBath      FullBath2      FullBath3
-3.881e-01      9.193e-05      2.944e-01      2.975e-02      2.517e-02      7.007e-02
HalfBath      BedroomAbvGr      KitchenAbvGr      KitchenQualFa      KitchenQualGd      KitchenQualTA
2.283e-02      -1.016e-02      -1.037e-01      -7.199e-02      -6.003e-02      -7.625e-02
Fireplaces1      Fireplaces2      Fireplaces3      GarageCars      GarageArea      PavedDriveP
2.785e-02      4.386e-02      8.510e-02      2.131e-02      1.233e-04      3.696e-02
PavedDriveY      WoodDeckSF      ScreenPorch      MoSold5      MoSold6      MoSold7
2.603e-02      1.108e-04      2.145e-04      2.052e-02      1.471e-02      1.733e-02
YrSold2009
-2.744e-02
```

(2.31)

```
> print(custom.model)
```

Linear Regression with Stepwise Selection

1460 samples
49 predictor

No pre-processing

Resampling: Cross-Validated (10 fold)

Summary of sample sizes: 1313, 1313, 1315, 1316, 1313, 1314, ...

Resampling results:

RMSE	Rsquared	MAE
0.1649202	0.8265013	0.09613509

(2.32)