Group 300: Comprehensive Predictions on Google Play Store Apps

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1. Introduction

Everyday many applications are developed based on different categories that can be business, games, lifestyle, health and fitness, etc. And at the same time there are many apps already present on the biggest platform for all user's i.e. Google Play Store. For the developers to find and predict whether the application they are developing in any category is appropriate enough to compete with other applications of similar type. For ex. Music Players, there are n number of music player applications already present on the platform and if there's a new music player app launched on google play store how it will perform where the competition is so high.

To help this issue we are proposing a solution in this project by predicting the Rating of the app before it is launched by keeping various other attributes as independent and Ratings variable as the only dependent variable. The developers can predict the Rating of the app according to the category, price and size. This project will predict the Rating of the app without taking reviews into consideration as we are trying to predict the Rating before the launch of the application. Once the application has been launched and the reviews start to build-in then it will change the overall rating of the application (which has not been included in this project).

2. Data

Our dataset consists of over 10,800 rows of entries of application with 13 columns of various attributes. The dataset has µbeen taken from Kaggle (https://www.kaggle.com/rodolfoluna/google-play-store-apps). In our dataset Rating is the dependent variable and other attributes are independent variables.

The 13 attributes used in this project are:

➢ App - Name of the Application

➢ Category- The belonging of the app

➢ Rating- Overall User rating of the app

➢ Reviews- Number of reviews by the users for that particular app.

➢ Size- Application Size

➢ Type- Whether it is Free or Paid

➢ Price- Application Price

➢ Content Rating- Target age group

➢ Genres- Contains Multiple Categories

➢ Last Updated- Date when the App was Recently updated

➢ Current Ver- Latest Version Available for the App

➢ Android Ver- Minimum android specifications requirements

Attribute	Type
App	Factor
Category	Factor
Rating	Number
Reviews	Integer
Size	Factor
Type	Factor
Price	Factor
Content Rating	Factor
Genres	Factor
Last Updated	Factor
Current Version	Factor
Android version	Factor

3. Problems to be Solved

3.1 Exploring the Data

This will include some key observations, how the performance of the application can be optimized from the reviews obtained and finding various ways to improve the business as well. Exploring the correlation between the price and size of the app, version and many more based on the number of installations.

Data Preprocessing: Transforming our data language into machine language which can be used for further encoding or decoding of the data required for the process.

- It requires data quality assessment which includes checking for missing values, inconsistent values and duplicate values.
- Dimensional reduction: In data analytics algorithm works better when the dimensions are lower and irrelevant features and noise could be eliminated.

3.2 Predicting the Ratings

Again, with the usage of Multiple Regression Model using various attributes, the rating of the application could be solved.

Prediction Analysis: The process of using data analysis to make predictions on data. It uses data along with analysis, statistics, and machine learning techniques to create a predictive model for forecasting future events.

- Using ANOVA to find out about the hypothesis used for linear or multiple regression. Here, we have considered that the average mean value of the ratings with respect to categories are same.
- Here, we will be predicting the rating of the app before its launch on the google play store platform using N- fold Cross Validation.

4. Solutions

4.1 Exploring the data:

For this problem we will be performing the preprocessing and data cleaning that can be finally be without inconsistent, duplicate and missing values. For example, removing “$”, “,” from the column Price, “M”, “K” from the size column. For dimensional cleaning we will be removing few columns which are not giving helpful information required in the final prediction of the model i.e. Current Version, last updated and Android version.

4.2 Predicting the Analysis:

For final prediction of app, we will first use linear model, step wise and finally using N- fold cross validation for the final prediction. We will also build ANOVA model and find out about the hypothesis. For the prediction models we have used Rating as the dependent variable. Category, Price, Type, Size, Reviews, Installs Content.Rating, Genres, Last.Updated, Current.ver, Android.ver.

5. Experiments and Results

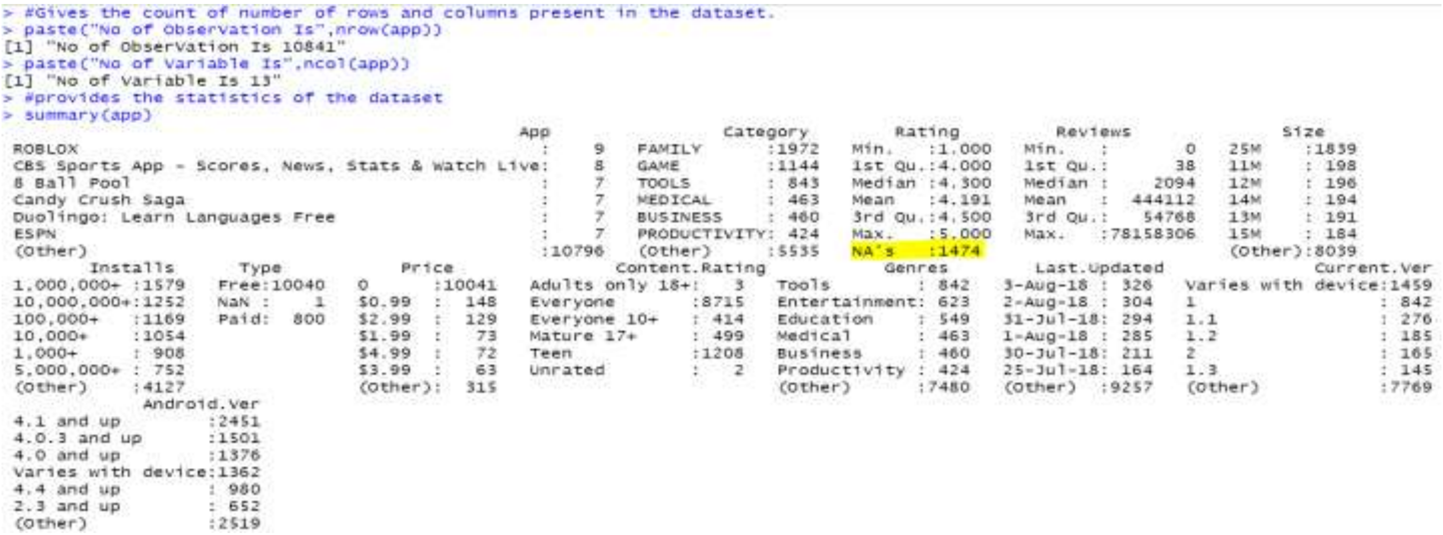
5.1. Methods and Process

5.1.1 Exploring the data

Data Preprocessing: Here we took the dataset from Kaggle for the applications present in google play store, we had around 10841 different rows of application with 13 different columns defining the various details about a particular app. In this there were many entries which had null values, duplicate entries and some inconsistent entries as well.

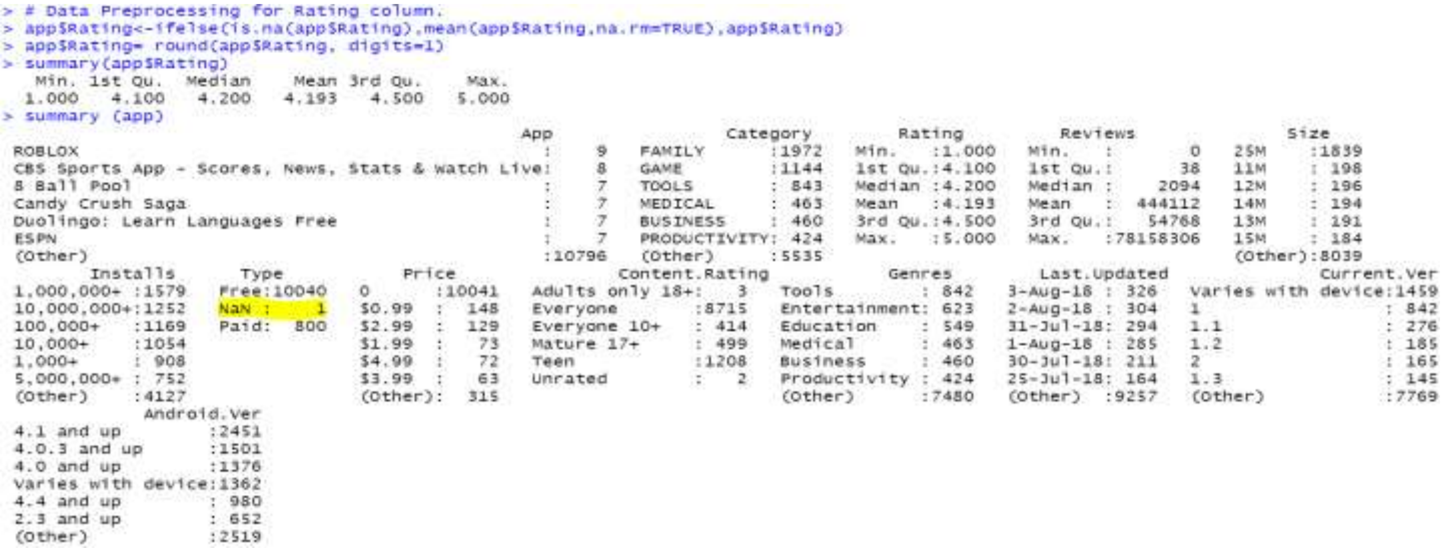
Quality Assessment

- First, we found the columns having null values. In the screenshot below we can see that only Ratings column has missing values. For that we have used (summary) to find the missing values in our dataset.



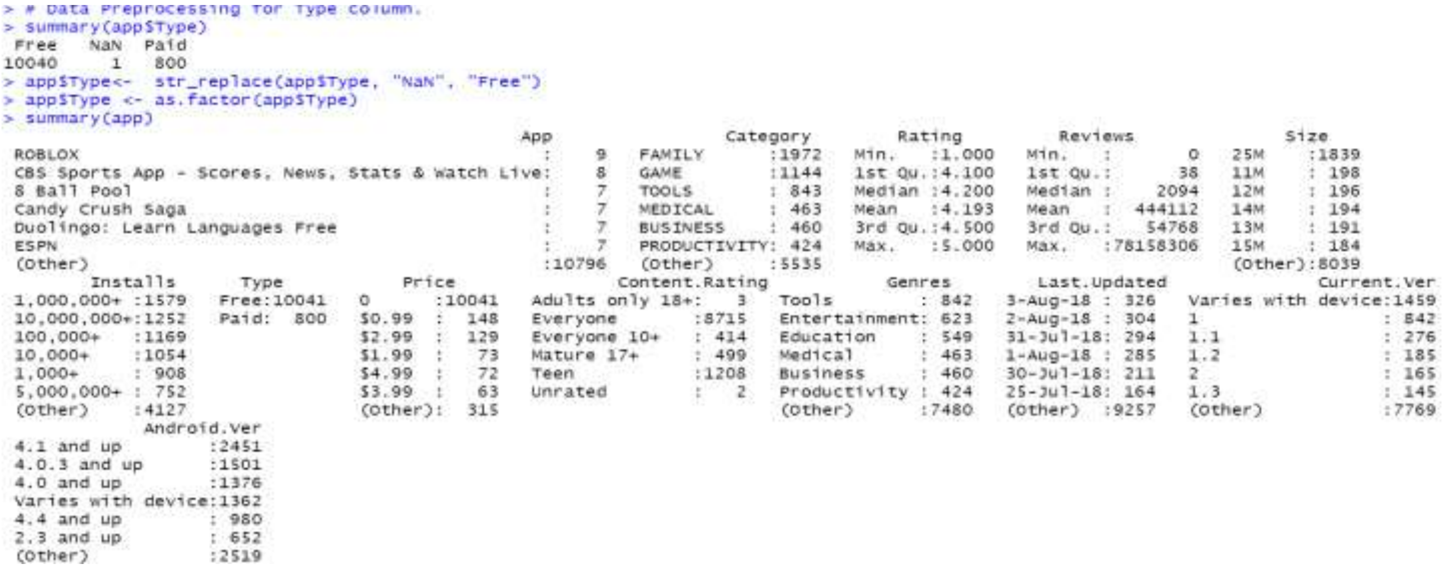
```
> #Gives the count of number of rows and columns present in the dataset.
> paste("No of Observation Is",nrow(app))
[1] "No of Observation Is 10841"
> paste("No of Variable Is",ncol(app))
[1] "No of Variable Is 13"
> #provides the statistics of the dataset
> summary(app)
                                                    App                  Category          Rating               Reviews                Size     
 ROBLOX                                            :    9   FAMILY         :1972   Min.    :1.000   Min.   :       0   25M     :1839  
 CBS Sports App - Scores, News, Stats & Watch Live:    8   GAME           :1144   1st Qu.:4.000   1st Qu.:      38   11M     : 198  
 8 Ball Pool                                       :    7   TOOLS          : 843   Median :4.300   Median :    2094   12M     : 196  
 Candy Crush Saga                                  :    7   MEDICAL        : 463   Mean   :4.191   Mean   :  444112   14M     : 194  
 Duolingo: Learn Languages Free                    :    7   BUSINESS       : 460   3rd Qu.:4.500   3rd Qu.:   54768   13M     : 191  
 ESPN                                              :    7   PRODUCTIVITY: 424   Max.   :5.000   Max.   :78158306   15M     : 184  
 (Other)                                           :10796   (Other)        :5535   NA's   :1474                        (Other):8039  
        Installs        Type            Price              Content.Rating            Genres          Last.Updated          Current.Ver   
 1,000,000+ :1579   Free:10040   0        :10041   Adults only 18+:   3   Tools          : 842   3-Aug-18 : 326   Varies with device:1459  
 10,000,000+:1252   NaN :    1   $0.99   :  148   Everyone        :8715   Entertainment: 623   2-Aug-18 : 304   1                  : 842  
 100,000+    :1169   Paid:  800   $2.99   :  129   Everyone 10+   : 414   Education      : 549   31-Jul-18: 294   1.1                : 276  
 10,000+     :1054                $1.99   :   73   Mature 17+     : 499   Medical        : 463   1-Aug-18 : 285   1.2                : 185  
 1,000+      : 908                $4.99   :   72   Teen            :1208   Business       : 460   30-Jul-18: 211   2                  : 165  
 5,000,000+ : 752                $3.99   :   63   Unrated         :   2   Productivity : 424   25-Jul-18: 164   1.3                : 145  
 (Other)     :4127                (Other):  315                            (Other)        :7480   (Other)  :9257   (Other)            :7769  
             Android.Ver  
 4.1 and up          :2451  
 4.0.3 and up        :1501  
 4.0 and up          :1376  
 Varies with device:1362  
 4.4 and up          : 980  
 2.3 and up          : 652  
 (Other)             :2519  
```

To get rid of those we have used the mean values of the rating column and have replaced all the NA's with those mean values. By using (is.na) we have replaced the values with mean values and now we can see there are no missing values in the dataset.



```
> # Data Preprocessing for Rating column.
> app$Rating<-ifelse(is.na(app$Rating),mean(app$Rating,na.rm=TRUE),app$Rating)
> app$Rating= round(app$Rating, digits=1)
> summary(app$Rating)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
  1.000   4.100   4.200   4.193   4.500   5.000 
> summary (app)
                                                    App                  Category          Rating               Reviews                Size     
 ROBLOX                                            :    9   FAMILY         :1972   Min.    :1.000   Min.   :       0   25M     :1839  
 CBS Sports App - Scores, News, Stats & Watch Live:    8   GAME           :1144   1st Qu.:4.100   1st Qu.:      38   11M     : 198  
 8 Ball Pool                                       :    7   TOOLS          : 843   Median :4.200   Median :    2094   12M     : 196  
 Candy Crush Saga                                  :    7   MEDICAL        : 463   Mean   :4.193   Mean   :  444112   14M     : 194  
 Duolingo: Learn Languages Free                    :    7   BUSINESS       : 460   3rd Qu.:4.500   3rd Qu.:   54768   13M     : 191  
 ESPN                                              :    7   PRODUCTIVITY: 424   Max.   :5.000   Max.   :78158306   15M     : 184  
 (Other)                                           :10796   (Other)        :5535                                        (Other):8039  
        Installs        Type            Price              Content.Rating            Genres          Last.Updated          Current.Ver   
 1,000,000+ :1579   Free:10040   0        :10041   Adults only 18+:   3   Tools          : 842   3-Aug-18 : 326   Varies with device:1459  
 10,000,000+:1252   NaN :    1   $0.99   :  148   Everyone        :8715   Entertainment: 623   2-Aug-18 : 304   1                  : 842  
 100,000+    :1169   Paid:  800   $2.99   :  129   Everyone 10+   : 414   Education      : 549   31-Jul-18: 294   1.1                : 276  
 10,000+     :1054                $1.99   :   73   Mature 17+     : 499   Medical        : 463   1-Aug-18 : 285   1.2                : 185  
 1,000+      : 908                $4.99   :   72   Teen            :1208   Business       : 460   30-Jul-18: 211   2                  : 165  
 5,000,000+ : 752                $3.99   :   63   Unrated         :   2   Productivity : 424   25-Jul-18: 164   1.3                : 145  
 (Other)     :4127                (Other):  315                            (Other)        :7480   (Other)  :9257   (Other)            :7769  
             Android.Ver  
 4.1 and up          :2451  
 4.0.3 and up        :1501  
 4.0 and up          :1376  
 Varies with device:1362  
 4.4 and up          : 980  
 2.3 and up          : 652  
 (Other)             :2519  
```

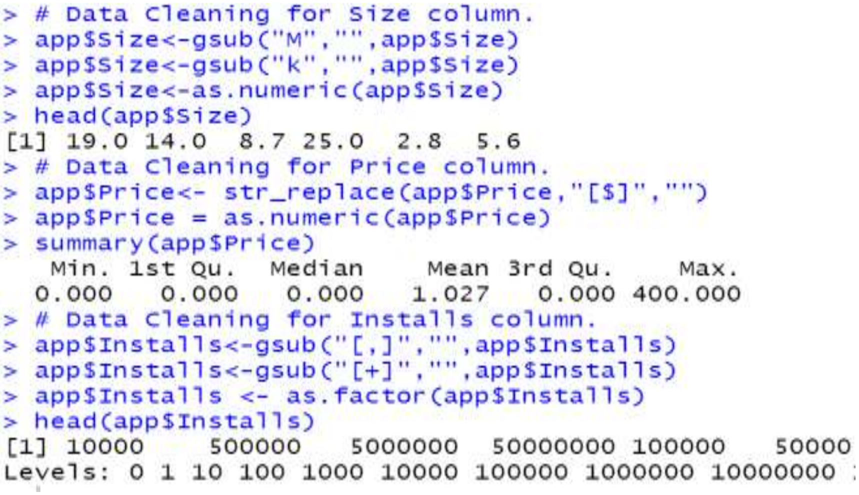
- We can notice that there is one more missing value in the column type. Here as the Type column is categorical, we cannot determine the mean or median for this hence I have replaced the NaN value with “Free” as it has larger number of entries.



```
> # Data Preprocessing for Type column.
> summary(app$Type)
 Free   NaN  Paid 
10040     1   800 
> app$Type<-  str_replace(app$Type, "NaN", "Free")
> app$Type <- as.factor(app$Type)
> summary(app)
                                                App                 Category        Rating          Reviews              Size     
 ROBLOX                                           :    9   FAMILY      :1972   Min.   :1.000   Min.   :       0   25M     :1839  
 CBS Sports App - Scores, News, Stats & Watch Live:    8   GAME        :1144   1st Qu.:4.100   1st Qu.:      38   11M     : 198  
 8 Ball Pool                                      :    7   TOOLS       : 843   Median :4.200   Median :    2094   12M     : 196  
 Candy Crush Saga                                 :    7   MEDICAL     : 463   Mean   :4.193   Mean   :  444112   14M     : 194  
 Duolingo: Learn Languages Free                   :    7   BUSINESS    : 460   3rd Qu.:4.500   3rd Qu.:   54768   13M     : 191  
 ESPN                                             :    7   PRODUCTIVITY: 424   Max.   :5.000   Max.   :78158306   15M     : 184  
 (Other)                                          :10796   (Other)     :5535                                      (Other):8039  
        Installs       Type           Price                  Content.Rating           Genres          Last.Updated             Current.Ver  
 1,000,000+ :1579   Free:10041   0       :10041   Adults only 18+:   3   Tools        : 842   3-Aug-18 : 326   Varies with device:1459  
 10,000,000+:1252   Paid:  800   $0.99   :   148   Everyone       :8715   Entertainment: 623   2-Aug-18 : 304   1                 : 842  
 100,000+   :1169                $2.99   :   129   Everyone 10+   : 414   Education    : 549   31-Jul-18: 294   1.1               : 276  
 10,000+    :1054                $1.99   :    73   Mature 17+     : 499   Medical      : 463   1-Aug-18 : 285   1.2               : 185  
 1,000+     : 908                $4.99   :    72   Teen           :1208   Business     : 460   30-Jul-18: 211   2                 : 165  
 5,000,000+ : 752                $3.99   :    63   Unrated        :   2   Productivity : 424   25-Jul-18: 164   1.3               : 145  
 (Other)    :4127                (Other):   315                           (Other)      :7480   (Other)  :9257   (Other)           :7769  
             Android.Ver  
 4.1 and up        :2451  
 4.0.3 and up      :1501  
 4.0 and up        :1376  
 Varies with device:1362  
 4.4 and up        : 980  
 2.3 and up        : 652  
 (Other)           :2519  
```

Dimension Reduction

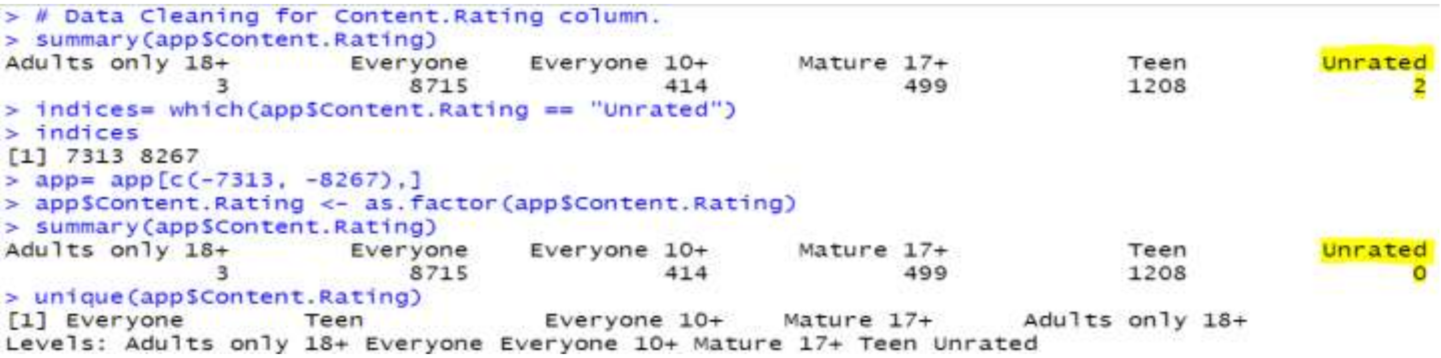
- In Data Analytics it is important that our data should be as simplified as it can so that the analysis we want to perform are easily conducted and for that we can remove some irrelevant features and dimensions from our columns. We can notice from above screenshot that in the column for size there are the dimensions like M and K representing the size in bytes. Hence, we have removed them. Similarly, for the price column we have removed the [$] dimension. Last, we have removed the [+], [,] dimensions from Installs column.



```
> # Data Cleaning for Size column.
> app$Size<-gsub("M","",app$Size)
> app$Size<-gsub("k","",app$Size)
> app$Size<-as.numeric(app$Size)
> head(app$Size)
[1] 19.0 14.0  8.7 25.0  2.8  5.6
> # Data Cleaning for Price column.
> app$Price<- str_replace(app$Price,"[$]","")
> app$Price = as.numeric(app$Price)
> summary(app$Price)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
  0.000   0.000   0.000   1.027   0.000 400.000 
> # Data Cleaning for Installs column.
> app$Installs<-gsub("[,]","",app$Installs)
> app$Installs<-gsub("[+]","",app$Installs)
> app$Installs <- as.factor(app$Installs)
> head(app$Installs)
[1] 10000     500000    5000000   50000000 100000    50000
Levels: 0 1 10 100 1000 10000 100000 1000000 10000000 
```

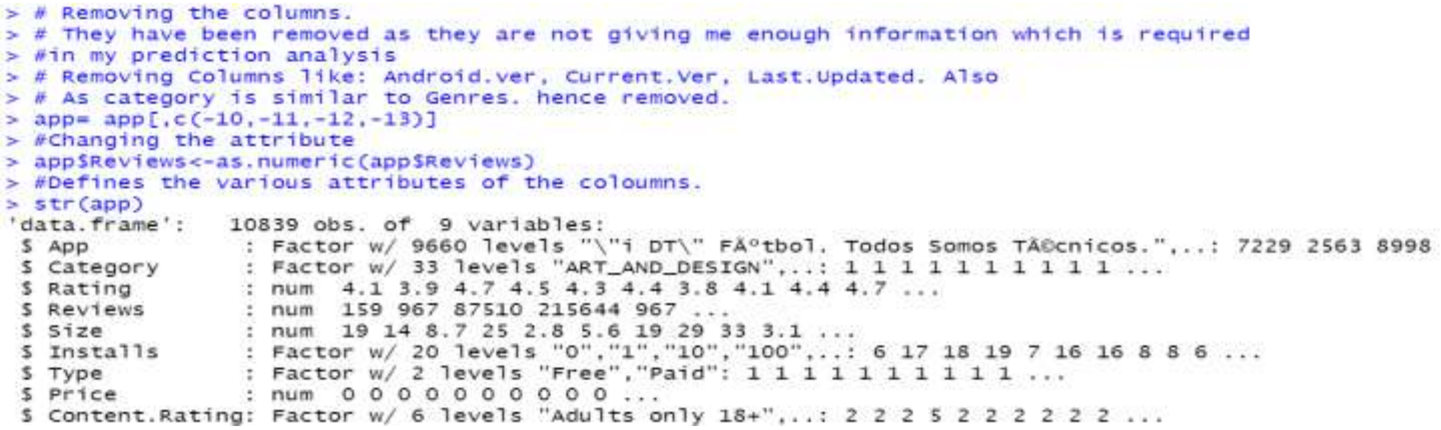
- It becomes easy to convert or replace some values or entries if they are numeric to remove noise, but some character entries are difficult to replace. Hence, in the Content.Rating where were two entries which couldn’t be replaced and at last, we have removed them as they were irrelevant entries too.

This is done using the function [indices], we found the two rows which were defined as Unrated and hence removed them. This ended up with no [Unrated] entries and displayed the unique entries in the Content.Rating column.



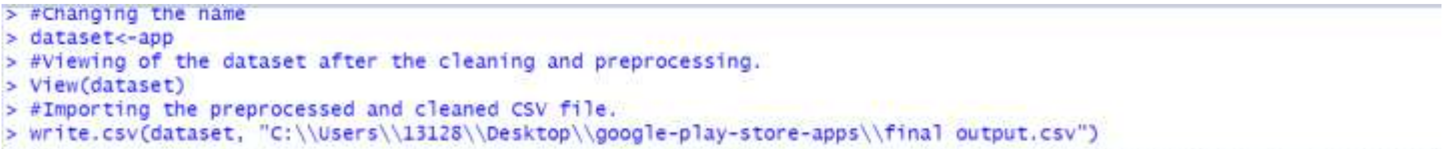
```
> # Data Cleaning for Content.Rating column.
> summary(app$Content.Rating)
Adults only 18+        Everyone     Everyone 10+      Mature 17+             Teen          Unrated
              3            8715              414             499             1208                2
> indices= which(app$Content.Rating == "Unrated")
> indices
[1] 7313 8267
> app= app[c(-7313, -8267),]
> app$Content.Rating <- as.factor(app$Content.Rating)
> summary(app$Content.Rating)
Adults only 18+        Everyone     Everyone 10+      Mature 17+             Teen          Unrated
              3            8715              414             499             1208                0
> unique(app$Content.Rating)
[1] Everyone        Teen            Everyone 10+    Mature 17+      Adults only 18+
Levels: Adults only 18+ Everyone Everyone 10+ Mature 17+ Teen Unrated
```

- Again, there were few columns which were not providing enough information to us for the final output we were looking for i.e. prediction of the Rating of the App and decided to remove them.
  These columns were Last.Updated, Current.ver, Android.Ver. Moreover, Genres was same as Category i.e. giving the same information.
  Changed the reviews datatype to numeric to make the dataset easy for processing and the final attributes we will be using for the model to predict using [str] function.

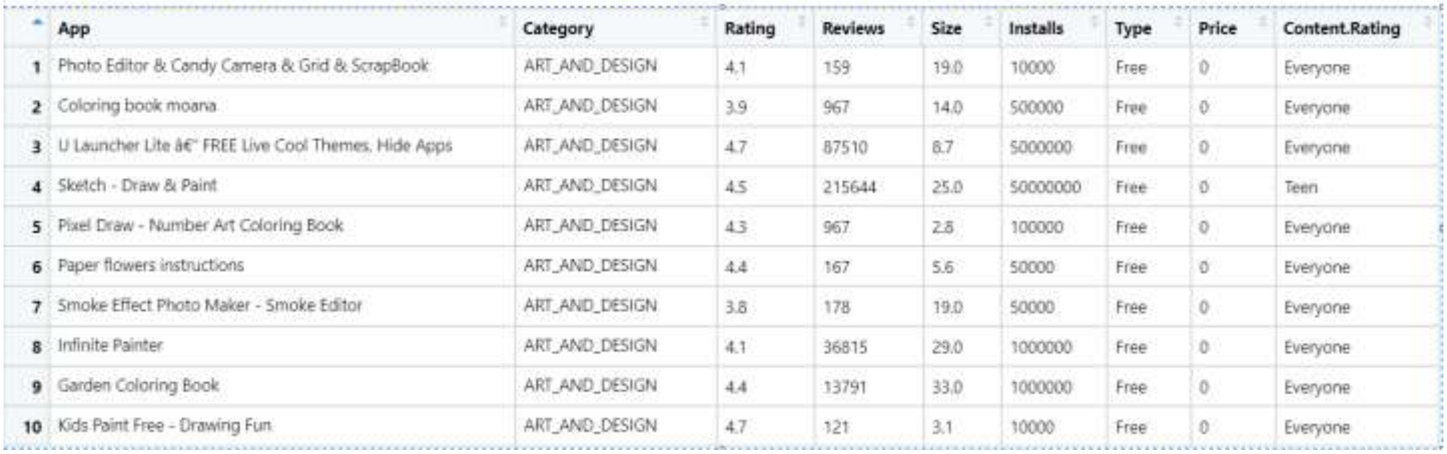


```
> # Removing the columns.
> # They have been removed as they are not giving me enough information which is required
> #in my prediction analysis
> # Removing Columns like: Android.ver, Current.Ver, Last.Updated. Also
> # As category is similar to Genres. hence removed.
> app= app[,c(-10,-11,-12,-13)]
> #Changing the attribute
> app$Reviews<-as.numeric(app$Reviews)
> #Defines the various attributes of the coloumns.
> str(app)
'data.frame':   10839 obs. of  9 variables:
 $ App           : Factor w/ 9660 levels "\"i DT\" FÃºtbol. Todos Somos TÃ©cnicos.",..: 7229 2563 8998
 $ Category      : Factor w/ 33 levels "ART_AND_DESIGN",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ Rating        : num  4.1 3.9 4.7 4.5 4.3 4.4 3.8 4.1 4.4 4.7 ...
 $ Reviews       : num  159 967 87510 215644 967 ...
 $ Size          : num  19 14 8.7 25 2.8 5.6 19 29 33 3.1 ...
 $ Installs      : Factor w/ 20 levels "0","1","10","100",..: 6 17 18 19 7 16 16 8 8 6 ...
 $ Type          : Factor w/ 2 levels "Free","Paid": 1 1 1 1 1 1 1 1 1 1 ...
 $ Price         : num  0 0 0 0 0 0 0 0 0 0 ...
 $ Content.Rating: Factor w/ 6 levels "Adults only 18+",..: 2 2 2 5 2 2 2 2 2 2 ...
```

- Finally, the final data has been renamed and viewed. Also, the final .CSV file has been generated after preprocessing and cleaning and is now ready for prediction analysis.



```
> #Changing the name
> dataset<-app
> #Viewing of the dataset after the cleaning and preprocessing.
> View(dataset)
> #Importing the preprocessed and cleaned CSV file.
> write.csv(dataset, "C:\\Users\\13128\\Desktop\\google-play-store-apps\\final output.csv")
```



	App	Category	Rating	Reviews	Size	Installs	Type	Price	Content.Rating
1	Photo Editor & Candy Camera & Grid & ScrapBook	ART_AND_DESIGN	4.1	159	19.0	10000	Free	0	Everyone
2	Coloring book moana	ART_AND_DESIGN	3.9	967	14.0	500000	Free	0	Everyone
3	U Launcher Lite â€" FREE Live Cool Themes, Hide Apps	ART_AND_DESIGN	4.7	87510	8.7	5000000	Free	0	Everyone
4	Sketch - Draw & Paint	ART_AND_DESIGN	4.5	215644	25.0	50000000	Free	0	Teen
5	Pixel Draw - Number Art Coloring Book	ART_AND_DESIGN	4.3	967	2.8	100000	Free	0	Everyone
6	Paper flowers instructions	ART_AND_DESIGN	4.4	167	5.6	50000	Free	0	Everyone
7	Smoke Effect Photo Maker - Smoke Editor	ART_AND_DESIGN	3.8	178	19.0	50000	Free	0	Everyone
8	Infinite Painter	ART_AND_DESIGN	4.1	36815	29.0	1000000	Free	0	Everyone
9	Garden Coloring Book	ART_AND_DESIGN	4.4	13791	33.0	1000000	Free	0	Everyone
10	Kids Paint Free - Drawing Fun	ART_AND_DESIGN	4.7	121	3.1	10000	Free	0	Everyone

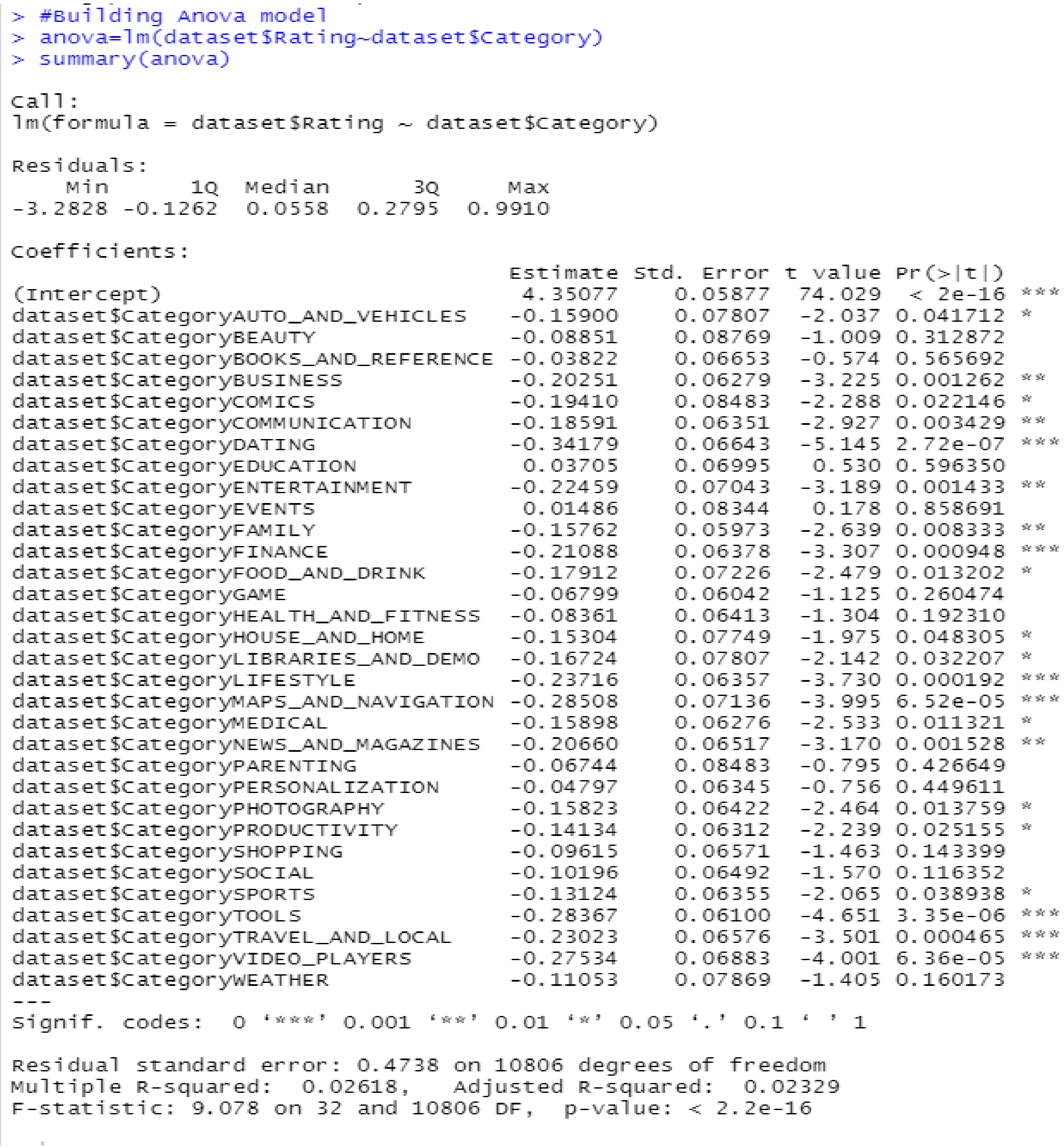
5.1.2 Predicting the Analysis:

The detailed analysis will be in section (5.2). Here we will work on the ANOVA model.

ANOVA model for hypothesis is used to differentiate between more than 2 box plots to determine the statistics value of the model.

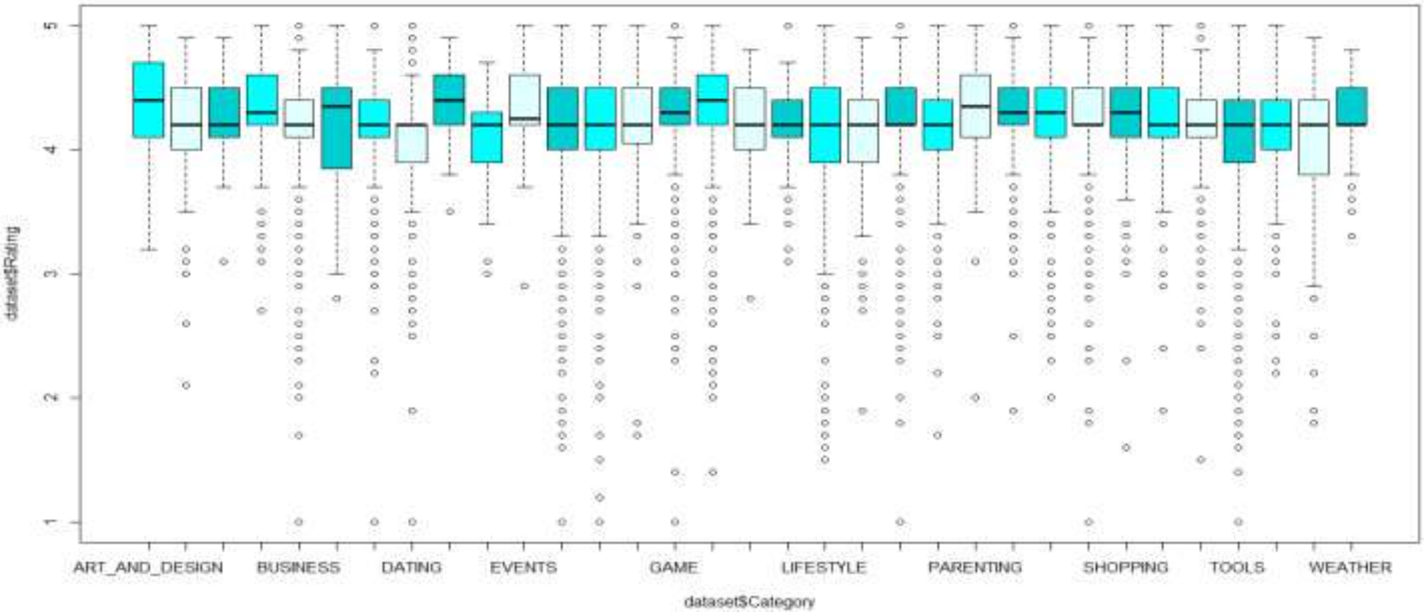
For the prediction we decide to make 2 hypotheses based on our project:

1) Null Hypothesis (μ_o) = Average mean of the ratings is same for all the categories.
   $\mu_{oCategoryGames} = \mu_{oCategoryLifestyles} = \mu_{oCategoryComics} = \mu_{oCategoryShopping} \ldots\ldots = \mu_o$
2) Alternate Hypothesis (μ_a) = Average mean of ratings is not same for all the categories.
   $\mu_{oCategoryGames} \neq \mu_{oCategoryLifestyles} \neq \mu_{oCategoryComics} \neq \mu_{oCategoryShopping} \ldots\ldots = \mu_a$



```
> #Building Anova model
> anova=lm(dataset$Rating~dataset$Category)
> summary(anova)

Call:
lm(formula = dataset$Rating ~ dataset$Category)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.2828 -0.1262  0.0558  0.2795  0.9910 

Coefficients:
                                    Estimate Std. Error t value Pr(>|t|)    
(Intercept)                          4.35077    0.05877  74.029  < 2e-16 ***
dataset$CategoryAUTO_AND_VEHICLES   -0.15900    0.07807  -2.037 0.041712 *  
dataset$CategoryBEAUTY              -0.08851    0.08769  -1.009 0.312872    
dataset$CategoryBOOKS_AND_REFERENCE -0.03822    0.06653  -0.574 0.565692    
dataset$CategoryBUSINESS            -0.20251    0.06279  -3.225 0.001262 ** 
dataset$CategoryCOMICS              -0.19410    0.08483  -2.288 0.022146 *  
dataset$CategoryCOMMUNICATION       -0.18591    0.06351  -2.927 0.003429 ** 
dataset$CategoryDATING              -0.34179    0.06643  -5.145 2.72e-07 ***
dataset$CategoryEDUCATION            0.03705    0.06995   0.530 0.596350    
dataset$CategoryENTERTAINMENT       -0.22459    0.07043  -3.189 0.001433 ** 
dataset$CategoryEVENTS               0.01486    0.08344   0.178 0.858691    
dataset$CategoryFAMILY              -0.15762    0.05973  -2.639 0.008333 ** 
dataset$CategoryFINANCE             -0.21088    0.06378  -3.307 0.000948 ***
dataset$CategoryFOOD_AND_DRINK      -0.17912    0.07226  -2.479 0.013202 *  
dataset$CategoryGAME                -0.06799    0.06042  -1.125 0.260474    
dataset$CategoryHEALTH_AND_FITNESS  -0.08361    0.06413  -1.304 0.192310    
dataset$CategoryHOUSE_AND_HOME      -0.15304    0.07749  -1.975 0.048305 *  
dataset$CategoryLIBRARIES_AND_DEMO  -0.16724    0.07807  -2.142 0.032207 *  
dataset$CategoryLIFESTYLE           -0.23716    0.06357  -3.730 0.000192 ***
dataset$CategoryMAPS_AND_NAVIGATION -0.28508    0.07136  -3.995 6.52e-05 ***
dataset$CategoryMEDICAL             -0.15898    0.06276  -2.533 0.011321 *  
dataset$CategoryNEWS_AND_MAGAZINES  -0.20660    0.06517  -3.170 0.001528 ** 
dataset$CategoryPARENTING           -0.06744    0.08483  -0.795 0.426649    
dataset$CategoryPERSONALIZATION     -0.04797    0.06345  -0.756 0.449611    
dataset$CategoryPHOTOGRAPHY         -0.15823    0.06422  -2.464 0.013759 *  
dataset$CategoryPRODUCTIVITY        -0.14134    0.06312  -2.239 0.025155 *  
dataset$CategorySHOPPING            -0.09615    0.06571  -1.463 0.143399    
dataset$CategorySOCIAL              -0.10196    0.06492  -1.570 0.116352    
dataset$CategorySPORTS              -0.13124    0.06355  -2.065 0.038938 *  
dataset$CategoryTOOLS               -0.28367    0.06100  -4.651 3.35e-06 ***
dataset$CategoryTRAVEL_AND_LOCAL    -0.23023    0.06576  -3.501 0.000465 ***
dataset$CategoryVIDEO_PLAYERS       -0.27534    0.06883  -4.001 6.36e-05 ***
dataset$CategoryWEATHER             -0.11053    0.07869  -1.405 0.160173    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4738 on 10806 degrees of freedom
Multiple R-squared:  0.02618,	Adjusted R-squared:  0.02329 
F-statistic: 9.078 on 32 and 10806 DF,  p-value: < 2.2e-16
```

From the above output of ANOVA model, we could find that many categories p value is less than 0.05 when taking confidence level of 95%, which falls in the rejection region and hence we can conclude that with 95% confidence level we have the evidence to reject the null hypothesis and come to conclusion that our alternative hypothesis is true that different categories have different mean of ratings or in other terms there will be at-least one category which will have different average mean value of rating from other categories mean.



To prove it further we will find which category have different or same average mean value from others, and for that we must perform individual parameter test.

To perform individual parameter testing we will convert the ANOVA model into linear regression model and clarify about the Beta Values.

For example: 𝛽VideoPlayer = µVideoPlayer − µCategoryDating

If we find the individual parameter test, we can notice there are many categories with different p values some are greater than 0.05 (95% Confidence level) and some are less than 0.05. If we watch closely the lowest value is of Video player category and lesser than that is Dating category. Here we can conclude that we can reject the null hypothesis and accept the alternate hypothesis.

Our Null Hypothesis, in this case, is, β coefficient corresponding to CategoryVideoPlayer and CategoryDating = 0,

whereas the Alternate Hypothesis ≠ 0.

And β value here is the difference between the average mean value of Rating of CategoryVideoPlayer/CategoryDating and CategoryLifeStyle (CategoryLifeStyle is considered as the base value here)

We can further do the analysis; which category has largest mean value of Rating and which has the lowest. Since t-value in case of CategoryVideoPlayer is positive, hence 𝛽VideoPlayer = µVideoPlayer − 𝜇 CategoryLifeStyle > 0 which means µVideoPlayer is greater than CategoryLifeStyle

Also, since t-value in case of CategoryDating is negative, hence 𝛽CategoryDating = µCategoryDating − 𝜇 CategoryLifeStyle < 0 which means µCategoryDating < 𝜇 CategoryLifeStyle

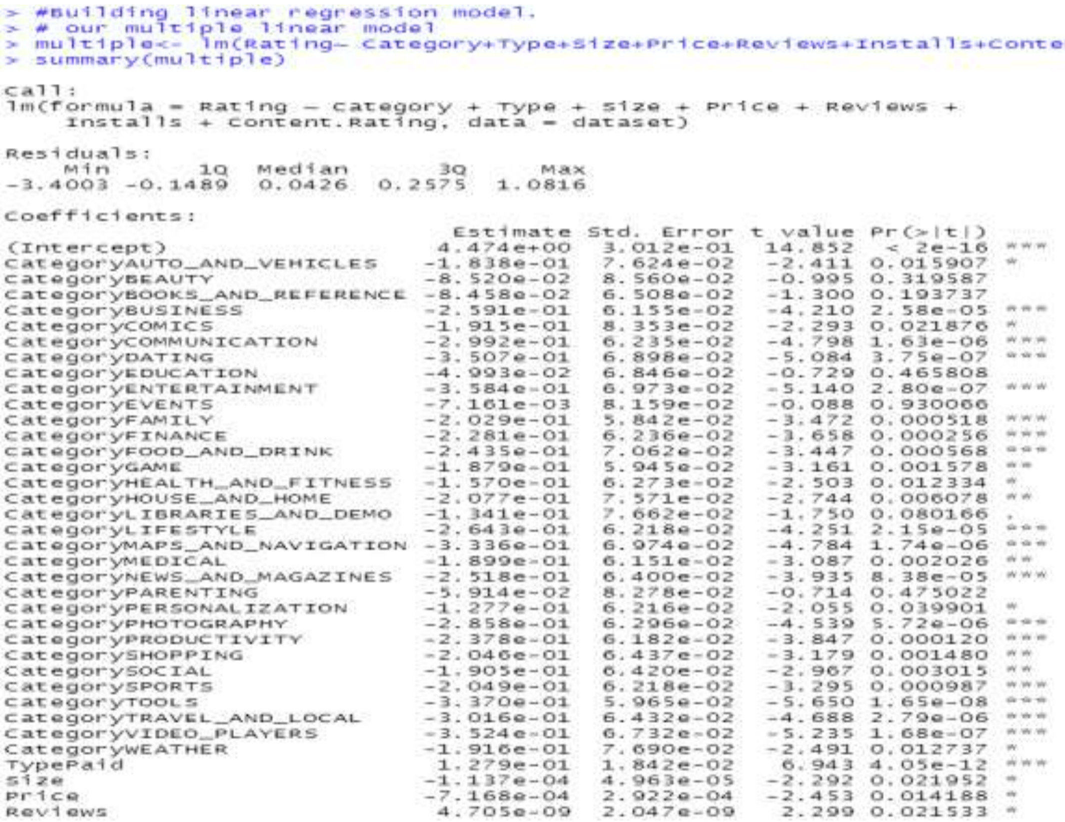
We can come up with the complete conclusion now that µCategoryDating will have the lowest average mean value of Rating whereas µVideoPlayer will have the highest value.

5.2. Evaluations and Results

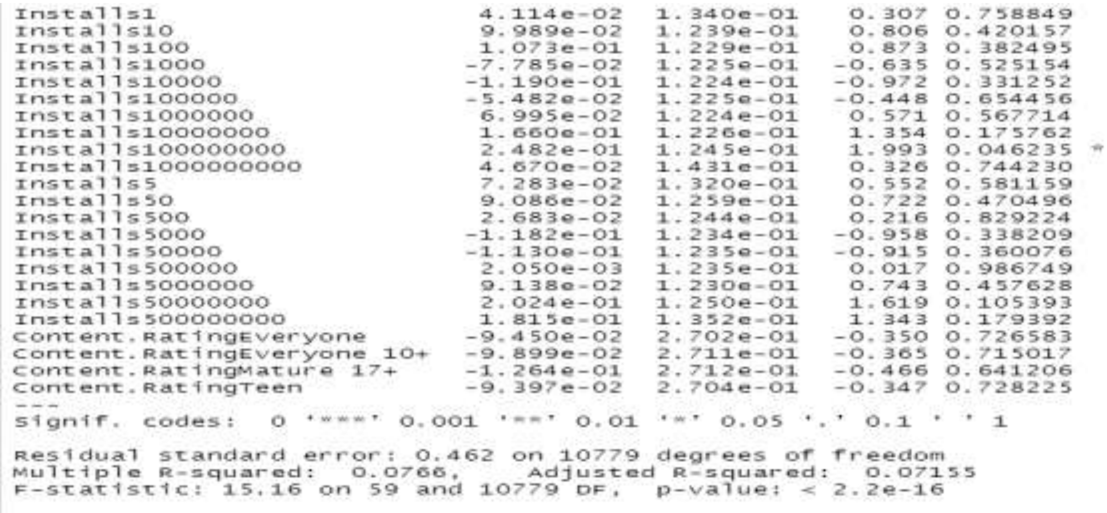
Predicting the Analysis: Firstly, we have used multiple linear regression to do the feature selection and finally used N-Fold cross validation to predict the model.

We have used stepwise analysis for all the directions and then selected the features that can be used for the final output used in N-Fold Cross validation.

- Building the linear model and rejecting the variables which have the p value greater than 0.05 as they are non-significant.

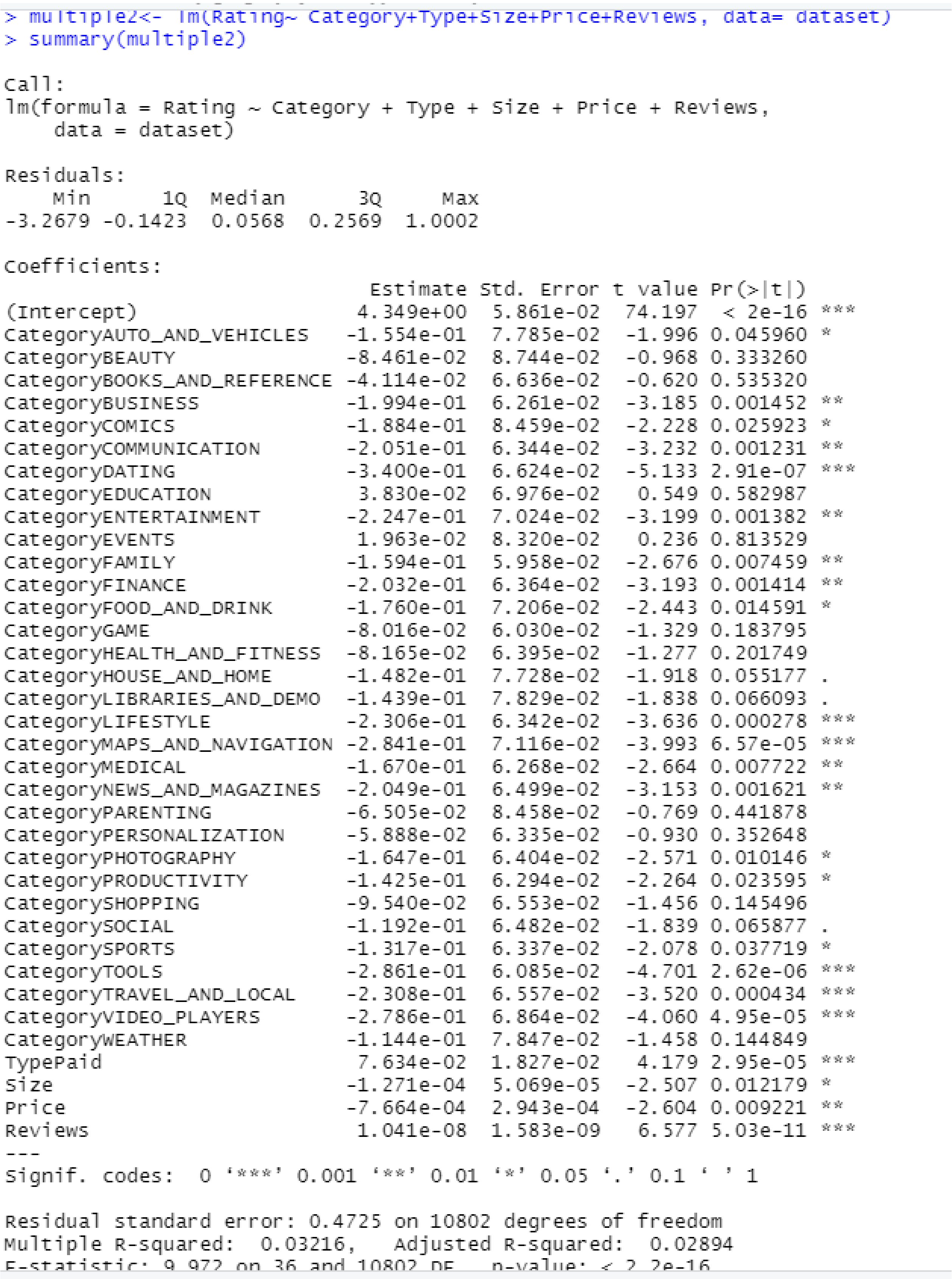


```
> #Building linear regression model.
> # our multiple linear model
> multiple<- lm(Rating~ Category+Type+Size+Price+Reviews+Installs+Content.Rating, data= dataset)
> summary(multiple)

Call:
lm(formula = Rating ~ Category + Type + Size + Price + Reviews + 
    Installs + Content.Rating, data = dataset)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.4003 -0.1489  0.0426  0.2575  1.0816 

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)    
(Intercept)                 4.474e+00  3.012e-01  14.852  < 2e-16 ***
CategoryAUTO_AND_VEHICLES  -1.838e-01  7.624e-02  -2.411 0.015907 *  
CategoryBEAUTY             -8.520e-02  8.560e-02  -0.995 0.319587    
CategoryBOOKS_AND_REFERENCE -8.458e-02  6.508e-02  -1.300 0.193737    
CategoryBUSINESS           -2.591e-01  6.155e-02  -4.210 2.58e-05 ***
CategoryCOMICS             -1.915e-01  8.353e-02  -2.293 0.021876 *  
CategoryCOMMUNICATION      -2.992e-01  6.235e-02  -4.798 1.63e-06 ***
CategoryDATING             -3.507e-01  6.898e-02  -5.084 3.75e-07 ***
CategoryEDUCATION          -4.993e-02  6.846e-02  -0.729 0.465808    
CategoryENTERTAINMENT      -3.584e-01  6.973e-02  -5.140 2.80e-07 ***
CategoryEVENTS             -7.161e-03  8.159e-02  -0.088 0.930066    
CategoryFAMILY             -2.029e-01  5.842e-02  -3.472 0.000518 ***
CategoryFINANCE            -2.281e-01  6.236e-02  -3.658 0.000256 ***
CategoryFOOD_AND_DRINK     -2.435e-01  7.062e-02  -3.447 0.000568 ***
CategoryGAME               -1.879e-01  5.945e-02  -3.161 0.001578 ** 
CategoryHEALTH_AND_FITNESS -1.570e-01  6.273e-02  -2.503 0.012334 *  
CategoryHOUSE_AND_HOME     -2.077e-01  7.571e-02  -2.744 0.006078 ** 
CategoryLIBRARIES_AND_DEMO -1.341e-01  7.662e-02  -1.750 0.080166 .  
CategoryLIFESTYLE          -2.643e-01  6.218e-02  -4.251 2.15e-05 ***
CategoryMAPS_AND_NAVIGATION -3.336e-01  6.974e-02  -4.784 1.74e-06 ***
CategoryMEDICAL            -1.899e-01  6.151e-02  -3.087 0.002026 ** 
CategoryNEWS_AND_MAGAZINES -2.518e-01  6.400e-02  -3.935 8.38e-05 ***
CategoryPARENTING          -5.914e-02  8.278e-02  -0.714 0.475022    
CategoryPERSONALIZATION    -1.277e-01  6.216e-02  -2.055 0.039901 *  
CategoryPHOTOGRAPHY        -2.858e-01  6.296e-02  -4.539 5.72e-06 ***
CategoryPRODUCTIVITY       -2.378e-01  6.182e-02  -3.847 0.000120 ***
CategorySHOPPING           -2.046e-01  6.437e-02  -3.179 0.001480 ** 
CategorySOCIAL             -1.905e-01  6.420e-02  -2.967 0.003015 ** 
CategorySPORTS             -2.049e-01  6.218e-02  -3.295 0.000987 ***
CategoryTOOLS              -3.370e-01  5.965e-02  -5.650 1.65e-08 ***
CategoryTRAVEL_AND_LOCAL   -3.016e-01  6.432e-02  -4.688 2.79e-06 ***
CategoryVIDEO_PLAYERS      -3.524e-01  6.732e-02  -5.235 1.68e-07 ***
CategoryWEATHER            -1.916e-01  7.690e-02  -2.491 0.012737 *  
TypePaid                    1.279e-01  1.842e-02   6.943 4.05e-12 ***
Size                       -1.137e-04  4.963e-05  -2.292 0.021952 *  
Price                      -7.168e-04  2.922e-04  -2.453 0.014188 *  
Reviews                     4.705e-09  2.047e-09   2.299 0.021533 *  
```



```
Installs1                   4.114e-02  1.340e-01   0.307 0.758849    
Installs10                  9.989e-02  1.239e-01   0.806 0.420157    
Installs100                 1.073e-01  1.229e-01   0.873 0.382495    
Installs1000               -7.785e-02  1.225e-01  -0.635 0.525154    
Installs10000              -1.190e-01  1.224e-01  -0.972 0.331252    
Installs100000             -5.482e-02  1.225e-01  -0.448 0.654456    
Installs1000000             6.995e-02  1.224e-01   0.571 0.567714    
Installs10000000            1.660e-01  1.226e-01   1.354 0.175762    
Installs100000000           2.482e-01  1.245e-01   1.993 0.046235 *  
Installs1000000000          4.670e-02  1.431e-01   0.326 0.744230    
Installs5                   7.283e-02  1.320e-01   0.552 0.581159    
Installs50                  9.086e-02  1.259e-01   0.722 0.470496    
Installs500                 2.683e-02  1.244e-01   0.216 0.829224    
Installs5000               -1.182e-01  1.234e-01  -0.958 0.338209    
Installs50000              -1.130e-01  1.235e-01  -0.915 0.360076    
Installs500000              2.050e-03  1.235e-01   0.017 0.986749    
Installs5000000             9.138e-02  1.230e-01   0.743 0.457628    
Installs50000000            2.024e-01  1.250e-01   1.619 0.105393    
Installs500000000           1.815e-01  1.352e-01   1.343 0.179392    
Content.RatingEveryone     -9.450e-02  2.702e-01  -0.350 0.726583    
Content.RatingEveryone 10+ -9.899e-02  2.711e-01  -0.365 0.715017    
Content.RatingMature 17+   -1.264e-01  2.712e-01  -0.466 0.641206    
Content.RatingTeen         -9.397e-02  2.704e-01  -0.347 0.728225    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.462 on 10779 degrees of freedom
Multiple R-squared:  0.0766,	Adjusted R-squared:  0.07155 
F-statistic: 15.16 on 59 and 10779 DF,  p-value: < 2.2e-16
```

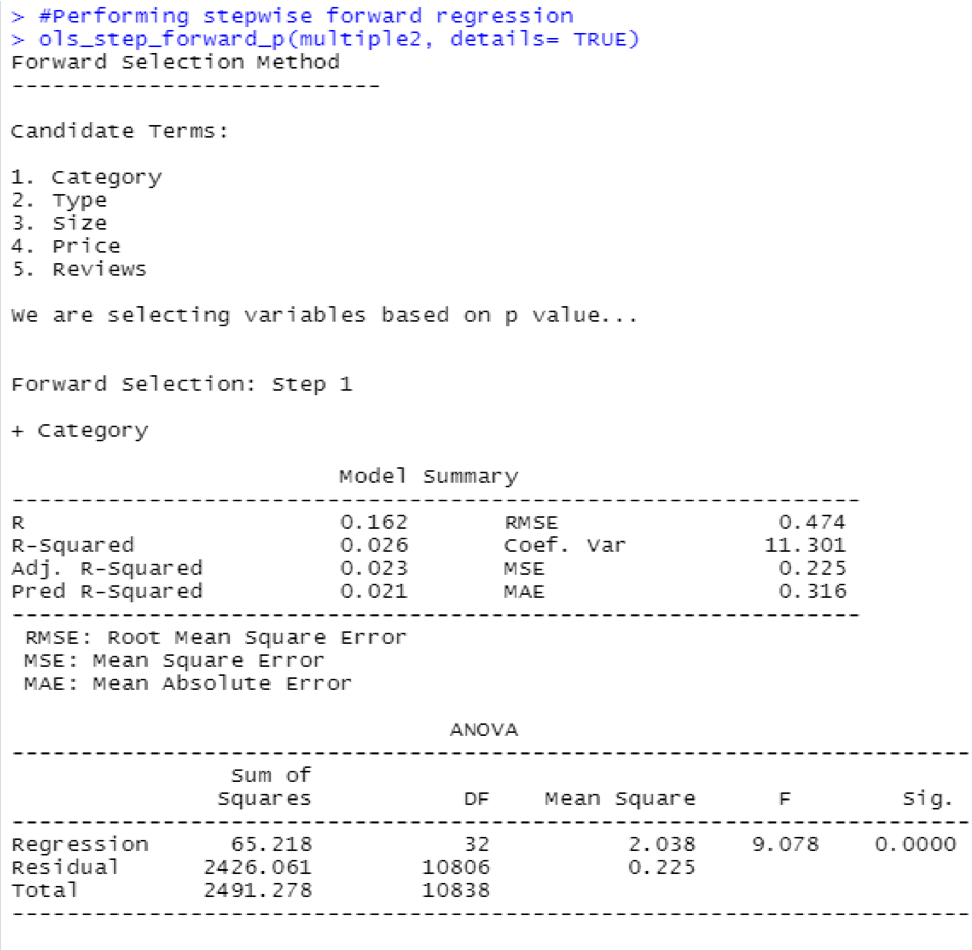
- From the above two screenshots we can find that all the values of install and content rating are greater than 0.05. hence, we can remove them for the final prediction and take the variables which are significant. The variables which are significant and can be used in the process of predictions are: Category, Type, Size, Price, Reviews.
- ***<u>Now we will build another model which will have just the above variables.</u>***



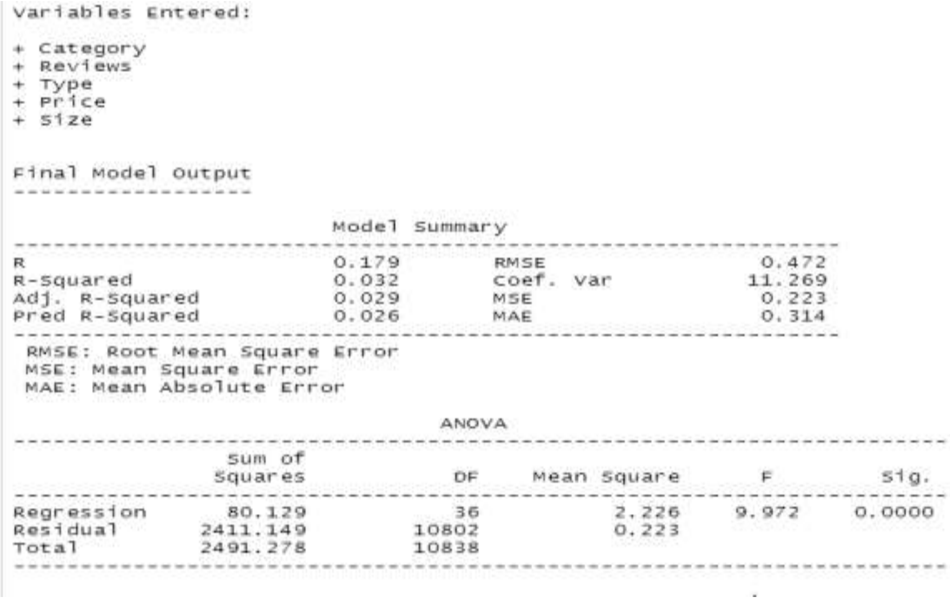
```
> multiple2<- lm(Rating~ Category+Type+Size+Price+Reviews, data= dataset)
> summary(multiple2)

Call:
lm(formula = Rating ~ Category + Type + Size + Price + Reviews,
    data = dataset)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.2679 -0.1423  0.0568  0.2569  1.0002 

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)    
(Intercept)                  4.349e+00  5.861e-02  74.197  < 2e-16 ***
CategoryAUTO_AND_VEHICLES   -1.554e-01  7.785e-02  -1.996 0.045960 *  
CategoryBEAUTY              -8.461e-02  8.744e-02  -0.968 0.333260    
CategoryBOOKS_AND_REFERENCE -4.114e-02  6.636e-02  -0.620 0.535320    
CategoryBUSINESS            -1.994e-01  6.261e-02  -3.185 0.001452 ** 
CategoryCOMICS              -1.884e-01  8.459e-02  -2.228 0.025923 *  
CategoryCOMMUNICATION       -2.051e-01  6.344e-02  -3.232 0.001231 ** 
CategoryDATING              -3.400e-01  6.624e-02  -5.133 2.91e-07 ***
CategoryEDUCATION            3.830e-02  6.976e-02   0.549 0.582987    
CategoryENTERTAINMENT       -2.247e-01  7.024e-02  -3.199 0.001382 ** 
CategoryEVENTS               1.963e-02  8.320e-02   0.236 0.813529    
CategoryFAMILY              -1.594e-01  5.958e-02  -2.676 0.007459 ** 
CategoryFINANCE             -2.032e-01  6.364e-02  -3.193 0.001414 ** 
CategoryFOOD_AND_DRINK      -1.760e-01  7.206e-02  -2.443 0.014591 *  
CategoryGAME                -8.016e-02  6.030e-02  -1.329 0.183795    
CategoryHEALTH_AND_FITNESS  -8.165e-02  6.395e-02  -1.277 0.201749    
CategoryHOUSE_AND_HOME      -1.482e-01  7.728e-02  -1.918 0.055177 .  
CategoryLIBRARIES_AND_DEMO  -1.439e-01  7.829e-02  -1.838 0.066093 .  
CategoryLIFESTYLE           -2.306e-01  6.342e-02  -3.636 0.000278 ***
CategoryMAPS_AND_NAVIGATION -2.841e-01  7.116e-02  -3.993 6.57e-05 ***
CategoryMEDICAL             -1.670e-01  6.268e-02  -2.664 0.007722 ** 
CategoryNEWS_AND_MAGAZINES  -2.049e-01  6.499e-02  -3.153 0.001621 ** 
CategoryPARENTING           -6.505e-02  8.458e-02  -0.769 0.441878    
CategoryPERSONALIZATION     -5.888e-02  6.335e-02  -0.930 0.352648    
CategoryPHOTOGRAPHY         -1.647e-01  6.404e-02  -2.571 0.010146 *  
CategoryPRODUCTIVITY        -1.425e-01  6.294e-02  -2.264 0.023595 *  
CategorySHOPPING            -9.540e-02  6.553e-02  -1.456 0.145496    
CategorySOCIAL              -1.192e-01  6.482e-02  -1.839 0.065877 .  
CategorySPORTS              -1.317e-01  6.337e-02  -2.078 0.037719 *  
CategoryTOOLS               -2.861e-01  6.085e-02  -4.701 2.62e-06 ***
CategoryTRAVEL_AND_LOCAL    -2.308e-01  6.557e-02  -3.520 0.000434 ***
CategoryVIDEO_PLAYERS       -2.786e-01  6.864e-02  -4.060 4.95e-05 ***
CategoryWEATHER             -1.144e-01  7.847e-02  -1.458 0.144849    
TypePaid                     7.634e-02  1.827e-02   4.179 2.95e-05 ***
Size                        -1.271e-04  5.069e-05  -2.507 0.012179 *  
Price                       -7.664e-04  2.943e-04  -2.604 0.009221 ** 
Reviews                      1.041e-08  1.583e-09   6.577 5.03e-11 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4725 on 10802 degrees of freedom
Multiple R-squared:  0.03216,	Adjusted R-squared:  0.02894 
F-statistic: 9.972 on 36 and 10802 DF,  p-value: < 2.2e-16
```

- ***Now we will perform forward selection model for the new model that we have used.***

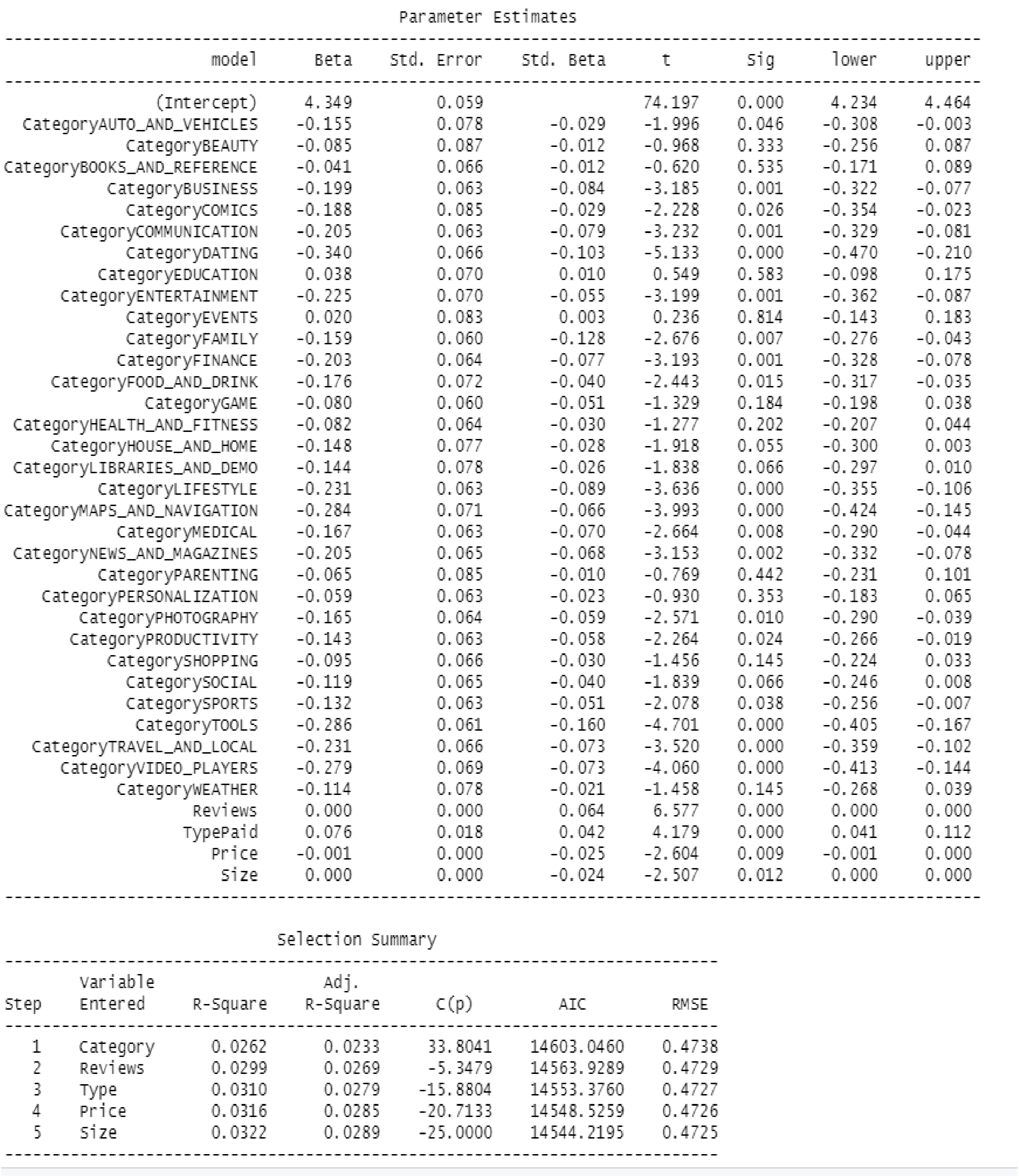
# there are many screenshots of each step but here included only the final output. Rest can be found in the Output pdf.



```
> #Performing stepwise forward regression
> ols_step_forward_p(multiple2, details= TRUE)
Forward Selection Method
---------------------------

Candidate Terms:

1. Category
2. Type
3. Size
4. Price
5. Reviews

We are selecting variables based on p value...


Forward Selection: Step 1

+ Category

                        Model Summary
--------------------------------------------------------------
R                       0.162       RMSE                0.474
R-Squared               0.026       Coef. Var          11.301
Adj. R-Squared          0.023       MSE                 0.225
Pred R-Squared          0.021       MAE                 0.316
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error

                                ANOVA
----------------------------------------------------------------------
               Sum of
              Squares          DF    Mean Square       F         Sig.
----------------------------------------------------------------------
Regression     65.218          32          2.038     9.078     0.0000
Residual     2426.061       10806          0.225
Total        2491.278       10838
----------------------------------------------------------------------
```



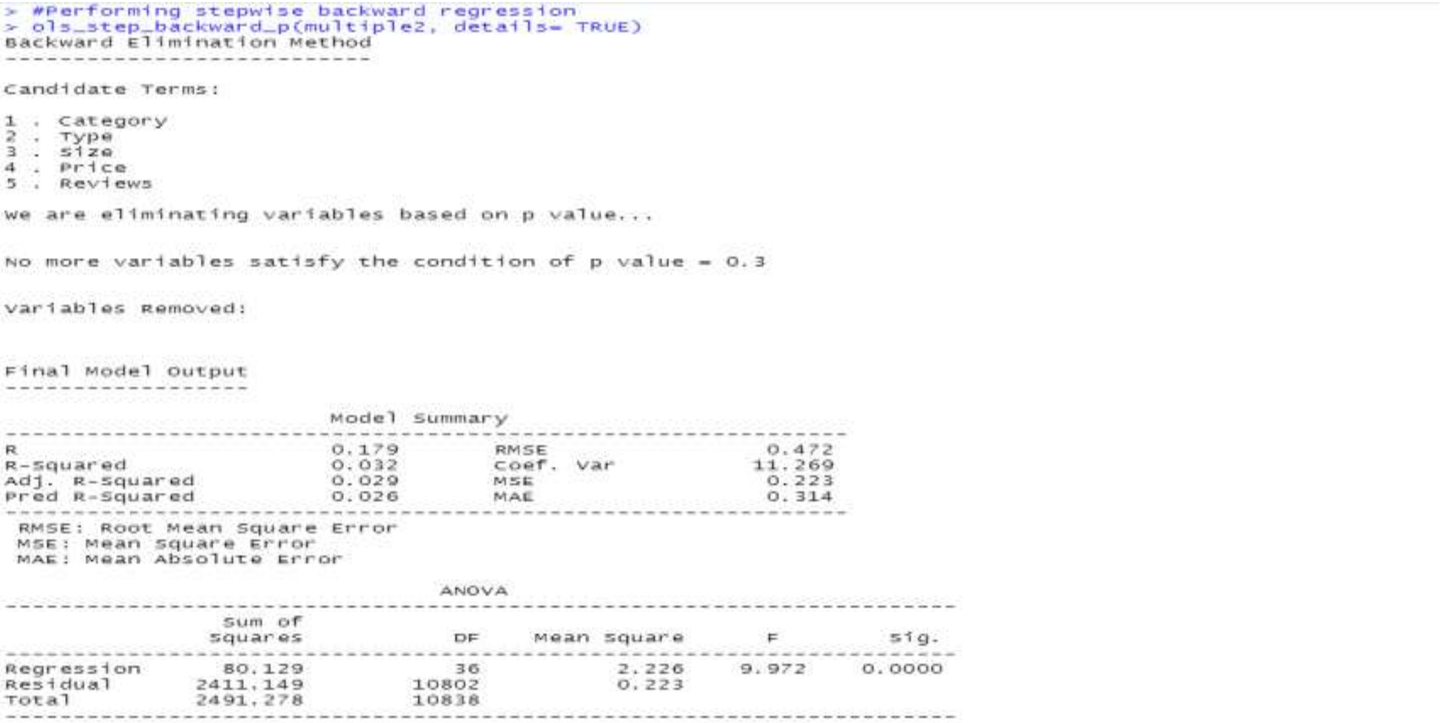
```
Variables Entered:

+ Category
+ Reviews
+ Type
+ Price
+ Size


Final Model Output
------------------

                        Model Summary
--------------------------------------------------------------
R                       0.179       RMSE                0.472
R-Squared               0.032       Coef. Var          11.269
Adj. R-Squared          0.029       MSE                 0.223
Pred R-Squared          0.026       MAE                 0.314
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error

                                ANOVA
----------------------------------------------------------------------
               Sum of
              Squares          DF    Mean Square       F         Sig.
----------------------------------------------------------------------
Regression     80.129          36          2.226     9.972     0.0000
Residual     2411.149       10802          0.223
Total        2491.278       10838
----------------------------------------------------------------------
```



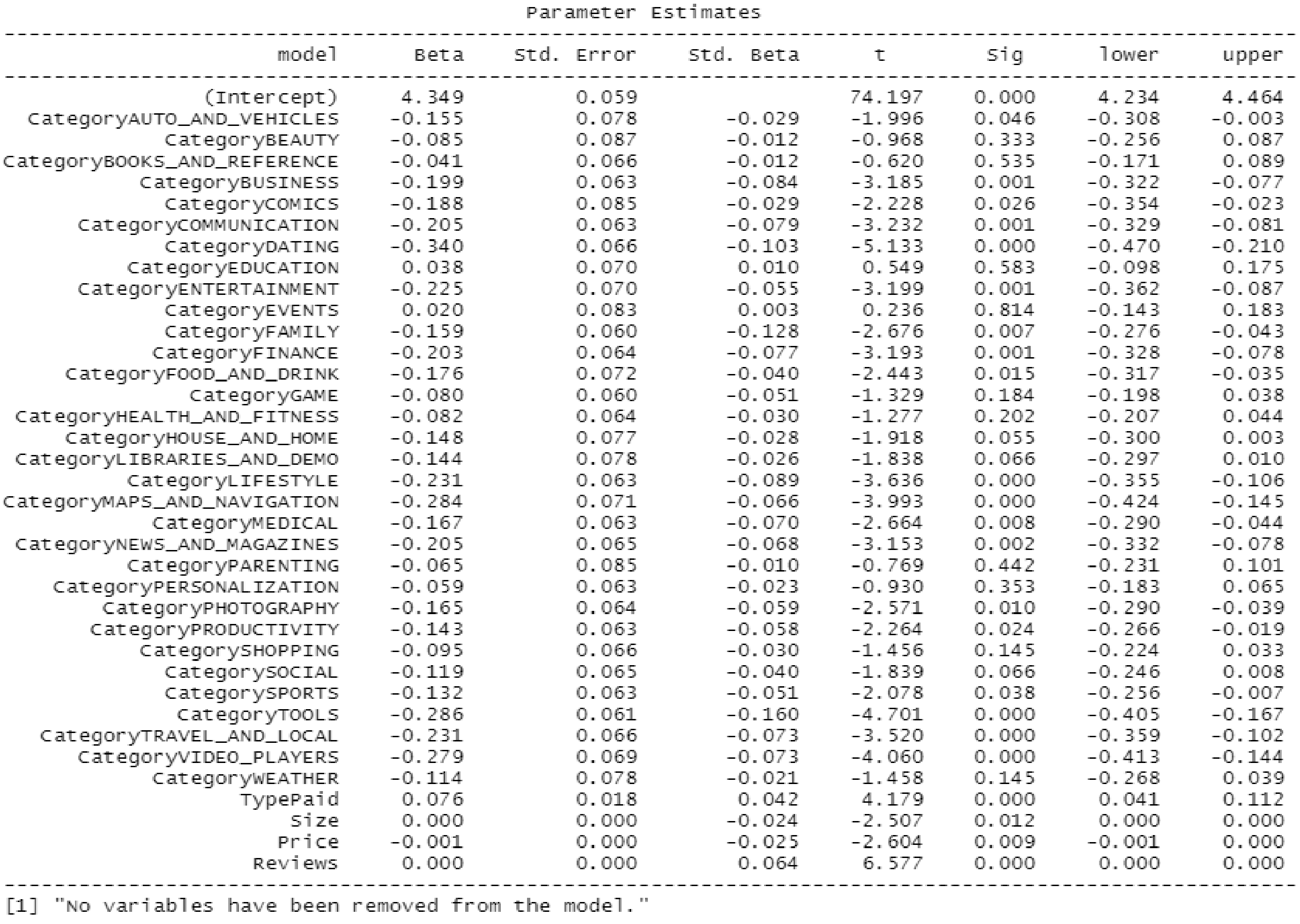
```
                                           Parameter Estimates
-----------------------------------------------------------------------------------------------------------
                      model      Beta    Std. Error    Std. Beta      t        Sig      lower     upper
-----------------------------------------------------------------------------------------------------------
                (Intercept)     4.349         0.059                 74.197    0.000     4.234     4.464
     CategoryAUTO_AND_VEHICLES -0.155        0.078       -0.029    -1.996    0.046    -0.308    -0.003
             CategoryBEAUTY    -0.085         0.087       -0.012    -0.968    0.333    -0.256     0.087
 CategoryBOOKS_AND_REFERENCE   -0.041         0.066       -0.012    -0.620    0.535    -0.171     0.089
           CategoryBUSINESS    -0.199         0.063       -0.084    -3.185    0.001    -0.322    -0.077
             CategoryCOMICS    -0.188         0.085       -0.029    -2.228    0.026    -0.354    -0.023
      CategoryCOMMUNICATION    -0.205         0.063       -0.079    -3.232    0.001    -0.329    -0.081
             CategoryDATING    -0.340         0.066       -0.103    -5.133    0.000    -0.470    -0.210
          CategoryEDUCATION     0.038         0.070        0.010     0.549    0.583    -0.098     0.175
      CategoryENTERTAINMENT    -0.225         0.070       -0.055    -3.199    0.001    -0.362    -0.087
             CategoryEVENTS     0.020         0.083        0.003     0.236    0.814    -0.143     0.183
             CategoryFAMILY    -0.159         0.060       -0.128    -2.676    0.007    -0.276    -0.043
            CategoryFINANCE    -0.203         0.064       -0.077    -3.193    0.001    -0.328    -0.078
     CategoryFOOD_AND_DRINK    -0.176         0.072       -0.040    -2.443    0.015    -0.317    -0.035
               CategoryGAME    -0.080         0.060       -0.051    -1.329    0.184    -0.198     0.038
  CategoryHEALTH_AND_FITNESS   -0.082         0.064       -0.030    -1.277    0.202    -0.207     0.044
     CategoryHOUSE_AND_HOME    -0.148         0.077       -0.028    -1.918    0.055    -0.300     0.003
  CategoryLIBRARIES_AND_DEMO   -0.144         0.078       -0.026    -1.838    0.066    -0.297     0.010
          CategoryLIFESTYLE    -0.231         0.063       -0.089    -3.636    0.000    -0.355    -0.106
 CategoryMAPS_AND_NAVIGATION   -0.284         0.071       -0.066    -3.993    0.000    -0.424    -0.145
            CategoryMEDICAL    -0.167         0.063       -0.070    -2.664    0.008    -0.290    -0.044
  CategoryNEWS_AND_MAGAZINES   -0.205         0.065       -0.068    -3.153    0.002    -0.332    -0.078
          CategoryPARENTING    -0.065         0.085       -0.010    -0.769    0.442    -0.231     0.101
    CategoryPERSONALIZATION    -0.059         0.063       -0.023    -0.930    0.353    -0.183     0.065
        CategoryPHOTOGRAPHY    -0.165         0.064       -0.059    -2.571    0.010    -0.290    -0.039
       CategoryPRODUCTIVITY    -0.143         0.063       -0.058    -2.264    0.024    -0.266    -0.019
           CategorySHOPPING    -0.095         0.066       -0.030    -1.456    0.145    -0.224     0.033
             CategorySOCIAL    -0.119         0.065       -0.040    -1.839    0.066    -0.246     0.008
             CategorySPORTS    -0.132         0.063       -0.051    -2.078    0.038    -0.256    -0.007
              CategoryTOOLS    -0.286         0.061       -0.160    -4.701    0.000    -0.405    -0.167
     CategoryTRAVEL_AND_LOCAL  -0.231         0.066       -0.073    -3.520    0.000    -0.359    -0.102
      CategoryVIDEO_PLAYERS    -0.279         0.069       -0.073    -4.060    0.000    -0.413    -0.144
            CategoryWEATHER    -0.114         0.078       -0.021    -1.458    0.145    -0.268     0.039
                    Reviews     0.000         0.000        0.064     6.577    0.000     0.000     0.000
                   TypePaid     0.076         0.018        0.042     4.179    0.000     0.041     0.112
                      Price    -0.001         0.000       -0.025    -2.604    0.009    -0.001     0.000
                       Size     0.000         0.000       -0.024    -2.507    0.012     0.000     0.000
-----------------------------------------------------------------------------------------------------------

                               Selection Summary
-------------------------------------------------------------------------------
        Variable                  Adj.
Step    Entered     R-Square    R-Square     C(p)         AIC          RMSE
-------------------------------------------------------------------------------
   1    Category      0.0262      0.0233     33.8041    14603.0460    0.4738
   2    Reviews       0.0299      0.0269     -5.3479    14563.9289    0.4729
   3    Type          0.0310      0.0279    -15.8804    14553.3760    0.4727
   4    Price         0.0316      0.0285    -20.7133    14548.5259    0.4726
   5    Size          0.0322      0.0289    -25.0000    14544.2195    0.4725
-------------------------------------------------------------------------------
```

- In the above screenshots we can find what all variables were used for forward stepwise regression. At last the final model we can find the variables with different values of prediction errors:
  1) RMSE: 0.472 2) R-Squared: 0.032

- ***Now we will find the stepwise regression model for backward direction.***



```
> #Performing stepwise backward regression
> ols_step_backward_p(multiple2, details= TRUE)
Backward Elimination Method
---------------------------

Candidate Terms:

1 . Category
2 . Type
3 . Size
4 . Price
5 . Reviews

We are eliminating variables based on p value...

No more variables satisfy the condition of p value = 0.3

Variables Removed:


Final Model Output
------------------

                        Model Summary
--------------------------------------------------------------
R                       0.179       RMSE               0.472
R-Squared               0.032       Coef. Var         11.269
Adj. R-Squared          0.029       MSE                0.223
Pred R-Squared          0.026       MAE                0.314
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error

                               ANOVA
-----------------------------------------------------------------------
                Sum of
               Squares           DF    Mean Square       F        Sig.
-----------------------------------------------------------------------
Regression      80.129           36          2.226     9.972    0.0000
Residual      2411.149        10802          0.223
Total         2491.278        10838
-----------------------------------------------------------------------
```

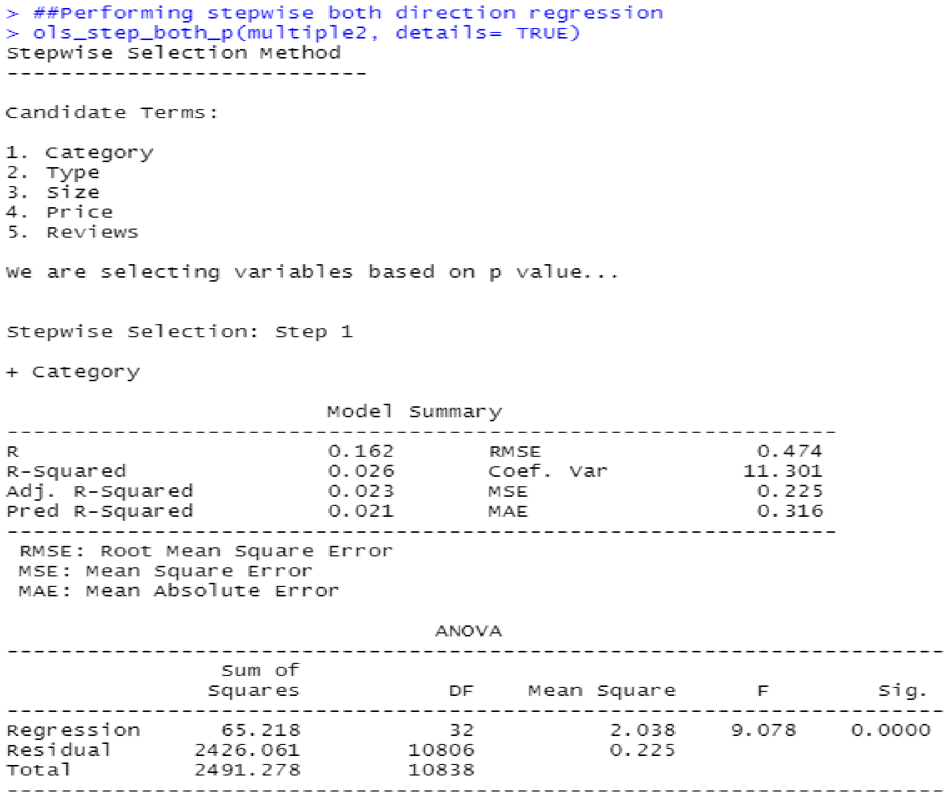


```
                                              Parameter Estimates
------------------------------------------------------------------------------------------------------------
                    model       Beta    Std. Error    Std. Beta         t        Sig      lower      upper
------------------------------------------------------------------------------------------------------------
              (Intercept)      4.349         0.059                 74.197      0.000      4.234      4.464
   CategoryAUTO_AND_VEHICLES  -0.155         0.078       -0.029    -1.996      0.046     -0.308     -0.003
           CategoryBEAUTY     -0.085         0.087       -0.012    -0.968      0.333     -0.256      0.087
CategoryBOOKS_AND_REFERENCE   -0.041         0.066       -0.012    -0.620      0.535     -0.171      0.089
         CategoryBUSINESS     -0.199         0.063       -0.084    -3.185      0.001     -0.322     -0.077
           CategoryCOMICS     -0.188         0.085       -0.029    -2.228      0.026     -0.354     -0.023
    CategoryCOMMUNICATION     -0.205         0.063       -0.079    -3.232      0.001     -0.329     -0.081
           CategoryDATING     -0.340         0.066       -0.103    -5.133      0.000     -0.470     -0.210
        CategoryEDUCATION      0.038         0.070        0.010     0.549      0.583     -0.098      0.175
    CategoryENTERTAINMENT     -0.225         0.070       -0.055    -3.199      0.001     -0.362     -0.087
           CategoryEVENTS      0.020         0.083        0.003     0.236      0.814     -0.143      0.183
           CategoryFAMILY     -0.159         0.060       -0.128    -2.676      0.007     -0.276     -0.043
          CategoryFINANCE     -0.203         0.064       -0.077    -3.193      0.001     -0.328     -0.078
   CategoryFOOD_AND_DRINK     -0.176         0.072       -0.040    -2.443      0.015     -0.317     -0.035
             CategoryGAME     -0.080         0.060       -0.051    -1.329      0.184     -0.198      0.038
 CategoryHEALTH_AND_FITNESS   -0.082         0.064       -0.030    -1.277      0.202     -0.207      0.044
   CategoryHOUSE_AND_HOME     -0.148         0.077       -0.028    -1.918      0.055     -0.300      0.003
 CategoryLIBRARIES_AND_DEMO   -0.144         0.078       -0.026    -1.838      0.066     -0.297      0.010
        CategoryLIFESTYLE     -0.231         0.063       -0.089    -3.636      0.000     -0.355     -0.106
CategoryMAPS_AND_NAVIGATION   -0.284         0.071       -0.066    -3.993      0.000     -0.424     -0.145
          CategoryMEDICAL     -0.167         0.063       -0.070    -2.664      0.008     -0.290     -0.044
 CategoryNEWS_AND_MAGAZINES   -0.205         0.065       -0.068    -3.153      0.002     -0.332     -0.078
        CategoryPARENTING     -0.065         0.085       -0.010    -0.769      0.442     -0.231      0.101
  CategoryPERSONALIZATION     -0.059         0.063       -0.023    -0.930      0.353     -0.183      0.065
      CategoryPHOTOGRAPHY     -0.165         0.064       -0.059    -2.571      0.010     -0.290     -0.039
     CategoryPRODUCTIVITY     -0.143         0.063       -0.058    -2.264      0.024     -0.266     -0.019
         CategorySHOPPING     -0.095         0.066       -0.030    -1.456      0.145     -0.224      0.033
           CategorySOCIAL     -0.119         0.065       -0.040    -1.839      0.066     -0.246      0.008
           CategorySPORTS     -0.132         0.063       -0.051    -2.078      0.038     -0.256     -0.007
            CategoryTOOLS     -0.286         0.061       -0.160    -4.701      0.000     -0.405     -0.167
  CategoryTRAVEL_AND_LOCAL    -0.231         0.066       -0.073    -3.520      0.000     -0.359     -0.102
    CategoryVIDEO_PLAYERS     -0.279         0.069       -0.073    -4.060      0.000     -0.413     -0.144
          CategoryWEATHER     -0.114         0.078       -0.021    -1.458      0.145     -0.268      0.039
                 TypePaid      0.076         0.018        0.042     4.179      0.000      0.041      0.112
                     Size      0.000         0.000       -0.024    -2.507      0.012      0.000      0.000
                    Price     -0.001         0.000       -0.025    -2.604      0.009     -0.001      0.000
                  Reviews      0.000         0.000        0.064     6.577      0.000      0.000      0.000
------------------------------------------------------------------------------------------------------------
[1] "No variables have been removed from the model."
```

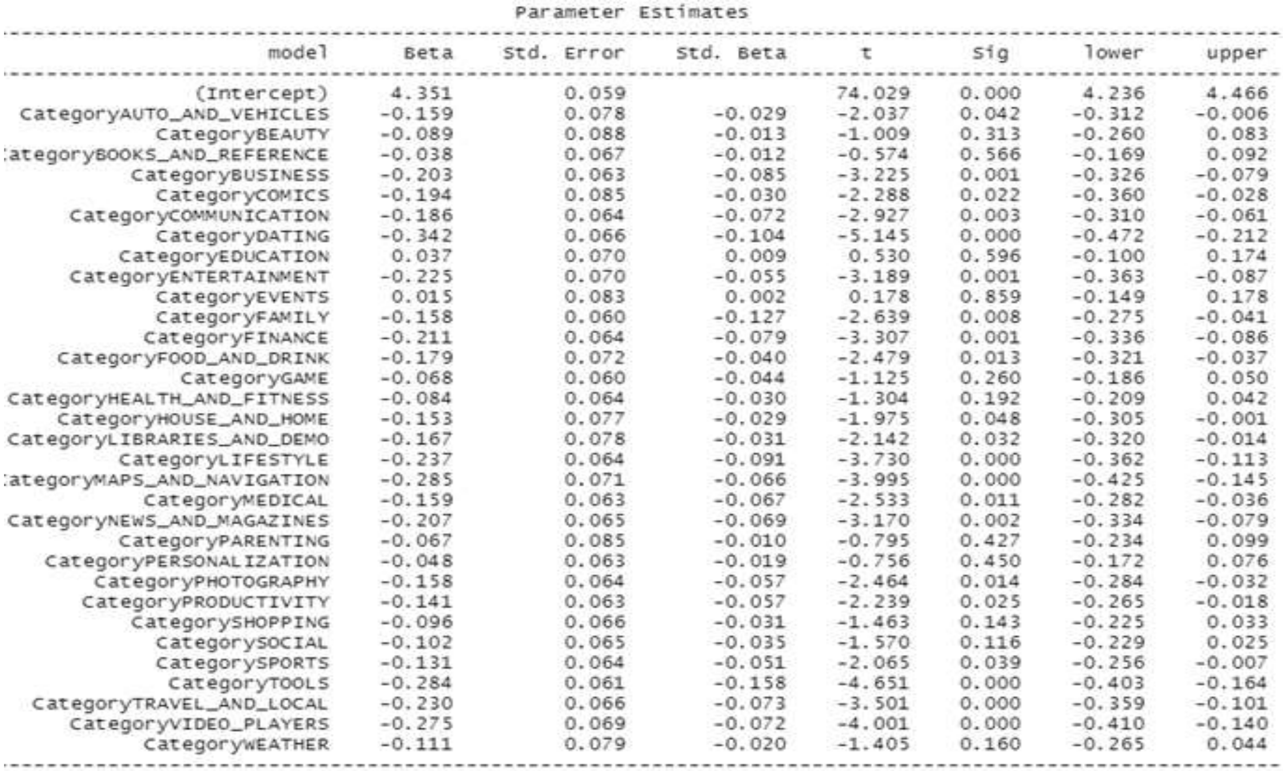
- We can notice in backward stepwise regression no variable was eliminated in the final model with prediction metrics:

  1) RMSE: 0.472 2) R-Squared: 0.032

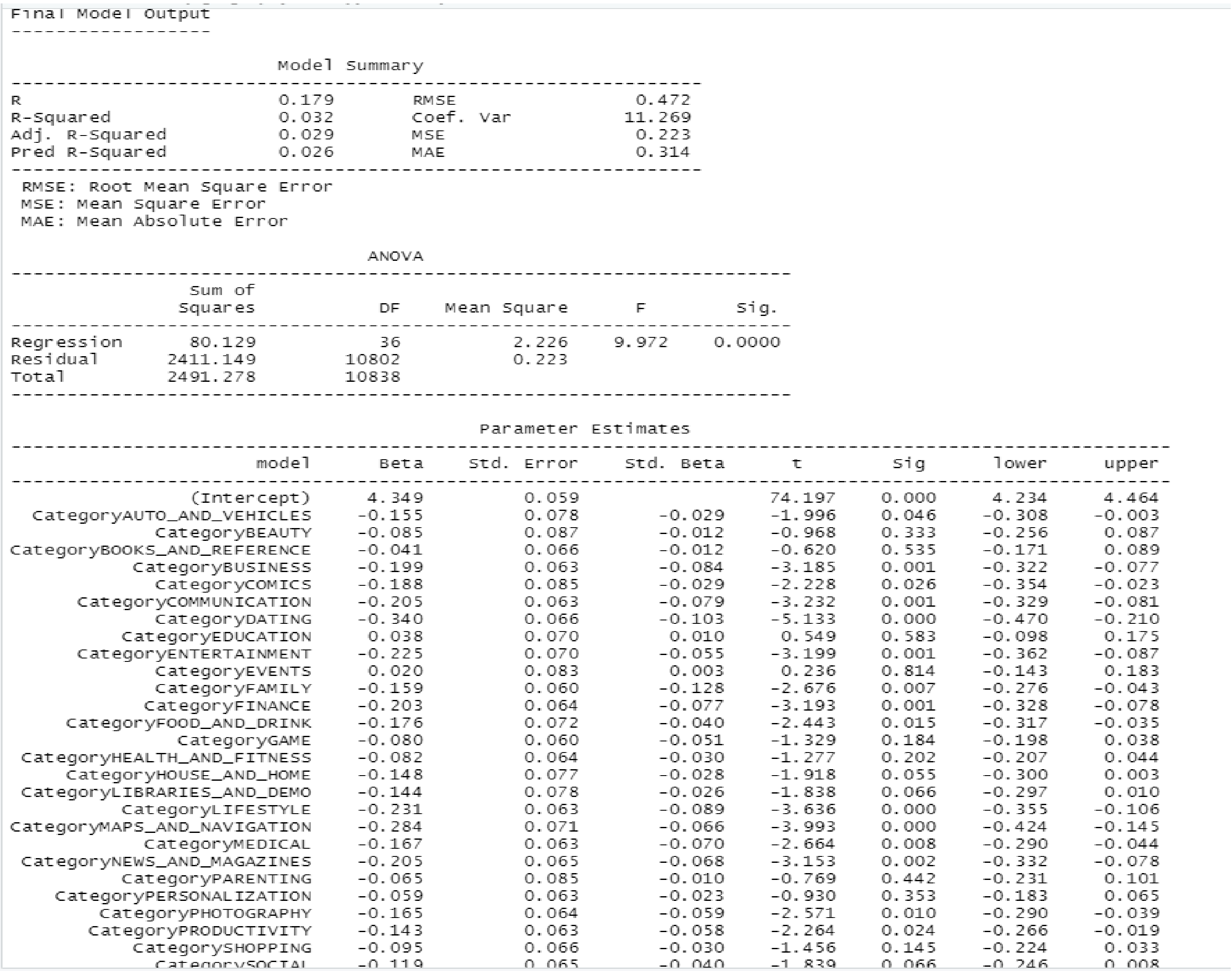
- ***<u>Now we will perform stepwise regression for both the directions.</u>***



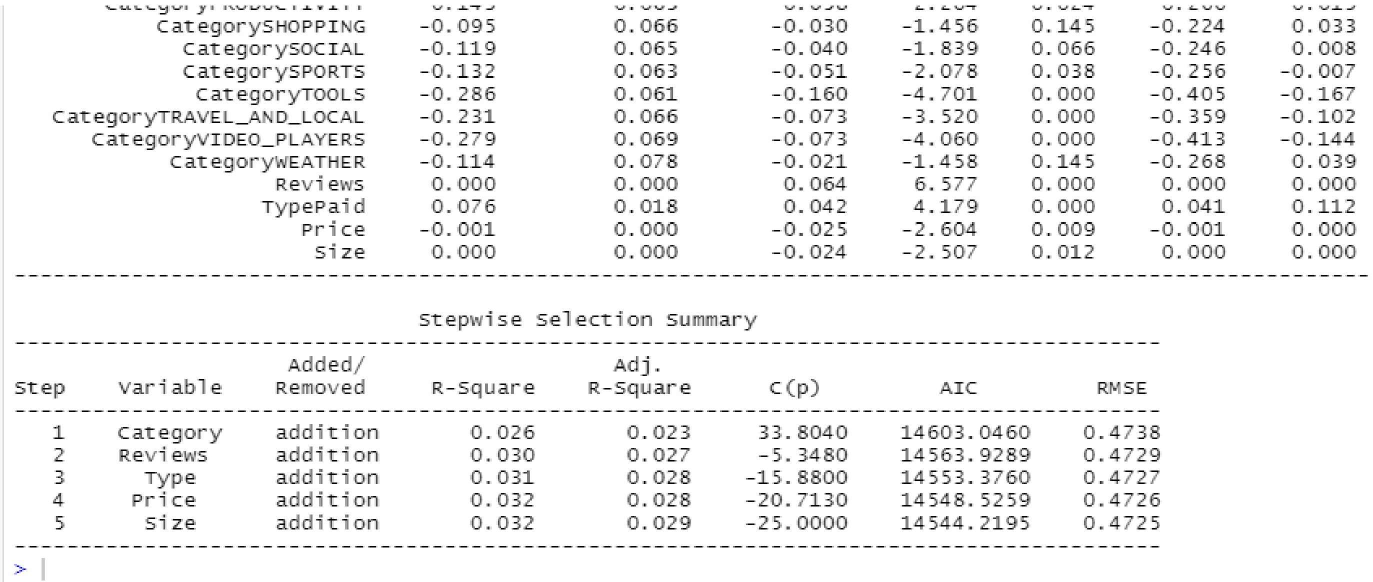
```
> ##Performing stepwise both direction regression
> ols_step_both_p(multiple2, details= TRUE)
Stepwise Selection Method
---------------------------

Candidate Terms:

1. Category
2. Type
3. Size
4. Price
5. Reviews

We are selecting variables based on p value...


Stepwise Selection: Step 1

+ Category

                        Model Summary
--------------------------------------------------------------
R                       0.162       RMSE                0.474
R-Squared               0.026       Coef. Var          11.301
Adj. R-Squared          0.023       MSE                 0.225
Pred R-Squared          0.021       MAE                 0.316
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error

                                ANOVA
----------------------------------------------------------------------
                Sum of
               Squares          DF    Mean Square      F         Sig.
----------------------------------------------------------------------
Regression      65.218          32          2.038    9.078     0.0000
Residual      2426.061       10806          0.225
Total         2491.278       10838
----------------------------------------------------------------------
```



```
                                          Parameter Estimates
----------------------------------------------------------------------------------------------------
                     model      Beta    Std. Error    Std. Beta        t      Sig     lower    upper
----------------------------------------------------------------------------------------------------
               (Intercept)     4.351         0.059                74.029    0.000     4.236    4.466
   CategoryAUTO_AND_VEHICLES  -0.159         0.078       -0.029   -2.037    0.042    -0.312   -0.006
            CategoryBEAUTY    -0.089         0.088       -0.013   -1.009    0.313    -0.260    0.083
ategoryBOOKS_AND_REFERENCE    -0.038         0.067       -0.012   -0.574    0.566    -0.169    0.092
          CategoryBUSINESS    -0.203         0.063       -0.085   -3.225    0.001    -0.326   -0.079
            CategoryCOMICS    -0.194         0.085       -0.030   -2.288    0.022    -0.360   -0.028
     CategoryCOMMUNICATION    -0.186         0.064       -0.072   -2.927    0.003    -0.310   -0.061
            CategoryDATING    -0.342         0.066       -0.104   -5.145    0.000    -0.472   -0.212
         CategoryEDUCATION     0.037         0.070        0.009    0.530    0.596    -0.100    0.174
     CategoryENTERTAINMENT    -0.225         0.070       -0.055   -3.189    0.001    -0.363   -0.087
            CategoryEVENTS     0.015         0.083        0.002    0.178    0.859    -0.149    0.178
            CategoryFAMILY    -0.158         0.060       -0.127   -2.639    0.008    -0.275   -0.041
           CategoryFINANCE    -0.211         0.064       -0.079   -3.307    0.001    -0.336   -0.086
    CategoryFOOD_AND_DRINK    -0.179         0.072       -0.040   -2.479    0.013    -0.321   -0.037
              CategoryGAME    -0.068         0.060       -0.044   -1.125    0.260    -0.186    0.050
CategoryHEALTH_AND_FITNESS    -0.084         0.064       -0.030   -1.304    0.192    -0.209    0.042
    CategoryHOUSE_AND_HOME    -0.153         0.077       -0.029   -1.975    0.048    -0.305   -0.001
CategoryLIBRARIES_AND_DEMO    -0.167         0.078       -0.031   -2.142    0.032    -0.320   -0.014
         CategoryLIFESTYLE    -0.237         0.064       -0.091   -3.730    0.000    -0.362   -0.113
ategoryMAPS_AND_NAVIGATION    -0.285         0.071       -0.066   -3.995    0.000    -0.425   -0.145
           CategoryMEDICAL    -0.159         0.063       -0.067   -2.533    0.011    -0.282   -0.036
CategoryNEWS_AND_MAGAZINES    -0.207         0.065       -0.069   -3.170    0.002    -0.334   -0.079
         CategoryPARENTING    -0.067         0.085       -0.010   -0.795    0.427    -0.234    0.099
   CategoryPERSONALIZATION    -0.048         0.063       -0.019   -0.756    0.450    -0.172    0.076
       CategoryPHOTOGRAPHY    -0.158         0.064       -0.057   -2.464    0.014    -0.284   -0.032
      CategoryPRODUCTIVITY    -0.141         0.063       -0.057   -2.239    0.025    -0.265   -0.018
          CategorySHOPPING    -0.096         0.066       -0.031   -1.463    0.143    -0.225    0.033
            CategorySOCIAL    -0.102         0.065       -0.035   -1.570    0.116    -0.229    0.025
            CategorySPORTS    -0.131         0.064       -0.051   -2.065    0.039    -0.256   -0.007
             CategoryTOOLS    -0.284         0.061       -0.158   -4.651    0.000    -0.403   -0.164
   CategoryTRAVEL_AND_LOCAL   -0.230         0.066       -0.073   -3.501    0.000    -0.359   -0.101
     CategoryVIDEO_PLAYERS    -0.275         0.069       -0.072   -4.001    0.000    -0.410   -0.140
           CategoryWEATHER    -0.111         0.079       -0.020   -1.405    0.160    -0.265    0.044
----------------------------------------------------------------------------------------------------
```



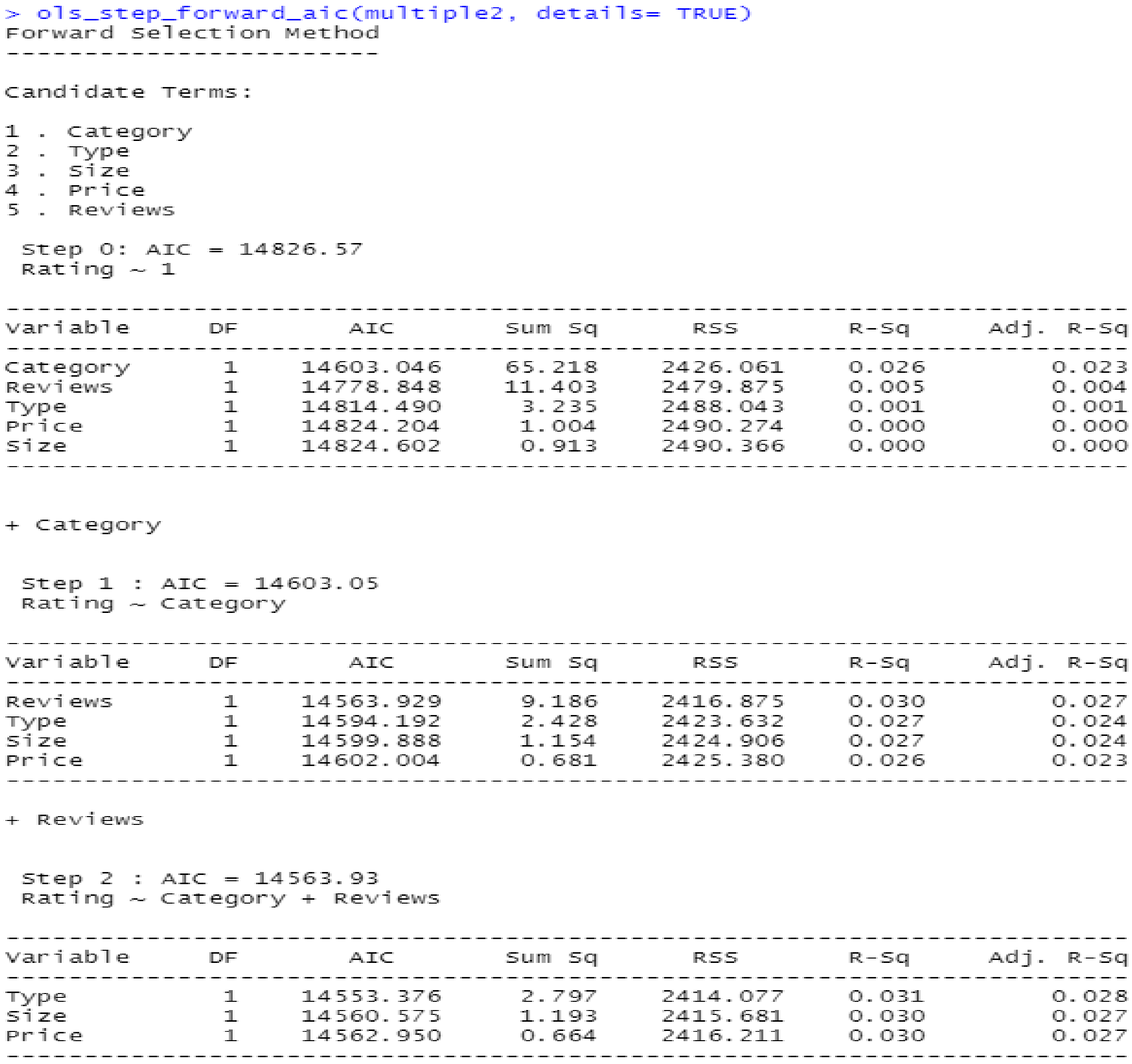
```
Final Model Output
------------------

                        Model Summary
--------------------------------------------------------------
R                        0.179       RMSE                0.472
R-Squared                0.032       Coef. Var          11.269
Adj. R-Squared           0.029       MSE                 0.223
Pred R-Squared           0.026       MAE                 0.314
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error

                                ANOVA
----------------------------------------------------------------------
                Sum of
               Squares          DF    Mean Square      F         Sig.
----------------------------------------------------------------------
Regression      80.129          36          2.226    9.972     0.0000
Residual      2411.149       10802          0.223
Total         2491.278       10838
----------------------------------------------------------------------

                                      Parameter Estimates
----------------------------------------------------------------------------------------------------
                      model      Beta    Std. Error    Std. Beta       t        Sig     lower    upper
----------------------------------------------------------------------------------------------------
                (Intercept)     4.349         0.059                 74.197    0.000     4.234    4.464
  CategoryAUTO_AND_VEHICLES    -0.155         0.078       -0.029    -1.996    0.046    -0.308   -0.003
             CategoryBEAUTY    -0.085         0.087       -0.012    -0.968    0.333    -0.256    0.087
CategoryBOOKS_AND_REFERENCE    -0.041         0.066       -0.012    -0.620    0.535    -0.171    0.089
           CategoryBUSINESS    -0.199         0.063       -0.084    -3.185    0.001    -0.322   -0.077
             CategoryCOMICS    -0.188         0.085       -0.029    -2.228    0.026    -0.354   -0.023
      CategoryCOMMUNICATION    -0.205         0.063       -0.079    -3.232    0.001    -0.329   -0.081
             CategoryDATING    -0.340         0.066       -0.103    -5.133    0.000    -0.470   -0.210
          CategoryEDUCATION     0.038         0.070        0.010     0.549    0.583    -0.098    0.175
      CategoryENTERTAINMENT    -0.225         0.070       -0.055    -3.199    0.001    -0.362   -0.087
             CategoryEVENTS     0.020         0.083        0.003     0.236    0.814    -0.143    0.183
             CategoryFAMILY    -0.159         0.060       -0.128    -2.676    0.007    -0.276   -0.043
            CategoryFINANCE    -0.203         0.064       -0.077    -3.193    0.001    -0.328   -0.078
     CategoryFOOD_AND_DRINK    -0.176         0.072       -0.040    -2.443    0.015    -0.317   -0.035
               CategoryGAME    -0.080         0.060       -0.051    -1.329    0.184    -0.198    0.038
 CategoryHEALTH_AND_FITNESS    -0.082         0.064       -0.030    -1.277    0.202    -0.207    0.044
     CategoryHOUSE_AND_HOME    -0.148         0.077       -0.028    -1.918    0.055    -0.300    0.003
 CategoryLIBRARIES_AND_DEMO    -0.144         0.078       -0.026    -1.838    0.066    -0.297    0.010
          CategoryLIFESTYLE    -0.231         0.063       -0.089    -3.636    0.000    -0.355   -0.106
CategoryMAPS_AND_NAVIGATION    -0.284         0.071       -0.066    -3.993    0.000    -0.424   -0.145
            CategoryMEDICAL    -0.167         0.063       -0.070    -2.664    0.008    -0.290   -0.044
 CategoryNEWS_AND_MAGAZINES    -0.205         0.065       -0.068    -3.153    0.002    -0.332   -0.078
          CategoryPARENTING    -0.065         0.085       -0.010    -0.769    0.442    -0.231    0.101
    CategoryPERSONALIZATION    -0.059         0.063       -0.023    -0.930    0.353    -0.183    0.065
        CategoryPHOTOGRAPHY    -0.165         0.064       -0.059    -2.571    0.010    -0.290   -0.039
       CategoryPRODUCTIVITY    -0.143         0.063       -0.058    -2.264    0.024    -0.266   -0.019
           CategorySHOPPING    -0.095         0.066       -0.030    -1.456    0.145    -0.224    0.033
```



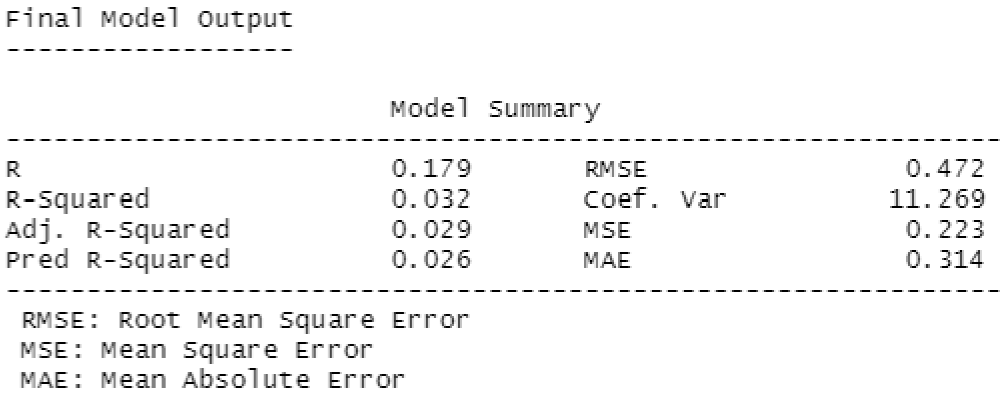
```
           CategorySHOPPING    -0.095         0.066       -0.030    -1.456    0.145    -0.224    0.033
             CategorySOCIAL    -0.119         0.065       -0.040    -1.839    0.066    -0.246    0.008
             CategorySPORTS    -0.132         0.063       -0.051    -2.078    0.038    -0.256   -0.007
              CategoryTOOLS    -0.286         0.061       -0.160    -4.701    0.000    -0.405   -0.167
   CategoryTRAVEL_AND_LOCAL    -0.231         0.066       -0.073    -3.520    0.000    -0.359   -0.102
     CategoryVIDEO_PLAYERS    -0.279         0.069       -0.073    -4.060    0.000    -0.413   -0.144
            CategoryWEATHER    -0.114         0.078       -0.021    -1.458    0.145    -0.268    0.039
                    Reviews     0.000         0.000        0.064     6.577    0.000     0.000    0.000
                   TypePaid     0.076         0.018        0.042     4.179    0.000     0.041    0.112
                      Price    -0.001         0.000       -0.025    -2.604    0.009    -0.001    0.000
                       Size     0.000         0.000       -0.024    -2.507    0.012     0.000    0.000
----------------------------------------------------------------------------------------------------

                               Stepwise Selection Summary
---------------------------------------------------------------------------------------
                     Added/                   Adj.
Step    Variable    Removed     R-Square    R-Square      C(p)         AIC         RMSE
---------------------------------------------------------------------------------------
   1    Category    addition       0.026       0.023    33.8040    14603.0460    0.4738
   2    Reviews     addition       0.030       0.027    -5.3480    14563.9289    0.4729
   3     Type       addition       0.031       0.028   -15.8800    14553.3760    0.4727
   4    Price       addition       0.032       0.028   -20.7130    14548.5259    0.4726
   5     Size       addition       0.032       0.029   -25.0000    14544.2195    0.4725
---------------------------------------------------------------------------------------
>
```

- After executing we have found all the prediction errors which were in both direction model.
  1) RMSE: 0.472   2) R-Squared: 0.032

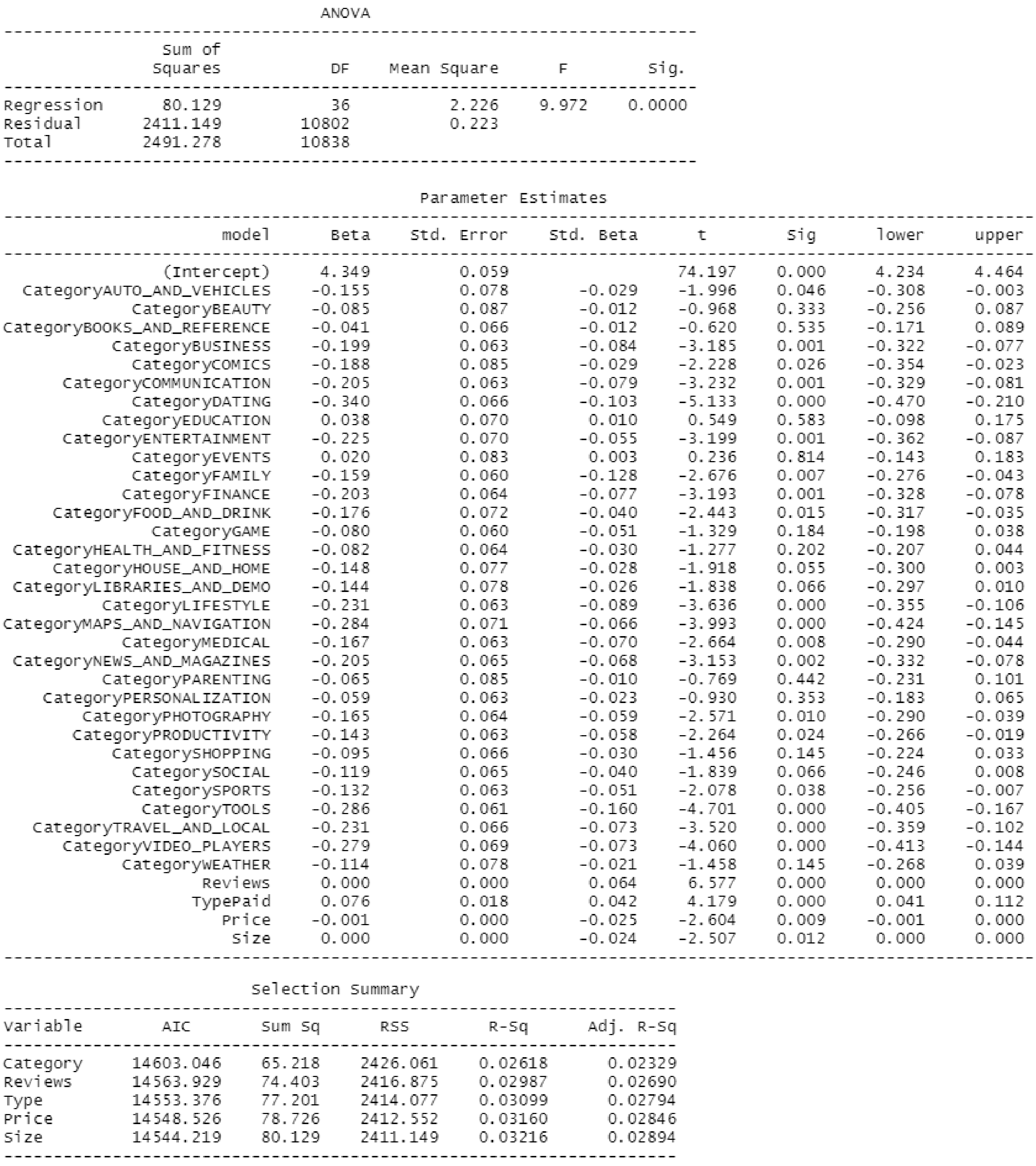
- ***<u>Now we will try to execute and do feature selection by stepwise forward AIC model.</u>***



```
> ols_step_forward_aic(multiple2, details= TRUE)
Forward Selection Method
------------------------

Candidate Terms:

1 . Category
2 . Type
3 . Size
4 . Price
5 . Reviews

 Step 0: AIC = 14826.57
 Rating ~ 1

-------------------------------------------------------------------------
Variable      DF        AIC        Sum Sq       RSS       R-Sq    Adj. R-Sq
-------------------------------------------------------------------------
Category       1     14603.046     65.218    2426.061    0.026       0.023
Reviews        1     14778.848     11.403    2479.875    0.005       0.004
Type           1     14814.490      3.235    2488.043    0.001       0.001
Price          1     14824.204      1.004    2490.274    0.000       0.000
Size           1     14824.602      0.913    2490.366    0.000       0.000
-------------------------------------------------------------------------


+ Category


 Step 1 : AIC = 14603.05
 Rating ~ Category

-------------------------------------------------------------------------
Variable      DF        AIC        Sum Sq       RSS       R-Sq    Adj. R-Sq
-------------------------------------------------------------------------
Reviews        1     14563.929      9.186    2416.875    0.030       0.027
Type           1     14594.192      2.428    2423.632    0.027       0.024
Size           1     14599.888      1.154    2424.906    0.027       0.024
Price          1     14602.004      0.681    2425.380    0.026       0.023
-------------------------------------------------------------------------

+ Reviews


 Step 2 : AIC = 14563.93
 Rating ~ Category + Reviews

-------------------------------------------------------------------------
Variable      DF        AIC        Sum Sq       RSS       R-Sq    Adj. R-Sq
-------------------------------------------------------------------------
Type           1     14553.376      2.797    2414.077    0.031       0.028
Size           1     14560.575      1.193    2415.681    0.030       0.027
Price          1     14562.950      0.664    2416.211    0.030       0.027
-------------------------------------------------------------------------
```



```
Final Model Output
------------------

                        Model Summary
--------------------------------------------------------------
R                       0.179       RMSE                0.472
R-Squared               0.032       Coef. Var          11.269
Adj. R-Squared          0.029       MSE                 0.223
Pred R-Squared          0.026       MAE                 0.314
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error
```

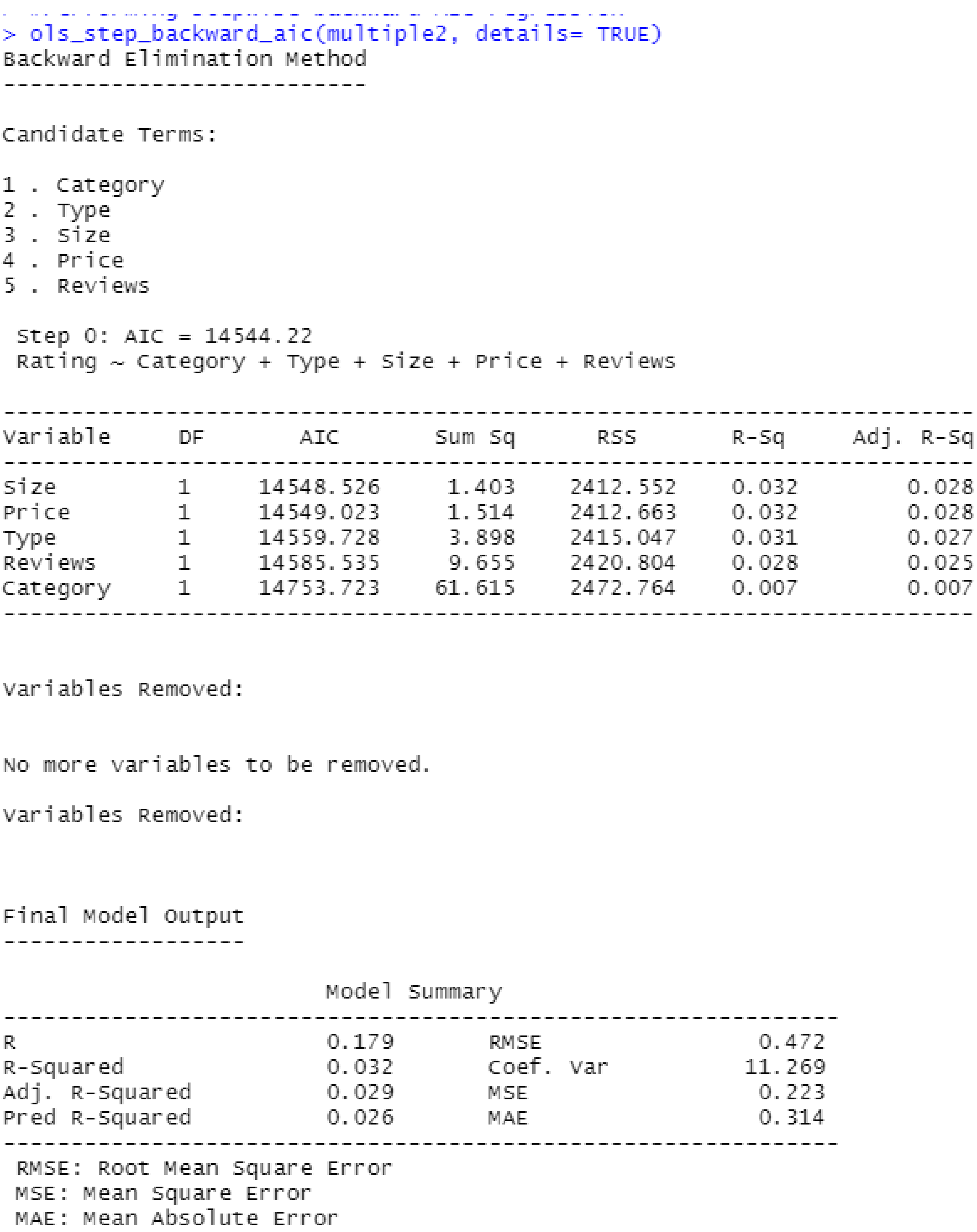


```
                                    ANOVA
----------------------------------------------------------------------
                  Sum of
                 Squares           DF     Mean Square       F         Sig.
----------------------------------------------------------------------
Regression        80.129           36           2.226     9.972     0.0000
Residual        2411.149        10802           0.223
Total           2491.278        10838
----------------------------------------------------------------------

                                          Parameter Estimates
----------------------------------------------------------------------------------------------------------
                       model       Beta    Std. Error    Std. Beta       t        Sig      lower     upper
----------------------------------------------------------------------------------------------------------
                 (Intercept)      4.349         0.059                 74.197    0.000      4.234     4.464
   CategoryAUTO_AND_VEHICLES     -0.155         0.078       -0.029    -1.996    0.046     -0.308    -0.003
              CategoryBEAUTY     -0.085         0.087       -0.012    -0.968    0.333     -0.256     0.087
CategoryBOOKS_AND_REFERENCE     -0.041         0.066       -0.012    -0.620    0.535     -0.171     0.089
            CategoryBUSINESS     -0.199         0.063       -0.084    -3.185    0.001     -0.322    -0.077
              CategoryCOMICS     -0.188         0.085       -0.029    -2.228    0.026     -0.354    -0.023
       CategoryCOMMUNICATION     -0.205         0.063       -0.079    -3.232    0.001     -0.329    -0.081
              CategoryDATING     -0.340         0.066       -0.103    -5.133    0.000     -0.470    -0.210
           CategoryEDUCATION      0.038         0.070        0.010     0.549    0.583     -0.098     0.175
       CategoryENTERTAINMENT     -0.225         0.070       -0.055    -3.199    0.001     -0.362    -0.087
              CategoryEVENTS      0.020         0.083        0.003     0.236    0.814     -0.143     0.183
              CategoryFAMILY     -0.159         0.060       -0.128    -2.676    0.007     -0.276    -0.043
             CategoryFINANCE     -0.203         0.064       -0.077    -3.193    0.001     -0.328    -0.078
      CategoryFOOD_AND_DRINK     -0.176         0.072       -0.040    -2.443    0.015     -0.317    -0.035
                CategoryGAME     -0.080         0.060       -0.051    -1.329    0.184     -0.198     0.038
  CategoryHEALTH_AND_FITNESS     -0.082         0.064       -0.030    -1.277    0.202     -0.207     0.044
     CategoryHOUSE_AND_HOME     -0.148         0.077       -0.028    -1.918    0.055     -0.300     0.003
  CategoryLIBRARIES_AND_DEMO     -0.144         0.078       -0.026    -1.838    0.066     -0.297     0.010
           CategoryLIFESTYLE     -0.231         0.063       -0.089    -3.636    0.000     -0.355    -0.106
CategoryMAPS_AND_NAVIGATION     -0.284         0.071       -0.066    -3.993    0.000     -0.424    -0.145
             CategoryMEDICAL     -0.167         0.063       -0.070    -2.664    0.008     -0.290    -0.044
  CategoryNEWS_AND_MAGAZINES     -0.205         0.065       -0.068    -3.153    0.002     -0.332    -0.078
           CategoryPARENTING     -0.065         0.085       -0.010    -0.769    0.442     -0.231     0.101
     CategoryPERSONALIZATION     -0.059         0.063       -0.023    -0.930    0.353     -0.183     0.065
         CategoryPHOTOGRAPHY     -0.165         0.064       -0.059    -2.571    0.010     -0.290    -0.039
        CategoryPRODUCTIVITY     -0.143         0.063       -0.058    -2.264    0.024     -0.266    -0.019
            CategorySHOPPING     -0.095         0.066       -0.030    -1.456    0.145     -0.224     0.033
              CategorySOCIAL     -0.119         0.065       -0.040    -1.839    0.066     -0.246     0.008
              CategorySPORTS     -0.132         0.063       -0.051    -2.078    0.038     -0.256    -0.007
               CategoryTOOLS     -0.286         0.061       -0.160    -4.701    0.000     -0.405    -0.167
    CategoryTRAVEL_AND_LOCAL     -0.231         0.066       -0.073    -3.520    0.000     -0.359    -0.102
       CategoryVIDEO_PLAYERS     -0.279         0.069       -0.073    -4.060    0.000     -0.413    -0.144
             CategoryWEATHER     -0.114         0.078       -0.021    -1.458    0.145     -0.268     0.039
                     Reviews      0.000         0.000        0.064     6.577    0.000      0.000     0.000
                    TypePaid      0.076         0.018        0.042     4.179    0.000      0.041     0.112
                       Price     -0.001         0.000       -0.025    -2.604    0.009     -0.001     0.000
                        Size      0.000         0.000       -0.024    -2.507    0.012      0.000     0.000
----------------------------------------------------------------------------------------------------------

                               Selection Summary
--------------------------------------------------------------------
Variable        AIC        Sum Sq        RSS         R-Sq       Adj. R-Sq
--------------------------------------------------------------------
Category     14603.046     65.218     2426.061     0.02618      0.02329
Reviews      14563.929     74.403     2416.875     0.02987      0.02690
Type         14553.376     77.201     2414.077     0.03099      0.02794
Price        14548.526     78.726     2412.552     0.03160      0.02846
Size         14544.219     80.129     2411.149     0.03216      0.02894
--------------------------------------------------------------------
```

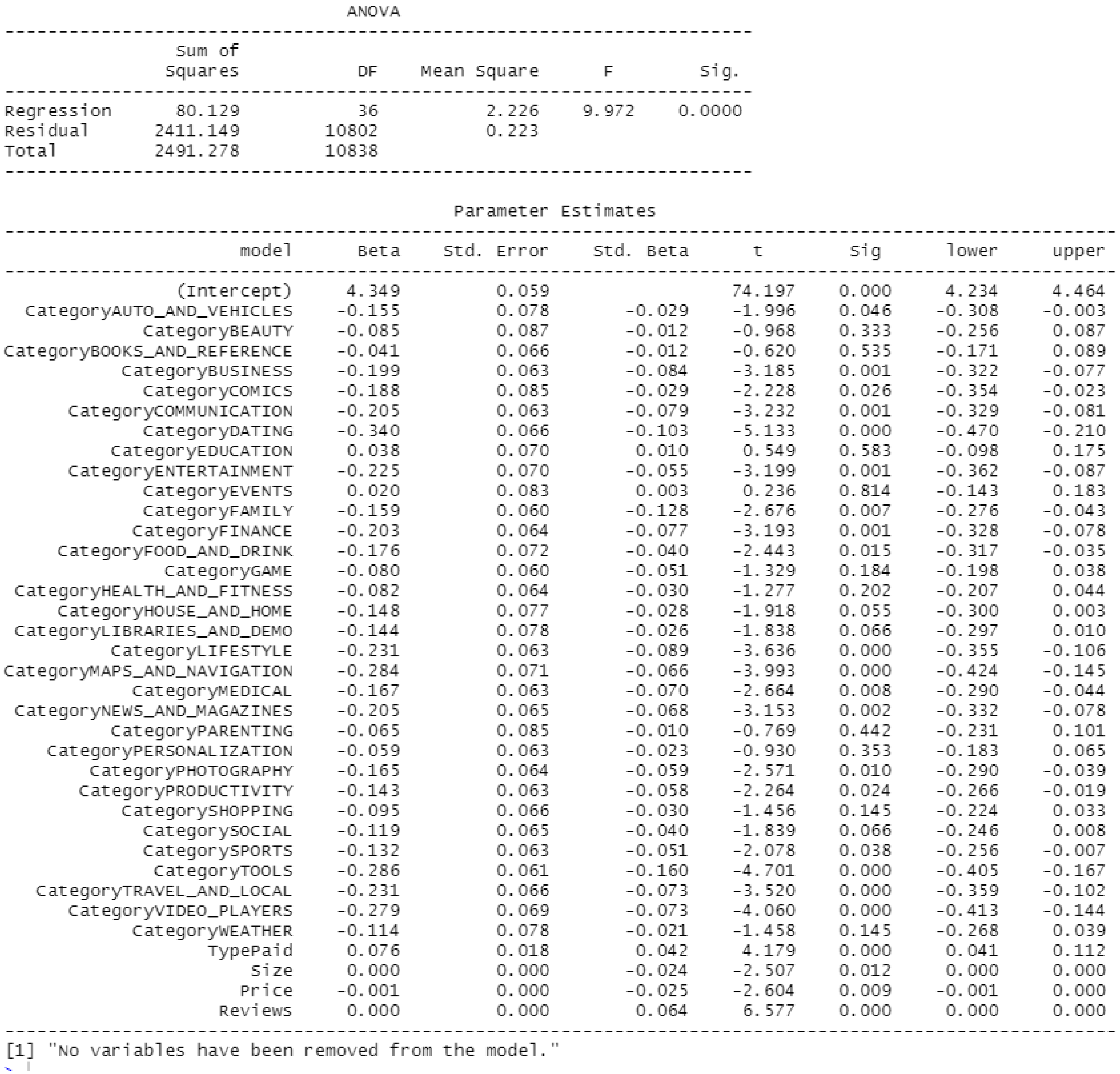
- We have seen that in forward AIC all the variables have been selected and AIC is been reduced and prediction metrics:

  1) RMSE: 0.472   2) R-Squared: 0.032

- ***We will now perform backward AIC model for the linear model we have used.***



```
> #Performing stepwise backward AIC regression
> ols_step_backward_aic(multiple2, details= TRUE)
Backward Elimination Method
---------------------------

Candidate Terms:

1 . Category
2 . Type
3 . Size
4 . Price
5 . Reviews

 Step 0: AIC = 14544.22
 Rating ~ Category + Type + Size + Price + Reviews

------------------------------------------------------------------------
Variable      DF        AIC        Sum Sq       RSS        R-Sq     Adj. R-Sq
------------------------------------------------------------------------
Size          1      14548.526      1.403     2412.552     0.032         0.028
Price         1      14549.023      1.514     2412.663     0.032         0.028
Type          1      14559.728      3.898     2415.047     0.031         0.027
Reviews       1      14585.535      9.655     2420.804     0.028         0.025
Category      1      14753.723     61.615     2472.764     0.007         0.007
------------------------------------------------------------------------


Variables Removed:


No more variables to be removed.

Variables Removed:



Final Model Output
------------------

                        Model Summary
--------------------------------------------------------------
R                       0.179       RMSE               0.472
R-Squared               0.032       Coef. Var         11.269
Adj. R-Squared          0.029       MSE                0.223
Pred R-Squared          0.026       MAE                0.314
--------------------------------------------------------------
 RMSE: Root Mean Square Error
 MSE: Mean Square Error
 MAE: Mean Absolute Error
```

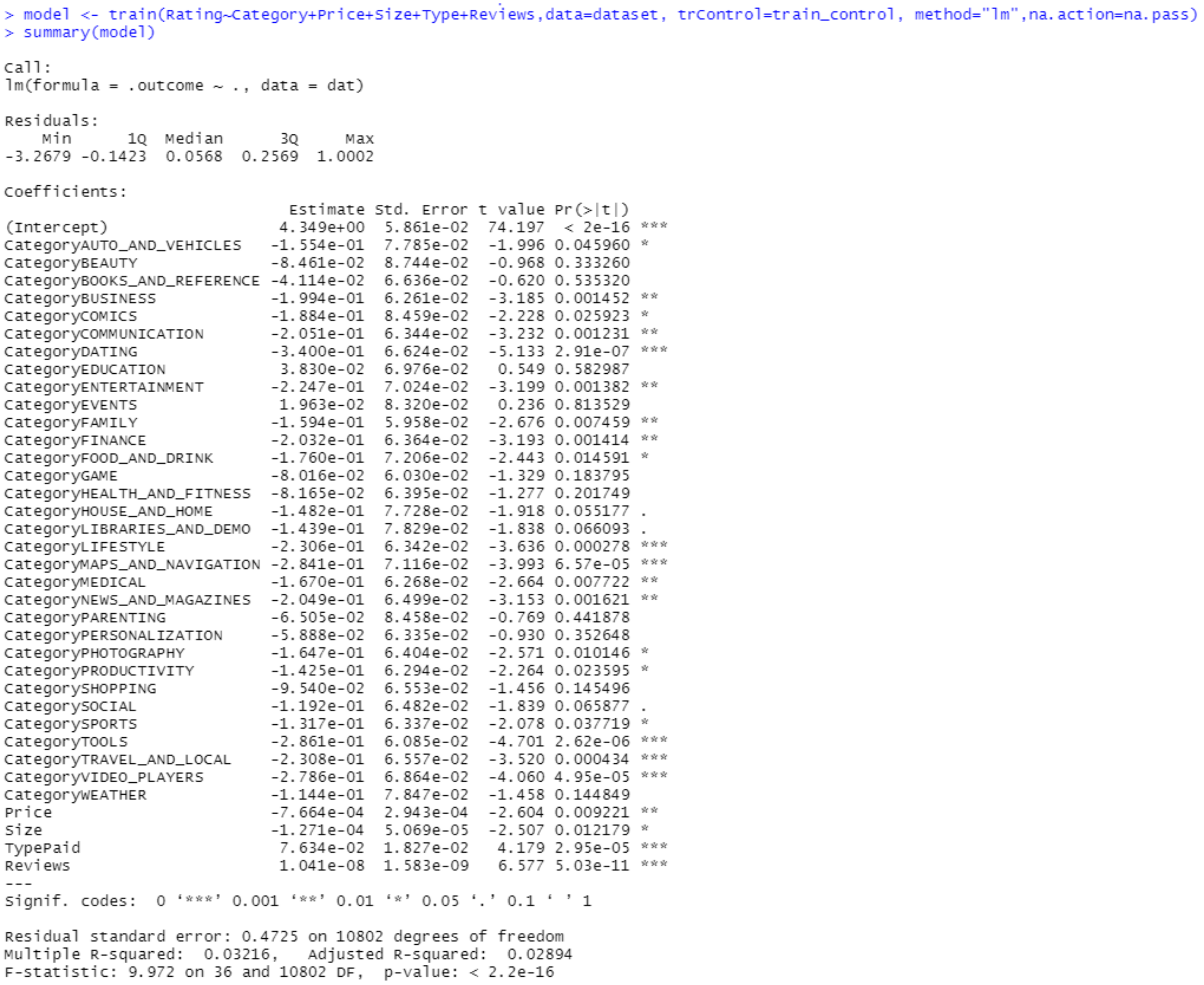


```
                               ANOVA
----------------------------------------------------------------------
                  Sum of
                 Squares          DF    Mean Square       F        Sig.
----------------------------------------------------------------------
Regression        80.129          36          2.226     9.972     0.0000
Residual        2411.149       10802          0.223
Total           2491.278       10838
----------------------------------------------------------------------

                                          Parameter Estimates
----------------------------------------------------------------------------------------------------------
                      model      Beta    Std. Error    Std. Beta        t        Sig      lower      upper
----------------------------------------------------------------------------------------------------------
                (Intercept)     4.349         0.059                 74.197     0.000      4.234      4.464
    CategoryAUTO_AND_VEHICLES  -0.155         0.078       -0.029    -1.996     0.046     -0.308     -0.003
             CategoryBEAUTY    -0.085         0.087       -0.012    -0.968     0.333     -0.256      0.087
CategoryBOOKS_AND_REFERENCE    -0.041         0.066       -0.012    -0.620     0.535     -0.171      0.089
           CategoryBUSINESS    -0.199         0.063       -0.084    -3.185     0.001     -0.322     -0.077
             CategoryCOMICS    -0.188         0.085       -0.029    -2.228     0.026     -0.354     -0.023
      CategoryCOMMUNICATION    -0.205         0.063       -0.079    -3.232     0.001     -0.329     -0.081
             CategoryDATING    -0.340         0.066       -0.103    -5.133     0.000     -0.470     -0.210
          CategoryEDUCATION     0.038         0.070        0.010     0.549     0.583     -0.098      0.175
      CategoryENTERTAINMENT    -0.225         0.070       -0.055    -3.199     0.001     -0.362     -0.087
             CategoryEVENTS     0.020         0.083        0.003     0.236     0.814     -0.143      0.183
             CategoryFAMILY    -0.159         0.060       -0.128    -2.676     0.007     -0.276     -0.043
            CategoryFINANCE    -0.203         0.064       -0.077    -3.193     0.001     -0.328     -0.078
       CategoryFOOD_AND_DRINK  -0.176         0.072       -0.040    -2.443     0.015     -0.317     -0.035
               CategoryGAME    -0.080         0.060       -0.051    -1.329     0.184     -0.198      0.038
  CategoryHEALTH_AND_FITNESS   -0.082         0.064       -0.030    -1.277     0.202     -0.207      0.044
      CategoryHOUSE_AND_HOME   -0.148         0.077       -0.028    -1.918     0.055     -0.300      0.003
  CategoryLIBRARIES_AND_DEMO   -0.144         0.078       -0.026    -1.838     0.066     -0.297      0.010
          CategoryLIFESTYLE    -0.231         0.063       -0.089    -3.636     0.000     -0.355     -0.106
CategoryMAPS_AND_NAVIGATION    -0.284         0.071       -0.066    -3.993     0.000     -0.424     -0.145
            CategoryMEDICAL    -0.167         0.063       -0.070    -2.664     0.008     -0.290     -0.044
  CategoryNEWS_AND_MAGAZINES   -0.205         0.065       -0.068    -3.153     0.002     -0.332     -0.078
          CategoryPARENTING    -0.065         0.085       -0.010    -0.769     0.442     -0.231      0.101
    CategoryPERSONALIZATION    -0.059         0.063       -0.023    -0.930     0.353     -0.183      0.065
        CategoryPHOTOGRAPHY    -0.165         0.064       -0.059    -2.571     0.010     -0.290     -0.039
       CategoryPRODUCTIVITY    -0.143         0.063       -0.058    -2.264     0.024     -0.266     -0.019
           CategorySHOPPING    -0.095         0.066       -0.030    -1.456     0.145     -0.224      0.033
             CategorySOCIAL    -0.119         0.065       -0.040    -1.839     0.066     -0.246      0.008
             CategorySPORTS    -0.132         0.063       -0.051    -2.078     0.038     -0.256     -0.007
              CategoryTOOLS    -0.286         0.061       -0.160    -4.701     0.000     -0.405     -0.167
   CategoryTRAVEL_AND_LOCAL    -0.231         0.066       -0.073    -3.520     0.000     -0.359     -0.102
      CategoryVIDEO_PLAYERS    -0.279         0.069       -0.073    -4.060     0.000     -0.413     -0.144
            CategoryWEATHER    -0.114         0.078       -0.021    -1.458     0.145     -0.268      0.039
                   TypePaid     0.076         0.018        0.042     4.179     0.000      0.041      0.112
                       Size     0.000         0.000       -0.024    -2.507     0.012      0.000      0.000
                      Price    -0.001         0.000       -0.025    -2.604     0.009     -0.001      0.000
                    Reviews     0.000         0.000        0.064     6.577     0.000      0.000      0.000
----------------------------------------------------------------------------------------------------------
[1] "No variables have been removed from the model."
```

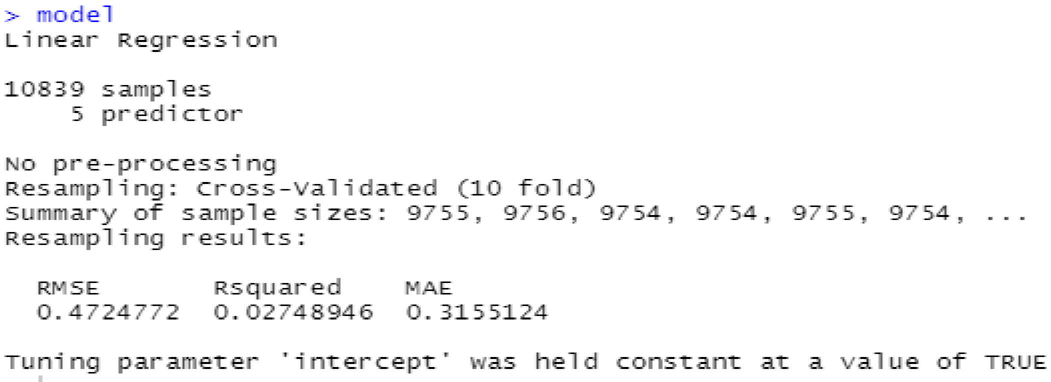
- Again, we have performed backward AIC model with final prediction error's:

1) RMSE: 0.472 2) R-Squared: 0.029

- ***Finally, we are performing N-Fold Cross validation for the final prediction of the rating of application***.



```
> model <- train(Rating~Category+Price+Size+Type+Reviews,data=dataset, trControl=train_control, method="lm",na.action=na.pass)
> summary(model)

Call:
lm(formula = .outcome ~ ., data = dat)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.2679 -0.1423  0.0568  0.2569  1.0002 

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)    
(Intercept)                  4.349e+00  5.861e-02  74.197  < 2e-16 ***
CategoryAUTO_AND_VEHICLES   -1.554e-01  7.785e-02  -1.996 0.045960 *  
CategoryBEAUTY              -8.461e-02  8.744e-02  -0.968 0.333260    
CategoryBOOKS_AND_REFERENCE -4.114e-02  6.636e-02  -0.620 0.535320    
CategoryBUSINESS            -1.994e-01  6.261e-02  -3.185 0.001452 ** 
CategoryCOMICS              -1.884e-01  8.459e-02  -2.228 0.025923 *  
CategoryCOMMUNICATION       -2.051e-01  6.344e-02  -3.232 0.001231 ** 
CategoryDATING              -3.400e-01  6.624e-02  -5.133 2.91e-07 ***
CategoryEDUCATION            3.830e-02  6.976e-02   0.549 0.582987    
CategoryENTERTAINMENT       -2.247e-01  7.024e-02  -3.199 0.001382 ** 
CategoryEVENTS               1.963e-02  8.320e-02   0.236 0.813529    
CategoryFAMILY              -1.594e-01  5.958e-02  -2.676 0.007459 ** 
CategoryFINANCE             -2.032e-01  6.364e-02  -3.193 0.001414 ** 
CategoryFOOD_AND_DRINK      -1.760e-01  7.206e-02  -2.443 0.014591 *  
CategoryGAME                -8.016e-02  6.030e-02  -1.329 0.183795    
CategoryHEALTH_AND_FITNESS  -8.165e-02  6.395e-02  -1.277 0.201749    
CategoryHOUSE_AND_HOME      -1.482e-01  7.728e-02  -1.918 0.055177 .  
CategoryLIBRARIES_AND_DEMO  -1.439e-01  7.829e-02  -1.838 0.066093 .  
CategoryLIFESTYLE           -2.306e-01  6.342e-02  -3.636 0.000278 ***
CategoryMAPS_AND_NAVIGATION -2.841e-01  7.116e-02  -3.993 6.57e-05 ***
CategoryMEDICAL             -1.670e-01  6.268e-02  -2.664 0.007722 ** 
CategoryNEWS_AND_MAGAZINES  -2.049e-01  6.499e-02  -3.153 0.001621 ** 
CategoryPARENTING           -6.505e-02  8.458e-02  -0.769 0.441878    
CategoryPERSONALIZATION     -5.888e-02  6.335e-02  -0.930 0.352648    
CategoryPHOTOGRAPHY         -1.647e-01  6.404e-02  -2.571 0.010146 *  
CategoryPRODUCTIVITY        -1.425e-01  6.294e-02  -2.264 0.023595 *  
CategorySHOPPING            -9.540e-02  6.553e-02  -1.456 0.145496    
CategorySOCIAL              -1.192e-01  6.482e-02  -1.839 0.065877 .  
CategorySPORTS              -1.317e-01  6.337e-02  -2.078 0.037719 *  
CategoryTOOLS               -2.861e-01  6.085e-02  -4.701 2.62e-06 ***
CategoryTRAVEL_AND_LOCAL    -2.308e-01  6.557e-02  -3.520 0.000434 ***
CategoryVIDEO_PLAYERS       -2.786e-01  6.864e-02  -4.060 4.95e-05 ***
CategoryWEATHER             -1.144e-01  7.847e-02  -1.458 0.144849    
Price                       -7.664e-04  2.943e-04  -2.604 0.009221 ** 
Size                        -1.271e-04  5.069e-05  -2.507 0.012179 *  
TypePaid                     7.634e-02  1.827e-02   4.179 2.95e-05 ***
Reviews                      1.041e-08  1.583e-09   6.577 5.03e-11 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4725 on 10802 degrees of freedom
Multiple R-squared:  0.03216,	Adjusted R-squared:  0.02894 
F-statistic: 9.972 on 36 and 10802 DF,  p-value: < 2.2e-16
```

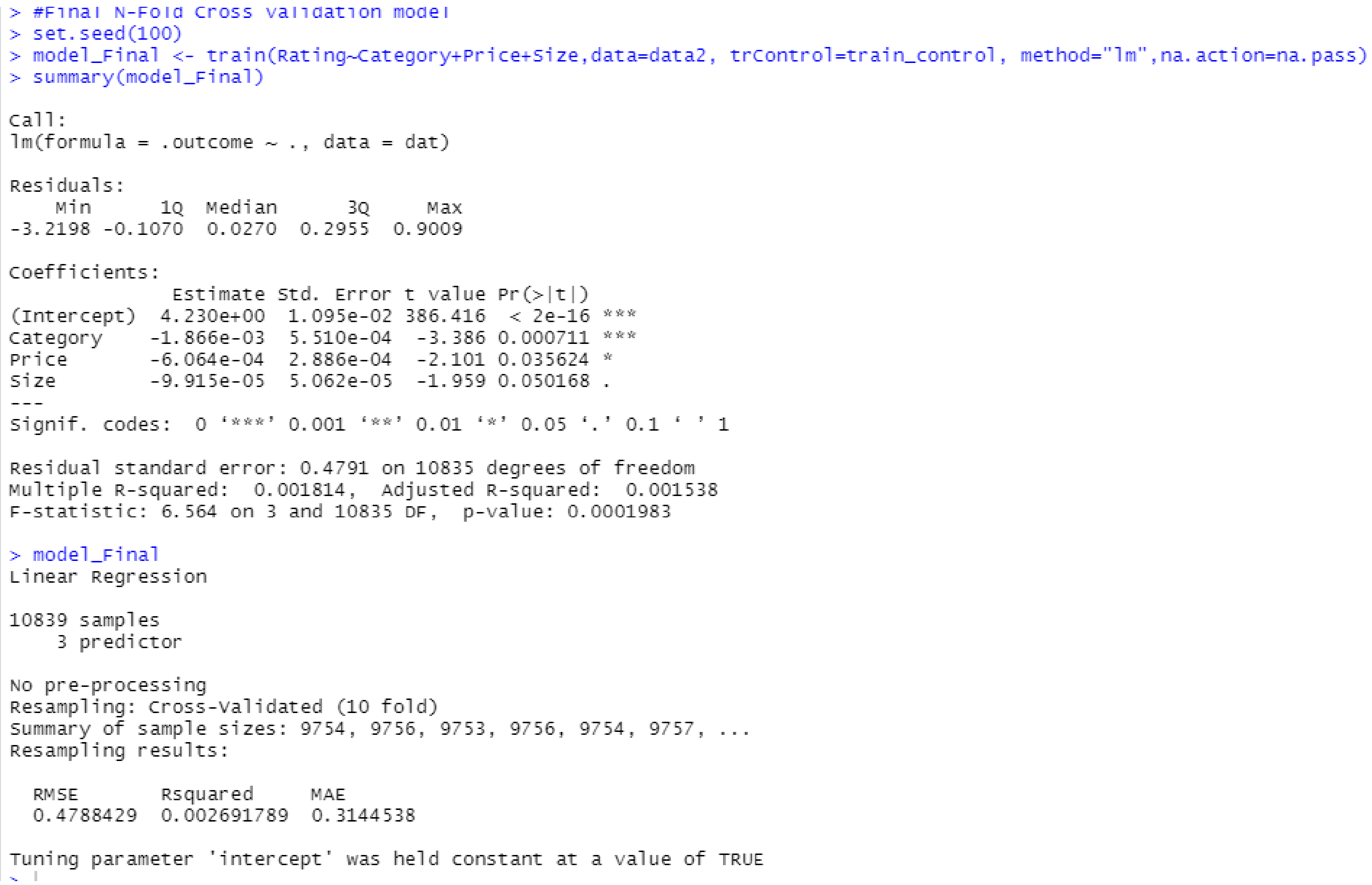


```
> model
Linear Regression 

10839 samples
    5 predictor

No pre-processing
Resampling: Cross-Validated (10 fold) 
Summary of sample sizes: 9755, 9756, 9754, 9754, 9755, 9754, ... 
Resampling results:

  RMSE       Rsquared    MAE      
  0.4724772  0.02748946  0.3155124

Tuning parameter 'intercept' was held constant at a value of TRUE
```

- We can notice that the above output is ready for the prediction model with prediction matrices:
  1) RMSE: 0.4724 2) R-Squared: 0.0274

5.3. Findings

Finally, for the prediction of the Rating of the app we have used N- Fold cross validation using linear model with the selected variables using the feature selection of the variables.



```
> #Final N-Fold Cross validation model
> set.seed(100)
> model_Final <- train(Rating~Category+Price+Size,data=data2, trControl=train_control, method="lm",na.action=na.pass)
> summary(model_Final)

Call:
lm(formula = .outcome ~ ., data = dat)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.2198 -0.1070  0.0270  0.2955  0.9009 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)  4.230e+00  1.095e-02 386.416  < 2e-16 ***
Category    -1.866e-03  5.510e-04  -3.386 0.000711 ***
Price       -6.064e-04  2.886e-04  -2.101 0.035624 *  
Size        -9.915e-05  5.062e-05  -1.959 0.050168 .  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4791 on 10835 degrees of freedom
Multiple R-squared:  0.001814,  Adjusted R-squared:  0.001538 
F-statistic: 6.564 on 3 and 10835 DF,  p-value: 0.0001983

> model_Final
Linear Regression 

10839 samples
    3 predictor

No pre-processing
Resampling: Cross-Validated (10 fold) 
Summary of sample sizes: 9754, 9756, 9753, 9756, 9754, 9757, ... 
Resampling results:

  RMSE       Rsquared     MAE      
  0.4788429  0.002691789  0.3144538

Tuning parameter 'intercept' was held constant at a value of TRUE
> 
```

Although we have all the independent variables present but we have finally worked on only three independent variables for the project that are Category, Price & Size. We have not used the variables such as Type and Reviews as their value in the above output as they are very small.

Finally, our prediction model is ready with prediction metrics to be: 1). RMSE = 0.4788 2) R-Squared = 0.0026

<u>Comparing all the models</u>

Regression Model	RMSE	R-Squared
Forward Stepwise	0.472	0.032
Backward Stepwise	0.472	0.032
Both Stepwise	0.472	0.032
Forward AIC	0.472	0.032
Backward AIC	0.472	0.029
N-Fold Model	0.472	0.027
N-Fold Final	0.478	0.002

6. Conclusions and Future Work

6.1. Conclusions

For an application developer, it is beneficial to know about how well the app is going to perform when it is launched on the application like google play store taking into consideration various variables related to the application. We have presented a small project based on the prediction of the app before it's launches, we have used rating as the dependent variable and price & category as the independent variable for the prediction of the rating.

Firstly, we have preprocessed & cleaned the dataset taken from Kaggle having more than 10,000 rows and 13 columns. Then performed the feature selection process using Multiple Linear Regression, ANOVA Hypothesis and at last used N-Fold Cross Validation to predict the rating.

We have been able to successfully predict the rating of the applications. Moreover, using ANOVA we determined that the mean of all the categories are based on the ratings are not same, mean value of videoplayer category is the highest and mean of the Dating category is the lowest. With N-Fold cross validation prediction model we have sed three variables for final output with prediction matrices of

1) RMSE = 0.478 2) R-Squared = 0.002

We have also designed the UI for user friendly approach of how our final model is predicting the rating without running the code again and again.

6.2. Limitations

Although we have been successful to complete our project, but we were limited to some features which could have been more helpful to get more accurate results. Limitations we faced are:

1) The dataset was small, if the dataset could have been with more entries the results would have been more précised.
2) We could only use three independent variables to predict the model, but we could have taken more variables to predict but due to lesser data we were restricted to three only.
3) For betterment of our project we could have grouped the Size column to various subparts as
   Low: 1Kb – 10MB, Medium: 11MB – 200 MB, High: 200MB – 1GB, Very High: > 1GB.
   Doing this we would have reduced the different entries in Size column and have been able to predict in a better way.

6.3. Potential Improvements or Future Work

Future improvement could be executed by adding more entries in dataset, used all the independent variables.

Using Classification models, logistic regression and multiple linear regression to determine which is the best model for the prediction of the ratings.